外部委託業者の募集

References: IO/25/OT/10030738/JPK

"Procurement of Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3"

（加熱中性粒子ビーム（HNB）1，2，3 用ダクトライナーの調達）

IO 締め切り 2025 年 1 月 28 日(月)

〇はじめに

本事前情報通知（PIN）は、作業契約の入札授与および実行につながる公開入札調達プロセスの最初のステップです。

本文書の目的は作業範囲と入札プロセスに関する技術的な内容の基本的な要約を提供することです。

国内機関は、次回の入札に先立って、これらのサービス/工事を提供することができる企業、機関またはその他の団体が入札の詳細を事前に通知する前に、この情報を公表するよう求められます。

〇背景

ITER は平和利用の核融合発電の科学的および技術的な実現可能性の実証を目的とした、国際共同研究開発プロジェクトです。ITER 機構の 7 つのメンバーは、;欧州連合（EURATOM が代表）、日本、中華人民共和国、インド、大韓民国、ロシア連邦、および米国です。

ITER の敷地はフランス南東部のブーシュデュローヌ地区にあり、ITER 本社（HQ）もあるフランス CEA サン・ポール・レ・デュランス に近いところに位置しています。詳細については、ITER のウェブサイト http://www.iter.org を参照して下さい。

〇作業範囲

現在の入札プロセスは、加熱中性ビーム（HNB）1、2、および3用のダクトライナー調達に関連するサービスおよび供給契約の確立を目的としています。この契約の範囲と目的は、7つの明確なフェーズに分かれています。

- フェーズ1: 生産前準備
- フェーズ2: 製造準備レビュー（MRR）
- フェーズ3: プロトタイプ認証（必要に応じて）
- フェーズ4: 製造
- フェーズ5: 工場受け入れ試験（FAT）
- フェーズ6: ITERサイトへの納品
- フェーズ7: 現地受け入れ試験（SAT）

加熱中性ビーム（HNB）1、2、および3用のダクトライナー3台の納品が求められます。それらは、インコタームズDAP ITERサイトに基づいてそれぞれITERサイトに出荷される予定です。

システム分類および適用されるコードと標準については、付録IIの2.3節に記載されています。これには、核安全に関する安全重要クラス1（SIC-1または非SIC）、耐震クラス、遠隔操作（RH）クラス、真空分類、トリチウムクラス、設計コード、および製造コードが含まれます。

この契約における品質クラスはQC1またはQC2です。

作業はオフサイトおよび/またはオンサイトで実施されます。

〇調達プロセスと目的

目的は、競争入札プロセスを通じて供給契約を落札することです。
この入札のために選択された調達手続きは公開入札手続きと呼ばれます。
オープン入札手順は、次の 4 つの主要なステップで構成されています。

- ステップ 1-事前情報通知（PIN）
  事前情報通知は公開入札プロセスの第一段階です。IO は、関心のある企業、機関又はその他の団体に事前に入札機会について通知するために、国内機関に対し、今後の入札に関する情報を公表するよう正式に要請します。

  特に注意:
  関心のある候補企業は、IO Ariba の電子調達ツール 「IPROC」 に登録してください（まだ登録していない場合）。手順については、https://www.iter.org/fr/proc/overview を参照してください。

  Ariba（IPROC）に登録する際には、お取引先様に最低 1 名の担当者の登録をお願いします。この連絡担当者は、提案依頼書の発行通知を受け取り、必要と思われる場合は入札書類を同僚に転送することができます。

- ステップ 2-入札への招待（ITT）
  事前指示通知（PIN）の公表から 14 日以内に、入札への招待（ITT）が公告されます。この段階では、PIN を見た関心のある入札者が入札書類を入手し、入札説明書に従って提案書を作成して提出することができます。
  特に注意:
  このツールに登録されている企業のみが入札に招待されます。

- ステップ 3-入札評価プロセス
  入札者の提案は、IO の公平な評価委員会によって評価されます。入札者は、技術的範囲に沿って、かつ、入札への招待（ITT)に記載された特定の基準に従って作業を実施するために、技術的遵守を証明する詳細を提供しなければなりません。

- ステップ 4-落札
  認定は、公開されている入札への招待 (ITT)に記載されている、コストに見合った最適な価格または技術的に準拠した最低価格に基づいて行われます。

〇概略日程

概略日程は以下の通りです：

マイルストーン	暫定日程
事前指示書（PIN）の発行	2025 年 1 月 7 日
関心表明フォームの提出	2025 年 1 月 28 日
入札への招待（ITT）の発行	2025 年 2 月 18 日
明確化のための質問（もしあれば）	2025 年 3 月 21 日
入札提出	2025 年 4 月 1 日
入札評価と契約授与	2025 年 4/5 月
契約調印	2025 年 5/6 月

〇契約期間と実行

ITER機構は2025年5/6月ごろに授与する予定です。予想される契約期間は4.5年の予定です。

〇経験

入札者は付属書 I に詳述された作業範囲に関連する技術的および産業上の経験を実証する必要があります。

ITERでの作業に使われる言語は英語です。プロレベルの流暢さが求められます（話す、書く両方)。

〇候補

参加は、個人またはグループ/コンソーシアムに参加するすべての法人に開放されます。法人とは、法的権利及び義務を有し、ITER 加盟国内に設立された個人、企業又は機構をいいます。ITER 加盟国は欧州連合(EURATOM メンバー)、日本、中華人民共和国、インド共和国、大韓民国、ロシア連邦、アメリカ合衆国です。

法人は、単独で、またはコンソーシアムパートナーとして、同じ契約の複数の申請または入札に参加することはできません。共同事業体は、恒久的な、法的に確立されたグループ又は特定の入札手続のために非公式に構成されたグループとすることができます。

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とめる権限をもつリーダーをもたなければなりません。このリーダーはコンソーシアムの各目メンバーのために責任を負わなければなりません。

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どのコンソーシアムメンバーも IPROC に登録する必要があります。
【※　詳しくは添付の英語版技術仕様書「**Procurement of Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3.**」をご参照ください。】
ITER 公式ウェブ　http://www.iter.org/org/team/adm/proc/overview からもアクセスが可能です。

「核融合エネルギー研究開発部門」の HP：　http://www.fusion.qst.go.jp/ITER/index.html
では ITER 機構からの各募集（IO 職員募集、IO 外部委託、IO エキスパート募集）を逐次更新しています。ぜひご確認ください。

イーター国際核融合エネルギー機構からの外部委託
に関心ある企業及び研究機関の募集について

＜ITER 機構から参加極へのレター＞

以下に、外部委託の概要と要求事項が示されています。参加極には、提案された業務に要求される能力を有し、入札すべきと考える企業及び研究機関の連絡先の情報を ITER 機構へ伝えることが求められています。このため、本研究・業務に関心を持たれる企業及び研究機関におかれましては、応募書類の提出要領にしたがって連絡先情報をご提出下さい。

china eu india japan korea russia usa
Route de Vinon-sur-Verdon - CS 90 046 - 13067 St Paul Lez Durance Cedex - France

7 January 2025

To: Domestic Agencies (DAs)

IO Tender Reference: IO/25/OT/10030738/JPK

Title: Procurement of Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3.

Subject: Prior Indicative Notice (PIN)

Dear colleagues,

The ITER Organization intends to launch an Open Tender process in the coming weeks as indicated above and in accordance with the details in the attached Prior Indicative Notice (PIN). In this regard, and to provide some introductory information about the forthcoming tender, we kindly request the attached PIN to be published on your DA website with immediate effect for a period of 15 working days.

china
eu
india
japan
korea
russia
usa

The advance notification is to alert companies, institutions, or other eligible entities to the forthcoming tender, and provide information to promote healthy competition, allowing interested parties time to decide whether to participate in the tender or not.

Please could you kindly acknowledge receipt of this e-mail and confirm once the PIN is published on your website.

Yours sincerely

JunHyung PARK
Procurement Officer
Procurement Division

Contact: JunHyung PARK – Procurement Division - Tel. +33 (0)4 42 17 61 59 - e-mail: junhyung.park@iter.org

china eu india japan korea russia usa
Route de Vinon-sur-Verdon - CS 90 046 - 13067 St Paul Lez Durance Cedex - France

PRIOR INDICATIVE NOTICE (PIN)

OPEN TENDER SUMMARY

IO/25/OT/10030738/JPK

For

Procurement of Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3.

Annexes
Annex I– Expression of Interest Form
Annex II – Technical Specifications

Abstract

The purpose of this summary is to provide prior notification of the IO's intention to launch a competitive Open Tender process in the coming weeks. This summary provides some basic information about the ITER Organisation, the technical scope for this tender, and details of the tender process for the procurement of the supplies and services related to the Pre-production, Manufacturing Readiness Review (MRR), Prototype Qualification, Manufacturing, Factory Acceptance Test (FAT), Delivery to the IO site, and Site Acceptance Test (SAT) and Transfer of Ownership.

1 Introduction

This Prior Indicative Notice (PIN) is the first step of an Open Tender (OT) Procurement Process leading to the award and execution of a Contract.

The purpose of this document is to provide a basic summary of the technical content in terms of the scope of work, and the tendering process.

2 Background

The ITER project is an international research and development project jointly funded by its seven Members being, the European Union (represented by EURATOM), Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA. ITER is being constructed in Europe at St. Paul–Lez-Durance in southern France, which is also the location of the headquarters (HQ) of the ITER Organization (IO).

For a complete description of the ITER Project, covering both organizational and technical aspects of the Project, visit www.iter.org.

3 Scope of Work

The present tender process aims to establish a Service and Supply Contract related to the Procurement of Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3. The scope and purpose of this contract has 7 distinct Phases:

- Phase 1: Pre-Production
- Phase 2: Manufacturing Readiness Review (MRR)
- Phase 3: Prototype Qualification (as and when required)
- Phase 4: Manufacturing
- Phase 5: Factory Acceptance Test (FAT)
- Phase 6: Delivery to the IO site
- Phase 7: Site Acceptance Test (SAT)

The delivery of the three Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3. Those shall be shipped to the ITER site respectively based on the Incoterms DAP ITER site.

Please find the System Classification and applicable Codes & Standards in section 2.3 of Annex II, it includes Safety Important Class 1 (SIC-1 or Non-SIC) for nuclear class safety and Seismic class, Remote Handling (RH) Class, Vacuum classification, a Tritium Class, Design Codes, and Manufacturing Codes.

The Quality class under this contract is QC1 or QC2.

The work shall be performed off-site and/or on-site.

4 Procurement Process & Objective

The objective is to award a Service Contract through a competitive bidding process.

The Procurement Procedure selected for this tender is called the **Open Tender** procedure.

The Open Tender procedure is comprised of the following four main steps:

- Step 1- Prior Information Notice (PIN)

  The Prior Information Notice is the first stage of the Open Tender process. The IO formally invites interested Suppliers to indicate their interest in the competitive process by returning to the Procurement officer in charge the attached "Expression of Interest and PIN Acknowledgement" by the date indicated under the procurement timetable.

  Special attention:

  Interested tenderers are kindly requested to register in the IO Ariba e-procurement tool called "IPROC". You can find all links to proceed along with instruction going to: https://www.iter.org/fr/proc/overview.

  When registering in Ariba (IPROC), suppliers are kindly requested to nominate at least one contact person. This contact person will be receiving the notification of publication of the Request for Proposal and will then be able to forward the tender documents to colleagues if deemed necessary.

- Step 2 - Invitation to Tender

  After at least 15 working days of the publication of the PIN, normally the Request for Proposals (RFP) will be published on our digital tool "Iproc". This stage allows interested bidders who have indicated their interest to the Procurement Officer in charge AND who have registered in IPROC to receive the notification that the RFP is published. They will then prepare and submit their proposals in accordance with the tender instructions detailed in the RFP.

  Only companies registered in this tool will be invited to the tender.

- Step 3 – Tender Evaluation Process

  Tenderers proposals will be evaluated by an impartial evaluation committee of the IO. Tenderers must provide details demonstrating their technical compliance to perform the work in line with the technical scope and in accordance with the particular criteria listed in the RFP.

- Step 4 – Contract Award

  A Service contract will be awarded on the basis of the Best Value For Money methodology according to the evaluation criteria and methodology described in the RFP.

Procurement Timetable

The tentative timetable is as follows:

Milestone	Date
Publication of the Prior Indicative Notice (PIN)	7 January 2025
Submission of expression of interest form	28 January 2025
Invitation to Tender (ITT) advertisement	18 February 2024
Clarification Questions (if any) and Answers	21 March 2025
Tender Submission	1 April 2025
Tender Evaluation & Contract Award	April/May 2025

Contract Signature	May/June 2025

5 Quality Assurance Requirements

Prior to the commencement of any work under this Contract, a "Quality Plan" shall be produced by the Supplier and submitted to the IO for approval, describing how they will implement the ITER Procurement Quality Requirements.

6 Contract Duration and Execution

The ITER Organization shall award the Service Contract around May/June 2025. The estimated contract duration shall be 4.5 years.

7 Cost Range

This scope of work is identified at Cost Range **D** which is above 10 000 000 EUR.

8 Experience

The tenderer shall demonstrate their technical and industrial experience related to the scope of work as detailed in Annex I.

The working language of ITER is English, and a fluent professional level is required (spoken and written).

9 Candidature

Participation is open to all legal entities participating either individually or in a grouping/consortium. A legal entity is an individual, company, or organization that has legal rights and obligations and is established within an ITER Member State, being, the European Union (represented by EURATOM), Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA.

Legal entities cannot participate individually or as a consortium partner in more than one application or tender of the same contract. A consortium may be a permanent, legally established grouping, or a grouping which has been constituted informally for a specific tender procedure. All members of a consortium (i.e. the leader and all other members) are jointly and severally liable to the ITER Organization.

In order for a consortium to be acceptable, the individual legal entities included therein shall have nominated a consortium leader with authority to bind each member of the consortium, and this leader shall be authorised to incur liabilities and receive instructions for and on behalf of each member of the consortium.

It is expected that the designated consortium leader will explain the composition of the consortium members in its offer. Following this, the Candidate's composition must not be modified without notifying the ITER Organization of any change. Evidence of any such authorisation to represent and bind each consortium member shall be submitted to the IO in due course in the form of a power of attorney signed by legally authorised signatories of all the consortium members.

Any consortium member shall be registered in IPROC.

10 Sub-contracting Rules

All sub-contractors who will be taken on by the Contractor shall be declared together with the tender submission. Each sub-contractor will be required to complete and sign forms including technical and administrative information which shall be submitted to the IO by the tenderer as part of its tender.
The IO reserves the right to approve any sub-contractor which was not notified in the tender and request a copy of the sub-contracting agreement between the tenderer and its sub-contractor(s).
Sub-contracting is allowed but it is limited to one level and its cumulated volume is limited to 30% of the total Contract value.

EXPRESSION OF INTEREST & PIN ACKNOWLEDGEMENT

To be returned by e-mail to: Junhyung.park@iter.org copy to Andrew.Brown@iter.org

Company Name:_____

TENDER No.	**IO/25/OT/10030738/JPK**
DESIGNATION of SERVICES:	**Procurement of Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3**
OFFICER IN CHARGE:	**JunHyung PARK – Procurement Division ITER Organization**

☐ WE ACKNOWLEDGE HAVING READ THE PIN NOTICE FOR THE ABOVE MENTIONED TENDER

☐ WE INTEND TO SUBMIT A TENDER

Are you registered in Iproc (only entities registered in iPROC will be invited to tender)?:

☐ YES

Please indicate your registration number: ……

☐ NO, but we shall register before the indicated tender launch date

.....

Signature:

COMPANY STAMP

Contact person: .....

Position: .....

Tel: .....

E-mail.....

Date: .....

IDM UID
93FAL2

VERSION CREATED ON / VERSION / STATUS
23 Apr 2024 / 1.6 / Approved

EXTERNAL REFERENCE / VERSION

Technical Specifications (In-Cash Procurement)

Technical Specification of the DL

This document defines the technical specifications of the Duct Liner for Manufacturing procurement.

Table of Contents

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0 DEFINITIONS

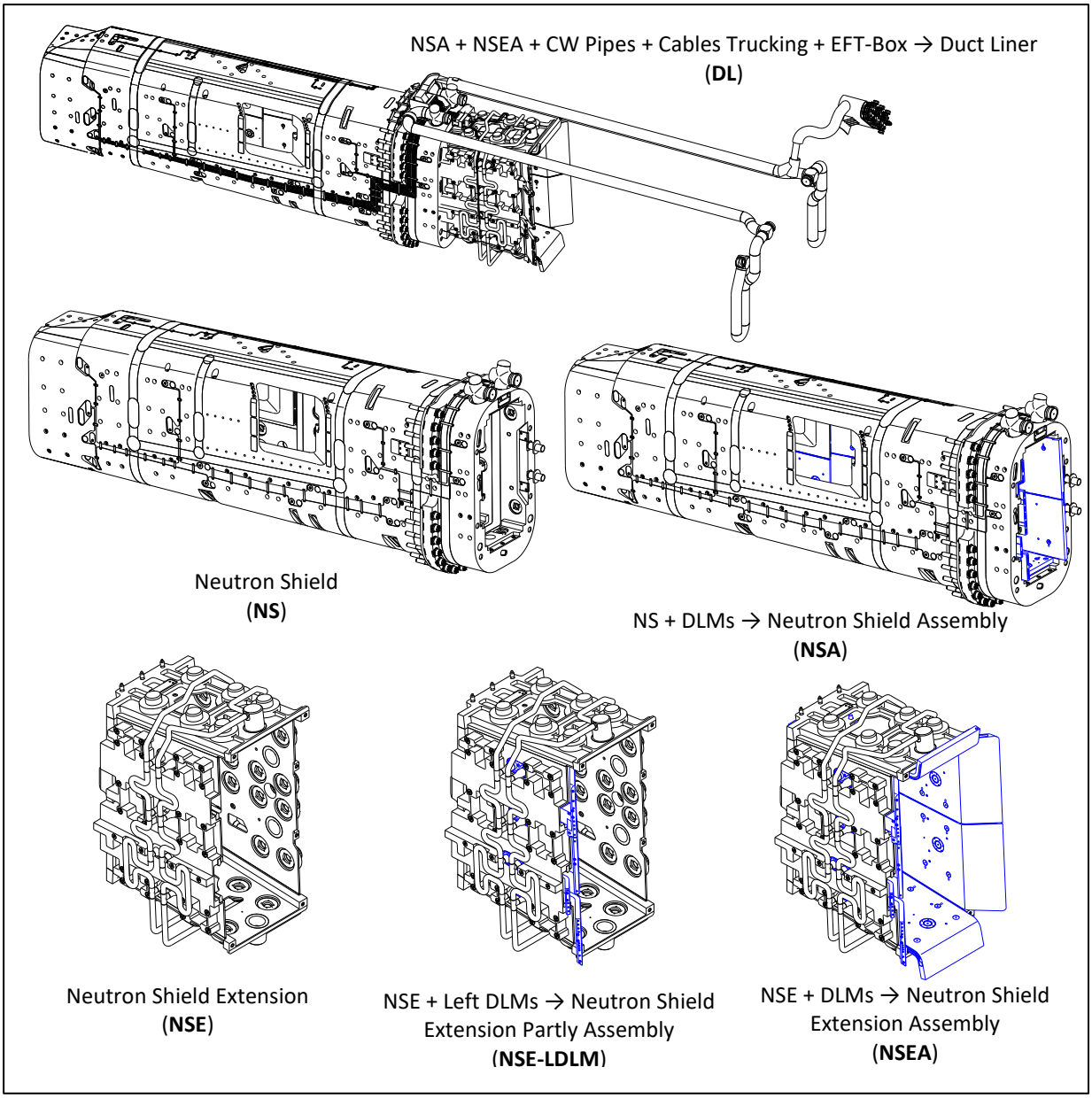

Figure 1: The Duct Liner naming definition illustrations

1 REQUIREMENT IDENTIFICATION

Each technical requirement in this technical specification is formally identified.

A requirement unambiguously starts with a paragraph containing the string [REQ-N], where N is the requirement number. Each requirement related to the annexure starts with a paragraph containing the string [Annexure REQ N].

2 SUBJECT

This document describes the technical requirements for procuring the HNB Duct Liner for Heating Neutral Beam (HNB) 1, 2, and 3. The PBS Node of each Duct Liner is 15NLP4 for the DL located in Port-4, 15NLP5 for the DL located in Port-5, and 15NLP6 for the DL located in Port-4.

The configuration of the HNB1 duct liner differs from others and allows the passing of the Diagnostic Neutral Beam (DNB) beam through the window provided in it, while the configuration of duct liners for the HNB#2 and the HNB#3 are identical.

This technical specification is a part of IO direct Procurement and provides all technical requirements related to the scope of supply, schedule, code and standards, regulatory requirements, manufacturing requirements, and acceptance requirements of all three Duct Liners (DL).

The DL I&C procurement is not part of this technical specification. However, the assembly of the I&C is part of this procurement. I&C includes Feed-Through-Box and Trucking, Cables, Connectors, and Thermocouples.

2.1 The function of the procurement

The procurement of the HNB DLs includes:

- Manufacturing the components for the injectors HNB1, HNB2 and HNB3.
- The delivery on the IO site.

The IO was responsible for carrying out the Final Design phase in compliance with the requirements as defined in the System Requirement Document (SRD) [RD1], Load Specification (LS) [RD2], and following the Design Review Procedure [RD3]. As such, ITER Organization (IO) is the Manufacturer in terms of equipment safety.

[REQ-1] Based on Build to Print (BtP) documentation provided by IO, the Manufacturer shall demonstrate that the related acceptance criteria are met.

2.2 Description of the system

2.2.1 Overview of Neutral Beam (NB) system

The ITER Tokamak is the latest step in progress toward realizing fusion energy. Several heating systems heat the plasma contained by the magnetic fields within the Tokamak. One such system is the neutral beam system, which projects neutral hydrogen isotope atoms into plasma at high energy. In addition, the neutral beam system can also be used to provide diagnostic information on the condition of the plasma.

The neutral beam system for ITER consists of two heating and current drive neutral beam injectors and a diagnostic neutral beam injector. The proposed physical plant layout allows a possible third HNB injector to be installed later.

The HNB system contributes to the fusion rate by heating the plasma and driving the current, a steady-state operation requirement. The beam extraction voltage is 1 MV, which is required primarily to obtain sufficient plasma penetration and current drive and maximize each injector's power. A Deuterium ion beam of 40 Amps is neutralized in each injector to form a D0 neutral beam, which delivers 16.7 MW to the plasma. Thus, the HNB system provides 33 MW from 2 injectors, with an optional upgrade to 50 MW with a third HNB injector. The HNB system operates for long-duration pulses of up to 3,600 seconds and rests for 10,800 seconds before starting to work. The HNB system operates for long-duration pulses of up to 3,600 seconds and rests for 10,800 seconds before starting to operate. Figure 1 shows the top view of the NB Cell, including three HNB and a Diagnostic Neutral Beam (DNB).

HNB injectors consist of several components, including context components (i.e., Duct Liner), as shown in Figure 3.

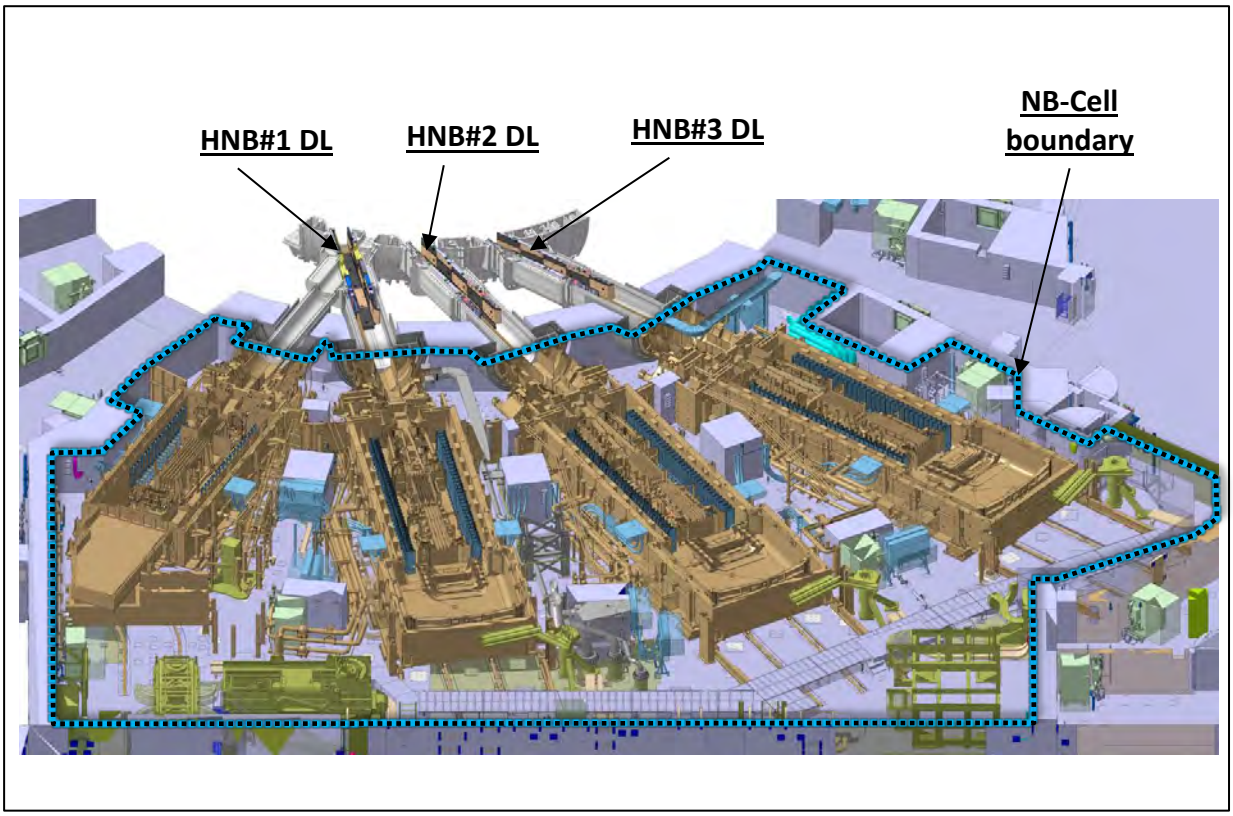

Figure 2: Overview of NB Cell

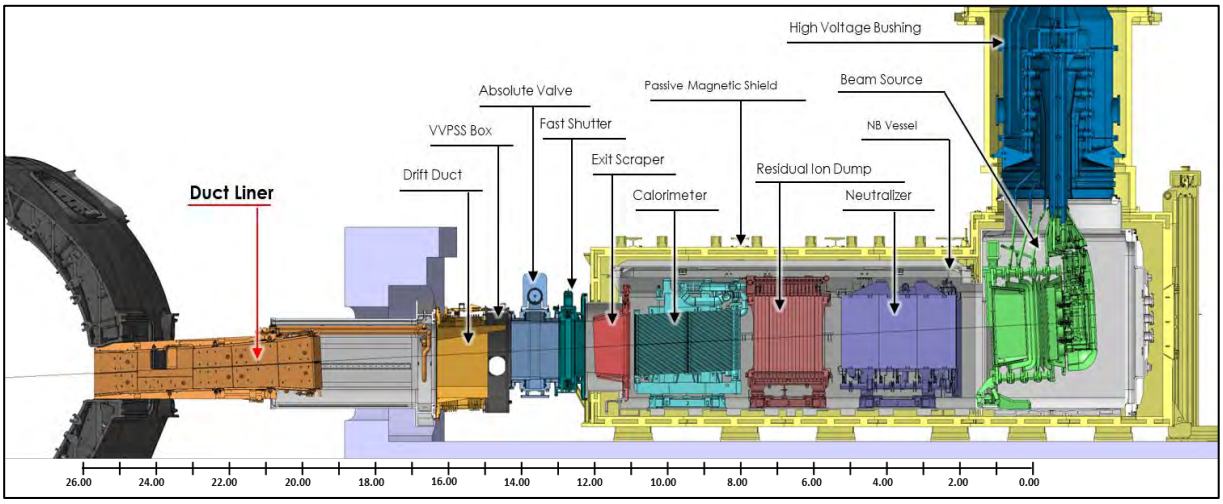

Figure 3: HNB Injector Components

2.2.2 Description of the component in context (Duct Liner)

Duct liners are localized in Sector 2 and Sector 3 of the Vacuum Vessel (VV), located within the Tokamak VV port extension, and mounted on the VV port extension flange, as shown in Figure 4 and Figure 5.

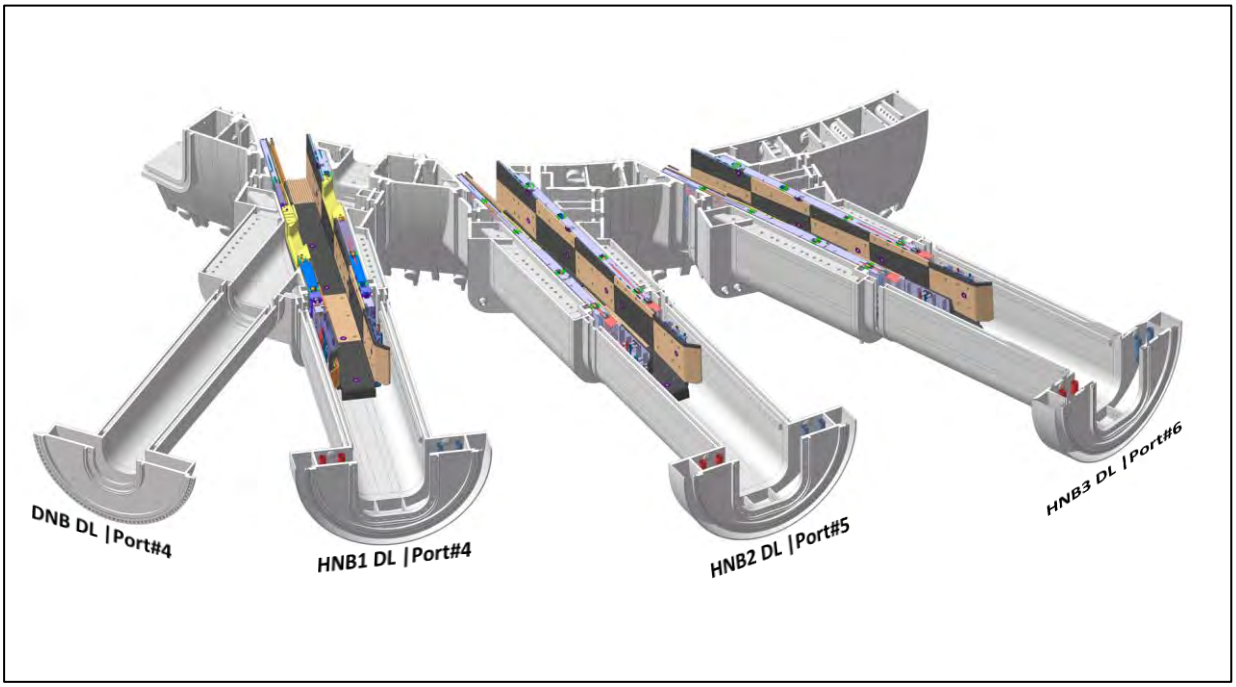

Figure 4: Cross section of HNB#1, HNB#2 and HNB 3 DL assemblies

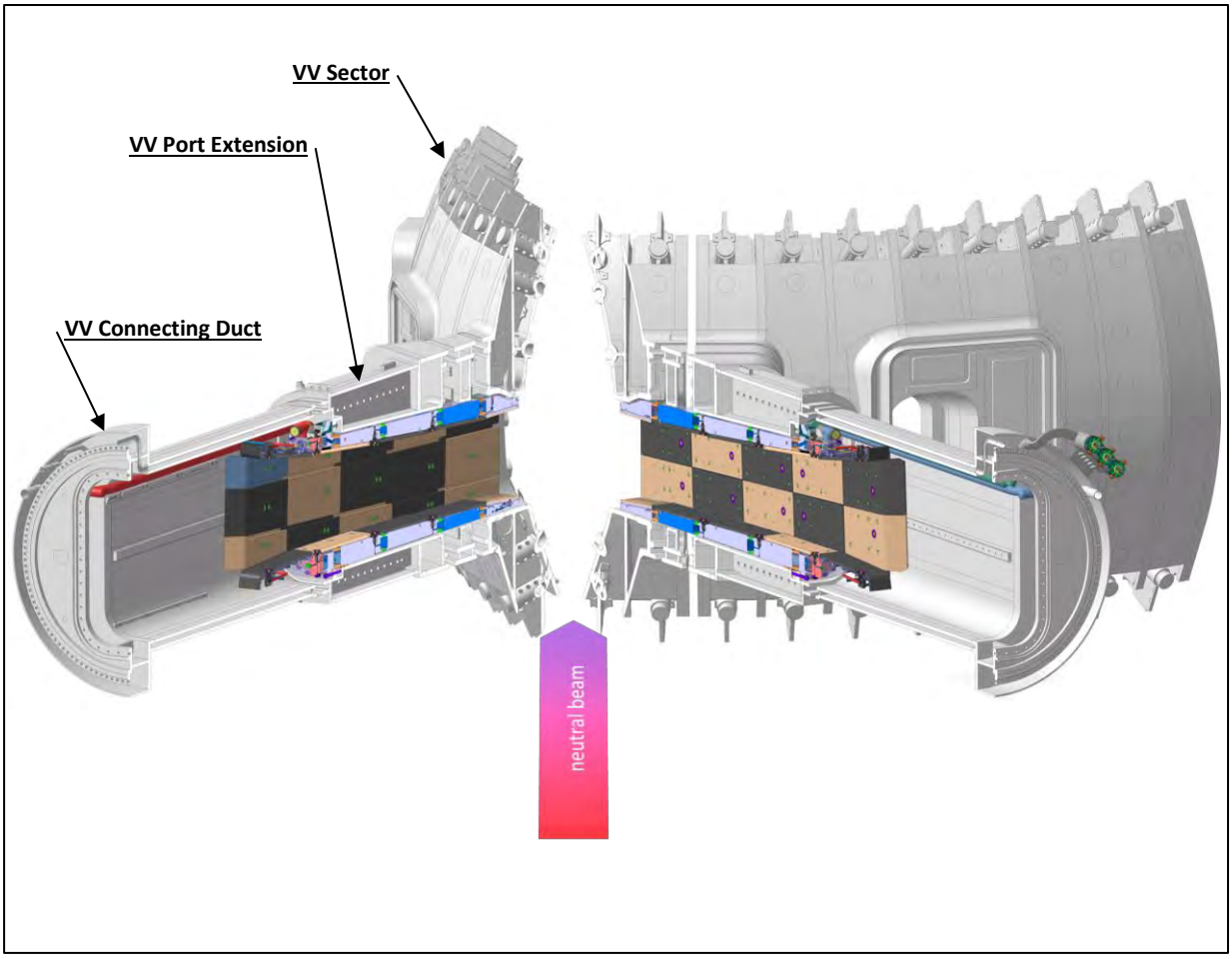

Figure 5: Duct liner location

2.2.2.1 Overall functions

Duct liners have the following significant functions.

- Define the edge of the beamline by absorbing the fringe of the HNB and DNB beams to protect the Vacuum Vessel (VV) from direct interception.
- Protect the HNB ducts against NB direct interception and re-ionization.
- Incorporate a Neutron Shield to mitigate neutron damage and heat loads to adjacent components. In particular, the neutron shield contributes as far as practicable to the radiation shielding of the Toroidal Field (TF) coils and shielding of the field welded joints between port components.

2.2.2.2 Design Description

The Duct liner is made of 5 principal sub-assemblies named Neutron Shield (NS), Duct Liner Modules (DLM), NSE, Instrumentation (DL feedthrough box, trucking, thermocouple cables), and DL cooling circuit (inlet /outlet cooling water pipes), as shown in Figure 6.

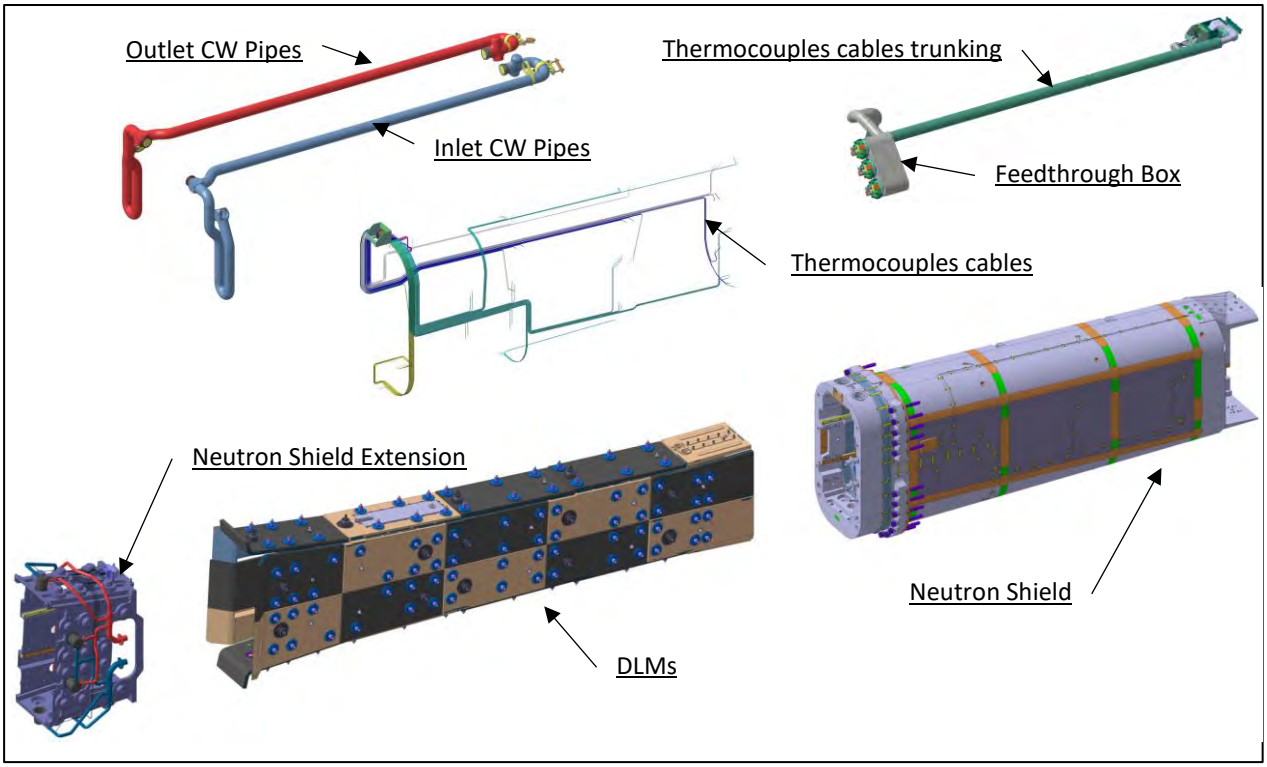

Figure 6: HNB Duct Liner sub-assemblies

2.2.2.2.1 NS

The NS is a welded assembly of deep-drilled machined blocks made of 316L(N)-IG, as shown in Figure 7. Neutron shield has the first function to provide radiation shielding of TF coils and filed welded joints between port components, and the second is to limit NS damage and heat loads to the surroundings of the VV port extension.

The NS also provides the supporting structure for the DLM and allows the flow to the DLM. The design of the NS incorporates large grooves generated by the manufacturing process used to assemble the different blocks. These large grooves are reused as water boxes cooling channels for the inlet circuit.

The NS has one support flange intended to be mechanically fixed to a mating flange on the VV Port extension. This interface supports the DL's main weight, and the twisting torques induced during the disruption. An additional machined flat plate on the bottom of the shield mates with a VV port plate. The structure of NS for HNB#1 DL is slightly different from others where a window has been provided to allow the passing of Neutral Beam.

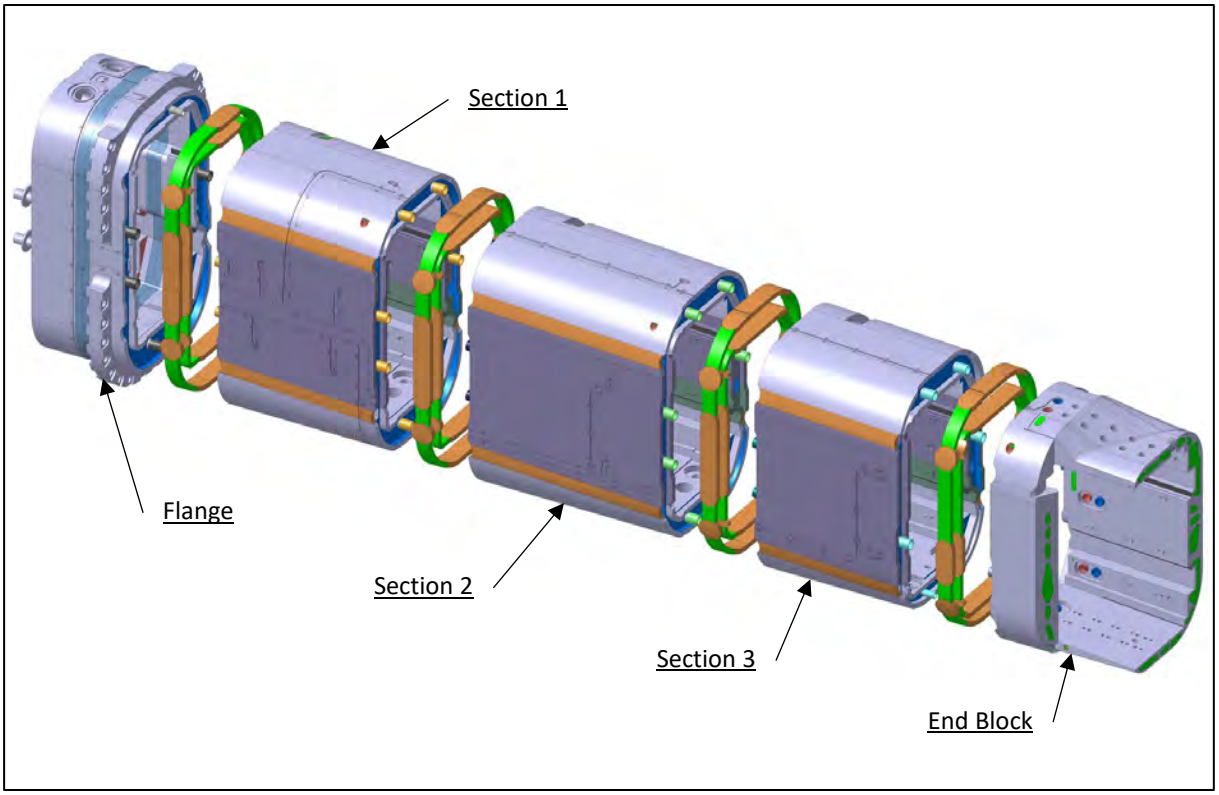

Figure 7: Neutron Shield Assembly (NS)

2.2.2.2.2 DLM

The DLMs are actively water-cooled using deep drilled channels that protect the duct from Neutral Beam interception, and plasma heating dissipates heat through the cooling system. DLM Panels are made from CuCrZr and SS 316L(N)-IG material depending on its position and power deposition. These panels are bolted to the NS. The exact size and profile of the various DLMs vary through the DL to accommodate changes in geometry and loading. Due to a configuration change, the number of DLM differs for HNB#1 DL (total of 40) from the other two DLs (total of 35 for each DL). The DLMs are classified as Remote Handling (RH) class 2 (RHC2) and RH class 3 (RHC3), depending on the power loading handled and the probability of failures. Configurations (cooling pattern and bolting methods) differ for both DLM types, as shown in Figure 8 and Figure 9.

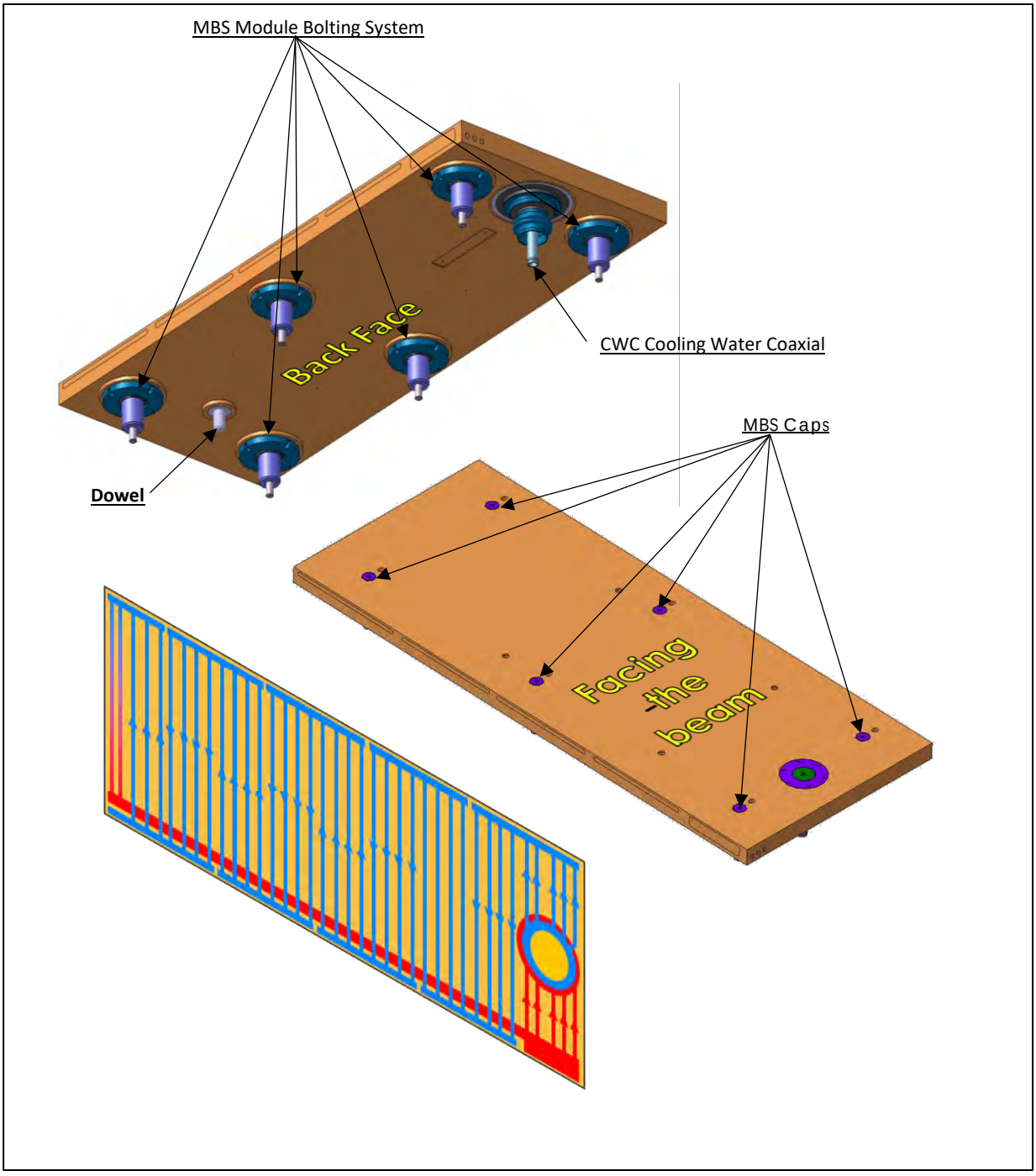

Figure 8: Typical DLM configuration – RH Class 2

For DLM RHC2, water flow and return are co-axial through the coaxial water pipe connection (CWC) provided on the panel, where water is fed through a central pipe while the return flows in an annular section, as shown in Figure 8. However, DLM RHC3 panels are designed so that water flow and return are independent, as shown in Figure 9.

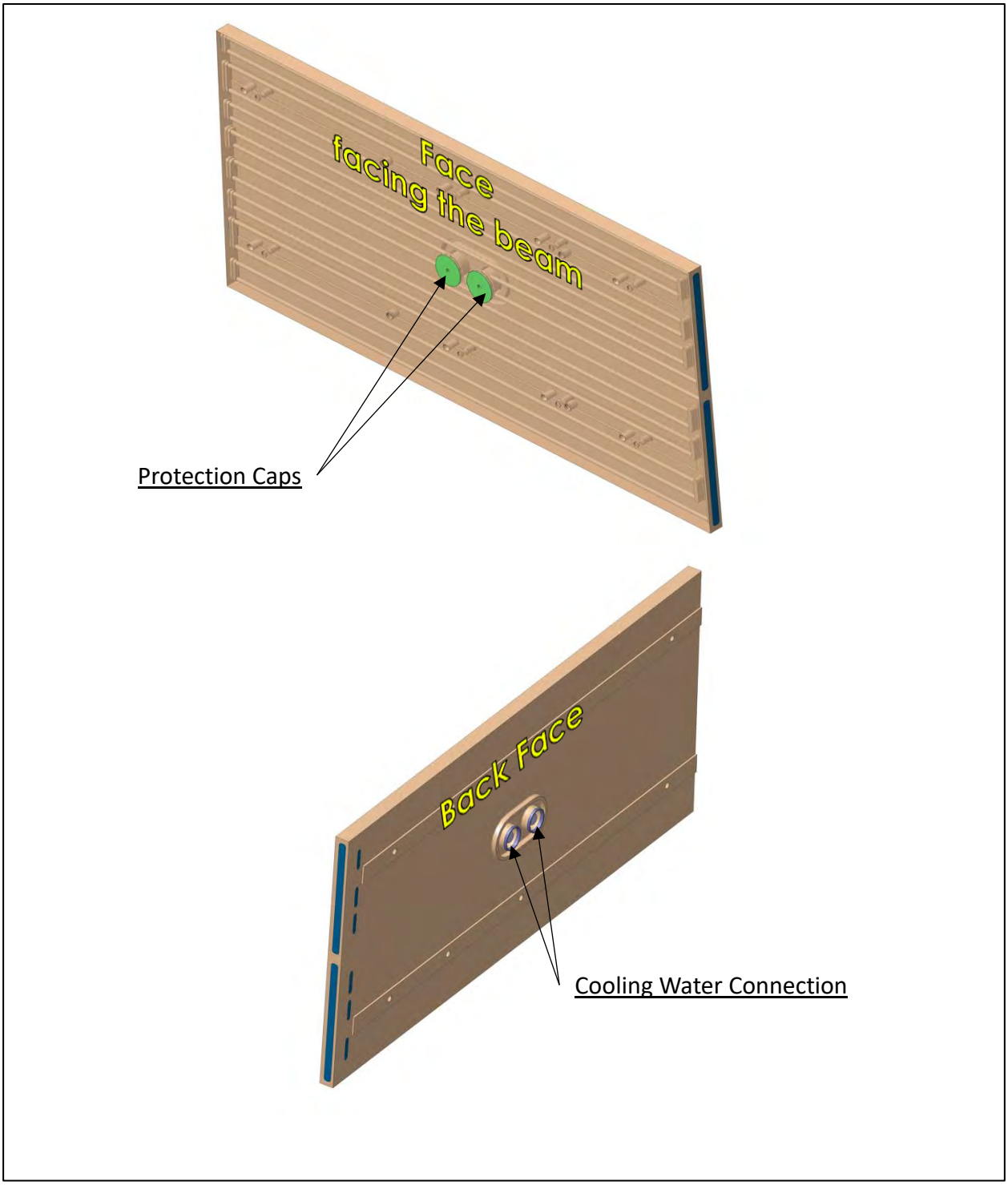

Figure 9: DLM Panels configuration – RH Class 3

Further, DLM RHC2 panels were bolted to the NS through 6 Modular Bolting Systems (MBS) for each panel while DML RHC3 panels were fixed through eight bolts fixed from the NS outside. MBS and CWC are designed to take all the expected operational loading conditions defined in the Load Specification [RD2]. In addition, ITER has launched a dedicated test program to prove the feasibility and reliability of the MBS and CWC connections for all expected operational scenarios. Details of the MBS and CWC connection configuration and its test program requirement can be referred to in technical specifications [RD4] and [RD5].

2.2.2.2.3 DLM Arrangement:

DLMs are arranged in HNB#1 and HNB#2 and 3, as shown in Figure 9, and Figure 11.

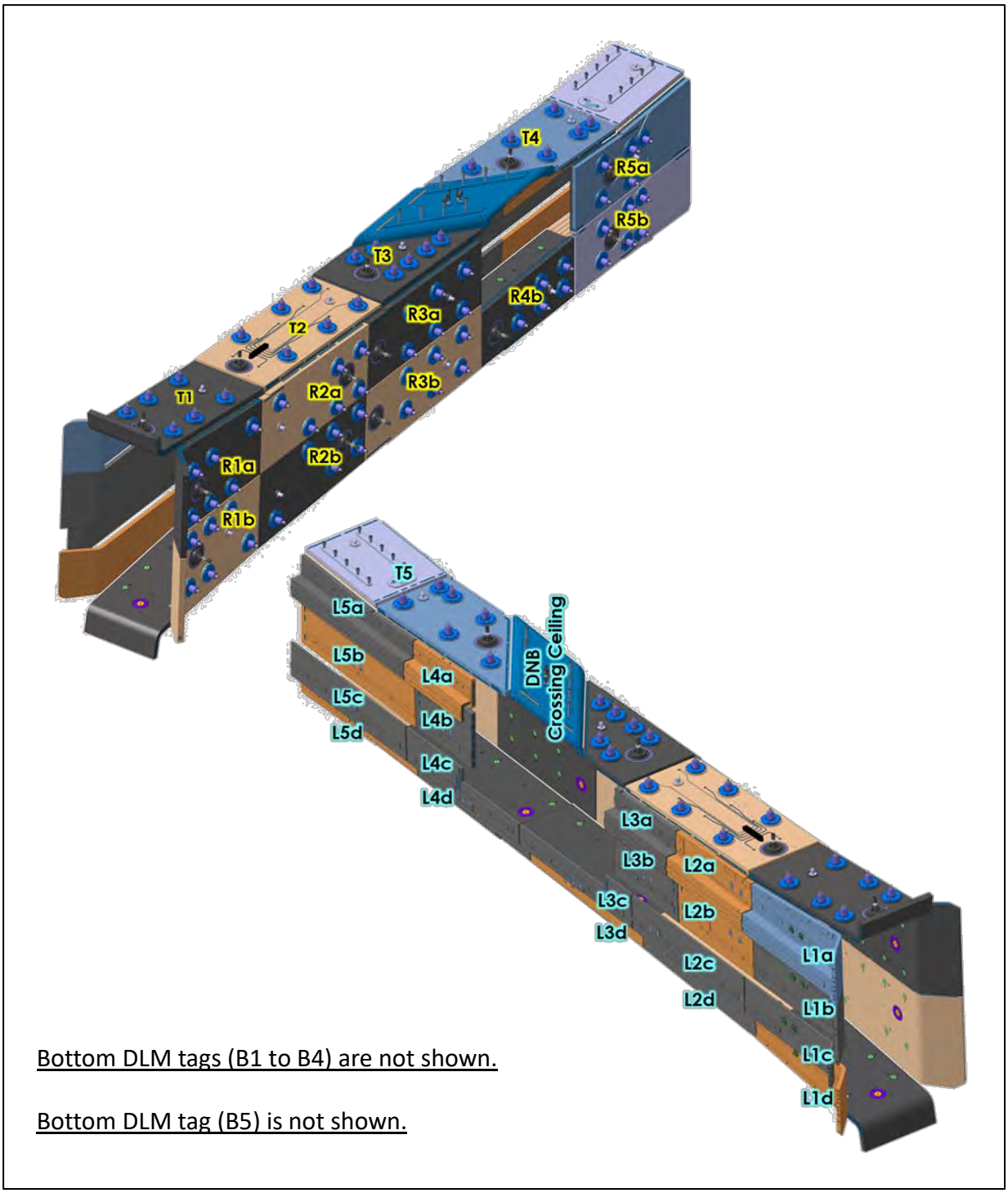

Figure 10: DLM Panels arrangement in HNB#1 DL

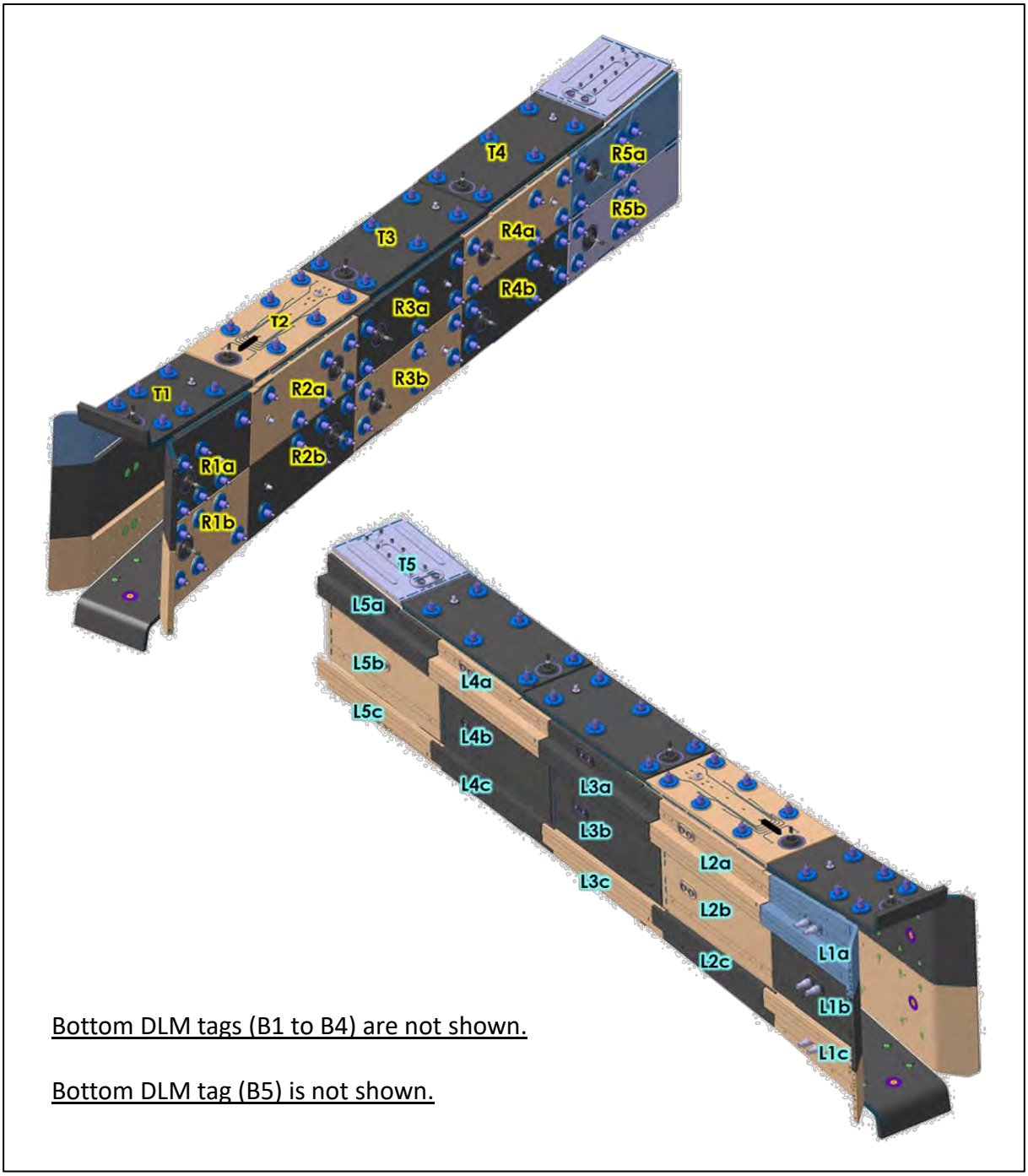

Figure 11: DLM Panels arrangement in HNB#2 and HNB#3 DL

DLM are numbered according to their potions in the DL as follows:

- Top DLM: T1 to T4 (RH Class 2) and T5 (RH Class 3)
- Bottom DLM: B1 to B4 (RH Class 2) and B5 (RH class 3)
- Right Side DLM: Start with suffix R. R1… Rx (RH Class 2)
- Left Side DLM: Start with suffix L. L1 … Lx (RH Class 3)
- In addition, the base material of DLM is selected based on the power loads they are expected to handle. For example, DLM T1 to T4 and B1 to B4 are made of CuCrZr, while all other DLM are made from SS 316LN-IG.

2.2.2.2.4 HNB#1 DL: DNB Entrance and Exit Windows

A dedicated window has been designed in Figure 12 to allow the passage of the DNB beam through the HNB#1 DL. The DNB window is made of a massive forged part of SS 316LN IG with a 2 mm copper layer (which could be realized by explosion bonding or electrodeposition) to distribute the heat load on its surface to enhance cooling evenly.

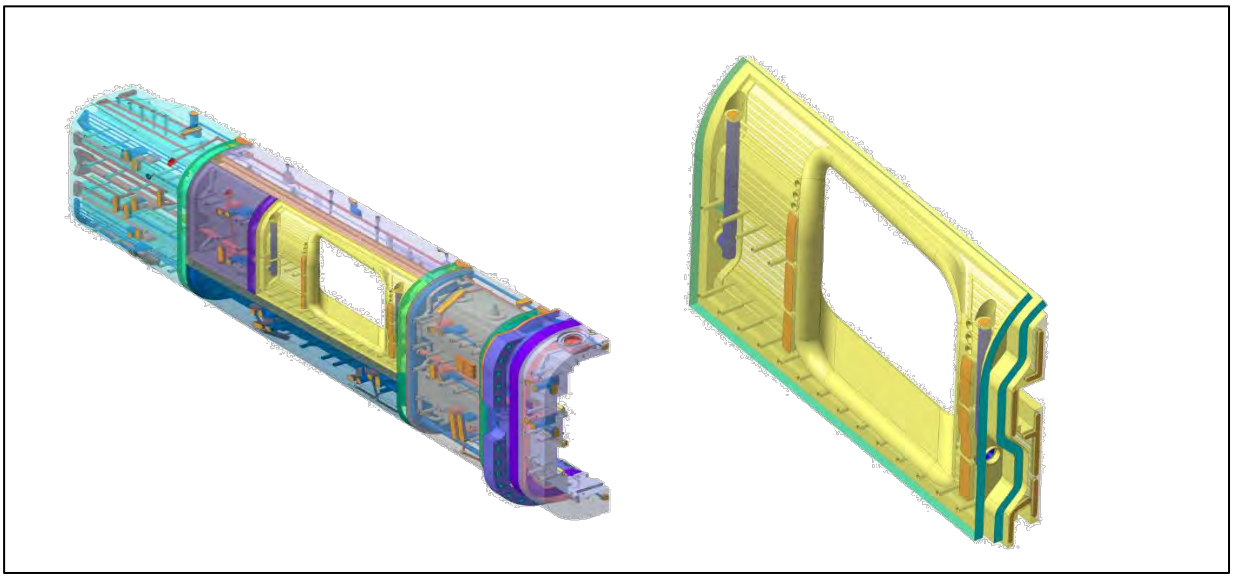

Figure 12: DNB Entrance and Exit window in HNB#1 DL

2.2.2.2.5 Cooling water:

The IBED PHTS circuit services the coolant circuit of the DLM and the NS via pipework routed along the connecting duct, as shown in Figure 13. This cooling network has a function to dissipate the heating energy intercepted by the DL subcomponents. Two DN100 pipes are used for the coolant feed and return.

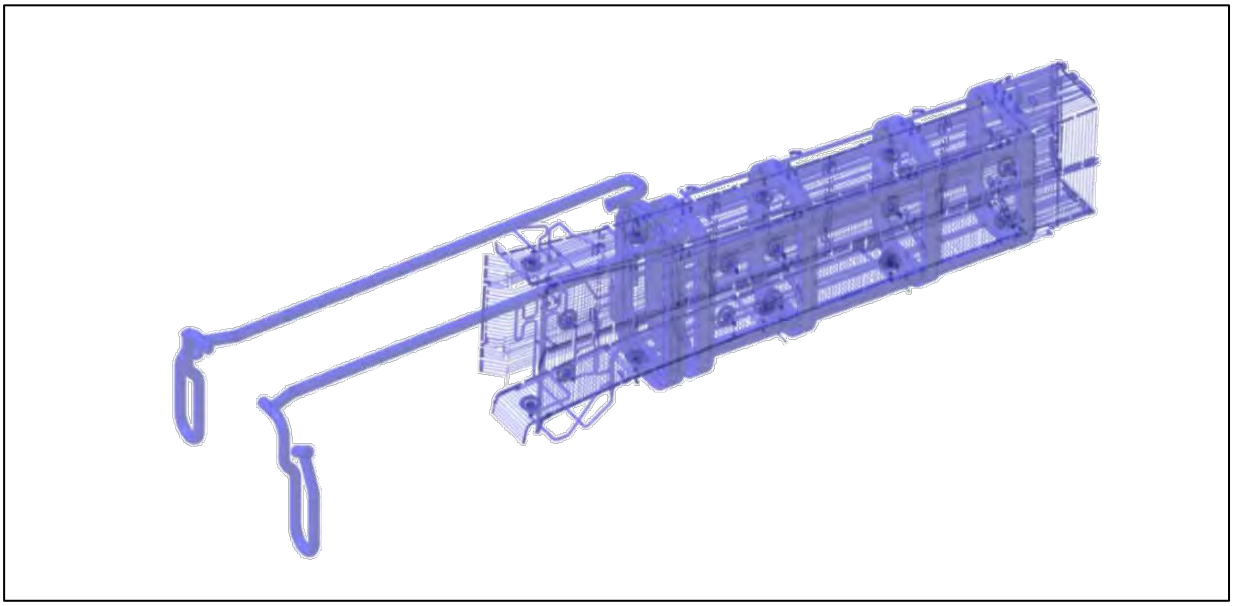

Figure 13: Cooling water network of HNB DL

2.2.2.2.6 NSE

The NSE comprises a frame comprising welded 316L(N)-IG plates. These contain additional bosses that replicate the bolt and coaxial water feed features present in the NS. The frame slides into the NS and is bolted along the top and bottom of the duct cavity.

The water is distributed around the frame primarily by a pipe network, providing flow to the DLMs in parallel. The main inlet and outlet headers of the extension, located on the right-hand side, are connected to the cooling manifolds of the main DL body.

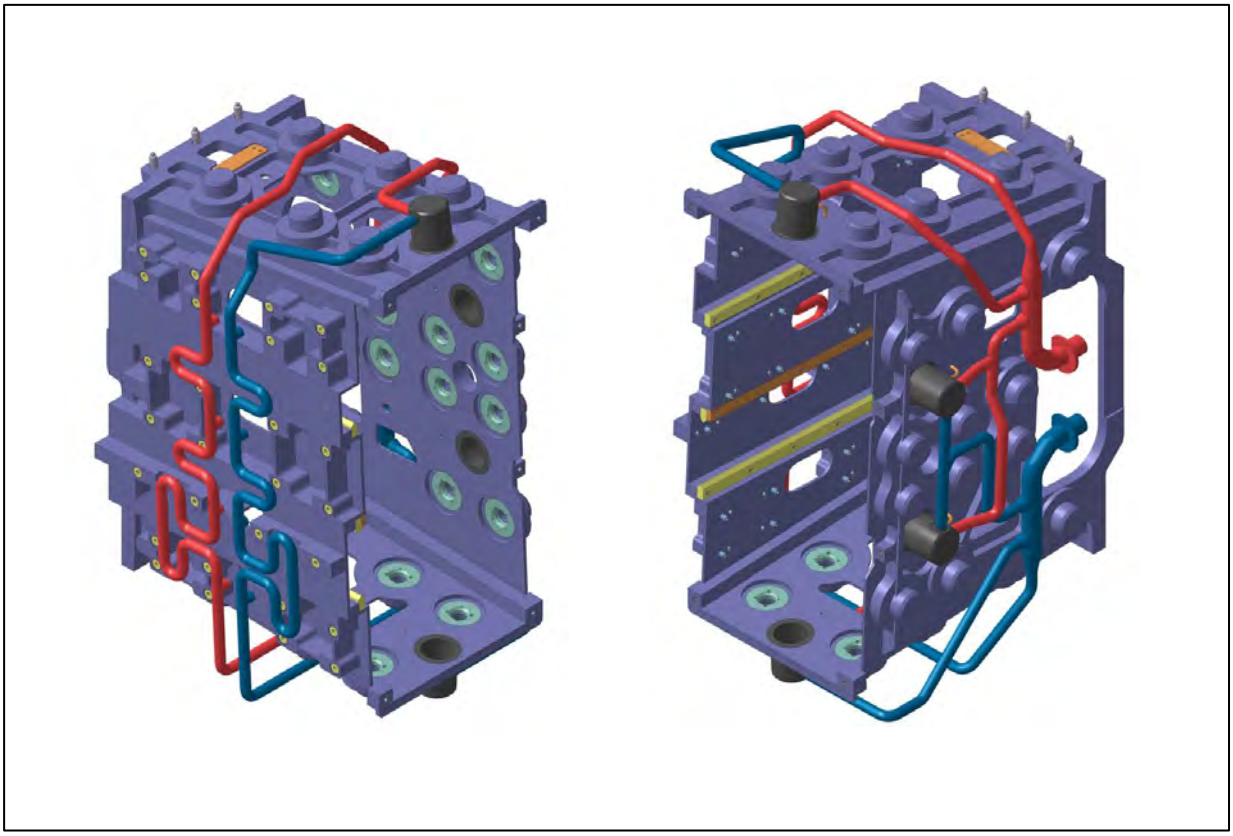

Figure 14: NSE isometric view

2.2.2.2.7 Instrumentation

Monitoring of the temperatures of some DLM and coolant temperatures is done through dedicated thermocouples. These instrumentation cables housed in the trunking pass through the dedicated feedthrough, which is mounted on a VV connecting duct flange by welding, forming the first confinement boundary. All instrumentation is connected to the CODAC system.

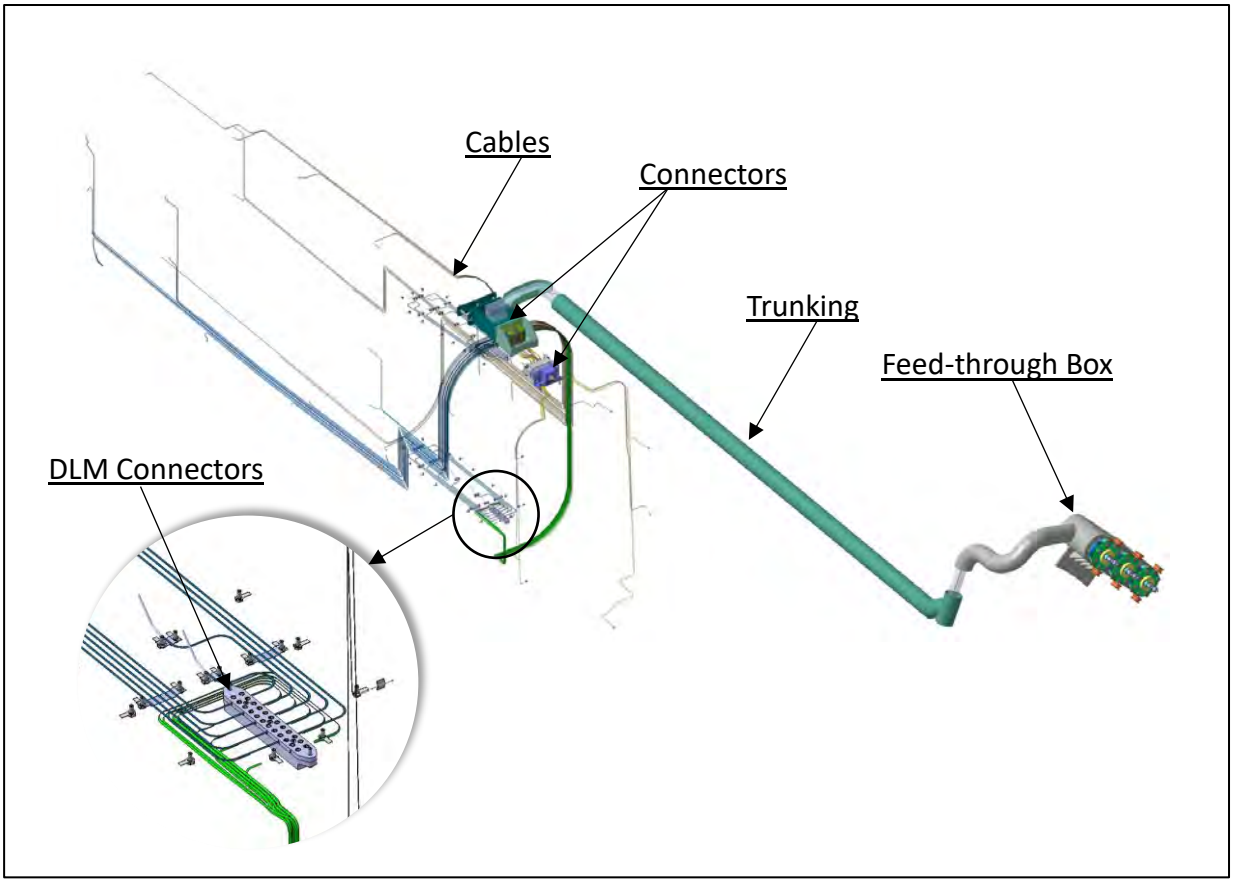

Figure 15: Instrumentation Overview

2.3 System Classifications and Applicable Codes & Standards

The DL Development Requirement Document (DRD) [AD1] defines the system classification based on the criteria and requirements specified in various ITER reference documents. In addition, system classifications and applicable codes and standards for each sub-component have been detailed in Table 1.

The design and manufacturing code selected for the Duct Liner follows the guidelines in the Code and Standards for ITER Mechanical Components [AD2].

Additionally, the DL is considered excluded from PED as per the stipulations in the document [AD26].

[REQ-2] For the component classified as “Non-SIC”, the Manufacturer can select either the RCC-MR, the ASME, or the EN as a manufacturing code and shall obtain an agreement from ITER before starting the manufacturing activity.

[REQ-3] The Manufacturer shall follow the RCC MR for the SIC component.

[REQ-4] The Manufacturer shall use the latest standards edition (as referred to in the selected manufacturing code) for the various manufacturing processes, e.g. material procurement, cleaning, fabrication, welding, testing, etc.

[REQ-5] In a conflict between technical specifications and the selected manufacturing code, technical specification requirements shall prevail over the chosen code.

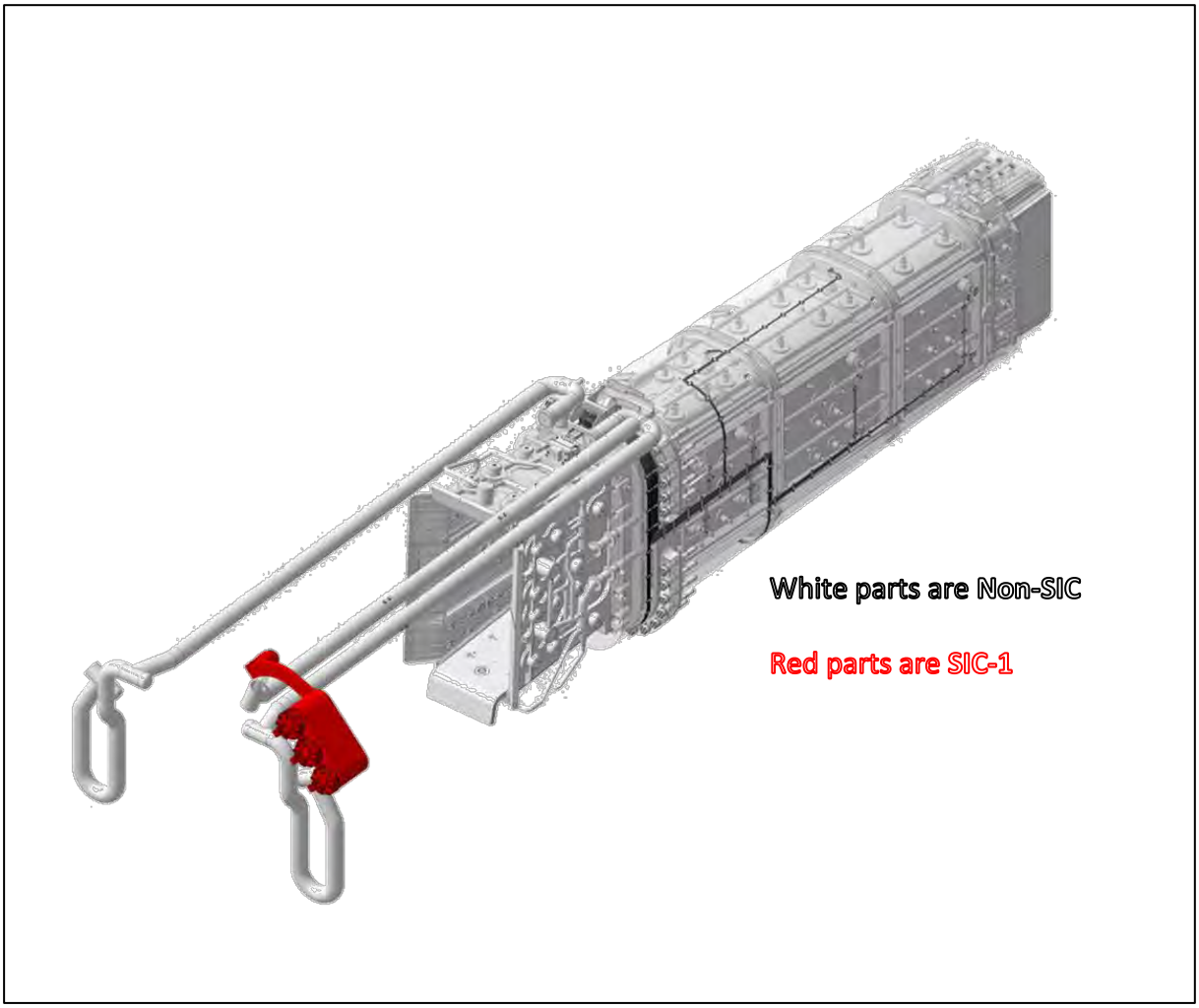

Figure 16: DL Safety Classification

Sub-assembly	Sub-components Description	Safety class [AD3]	Quality Class [AD4]	Seismic Class [AD5]	RH Class [AD6]	Vacuum [AD7]	Tritium Class [AD8]	Design Code	Manufacturing Code
Neutron Shield (NS)	Neutron Shield (NS) DNB-Entrance; DNB-Exit (only for HNB1)	Non-SIC	QC1	SC1(S)	Class3	VQC 1A	1A	SDC-IC	RCC-MR / ISO /ASME / EN
Duct Liner Modules (DLM)	T1; T2; T3; T4; B1; B2; B3; B4; R1a; R2a, R3a; R5a; R1b; R2b, R3b; R4b; R5b;	Non-SIC	QC1	SC1(S)	Class2	VQC 1A	1A	SDC-IC	RCC-MR / ISO /ASME / EN
	T5; B5; L1a; L2a; L3a; L4a; L5a; L1b; L2b; L3b; L4b; L5b L1c; L2c; L3c; L4c; L5c; L1d; L2d; L3d; L4d; L5d	Non-SIC	QC1	SC1(S)	Class3	VQC 1A	1A	SDC-IC	RCC-MR / ISO /ASME / EN
Duct Liner Extension (DL-Ext)	DL-Ext	Non-SIC	QC1	SC1(S)	Class3	VQC 1A	1A	SDC-IC	RCC-MR / ISO /ASME / EN
Main Water Pipes	Inlet Pipe Outlet Pipe	Non-SIC	QC1	SC1(S)	Unclassified	VQC 1A	1A	SDC-IC	RCC-MR / ISO /ASME / EN
Instrumentation	Feedthrough Box	SIC	QC1	SC1(S)	Class3	VQC 1A	1A	RCC-MR	RCC-MR / ISO /ASME / EN
	Thermocouples	Non-SIC	QC2	SC1(S)	N/A	N/A	1A	N/A	RCC-MR / ISO /ASME / EN
	Connectors	Non-SIC	QC2	SC1(S)	N/A	VQC 1A	1A	N/A	RCC-MR / ISO /ASME / EN
	Cables Trunking	Non-SIC	QC2	N/A SC1(S)	N/A	VQC 1A	1A	SDC-IC N/A	RCC-MR / ISO /ASME / EN

Table 1: Classification of the Duct Liner

2.4 CAD Models

The detailed model of the 3 DLs is stored in Enovia, as shown in Figure 17.

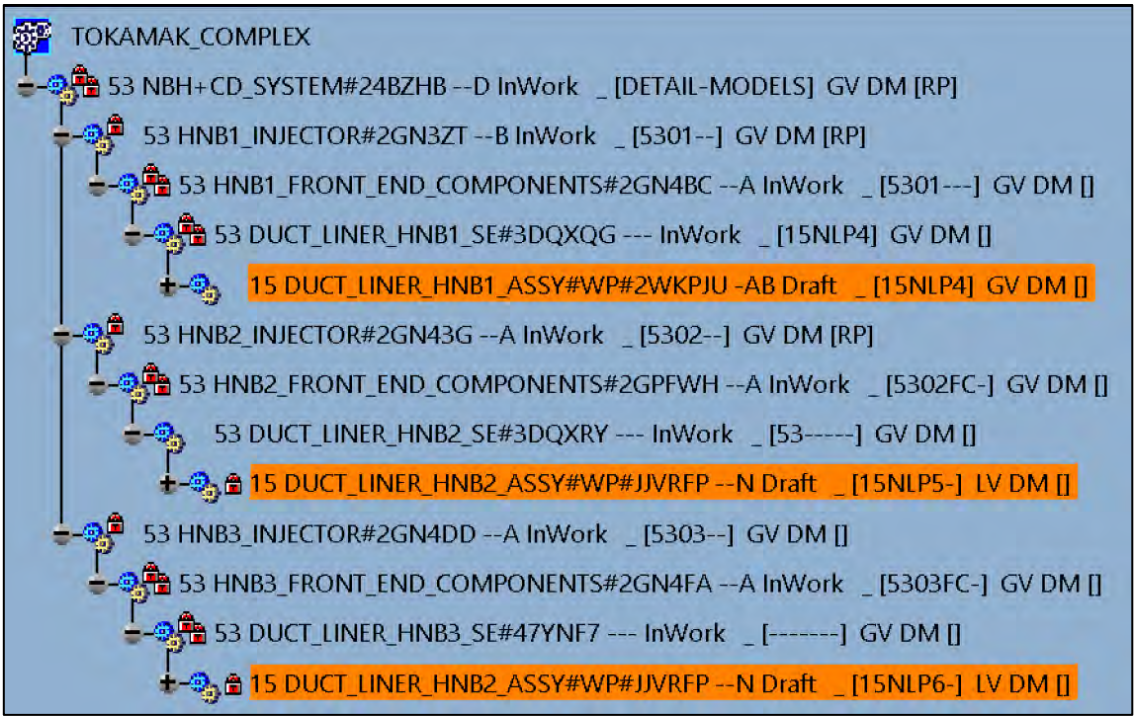

Figure 17: DM location in Enovia

3 SCOPE OF THE TECHNICAL SPECIFICATION

The scope of essential supply includes the procurement and delivery of all the items listed in sections 3.1, 3.2, and 3.3 (Document Deliverables) in this document.

3.1 Scope of supply

[REQ-6] The Duct Liners assembly consisting of the following items, as shown in Table 2, shall be supplied to IO.

[REQ-7] In Table 2, the main sub-assemblies are listed. The detailed Bill of Material in the BtP Drawings shall be considered the scope of supply.

Sl.no.	Main items	Quantity
1	Duct Liner Assembly for HNB#1 Injector	01 Set
	- Neutron Shield (NS) assembly, including DNB entrance and Exit Window	
	- DLM Panels (RH Class 2 and RH Class 3)	
	- Duct Liner Extension	

	- Main Water pipes	
	- Feedthrough Box	
	- I&C*	
2	Duct Liner Assembly for HNB#2 Injector	01 Set
	- Neutron Shield (NS) assembly	
	- DLM Panels (RH Class 2 and RH Class 3)	
	- Duct Liner Extension	
	- Main Water Pipes	
	- Feedthrough Box	
	- I&C*	
3	Duct Liner Assembly for HNB 3 Injector	01 Set
	- Neutron Shield (NS) assembly	
	- DLM Panels (RH Class 2 and RH Class 3)	
	- Duct Liner Extension	
	- Main Water pipes	
	- Feedthrough Box	
	- I&C*	

4	All the jigs and fixtures, special tooling, and blind flanges are to be used for inspection and final acceptance tests (these are to be supplied at the IO site along with the components and shall remain the property of the IO)	As applicable
5	Spares to be delivered to the IO site: Modul Bolting System (MBS) – 6 per DL (in total 18). Cooling Water Coaxial (CWC) – 1 per DL (in total 3). Base plate of CuCrZr (Dimension – overall dimension of the whole DLMs) – 3 plates in total. (Fasteners, thermocouples, etc.) – 20% of the actual requirements of BOM	
*: The DL I&C procurement is not part of this technical specification. However, the assembly of the I&C is part of this procurement. I&C includes Feed-Through-Box and Trunking, Cables, Connectors, and Thermocouples.		

Table 2: List of Hardware items

3.2 Scope of Work of this technical specification

The detailed scope of work under this procurement is as follows.

[REQ-8] This procurement shall comprise the Duct Liner assemblies for HNB#1, HNB#2, and HNB 3 injectors.

[REQ-9] All engineering required for DL manufacturing shall comply with this technical specification's requirement and selected manufacturing code.

[REQ-10] The manufacturer shall select the appropriate manufacturing process to achieve the desired requirements as specified by this technical specification, engineering drawings, and critical functional tolerances.

[REQ-11] The Manufacturer shall perform a manufacturing design assessment to evaluate the manufacturing feasibility and prepare manufacturing/fabrication drawings based on the BtP design (engineering drawings/3D CAD models) provided by IO.

[REQ-12] The Manufacturer shall define the need for prototype/mock-ups, based on the manufacturing feasibility study, to address the critical manufacturing aspects of DL and qualify them before the start of the relevant manufacturing process.

[REQ-13] As specified in ITER Procurement Quality Requirement [AD9], the Manufacturer shall produce a Quality Plan (QP) and Manufacturing and Inspection Plan (MIP) and submit them to IO for acceptance before the start of any manufacturing activity.

[REQ-14] The Manufacturer shall provide manufacturing and inspection procedures, qualification procedures, and quality assurance documents (as listed in section 3.3) to set the manufacturing process defined in the ITER Procurement Quality requirements [AD9], including the welders and NDE Operator's qualification.

[REQ-15] The Manufacturer shall provide engineering design and analysis, manufacturing, and supply of jigs, fixtures, and tooling required for the assembly, inspection and testing, disassembly, and transportation of Duct Liner assemblies.

[REQ-16] The manufacturing plan shall include all aspects of manufacturing, including material procurement, cutting, forming, welding, inspection, marking, and cleaning, complying with the requirements of this technical specification and relevant appendices.

[REQ-17] All necessary raw materials and procured items shall be acquired following Annexure 1.

[REQ-18] Materials, parts, components, and assemblies shall undergo Testing and Inspection at suitable stages as defined by this technical specification.

[REQ-19] The factory acceptance test shall comply with section 8.2 before packing and shipment of the component.

[REQ-20] Cleaning of Duct liner assemblies shall comply with Annexure 6.

[REQ-21] Pickling and passivation of Duct Liner assemblies shall comply with the requirements of section 7.6.15.

[REQ-22] The assembly and disassembly plan of the Duct liner assembly shall be developed and submitted to IO for acceptance before the DL assembly activities start.

[REQ-23] Duct Liner assemblies' Blowout, drying, and baking shall comply with the technical specifications.

[REQ-24] Packing and Shipment of the component to the IO site shall follow Chapter 9 of this technical specification.

[REQ-25] The Manufacturer shall liaise with the IO for the identified Manufacturing Inspection Plan (MIP) interventions during manufacturing and final acceptance test of the components delivered to the IO.

[REQ-26] At the end of factory fabrication, the Manufacturer shall prepare a contractor release note document, including a certificate of compliance, justification/tracking of non-conformance, and the IO acceptance through a tracking sheet.

[REQ-27] The Manufacturer shall perform gate reviews (e.g. Manufacturing Readiness Review and Delivery Readiness Review) complying with the IO System engineering management plan [RD6] at the appropriate contract execution stage.

[REQ-28] The Manufacturer shall participate in the final acceptance test performed by IO at the IO site.

[REQ-29] The IO shall grant the Final acceptance, if the entire scope is successfully completed by the Manufacturer.

[REQ-30] The Manufacturer shall prepare the as-built drawings and 3D CAD incorporating all the modifications and amendments resulting from all the activities up to the on-site assembly and testing.

3.3 Document Deliverables

[REQ-31] All contractual deliverables shall be uploaded by the manufacturer on the ITER IDM database for review and approval by the ITER Organization.

[REQ-32] The structure of the folder in the IDM database shall be agreed upon among the Manufacturer and ITER organization.

[REQ-33] The Duct Liners shall be supplied with all the manufacturing and quality documentation (as referred to in this section) required to satisfy reviews, validations, verifications, and other regulatory and licensing activities.

Document Description	Issued by	Approver	Reference	Comment
Phase 1: Pre-Production				
Schedule	Manufacturer	IO		
Quality Plan (supplier and Major sub-suppliers)	Manufacturer	IO	[AD10]	
Manufacturing and Inspection Plan	Manufacturer	IO	[AD11]	
List of sub-suppliers	Manufacturer	IO		
Manufacturing drawings and Bill of Material	Manufacturer	IO		Based on manufacturing design and engineering drawings supplied along with technical Specifications,
Weld Plan	Manufacturer	IO	Annexure 2 and Annexure 3	
Purchase order for material procurement	Manufacturer			
Material Specification (if any)	Manufacturer	IO	Annexure 1	
Phase 2: Manufacturing Readiness Review (MRR)	Manufacturer			
Welding data package including Welding procedure specification (WPS), Welding procedure qualification records (WPQR), and welder/welding operator qualification record (WPQ)	Manufacturer	IO	Annexure 2 and Annexure 3.	See details in Annexure 2 and Annexure 3.
Manufacturing and QA Procedures (as follows)	Manufacturer	IO		
- Identification and traceability	Manufacturer	IO	[AD13]	The FR identification is given in the document [RD30]
- Cleaning	Manufacturer	IO	Annexure 6	

- Clean work plan	Manufacturer	IO	Annexure 6	
- Heat Treatment	Manufacturer	IO	Section 6.5.9	
- Vacuum baking and Outgassing	Manufacturer	IO	IVH appendix 15 [AD7] [AD12]	
- Leak testing	Manufacturer	IO	Annexure 5	
- Pressure testing	Manufacturer	IO	Annexure 4	
- NCR and DR management	Manufacturer	IO	[AD13] [AD14]	
- Special process, e.g. forming, electrodeposition (if any)	Manufacturer	IO	Section 7.6.11	
- Weld repair	Manufacturer	IO	Annexure 2 or 3	
Assembly Plan (including assembly sequence)	Manufacturer	IO		Based on a feasibility study during manufacturing design
Phase 3: Prototype Qualification (as and when required)			Section 7.6.3	To be proposed by the Manufacturer based on their feasibility study during manufacturing design
Identification of the prototyping needs	Manufacturer	IO	Section 6.5.3	
Prototype qualification plan	Manufacturer	IO	Section 6.5.3	
Qualification reports	Manufacturer	IO	Section 6.5.3	
Phase 4: Manufacturing	Manufacturer			
Material test certificates	Manufacturer	IO	Annexure 1	
Production weld report (including weld repair)	Manufacturer	IO	Annexure 2 and Annexure 3.	
Production Proof Sample examination reports	Manufacturer	IO	Annexure 2 and Annexure 3.	
NDE Procedures (RT, UT, PT) as applicable	Manufacturer	IO	Section 8.1.7	
NDE operator qualification records	Manufacturer	IO	Annexure 2 and Annexure 3.	
Non-conformity report (whenever detected)	Manufacturer	IO	[AD14]	
Deviation Request	Manufacturer	IO	[AD15]	
Inspection and test report (during manufacturing)	Manufacturer	IO	Section 8.1	
Phase 5: Factory acceptance test				
End of manufacturing report (EMR)	Manufacturer	IO	[AD9]	
Factory acceptance test procedure	Manufacturer	IO	Section 8.2	
Factory acceptance test report	Manufacturer	IO	Section 8.2	

Contractor release note	Manufacturer	IO	[AD16]	
BOM, as-built drawings, and 3D CAD model	Manufacturer	IO	[AD24]	
Phase 6: Delivery				
Packing procedure	Manufacturer	IO	Section	
Storage procedure	Manufacturer	IO	Section 8.1	
Transportation procedure	Manufacturer	IO	Section 8.1	
Delivery report	Manufacturer	IO	[AD17]	
Phase 7: Site Acceptance test				
Site acceptance test procedure	Manufacturer	IO	Section 8.2	
Site acceptance test report	Manufacturer	IO	Section 8.2	
Transfer of Ownership	Manufacturer	IO		Check if there are any guidelines for transferring ownership.

Table 3: Document deliverables

3.4 Out of scope of this Technical spec (Scope of PBS 22)

This technical specification does not encompass the following activities, which are therefore not the Manufacturer's responsibility. The IO will perform these activities after receiving the DL assemblies at the ITER worksite.

- Handling of DL assemblies from Storage area to NB cell;
- Assembly and Installation of DL assemblies on NB Duct;
- Welding of In/Out cooling water manifold pipes with DL and Connecting Duct;
- Welding of Trunking and Feed through box interface with Connecting duct.

3.5 Duration

[REQ-34] The manufacturing phase for the 3 DLs shall be completed within a maximum period of 4.5 years, commencing from the T0 date of the contract signature.

4 DOCUMENT ORGANIZATION

This technical specification document has the associated applicable documents as follows.

[REQ-35] ANNEXURE 1 to ANNEXURE 6 shall be considered mandatory and obligatory and applied during the execution of the contract.

[REQ-36] Applicable Documents [AD] (section 11.2) shall be considered mandatory and obligatory and applied during the execution of the contract.

[REQ-37] Reference Documents (section 11.3) shall be used as a set of guidelines to assist in executing the contract.

[REQ-38] All information present on the drawings (e.g.: dimensions, tolerances, materials, coatings) as well as on the 3D CAD Models shall be considered as mandatory requirements as part of this technical specification.

5 MANAGEMENT OF THE PROCUREMENT

The overall procurement cycle is divided into the following major milestones:

1. Tendering and manufacturing contract;
2. Manufacturing Design (including approval of manufacturing drawings);
3. Manufacturing Readiness Review;
4. Qualification of special processes like welding and Mock-ups (if any);
5. Manufacturing;
6. Factory Acceptance Test (FAT) (including delivery of associated documents);
7. Transportation and Delivery at the IO site (including Delivery Readiness Review);
8. Site Acceptance Testing (SAT) at the IO site.

The content and requirements of each phase are detailed in the following sections.

5.1 Share of Responsibility

The ITER Organization (IO) is the ITER facility's operator and the component's owner. IO is responsible for the overall design and integrated commissioning of the items at the IO site.

[REQ-39] The Manufacturer shall be responsible for supplying the three Duct Liners following this technical specification, which includes manufacturing design, qualification, manufacturing, acceptance testing at the factory, delivery of components, and acceptance testing at the IO site. As the sole supplier to the IO, the Manufacturer holds legal responsibility for providing the required items.

[REQ-40] The Manufacturer shall supply the documentation listed in section 3.3 to the IO to assess the component's conformity.

[REQ-41] The Manufacturer shall grant free access to the IO or IO-authorised inspection agency to his premises or any of his supplier's premises.

[REQ-42] The Manufacturer shall take appropriate action to ensure such access is available at both the Manufacturer's and its sub-supplier's sites.

Description of the Activity	IO	Manufacturer
Design of component		
The final design of the component, including 3D Models and 2D drawings	R	
Technical specification	R	
Market Survey, call for tender, and contract award		
Market survey and preparation of call for tender, including contract documents	R	
Technical evaluation of bidders and contract awards	R	
Manufacture, Assembly, Factory Acceptance Test (FAT), and Delivery		
Manufacturing Design	A	R
Manufacturing drawings	A	R
Quality Plan (QP) and Manufacturing and Inspection Plan (MIP)	A	R
Manufacturing Readiness Review (MRR)	A	R
Materials and component procurement	A	R
Manufacturing and assembly	A	R
Factory Acceptance Testing, including manufacturing documentation	A	R
Delivery Readiness Review (DRR)	A	R
Packing and Delivery to the IO site	A	R
As built drawings and 3D models	A	R
Integration and Acceptance at the Site		
Incoming inspection at the IO site	A	R
Site Acceptance Test	R	S
Installation of the component at the IO site	R	S
Commissioning of component	R	S
R = Responsible for organizing, performing, and for the content A = Review/Comment/Accept/Approve S = Providing technical support		

Table 4: Summary of the Responsibilities between the IO and the Manufacturer

5.2 Time Schedule

[REQ-43] DL assemblies and accessories stated in Table 2 shall be delivered to the IO site according to the contract's specified date.

[REQ-44] The Manufacturer shall produce a detailed schedule showing all contract phases and how the overall IO Schedule complies with them.

[REQ-45] The detailed Schedule shall be submitted to the IO for approval/acceptance before starting any work concerning the Contract.

5.3 Procurement follow-up

5.3.1 Control points

[REQ-46] The Manufacturer shall ensure a close oversight of the production plan at their factory and sub-suppliers end following the approved Manufacturing and Inspection Plan (MIP).

[REQ-47] The monitoring shall include Notification points (NP), Hold Points (HP), Witness points (W), and Authorization to Proceed Points (ATPP) at critical steps in the Suppliers' manufacturing and inspection plans.

[REQ-48] These control points shall be integrated into the agreed schedule and MIPs.

The control point definition is taken from the Inspection Plan (IP) Template [AD18]:

- Notification Point (NP) is a milestone where the Manufacturer is required to notify the IO that it has completed a specific task or a specific deliverable and is proceeding to the next task or the following action on the specific deliverable. An NP is meant to enable the IO personnel to follow the contract's progress and possibly witness a critical manufacturing step at the Supplier's premises. The Notification will be sent at least ten working days before the scheduled manufacturing step. After that, the IO decides whether they want to attend within the following five working days. An NP will not affect the production flow of the Supplier, who will continue the work even without a reply from the IO.
- Hold Point (HP) is a milestone where the Manufacturer must notify the IO that it has completed a specific task or a specific deliverable and must stop the associated processes until an HP Clearance is issued. The HP Clearance will be issued based on clearly identified Quality Control and data and Acceptance test results to be provided to the IO at the time of the request.
- Witness Point (W) is a milestone identifying an operation that will be witnessed. Adequate notice will be given to the IO to allow the IO to participate in the operation.
- Review (R) identifies a document or report that will be reviewed.
- Where R/W is used for Radiography, actual radiographs and reports will be checked.

Final control points during various phases of the manufacturing cycle will be mutually agreed upon during the finalization of MIPs (before MRR). However, the preliminary list of control points is defined in the table below.

Phase / Activities	IO control point		
	Hold Point	Witness	Review
Phase 1: Pre-production			
Manufacturing schedule			R
List of supplier's sub-contractors	HP		R
Kick-off Meeting with the successful bidder	NP		
Approval of Quality Plan (Supplier and its major sub-contractors) and Manufacturing and Inspection plan	HP		R
Approval of manufacturing drawings, models, and bill of material	HP		R
Approval of material specifications	HP		R
Purchase order for material procurement			R
Phase 2: Manufacturing Readiness Review			
Conduct MRR	HP		R
Approval of documents (including weld qualification documents) as defined in table 3 (Phase2)	HP		R
Phase 3: Prototype/mock-up qualification (as and when required)			
Prototype/ mock-up qualification plan	NP		R
Welding/machining inspection and test report	NP		R
Phase 4: Manufacturing			
Raw material inspection, including material test certificates	NP		R
Jigs, Fixtures, and Tooling Design	NP		R
Production welding report and weld inspections	NP		R
Approval of NDE procedures	HP		R
Approval of NDE reports (including qualification)	NP		R
Completion of visual and Dimensional inspection of component/ sub-assemblies / assemblies	NP		R
Non-destructive examinations, including personnel qualification	NP		R
Cleaning of components	NP		R
In-process inspections (e.g. cleanliness check, pressure test, leak tests, etc.) of various sub-components during manufacturing	NP		R
Non-Conformity Request (NCR) and Deviation Requests (DR)	HP		R
Phase 5: Factory Acceptance test (FAT)			
Factory acceptance tests, as mentioned in section 7.2	HP	W	R
FAT test reports	HP		R
Manufacturing data package (including release note)	HP		R
Final cleaning and Packing	NP	W	R
Phase 6: Delivery			
Conduct Delivery Readiness Review and related documentation	HP		R
Packing, storage, and transportation procedure	HP		R
Delivery report	HP		R
Receipt inspection at IO	HP	W	R
Phase 7: Site Acceptance Test			
Site Acceptance, as mentioned in section 7.2	HP	W	R
SAT report	HP		R

Table 5: Preliminary list of IO control points

5.3.2 Data Management

[REQ-49] The data generated during the execution of this contract shall be entered into the ITER IDM following [RD7].

[REQ-50] The exchange of documentation between the Manufacturer and the IO shall comply with the “Procedure on Procurement Documentation Exchange between IO, DA, and contractors” [RD7].

[REQ-51] These engineering data shall be organized according to the “ITER Document Breakdown Structure Overview” [RD8] and to the document “ITER Plant Breakdown Structure” [RD9].

[REQ-52] Data flow from the manufacturer to the IO: Relevant data shall be made available by the manufacturer to the IO through the existing database each time a control point is requested, a deviation request, or any other document that is part of the contract.

[REQ-53] Non-conformities shall be processed by the manufacturer using the NCR database following the procedure [AD14].

[REQ-54] CAD data files managed through specialized CAD software (e.g., CATIA) shall undergo other requirements specified in the DCIF. For this contract, as detailed in Section 7.2.

5.3.3 Progress Monitoring

[REQ-55] The Manufacturer shall be responsible for the supply of the Duct Liners following this technical specification, which includes manufacturing, acceptance testing at the factory, delivery of components, and acceptance testing at the ITER site. As the sole supplier to the IO, the Manufacturer holds legal responsibility for providing the required items and their compliance certificates with applicable EU directives (e.g.: CE marking if applicable).

[REQ-56] The Manufacturer shall provide the IO with a monthly progress report on all works under this contract by the 5th calendar day of each month using the standard template [RD10] and agree on periodic review meetings to monitor contract execution.

[REQ-57] The Manufacturer shall report to the IO as soon as possible any occurrence that could delay or jeopardize the proper execution of activities related to this contract.

[REQ-58] Project progress meetings shall be conducted based on mutual agreement, with the frequency varying throughout the tender's progress, typically from once per month in the initial phase to once per three months towards the end. The meetings may be conducted through video/teleconferencing or in-person discussion at the supplier's premises.

[REQ-59] In case of specific needs for technical or contractual discussions, ad-hoc meetings could also be organized.

[REQ-60] The Manufacturer shall prepare the project progress meeting minutes within seven (7) days and submit them to the IO.

5.3.4 Right of Access

5.3.4.1 Right to access the IO or its representatives

[REQ-61] The Manufacturer shall ensure that the IO representatives are granted access to the suppliers' premises and sub-suppliers to witness on-site tests and critical fabrication operations and participate in periodic review meetings at any time for witnessing and for the periodic review meeting, free of charge.

[REQ-62] IO representative shall also be granted access at all reasonable times to carry out on-the-spot checks in addition to the tests foreseen in the technical specifications.

[REQ-63] IO shall ensure that the Manufacturer and suppliers are granted appropriate access rights to the IO site.

[REQ-64] The supplier shall allow the IO to photograph the ITER equipment during the contract execution at the supplier's premises.

5.3.4.2 Right to access the Third-Party Inspection Agency (TPIA)

[REQ-65] For the supply of items under this contract, the Manufacturer shall ensure that TPIA (appointed by IO) is granted free and appropriate access to their site and its subcontractor's facilities where this component is being manufactured to records for surveillance, inspection (including unscheduled inspections) or audit as requested by them under the applicable national laws and regulations.

5.3.4.3 Right to access of the Autorité de sûreté nucléaire (ASN)

[REQ-66] The Manufacturer shall ensure that the ASN is granted free and appropriate access to their site and its sub-contractors.

5.3.5 Reviews

[REQ-67] The IO shall organize reviews and status /Quality control reviews by mutual agreement at various execution stages. These may be focused on different manufacturing stages and particular areas of production. If required, IO will appoint the review group and define its terms of reference. The main reviews are listed in Table 6.

Sl. No.	Type of review	Remarks

1	Manufacturing readiness review (MRR)	[AD19]
2	Approval of pre-manufacturing documents (Manufacturing drawings, Quality Plans, MIP and Procedure)	This technical specification
3	Project progress review	Periodic reviews as per mutual convenience
4	Delivery readiness reviews	[AD20]

Table 6: IO reviews

6 TECHNICAL INTERFACES

[REQ-68] The Duct Liner shall comply with all the technical interfaces described in this chapter.

As stated below, the duct liner has various physical interfaces (internal and with surrounding PBS.

The duct liner assembly is bolted to the Vacuum vessel (PBS 15) port extension flange. DL assembly maintains geometrical 20 mm clearance with all the surrounding components (Port extension (PBS 15), connecting duct (PBS 15), vacuum vessel (PBS 15), blanket shield block (PBS 16)) except in the region of the pad where a tight tolerance is required with the port extension wall to enable close fitting during assembly/ RH installation phase. Cooling water is supplied through the IBED PHTS cooling circuit (PBS 26). The cooling water pipe is welded to the connecting duct. Instrumentations are routed through dedicated feedthrough and trunking for the diagnostic function of DL. The Feedthrough box and trunking are welded to the connecting duct. There is a DNB crossover in the HNB#1 Duct Liner.

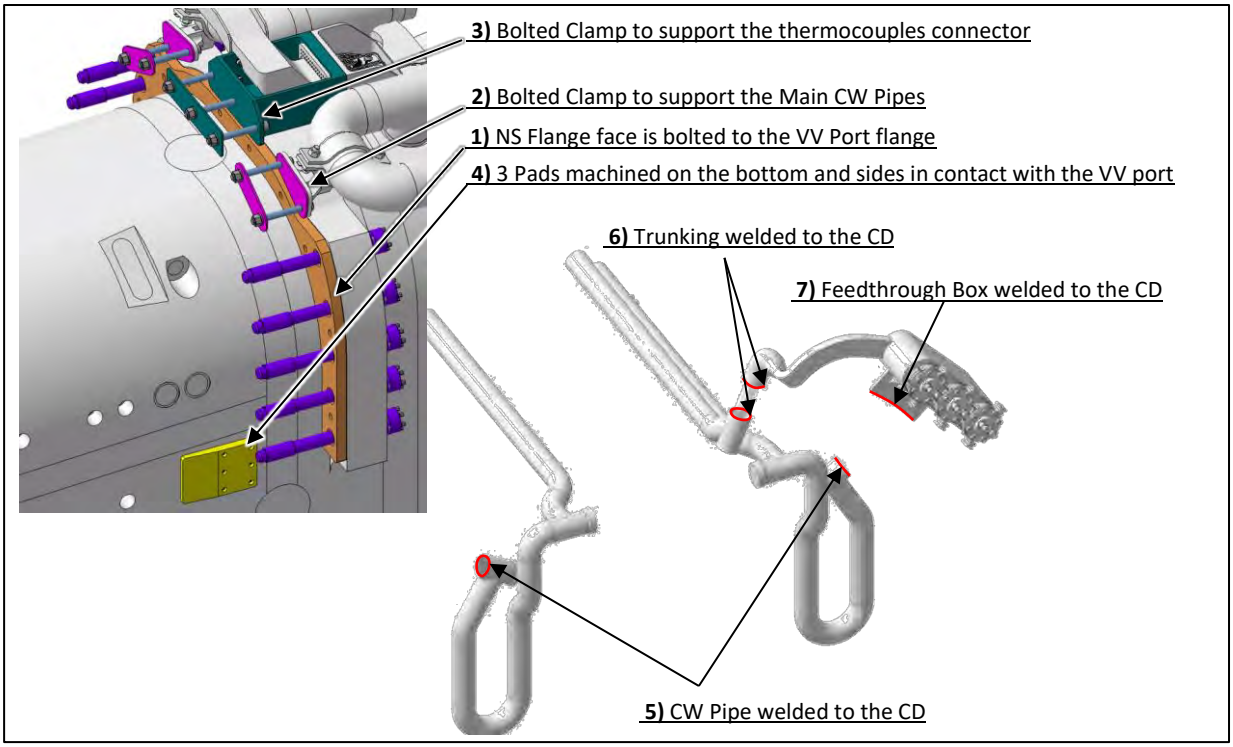

Figure 18: DL physical interfaces

Apart from the internal interface with PBS 53, DL assembly has various functional interfaces with other PBS as described below;

Vacuum Vessel (PBS 15): DL assembly is bolted onto the VV port extension flange. Refer to ICD [RD11], IS [RD12].

Assembly (PBS 22): DL will be assembled using dedicated tooling. The neutral Beam is positioned by dedicated tooling (Laser + targets). Refer to ICD [RD13].

Cooling (PBS 26): Cooling water feeds through the IBED PHTS cooling circuit. Refer to ICD [RD15] and IS [RD16].

Remote handling (PBS 23): Interface for component maintenance. Refer to ICD [RD17], IS [RD18] and IS [RD19].

Blanket (PBS 16): Clearance between the DL and Blanket block shield. Refer to ICD [RD20], IS [RD21].

Cable Tray System (PBS 44): Interface between the instrumentation cable and the cable tray. Refer to ICD [RD22], IS [RD23].

7 TECHNICAL REQUIREMENTS

7.1 Design Requirements

Duct Liners are procured as a “Built to Print” where IO is responsible for completing the final design of the Duct Liner, and related technical specifications and documents (DDD, ICDs IS, CMMs,3D Models and 2D engineering drawings) have been provided to the Manufacturer. This BtP technical specification is refined to a level where analyses, qualification processes, preliminary tests, preliminary manufacturing, and assembly processes justify the component design.

[REQ-69] The Manufacturer shall take over the responsibilities of the Manufacturing design, manufacture, and delivery of the Duct Liner assemblies to IO in compliance with the final design, technical specifications, and applicable reference documents, as well as demonstrate that it fulfills the acceptance criteria laid down by all these documents.

The scope of Design activity for the Manufacturer is as follows:

- Manufacturing design of the 3 DLs, including assembly analysis.
- Design of Jig and Fixtures for Inspection, testing[1], assembly[2] , and transportation of the 3 Duct liners.

[REQ-70] The IO shall provide models at final design maturity, 2D engineering drawings (BtP), and BOMs.

[REQ-71] Tolerances for components and subassemblies shall be stated on the BtP drawings included in the subassemblies' BOMs.

[REQ-72] The Manufacturer shall develop a detailed plan based on the IO input, perform analysis, and prepare shop drawings if required.

[REQ-73] The Manufacturer shall assess the design provided by IO, conduct the manufacturing feasibility study, and propose design changes (if required) to improve the feasibility of component/subassembly manufacturing.

[REQ-74] The Manufacturer shall assess the need for prototyping/mock-ups to demonstrate the feasibility of critical manufacturing processes and component assembly.

[REQ-75] The manufacturer shall prepare manufacturing design models based on the final design models IO provided and the outcome of the feasibility study.

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[1] IO will provide a preliminary ongoing test of the Cooling Water Coaxial (CWC) and the Module Bolting System (MBS).

[2] IO will provide the conceptual design of assembly tooling that will be used during the assembly in ITER.

[REQ-76] The IO shall check, approve, and accept the manufacturing design models.

[REQ-77] Based on the BtP drawings and the manufacturing design model, the Manufacturer shall develop detailed manufacturing drawings to achieve the required functional tolerance (geometrical and form) and surface finishing.

[REQ-78] The Manufacturer shall submit the manufacturing drawings for the Manufacturing Readiness Review (MRR) and obtain IO's acceptance.

[REQ-79] The manufacturer shall submit the manufacturing drawings using the SMDD database for review/approval in advance of the MRR.

[REQ-80] The Manufacturer shall commence manufacturing based on the approved drawings following the MRR.

7.2 CAD design requirements

[REQ-81] The Supplier shall work in a fully synchronous manner on the ITER CAD platform (see detailed information about synchronous collaboration in the Specification for CAD data Production in ITER direct contracts (P7Q3J7)). This implies the usage of the CAD software versions as indicated in the CAD Manual 07 - CAD Fact Sheet (249WUL) and the connection to the IO ENOVIA database.

[REQ-82] The supplier shall ensure that all CAD data (Schematics, Models, and Drawing) delivered to IO comply with the "Procedure for the Usage of the ITER CAD Manual (2F6FTX)" and with the "Procedure for the CAD management plan (2DWU2M)".

[REQ-83] Drawing registration in the IO system shall be performed according to the Procedure for the Management of Diagrams and Drawings Management System Working Instruction (KFMK2B).

[REQ-84] The Supplier shall provide a design plan for approval of IO. Such a plan shall identify all design activities and deliverables to be provided by the supplier as a part of the contract.

[REQ-85] The CAD data identified as input shall be transferred to the contractor through the appropriate Data Exchange Task (DET) performed by the IO at the kick-off date.

[REQ-86] The Supplier shall ensure that any deviation against this requirement is defined in a Design Collaboration Implementation Form (DCIF) prepared and approved by the Design Office (DO) and included in the call for tender package.

[REQ-87] Any cost or labor resulting from a deviation or non-conformance of the supplier concerning the CAD collaboration requirement shall be incurred by the supplier.

7.3 Functional requirements

The Duct Liner's functional requirements are defined in the SRD document [RD1].

[REQ-88] The IO shall design the Duct Liner up to the final design level in compliance with IO design requirements.

[REQ-89] The final Design Review of the HNB DL shall be closed following the Design review procedure [RD3].

[REQ-90] The Manufacturer shall ensure that all functional requirements defined by IO are well propagated/considered in the manufacturing phase.

[REQ-91] The Manufacturer shall ensure that all technical requirements from this technical specification, including applicable documents (listed in chapter 11.2) that IO observed during the design phase, are well propagated during the manufacturing phase, which includes manufacturing design and further execution of the contract.

[REQ-92] The Manufacturer shall identify critical technical requirements that may directly affect the component's functions and ensure compliance with the specification.

[REQ-93] The Manufacturer shall immediately inform IO regarding any deviations / non-conformance in the manufacturing activity that may affect the overall function of the component. Such incidents will be handled using a non-conformance management process [AD14].

7.4 Material Requirements

[REQ-94] Raw material procured for the Duct Liner shall meet the requirements of Annexure 1.

7.5 Nuclear safety function and regulatory requirements

ITER is a Nuclear Facility identified in France by INB 174 (“Installation Nucléaire de Base”).

The Duct Liner is a “non-SIC” component except for the Feedthrough box and the welding between the main CW pipes and the Connecting Duct. These welds are not in the scope of this technical specification (PBS 22 scope).

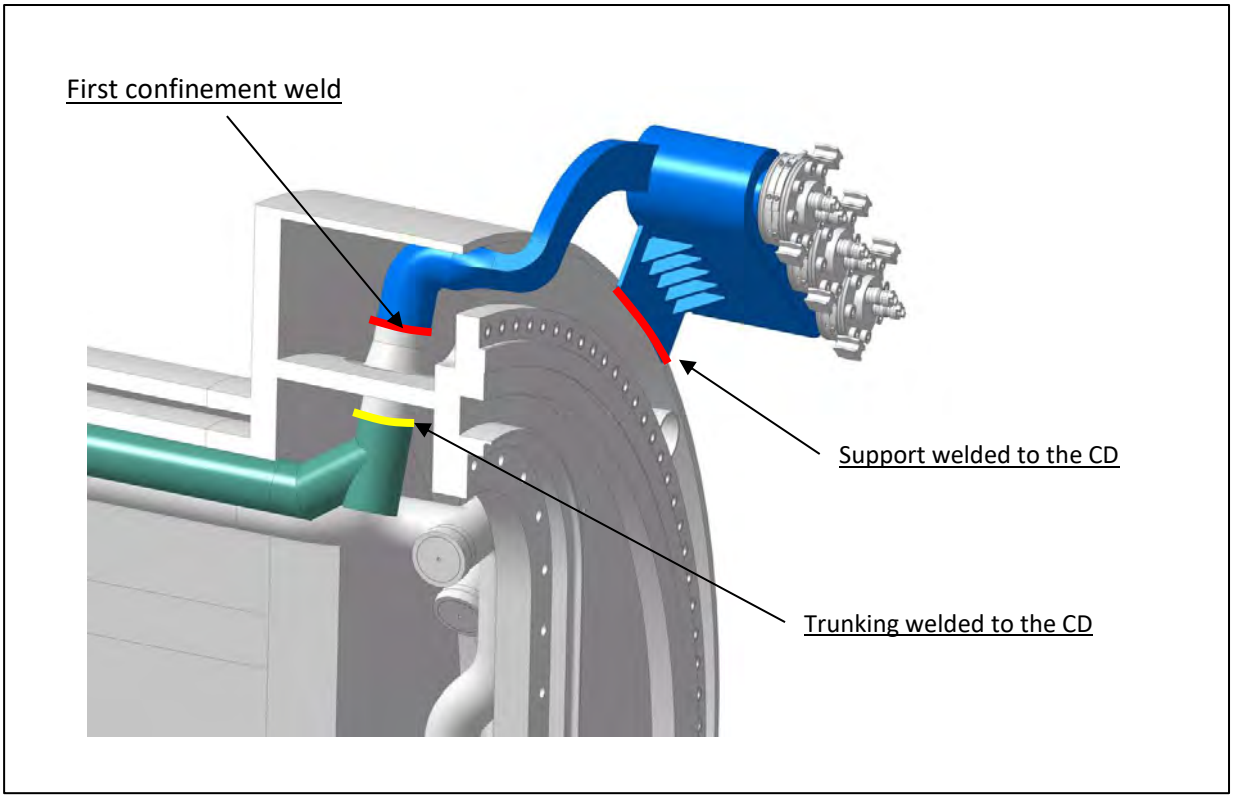


Figure 19: Feed Through Box interface with the Connecting Duct

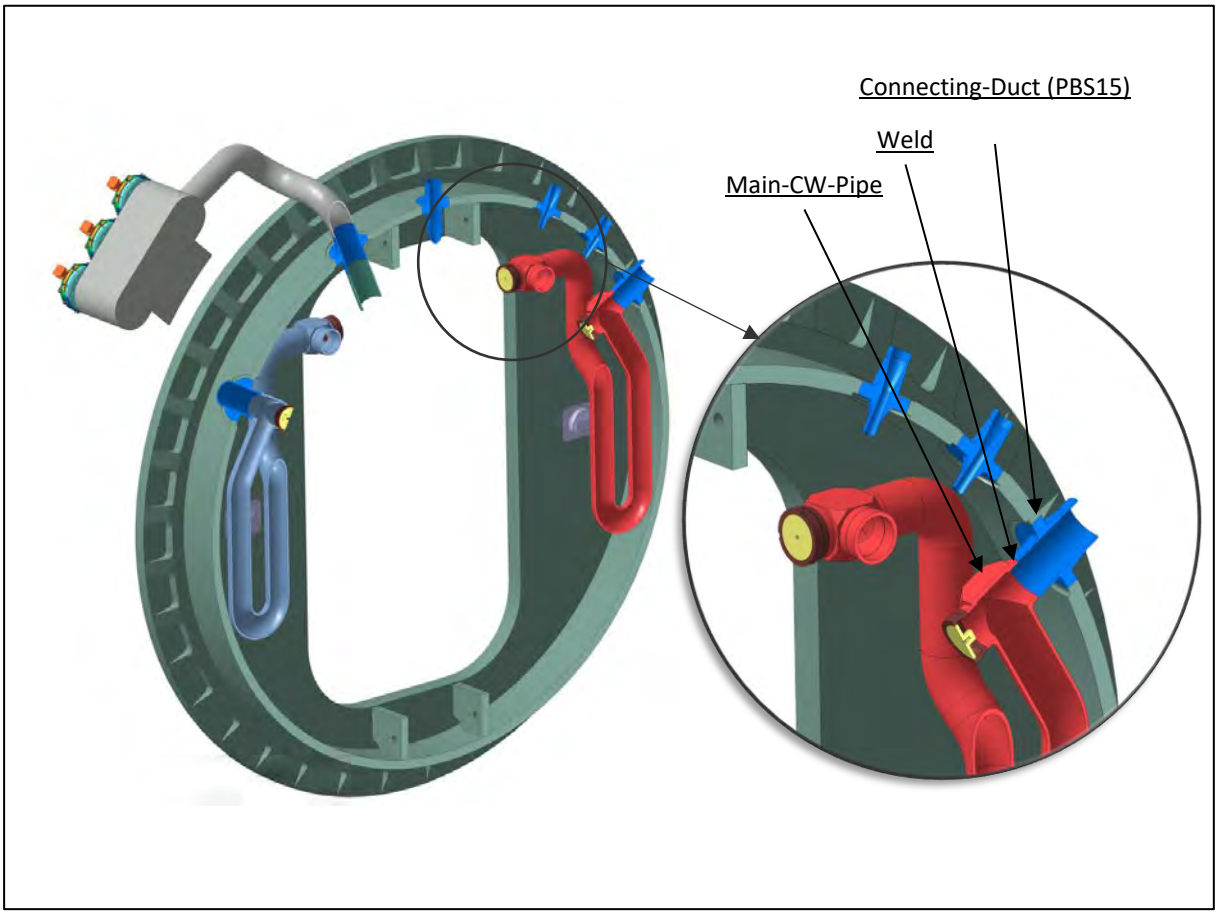


Figure 20: CW pipes interface with the Connecting Duct

Duct Liner assemblies have the following nuclear safety functions.

- Feed through Box (including its welding with the CD)
  - Confinements
  - Minimization of radiological exposure: using raw materials with a restricted concentration of Co, Nb, and Ta contents.

- HNB DL sub-assemblies / sub-components (Except feedthrough box)
  - Minimization of radiological exposure: using raw materials with a restricted concentration of Co, Nb, and Ta contents.
    - PIAs for HNB DL assemblies (except feedthrough box): Measurement of chemical compositions during raw material procurement.

Defined requirements and Protection Important Activities (PIAs) for HNB DL are detailed in [RD24] and [RD25], respectively. The preliminary list of PIAs is as below.

Nuclear safety function	PIAs
Confinement	All analyses based on the Load Specification [RD2] outside this technical specification's scope ensure the confinements' integrity.
	All the activities linked to the welding and their associated controls
Minimization of radiological exposure	Measurement of the chemical composition of raw material
	Material certificate deliverables

Table 7: Preliminary list of PIAs

[REQ-95] [DR] The PIAs shall be identified in the MIPs.

[REQ-96] [DR] The safety functions associated with PIA shall be described in QP.

[REQ-97] Prior to initiating the manufacturing process, the Manufacturer is mandated to obtain the IO approval. This prerequisite applies to the MRR, MIP, HP, and NCR.

[REQ-98] [DR] The Manufacturer shall ensure compliance with the generic safety requirements described in the "Provision for implementation of generic safety requirements by external actors/interveners" [AD21] throughout the supplier and subcontractor chain, using a specific management system to perform PIAs.

[REQ-99] [DR] The Manufacturer and its subcontractors shall take note that:

- The Order 7th February 2012 [AD22] applies to all the components important for the protection (PIC) and the activities important for the safety (PIA).
- Compliance with the INB order [AD22] must be demonstrated in the chain of external contractors.

- In application of article II.2.5.4 of the Order 7th February 2012 [AD22], contracted activities for supervision are also subject to control by the nuclear operator.

[REQ-100] [DR] The Manufacturer and its subcontractors shall comply with the Order 7th February 2012 [AD22] for all components important for protection (PIC) and activities important for protection (PIA).

[REQ-101] [DR] Compliance with the INB order [AD22] shall be demonstrated in the chain of external contractors.

[REQ-102] [DR] The contracted activities for supervision purposes shall be subject to supervision by the Nuclear Operator, per article II.2.5.4 of the Order 7th February 2012 [AD22].

7.6 Manufacturing Requirements

7.6.1 Manufacturing process

The major manufacturing process involved in the manufacturing of Duct Liners is the following:

- Procurement of CuCrZr treatment-B and ITER Grade Stainless steel (with restricted composition) raw material;
- Forming and Precision machining;
- Deep hole drilling (in longitudinal and vertical directions) of DLM panels to create cooling water flow channels;
- Fabrication (including cutting, machining, and welding) of CuCrZr and Stainless steel materials;
- Joining of similar (SS to SS, CuCrZr to CuCrZr) and Dissimilar (CuCrZr – Inconel – SS 316L(N)) materials by Electron beam welding (EBW) and Orbital TIG welding.;
- Post-weld heat treatment (i.e. Aging) of CuCrZr welded components;
- Thermal cycling of components having dissimilar joints;
- Copper layer on the SS surface facing the beam is applied to better propagate the temperature;
- Outgassing and Baking;
- Cleaning and Surface finish;
- Assembling of finished parts;
- Draining and drying of components after intermediate testing.

7.6.2 General requirements

[REQ-103] The non-SIC component's fabrication shall comply with the selected manufacturing code, whether ISO, or EN, or ASME.

[REQ-104] The fabrication of the SIC component, specifically the feedthrough box, shall comply with the "Section 5: Fabrication" guidelines outlined in RCC-MR.

[REQ-105] The Manufacturer shall develop the manufacturing and factory assembly process to guarantee the fulfillment of the functional requirement of the component (including functional tolerance of the assembly).

[REQ-106] The Manufacturer shall develop a Manufacturing Inspection Plan (MIP) and submit it to IO for acceptance for the MRR.

[REQ-107] Part of the manufacturing, particularly the assembly of DL at the factory, shall be performed in a suitably clean area.

[REQ-108] The Manufacturer shall ensure no contact between stainless steel and CuCrZr with carbon steel during fabrication.

[REQ-109] The SS fabrication areas shall be kept separate from neighboring fabrication areas to prevent contamination (i.e. non stainless-steel material, liquids, dust…).

[REQ-110] Separate storage areas for stainless steel material away from Carbon Steel material shall be used.

[REQ-111] Identification of all materials and offcuts, including the heat number, plate number, rolling direction, and other necessary details, shall be maintained by transferring them to another location before cutting.

7.6.3 Prototyping/mock-up requirements

HNB DL component manufacturing involves several critical manufacturing operations like the following points:

- Deep hole drilling of precipitation-hardened copper alloys with controlled drilling deviations,
- Welding of thick CuCrZr alloy in different configurations of partial and full penetrations;
- Welding the DLM panels to the NS in restricted space availability;
- Assembly of MBS system with DLM panels;
- Achieving the functional tolerances of the DL after the DL fabrication process.

Due to the nature of the above processes, several technical uncertainties are associated with them, which may delay the manufacturing stage. Therefore, it is recommended to establish

and qualify such critical processes on one or more scaled mock-ups before implementing that process in production to mitigate those delay risks.

[REQ-112] During the stage of manufacturing design (feasibility study), the Manufacturer shall identify the critical areas/processes where the prototype is needed to demonstrate the feasibility of manufacturing and inspection for the MRR.

[REQ-113] The Manufacturer shall develop the prototype/mockup qualification plan for all such processes/activities and submit it to IO for acceptance.

[REQ-114] The Manufacturer shall integrate the qualification plan into the component manufacturing schedule and agree with IO for its execution at a relevant manufacturing stage.

[REQ-115] Prototype/mock-up coupons shall meet this technical specification's relevant requirements (material, manufacturing, fabrication, etc.).

[REQ-116] IO shall be the approver of the qualification plan.

[REQ-117] The Manufacturer shall notify the IO representative of the prototype qualification four weeks before. The IO representative will then decide whether to witness the qualification or not.

A preliminary list of critical areas is stated below. The prototype requirements mentioned herein are indicative.

N	Critical process Activity	Objectives
1	Deep hole drilling in the DLM	Deep hole drilling in Copper alloys (CuCrZr treatment-B) and SS 316L(N)-IG with controlled drift (<500 microns/meter) to ensure the heat absorption/ removal function of DLM panels.
2	EB welding and NDE of DLMs	Demonstrate the feasibility of 1. EB welding in the given configuration 2. NDE examinations as envisaged during the design phase of this component. Note: *The Manufacturer may cover this as a part of welding qualification on the production proof sample (PPS).*

3	Welding of Co-axial welding connector with DLM panels in restricted space availability	- Demonstrate the feasibility of welding (similar and dissimilar material) in constrained space. - Develop the welding/ assembly sequence* (including the RT feasibility) - Demonstrate the successful installation of CWC in DL assembly (considering welding distortion) *IO will provide the reference welding and assembly methodology of CWC installation as considered during the design phase. The Manufacturer must use it to Develop a detailed process.
4	Assembly of Modular Bolting system (MBS) in DL	- Demonstrate the manufacturing and assembly feasibility of the given design of MBS in constrained available space - Functional demonstration of the MBS design assumptions (e.g. maintaining the gap)
5	Fabrication of Neutron shield segments and DNB windows	- Study of welding distortion due to welding of thick Neutron shield segments - Develop welding and assembly sequence of Neutron shield Fabrication of Neutron shield segments by keeping the Functional critical tolerance of DL assembly intact, etc

[REQ-118] The Manufacturer shall explore the need for any additional prototype from his perspective and propose the same to the IO with a proper technical justification of the need for agreement.

[REQ-119] The agreement of the proposed prototype shall be at the MRR stage.

7.6.4 Marking

[REQ-120] As the full DL is VQC-1A the whole DL shall be compatible with the IVH marking/identification.

[REQ-121] The marking of items shall not result in contamination of the material, significant strain hardening, or sharp discontinuities.

[REQ-122] The items shall be marked in areas not facing the neutral beam, especially for the DLMs.

[REQ-123] The items shall not be marked in areas with stress concentration or the weld heat-affected zone.

[REQ-124] Marking shall not affect Non-Destructive Examination (NDE) results in interpretations.

[REQ-125] Markers shall contain sulfur, phosphorus, and halogen (fluoride and chloride) content below 200 ppm for each.

[REQ-126] Only approved dyes, marker pens, paints, etc. (as listed in Appendix 4 of IVH [AD12]) shall be used on surfaces exposed to vacuum.

[REQ-127] Any markers not included in the approved list shall be subject to the acceptance of ITER Vacuum RO.

[REQ-128] To use a particular marker not included in Appendix 4 of IVH [AD12], the supplier shall obtain acceptance by submitting an "Acceptance Request form" to the ITER Vacuum Responsible Officer.

[REQ-129] For the DL Feedthrough Box that has to follow the RCC-MR, the marking procedure of the feedthrough box component shall comply with RF 2000.

7.6.4.1 Marking methods

[REQ-130] Marking shall be done by scribing with a clean, sharp point: laser scribing or electromagnetic dot peen method.

All methods which meet the general marking requirements stated above may be used, taking into account the following rules:

[REQ-131] The use of electric arc marking pencils shall be forbidden.

[REQ-132] Stamping is permitted on materials more than 6 mm in thickness. Metal stamps shall be round-nosed or ball-type.

[REQ-133] Chemical etching shall not be used unless accepted by the ITER Vacuum RO.

[REQ-134] A vibrating marking tool may be used for thicknesses less than 6 mm. The instrument shall be carbide-tipped.

[REQ-135] The indentation depth shall be approximately 0.25 mm or less.

7.6.5 Cutting and Machining

[REQ-136] All material shall be cut to shape and sized or prepared for welding by machining, grinding, or thermal cutting. Cutting can be done by machining, grinding, shearing, or plasma cutting.

[REQ-137] In the case of shearing, the supplier shall remove the strain-hardened zone by machining/grinding.

[REQ-138] After plasma arc cutting, the supplier shall remove at least 1mm of metal from the cut edges by grinding to ensure that all residual traces, such as metal roll-over and grooves, are removed from the face of the cut.

[REQ-139] The supplier shall visually inspect the cut edges for cracks.

[REQ-140] The supplier shall avoid local material overheating during grinding.

[REQ-141] For the DL feedthrough box fabrication that has to follow the RCC-MR, the cutting process shall comply with RF 3000.

7.6.6 Deep hole drilling

[REQ-142] Manufacturing of DL components includes intense deep drilling operations to manufacture the cooling channels. As the drilling hole position plays an essential role in the heat absorption functions of the DLM, the drilling deviations shall be controlled during the drilling process.

[REQ-143] Drift (i.e. drill deviation) of the drilled holes in DLM Panels shall be controlled up to 0.5mm/meter to ensure the desired operational performance of the DL.

[REQ-144] To achieve required drift control, the Manufacturer shall choose the appropriate material condition, drilling technique (i.e. staged drilling, counter-rotating of tool and job, etc.), coolant, cutting tool design, etc. Manufacturers may consider small prototypes to establish these process parameters.

[REQ-145] After the deep drilling process, each panel shall be checked for the following:

- Visual inspection;
- Measure wall thickness with a suitable technique (e.g. ultrasonic) to measure the drilling drift.

7.6.7 Fluids used for various manufacturing operations

[REQ-146] The Manufacturer shall take care during the manufacturing processes to prevent the introduction of contamination into surfaces that may be difficult to remove later and could result in degraded vacuum performance.

[REQ-147] The fluids used in various manufacturing processes shall meet the following requirements.

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

Table 8: Fluid requirements

[REQ-148] Only ITER-qualified LPT on systems baked to > 200 C° (at least 24 hours prior to leak testing) shall be used.

[REQ-149] All cutting fluids, and coolant used during the machining of the DL parts, shall comply with the requirement of IVH Appendix 4 [AD12] for VQC 1 components.

[REQ-150] If any fluid other than those listed in Appendix 4 of IVH [AD12] is required, specific acceptance shall be obtained from the IO before its use.

[REQ-151] The Manufacturer shall submit details about the intended fluids for ITER's approval and potential acceptance through the designated "Fluid Acceptance Request Form" to be raised in the database [RD31]. These details include the fluid datasheets, the rationale for selecting this fluid over others listed in the IVH-approved alternatives, compatibility with vacuum conditions, the volume of fluid to be utilized, and the proposed cleaning method.

[REQ-152] The Manufacturer shall agree in advance with ITER a plan detailing the type and method of testing to qualify the fluid for use.

[REQ-153] The Manufacturer shall submit the Fluid Acceptance Request Form in the ITER database, as per [REQ-151] along with the test data, report, and supporting documentation, including any supplier's data (Certificates of Conformity, etc.), for consideration.

Criteria for the selection of fluids for the various purposes (i.e. cutting, cleaning, NDE examinations) should be as follows:

- Fitness for the 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 (i.e. increased outgassing)
- No significant physical damage to the surface
- Health and Safety Considerations

7.6.8 Welding qualification and Production welding

[REQ-154] Qualification of welding process/welding operator and welding production of Duct Liner components shall meet the requirements of Annexure 2 and Annexure 3.

7.6.9 Post Weld heat treatment (applicable for EB welded CuCrZr DLM Panels)

[REQ-155] After completion of Electron Beam Welding, DLMs made of CUCrZr shall be Post Weld Heat Treated (i.e. Aging treatment) at 475°C with a temperature variation of ±10°C for 3 Hours. It is required to regain the mechanical properties of the CuCrZr material, which was degraded due to EBW operation because of the localized heating.

[REQ-156] The Manufacturer shall take appropriate measures to prevent or minimize deformation of the DLMs, ensuring compliance with the tolerances specified in the BtP drawings.

[REQ-157] Post-Weld Heat Treatment shall be carried out in a vacuum furnace containing filaments not exposed to a vacuum.

[REQ-158] In the case of vacuum furnaces using heating filaments exposed to vacuum, the contamination level shall not surpass the thresholds defined in Table 9.

[REQ-159] The concentration of contamination shall be measured using a Residual Gas Analyzer following the criteria in Table 9.

General Contaminants	Perfluoropolyphenylethers The sum of the peak at 69 and 77 amu	Chlorinated species (Sum of peaks at 35 and 37amu)
0.1	0.01	0.01

Table 9: Allowed concentration of contamination in the vacuum furnace

7.6.10 Thermal cycling of component

[REQ-160] Components, including joints of dissimilar material classified as VQC 1A (i.e. DLM Panels, CWC, etc.), shall be subject to at least three thermal cycles from the ambient to its maximum possible operating temperature prior to leak testing of that joint.

[REQ-161] Metallic joints shall be considered dissimilar materials if the difference in linear thermal expansion coefficients over the operating temperature range of the material comprising the joint is greater than or equal to 20%.

[REQ-162] Joints between non-metallic materials shall be considered dissimilar.

7.6.11 Copper layer

[REQ-163] As given in the BtP drawings [AD24], some parts of the DL shall be deposited with copper.

[REQ-164] As given in the BtP drawings [AD24], some DLMs made of stainless steel shall have a copper layer facing the beam made of copper to mitigate the thermal gradient. Four distinct processes are identified for this coating application: Electrodeposition, Vacuum Plasma Spraying, Explosive Bonding, and Hot Isostatic Pressing.

[REQ-165] The chosen manufacturing process shall guarantee that the thermal conductivity at the junction between the two materials is equivalent to or exceeds the thermal conductivity of 316L(N).

[REQ-166] The chosen process shall be submitted to the IO for approval.

[REQ-167] A test mock-up of 5 small specimens representative of the DLM shall be created to prove the copper deposition process reliability.

[REQ-168] The 5 specimens shall be subjected to a heating process where the copper face is heated up to 300°C within a vacuum chamber.

[REQ-169] After the test heating process, the temperature on the reverse side of the sample shall be measured and compared with the theoretically calculated value. This test aims to confirm the satisfactory adhesion between the two materials.

[REQ-170] Acceptance of the test samples shall be based on the criterion that the measured temperature variation from the calculated value does not exceed 10%.

[REQ-171] During the Copper deposition process on the DLMs having the copper layer, the Manufacturer shall include one witnessing sample, using the same material, process, and conditions as the actual SS DLMs. This sample shall then be subjected to testing to validate the Copper deposition on the real Stainless Steel DLMs.

[REQ-172] To verify the quality of the deposited copper, five standard flat-shaped specimens, following EN10002-1, shall be produced at the same time as the main production and following the manufacturing steps of the production parts.

[REQ-173] The deposited surface shall be smooth and free of visual defects such as surface oxidation, blisters, pits, roughness, cracks, flaking, and burned deposited and uncoated areas.

[REQ-174] The deposition boundaries shall be free from beads, nodules, jagged edges, and other detrimental irregularities after finishing as indicated in the drawing.

[REQ-175] Imperfection and variation in the copper layer appearance resulting from the surface condition of the base metal (e.g., scratches, pores, roll marks, inclusions) that remain despite following good metal finishing practices shall not be grounds for rejection.

[REQ-176] Deposited thickness shall meet the requirements of the BtP drawings.

[REQ-177] The procedure for thickness measurement shall be submitted to IO for approval.

[REQ-178] Locations and the number of measurement readings shall be decided as a mutual agreement between the Manufacturer and IO.

[REQ-179] In addition to the above checks, specimen samples shall be tested for the following tests to ensure that the electrodeposition process meets the end requirements.

[REQ-180] Adhesion between the base metal and electrodeposited copper shall be flawless.

[REQ-181] Adhesion test shall be carried out following ASTM B 571.

[REQ-182] The electrodeposited surface shall be sufficiently free from pores and other discontinuities.

[REQ-183] If more than the specified number of pores per unit area is found (the maximum number of allowable pores per unit area will be decided as a mutual agreement between the Manufacturer and IO in advance), the component shall be rejected.

[REQ-184] Porosity shall be evaluated following ASTM-B765.

[REQ-185] Metallurgical characteristics of the copper layer and interface shall be checked with Macro and Micro examination.

[REQ-186] The adhesion of the copper to the stainless steel shall be evaluated following the Rockwell adhesion test ISO 26443:2008.

[REQ-187] Magnification and suitable metallographic practice shall be utilized to check for proper bonding, the absence of intermetallic, or any other undesirable phases.

7.6.12 Outgassing of material

Materials listed in Appendix 3 of the ITER Vacuum Handbook [AD12]required no outgassing tests.

[REQ-188] The materials that are not listed in the ITER Vacuum Handbook shall be subjected to the Outgassing test as per clause 5.4 of the ITER Vacuum Handbook [AD7] and Appendix 17 of ITER Vacuum Handbook [AD12] as a part of the material acceptance request.

[REQ-189] The supplier shall provide the material datasheet details, justification for not using an approved IVH material, and the area/quantity of use for this additional material.

[REQ-190] The Manufacturer shall provide the details of methods used for outgassing and equipment used (including calibration status of measuring equipment) for the test.

[REQ-191] The Manufacturer shall supply the test certificate showing compliance with the specified value.

7.6.13 Aluminium Nickel Bronze Hardening

[REQ-192] Some faces of Aluminium Nickel Bronze parts shall be hardened to withstand the friction due to the thermal expansion of the DLMs.

[REQ-193] The hardness value shall be as given in the drawing [AD24].

7.6.14 Cleaning

[REQ-194] DL components / sub-assemblies shall be cleaned following Annexure 6.

7.6.15 Pickling and Passivation of material

[REQ-195] In case pickling and passivation of stainless steel and copper alloys is needed during the manufacturing of Duct liner components, it shall be strictly carried out following the guidelines provided in Appendix 14 of the ITER Vacuum Handbook [AD12].

[REQ-196] Pickling and passivation shall always be followed immediately by the cleaning process.

It should be noted that thermal outgassing from the surface, which has been pickled/passivated, might be greater than that from a native metal surface and hence require additional baking to achieve the outgassing requirements of the Duct Liner component.

7.6.16 Baking

[REQ-197] Duct Liner components shall be baked to ensure satisfactory vacuum performance.

[REQ-198] The baking process of the Duct Liner shall meet the requirement of Appendix 15 of IVH [AD12].

[REQ-199] Precipitation-hardened copper (CuCrZr) and stainless-steel components shall be baked at 240°C -5°C / +0°C.

[REQ-200] Final baking shall be performed after the FAT on the individual sub-assemblies listed in Figure 21.

[REQ-201] Vacuum ovens containing heating filaments within the vacuum shall not be permitted for the Duct Liner components baking operation unless a complete qualification is performed.

[REQ-202] For all vacuum components that require baking, a detailed procedure describing the baking process (including method, equipment, and calibration details) shall be submitted for IO acceptance before any baking is started.

[REQ-203] The Manufacturer shall supply the certificate showing compliance with the specified value.

[REQ-204] The time taken for any component to reach the specified baking temperature from ambient shall be less than 100 hours.

[REQ-205] The component shall be held at baking temperature for at least 24 hours.

The baking cycle may be performed as part of the cleaning process or, if applicable, the hot leak test.

7.6.17 Surface finish and surface roughness

[REQ-206] If not mentioned differently on drawings, metallic components shall be supplied with surface roughness in compliance with the requirements defined in Table 10. Surface roughness is defined following ISO 4287: 2000.

Classification	Maximum average Surface Roughness	Measurement Technique
VQC1	6.3	Electric stylus

Table 10: Surface finish for VQC 1A component

[REQ-207] Where the base material is not produced with an acceptable surface finish, such surface finishes shall be achieved using techniques including:

- Machining
- Electro polishing.
- Bead Blasting in a slurry in a water jet with alumina or glass beads.
- Surface Passivation / Pickling (see “Appendix 14: Pickling and passivation” of the IVH [AD-12]).

[REQ-208] All processes on vacuum surfaces shall be followed by appropriate surface cleaning (see “Annexure 6: Cleaning and Cleanliness”).

[REQ-209] Following the IVH requirements, the grinding shall not be used for the components classified VQC-1 as final machining.

7.6.18 Fasteners and Fixing

7.6.18.1 Tapped holes

[REQ-210] Blind-tapped holes shall be avoided since they provide a potential trap for contaminants and are a source of virtual leaks by using vented screws.

[REQ-211] Where the use of blind holes is unavoidable, vented screws or bolts shall be used.

[REQ-212] All female threaded holes shall be made using Spiralock technology type or equivalent to avoid loosening. Any alternative technology required the approval of the IO.

7.6.18.2 Bolts

[REQ-213] In case of deviation from the design, the Manufacturer shall submit the DR to IO for approval.

[REQ-214] Bolts shall be treated to prevent seizing. Approved solid (dry) lubricants, or coatings are preferred. Appendix 3 of the IVH [AD12] lists each class's lubricants. The use of any other lubricant is subject to prior acceptance.

[REQ-215] A procedure of the MoS_2 shall be submitted to IO for approval.

7.6.19 Trapped volumes

[REQ-216] In case of deviation from the design, the Manufacture shall follow the requirements below and submit the DR to IO approval.

[REQ-217] Large surface contact areas shall be avoided through imperfect flatness, which can provide a trap for gas and impurities.

[REQ-218] In the area of large surface of contact, grooves or slits shall be machined to enhance vacuum pumping.

7.7 Assembly and Installation requirements

The scope of this technical specification does not cover the IO site assembly.

[REQ-219] The Manufacturer shall perform a whole factory assembly of all the subcomponents listed in Figure 21 before shipping.

[REQ-220] The cooling connections between the DLMs (T1, B1, R1a, R1b) and the NS, and between the NSE and the NS, shall not be established.

[REQ-221] The alignment of the connection as defined for the MRR shall be verified.

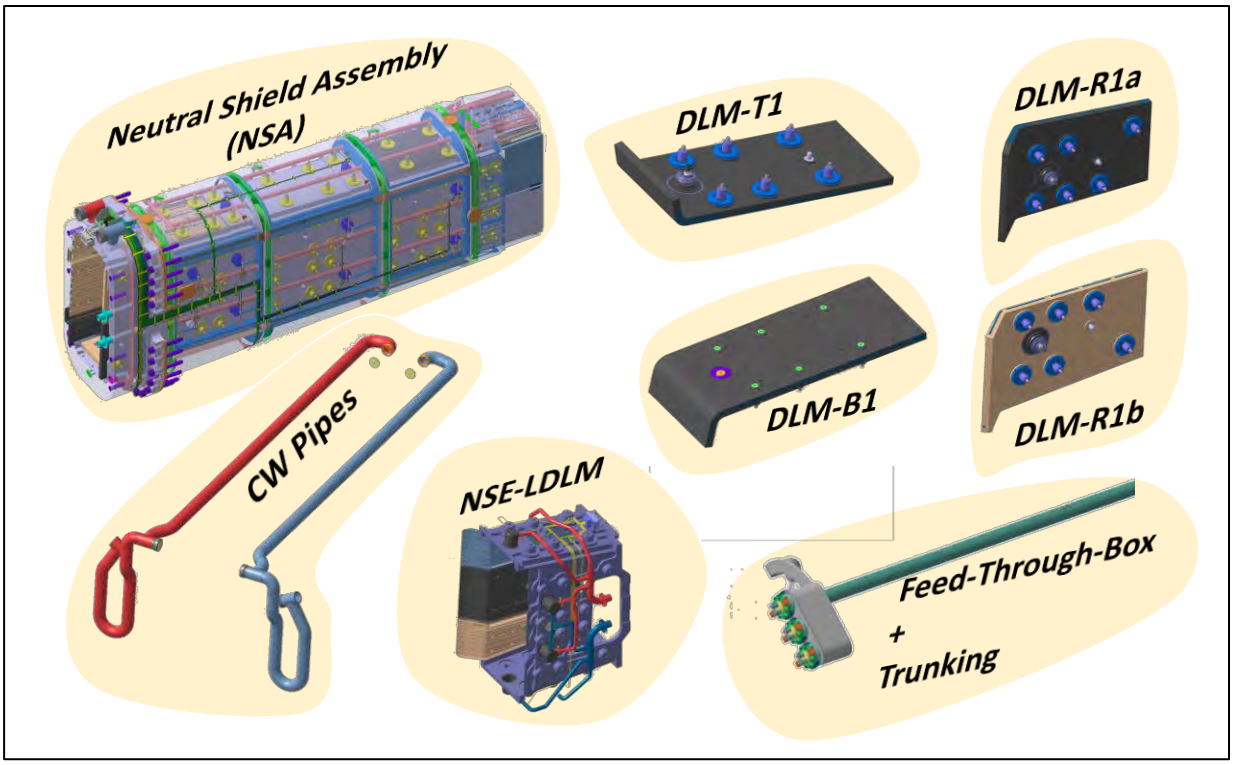


Figure 21: Sub-assemblies to be shipped

[REQ-222] For the component, which will be assembled on-site, the Manufacturer shall ensure that they meet all the requirements (weld edge preparation, orientation, tolerances, etc.) as specified in the drawings for the successful assembly with interfacing components.

[REQ-223] The Manufacturer shall develop the assembly plan by considering several aspects:

- The outcome of the feasibility study during the manufacturing design phase;
- The strategy to achieve the functional tolerances of DL assembly, considering the manufacturing and assembly tolerance stack up, welding distortions, and other relevant factors;
- Factory assembly sequence[3] definition.

[REQ-224] The Manufacturer shall submit the assembly plan to IO for approval at the appropriate manufacturing stage as defined in section 3.3 and the preliminary manufacturing report [RD32].

Assembly activities can be initiated after IO approves the assembly plan.

[3] *Manufacturer may use the assembly sequence considered by IO during design phase for developing the detailed assembly plan for DL.*

8 INSPECTION AND TESTING

8.1 Examinations

8.1.1 General requirements

[REQ-225] Inspection and testing shall ensure that the component can meet the performance described in the SRD document [RD1].

[REQ-226] The Manufacturer shall examine all the parts, sub-assemblies, final assemblies, etc., for complete compliance with the applicable code and standards, technical specification, approved drawings, and bill of material [AD24].

[REQ-227] All geometrical dimensions, tolerances, and material specified on the DL drawings listed in [AD24] shall be considered as requirements as part of this TS.

[REQ-228] The Manufacturer shall provide the details of the inspection and testing facilities. If deemed necessary, the IO will have the right to specify additional inspection/testing other than what is defined in this specification, and the IO will bear the cost of such test/inspection.

[REQ-229] The Manufacturer shall maintain the records of all the tests and inspections, which will be a part of the final documentation.

[REQ-230] All the tolerance dimensions/features in the individual parts, sub-assemblies, and the completed assembly shall be inspected.

[REQ-231] All tests carried out shall comply with written procedures submitted by the Manufacturer and approved by IO.

[REQ-232] The tests described in the technical specification shall be included in the MIP at the appropriate stage.

[REQ-233] The Manufacturer shall provide all necessary equipment and personnel to perform the tests.

[REQ-234] Records, certificates, and performance curves (if any) for all tests shall be provided to IO.

8.1.2 Failure of compliance

[REQ-235] Non-conformities shall be recorded and handled following the non-conformity management procedure [AD14] after each test.

[REQ-236] In case of failure to comply with TS requirements, the parts/assemblies shall be assessed according to the NCR procedure [AD14]. It could result in a "use as is", "repair", "rework", "reject", "scrap" of the part/assembly.

[REQ-237] The Manufacturer shall propose and undertake all necessary actions to comply with all requirements, including adjustments, modifications, or repairs as directed by IO.

[REQ-238] After adjustment, modification, or repair as directed by IO, the Manufacturer shall submit the item for further inspection and/or tests.

[REQ-239] The Manufacturer shall meet the technical specification requirements regardless of IO's approval of any test.

8.1.3 Calibration of measuring equipment

[REQ-240] Measures shall be established to ensure that tools, gauges, instruments, and other inspection, measuring, and testing equipment and devices used to determine the acceptance criterion's conformance are acceptable range, type, accuracy, and precision.

[REQ-241] Testing and measuring devices used in activities affecting quality shall be controlled, calibrated, and adjusted at specified intervals (at least once a year) on or before use to maintain accuracy within limits.

[REQ-242] The Manufacturer shall perform the above activities in a calibration laboratory accredited to EN 45011 / A2LA / ISO 17025, which may be the Manufacturer's own or external.

[REQ-243] The acceptance of other international standards for accreditation shall be subject to IO approval.

8.1.4 Qualification of personnel

[REQ-244] The personnel performing and evaluating the component's non-destructive examinations (NDEs) shall be qualified and certified following EN 473, ISO 9712, or ASNT Level 2.

[REQ-245] The Manufacturer shall ensure that the personnel who perform and evaluate the non-destructive examinations (NDEs) are qualified and certified following EN 473, ISO 9712, or ASNT Level 2.

[REQ-246] Manufacturer shall ensure that personnel performing tests other than NDEs have experience performing similar tests/inspections.

8.1.5 Visual Examination

[REQ-247] The Manufacturer shall visually examine all sub-components and sub-assemblies of DL for weld spatter, surface cracks, surface porosity, and other defects at the appropriate manufacturing stage, as defined in the selected manufacturing code.

[REQ-248] The finishing of the surface shall be as required in the manufacturing drawings.

[REQ-249] The cleanliness of the surface shall be as defined in Annexure 6.

8.1.6 Dimensional control

8.1.6.1 General requirements

[REQ-250] According to the ITER Dimensional Metrology Handbook, the geometrical shape and tolerances shall be measured using a testing protocol [RD26].

[REQ-251] According to the ITER Dimensional Metrology Handbook [RD26], during contract implementation, the manufacturer shall propose the metrology classes for the Alignment and Metrology to IO for approval during the MRR process.

[REQ-252] Dimensional inspections shall be carried out at all required manufacturing stages to satisfy the tolerance requirement, which shall be incorporated in the relevant MIP.

[REQ-253] The Manufacturer and IO shall agree on the interventions related to dimensional measurement during the Manufacturing Readiness Review (MRR).

[REQ-254] Each assembly shall be dimensionally inspected at every important manufacturing stage, and the results shall be compared with the approved manufacturing drawings.

[REQ-255] A Dimensional Control Plan (DCP) shall be prepared and provided (according to 6.4 of ITER Dimensional Metrology Handbook [RD26] during the MRR and approved by IO.

[REQ-256] A dimensional check for the individual components and the completed equipment shall be carried out at a constant temperature per the approved procedure and meet the requirements specified in the approved drawing.

[REQ-257] All the dimensions in the drawing are at 20 °C. The measurement carried out at any other temperature shall be corrected to 20°C before comparing with the dimensions in the drawing.

[REQ-258] Dimensional measurements concerning the coordinate system defined in tolerance drawings shall be used.

[REQ-259] All dimensions mentioned in the approved manufacturing drawings shall be measured.

[REQ-260] During measurement, the Manufacturer shall ensure that components are in free condition without any restraints.

[REQ-261] During measurement, if any supports or tools are considered, they shall be guaranteed not to impact the final dimensions.

[REQ-262] Dimensional control for factory acceptance shall be carried out in a controlled environment with a maximum temperature variation of ± 2˚C.

8.1.6.2 Acceptance

[REQ-263] The component's dimensions shall be within the tolerance specified in the manufacturing drawings.

[REQ-264] The Manufacturer shall produce “manufacturing” drawings to demonstrate compliance with the BtP provided by IO.

[REQ-265] Any non-conformance in the measurement process shall be handled through a Non-conformity procedure [AD14].

8.1.6.3 Dimensional measurement report

[REQ-266] All inspection reports shall include the following information as a minimum:

- Identification of measuring instruments with the date of calibration and validity;
- Identification of components/parts examined;
- Dimensional inspection procedure along with revision details;
- Material grade and thickness of the part;
- Drawing no. along with revision details;
- Date of Examination;
- Name of operator along with signed and date;
- Non-Conformity Report, if any;
- Meteorological data (temperature, etc.);
- Interpretation of result (Acceptance / Non Acceptance);

[REQ-267] All inspection reports shall be in a format acceptable to IO.

8.1.7 Non-destructive examination of production welds

[REQ-268] For All VQC 1A water boundaries and vacuum boundary production welds (refer to respective engineering drawing for vacuum classification) that become inaccessible, 100% volumetric examination of production welds shall be performed unless a method of pre-production proof sampling is approved.

[REQ-269] On welds specified that volumetric examination be performed as described in the welding table [RD33], and radiography or ultrasonic inspection is impossible, Production Proof Sampling shall be completed.

[REQ-270] All welds shall be examined in accordance with the specifications outlined in the welding table [RD33].

[REQ-271] The selection of the non-destructive examination method shall be based on the following guidelines and prevail on the welding table [RD33].

Wall Thickness	Preferred Volumetric Examination Method
wt < 12 mm	Radiography
12 mm > wt < 19 mm	Radiography or Ultrasonic
wt > 19 mm	Ultrasonic or Radiography

Table 11: NDE examination of production welds

8.1.7.1 Radiography examination

[REQ-272] Radiography examination shall follow ASME Sec V / ISO 17636 /EN 1435.

[REQ-273] Acceptance criteria for the RT examination shall be as per Annexure 2 and Annexure 3.

8.1.7.2 Ultrasonic examination

[REQ-274] Ultrasonic inspection shall follow ASME Sec V / ISO 17640 /EN 1714.

[REQ-275] Acceptance criteria for the UT examination shall be as per Annexure 2 and Annexure 3.

8.1.8 Production Proof sample (PPS) examination of production welds

[REQ-276] Each PPS shall only represent a specific type of weld.

[REQ-277] Each PPS shall use the same material, thickness, and setup as the production weld.

[REQ-278] A PPS shall be welded during the same shift as the production welds and by the same welder using the same equipment; otherwise, it would not represent the production welding.

[REQ-279] If more than one welder welds the production welds, each welder shall perform PPS.

[REQ-280] PPSs shall be prepared for each shift of production welding to represent the welds performed on that shift.

[REQ-281] PPS shall be sectioned and macro-examined in four places (including a one-stop /start area).

[REQ-282] Photographs of the macros showing the date the PPS was welded, the welder's identity, and the identification of the production welds it covers shall be included in the final documentation package. In addition, an IO representative may witness PPS welding.

[REQ-283] IO representative shall review all Macros of PPS.

[REQ-284] As the PPS is a representative sample, rejection of the macros shall reject all welds represented by those PPS.

8.1.9 Measurement of drilling deviation (drift) in deep-drilled component

[REQ-285] Drift shall be measured on each finished DLM Panel. It can be measured by measuring the wall thickness of elements (parallel and perpendicular axis of deep drilling).

[REQ-286] The Manufacturer shall measure the drift along the DLM Panels, potentially using a special ultrasonic probe (with a minimal dead zone) or a submerged ultrasonic technique.

[REQ-287] The measurement shall be taken at every interval of 100 mm distances.

[REQ-288] The measured drift control shall be within 500 microns/meter.

[REQ-289] The Manufacturer may propose other alternative methods for measuring the drift. However, such a proposal shall be submitted to IO for approval before application.

8.2 Acceptance Tests

8.2.1 Requirements applicable to all stages of acceptance tests

[REQ-290] The construction of the Duct Liner assemblies shall be considered acceptable if they comply with the TS requirements (including annexures and appendices), the BtP drawings, and 3D CAD models.

[REQ-291] The Manufacturer shall deliver entirely acceptable items. Therefore, the IO's participation in the execution of the contract does not relieve the Manufacturer from its responsibility to deliver items per the requirements and criteria set out in the technical specifications.

[REQ-292] The Manufacturer shall ensure that the items align with regulatory requirements and documentation. Acceptance of IO IDM of the Manufacturer's documentation (e.g.: results, tests, certificates, or any other reports/documents) does not relieve the Manufacturer of the responsibility for compliance with all contractual requirements.

[REQ-293] Any discrepancy with contractual requirements arising during the execution of this contract shall be handled through a non-conformity procedure [AD14].

[REQ-294] Acceptance tests shall be performed at various execution stages, as described in the following chapters, to ensure compliance with the technical specifications.

8.2.2 Stage 1: During Manufacturing (at the factory site)

Test Description	Requirements and Acceptance Criteria
Raw material Inspection	Annexure 1
Weld Qualification	Annexure 2 and Annexure 3
Production welding Inspection and tests	Section 8.1.7 and 8.1.8
Visual Inspection and cleanliness check	Section 8.1.5 and Annexure 6
Dimensional Inspection (Including measurement of drift)	Approved manufacturing drawing, Sections 8.1.6 and 8.1.9
Pressure test of sub-component/ sub-assemblies followed by a draining drying	Annexure 4
Leak test of sub-component / sub-assemblies (Room temp. and Elevated temp.)	Annexure 5
Baking and Outgassing	Section 7.6.12 and 7.6.16

8.2.3 Stage 2: After completion of manufacturing at the factory: Factory Acceptance Tests (FAT)

[REQ-295] The components and parts shall be made available at the supplier’s factory for factory acceptance tests by IO.

[REQ-296] The Manufacturer shall ensure compliance with the IO's factory acceptance criteria:

- Conformance with the requirements as set out by this technical specification;

- Identification of the component and parts in the scope of supply;
- Evidence of material traceability, material test reports, and certificate of conformance for all material and items being delivered;
- Control of stamping;
- Successful completion of the following factory acceptance tests;

Test Description	Requirements and Acceptance Criteria
Visual Inspection	Section 8.1.5
Dimensional Inspection	Approved manufacturing drawing, Section 8.1.6
Pressure test	Annexure 4
He Leak test	Annexure 5

[REQ-297] The integrity of the component shall be preserved during transportation until arrival at the site.

[REQ-298] Checks shall be conducted on the packing provisions and transportation plan.

[REQ-299] FAT shall be considered as completed after reviewing and checking the Manufacturing File and after a certificate of compliance along with a Release note as per the format prescribed in [AD 16] is issued by the Manufacturer and counter-signed by IO.

8.2.4 Stage 3: After delivery of the 3 Duct Liners to the IO site: Site Acceptance Tests (SAT)

[REQ-300] The Manufacturer shall ensure that all components and parts are available for inspection at the IO site.

Upon the arrival of Duct Liner assemblies at the IO site, the following post-delivery inspections will be performed by IO.

Test Description	Requirements and Acceptance Criteria
Visual Inspection	Check for the physical state and condition of the packing to ensure that the integrity of the component has been preserved until arrival at the site. Accelerometer check Unpacking of package and checking following on component; Component's cleaning and conservation Visually inspect the transportation damage (if any) on the component

[REQ-301] If any test or inspection prescribed in the present specification reveals a defect due to a fault or damage during transport, the Manufacturer shall raise a Non-conformity.

[REQ-302] The Manufacturer shall bear the risk of loss or damages to the components during the execution of this contract up to delivery on ITER site, including any failure of the components during transport.

The Acceptance Data Package (ADP) is the documentation package linked with all deliverables to be submitted by the Manufacturer.

[REQ-303] The Acceptance Data Package for the whole Supply shall be submitted before final approval by IO and closure of the Contract.

[REQ-304] The final acceptance for this procurement shall be granted when:

- All the requirements from this specification are respected unless Deviation or NCR are approved by IO.
- All the documentation described in section 3.3 is approved by IO.
- All the tests described in this document are accepted and report approved.
- All the components are delivered at the IO site, and the post-delivery inspection is passed.
- After verification of all the above and the approval of the ADP, final IO acceptance of the items will be granted.

9 REQUIREMENTS FOR LABELLING, CLEANING, PACKAGING, HANDLING, SHIPMENT AND STORAGE

9.1 Scope of application

The following generic requirements apply for the shipment of Duct Liner assemblies and associated specific tools and parts from the manufacturing/assembly site to the IO site and/or any intermediate site.

[REQ-305] Suitable precautions shall be taken to avoid damage to the component.

[REQ-306] In all cases (shipment to the intermediate or IO site), the component shall be subjected to control and inspection before and after transportation, as defined in section 9.1.5.

9.1.1 Labelling and Traceability

[REQ-307] The DL assemblies and their sub-components shall be marked permanently and in a visible place with the IO official numbering system according to the document “ITER Numbering System for Components and Parts” [AD23].

[REQ-308] When the functional reference is needed (described in [AD23]), the following PBS identifier shall be used for the PPPPPP code. IO will provide the PNI for the MRR.

[REQ-309] The traceability of all material shall be established to ensure that only correct and accepted products and parts are used during manufacturing.

[REQ-310] The traceability, including the materials, shall be guaranteed from reception to delivery. It includes all intermediate steps during the manufacturing route.

[REQ-311] The traceability, including the material, shall be implemented through the dedicated procedure to be subjected to IO’s approval before the start of any manufacturing activities.

[REQ-312] For the DL Feedthrough box that has to follow RCC-MR, chapter RF 2000 requires the Manufacturer to establish an identification and marking procedure that shall be made mandatory for all sub-contractors to ensure the traceability of all the plates, parts or welds throughout the manufacturing process.

[REQ-313] All permanent inspection records shall refer to the above markings.

9.1.2 Cleaning before shipment

[REQ-314] During final cleaning, particular attention shall be given to removing debris and other foreign matter, particularly from the coolant channels and sealing surfaces.

[REQ-315] Final cleaning shall ensure effective cleanliness without damage to the materials' surface finish, material properties, or metallurgical structure and meet the requirements specified in Annexure 6.

[REQ-316] Chapter 24 of the IVH shall apply to the above requirements.

[REQ-317] Besides the above requirements, the cleanliness class B requirements from RF 6000 and work area level II requirements from RF 6240 shall apply to the DL feedthrough Box.

[REQ-318] The Manufacturer shall submit the proposed cleaning procedure to the IO for approval/acceptance.

[REQ-319] The Manufacturer shall provide the final cleaning report to IO for acceptance at the end of the cleaning.

The demonstration of meeting the above cleaning requirements represents a Hold Point (HP).

9.1.3 Packaging and Handling

[REQ-320] After the FAT, the DL assemblies shall be partially disassembled for transportation (In/Out cooling manifold pipes, instrumentation trunking, feedthrough box, NSE).

[REQ-321] All components requiring assembly at the IO site shall be clearly labeled and tagged.

[REQ-322] The Manufacturer shall design and supply appropriate packaging to prevent damage during shipping, lifting, and handling operations.

[REQ-323] At least two accelerometers shall be rigidly fixed onto each box and capable of recording the acceleration along three perpendicular directions.

[REQ-324] Components shall be packed with adequate protection from thermal or mechanical stresses, which may adversely affect the operation of the component.

[REQ-325] All vacuum components shall be shipped dry internally and externally, irrespective of final acceptance testing at the Manufacturer’s site.

[REQ-326] Aluminum foil is recommended for sealing pipe openings, and protective caps shall be fitted to flanges before packaging and sealing.

[REQ-327] Where it is not practical to pack the components, e.g. due to size, all openings shall be sealed to prevent the ingress of contaminants during transit.

[REQ-328] Sealing surfaces shall be protected to prevent damage by scratching, impact, etc.

[REQ-329] The use of adhesive tape for the protection and packaging of vacuum components shall be restricted to prevent contamination from the adhesive tape.

[REQ-330] The adhesive tape used on austenitic stainless steel shall meet leachable chloride and fluoride limits of 15 ppm and 10 ppm, respectively.

[REQ-331] Where used, adhesive tape shall be fully removable, leaving no residue, using isopropyl alcohol or acetone as the solvent to remove all traces of the adhesive.

[REQ-332] Shock-absorbing material shall be used.

[REQ-333] The volumes of the cooling water circuit shall be evacuated and then backfilled with dry inert gas to a positive pressure of 0.12 MPa. Subsequently, all openings shall be temporarily sealed.

[REQ-334] Where practical, vacuum components shall be entirely wrapped in heat-sealed polyethylene packaging for shipping.

[REQ-335] The polyethylene packaging shall be purged and backfilled with dry air or inert gas (<100 ppm H_2O).

[REQ-336] Where this is not practical, alternative conditions shall be proposed by the manufacturer and accepted by the IO.

[REQ-337] On the packaging, all reference to the contents and other information shall be clearly shown in the English language, including at least the following:

- The complete address of the delivery location, the name of the individual responsible for receiving the packages, and the sender's full name and address;
- Contents description;
- Dimensions;
- Mass;
- Centre of gravity position (with the corresponding datum);
- Chemical or radiological hazards, if any;
- Lifting points;
- Instruction from supplier for unloading.

[REQ-338] The supplier shall consider all risks and consequent safety rules to be adopted during all the phases of packing and transport.

IO will be responsible for unloading on-site.

9.1.4 Delivery report

[REQ-339] Each shipment shall be accompanied by a Delivery Report [AD17] prepared by the Manufacturer, stating as a minimum:

- The packing date;
- The full address of the delivery place, the name of the person responsible for receiving the package, as well as the Supplier's name with his full address;
- Bill of Materials;
- Release Note [AD16];
- Packing List;
- Material Safety Sheet;
- The declaration of the integrity of the package;
- The declaration of the component's integrity;
- Any additional relevant information on the status of the components.

[REQ-340] A representative of the IO and Manufacturer shall sign the Delivery Report.

[REQ-341] The IO's signature of the Delivery Report before shipment represents a Hold Point (HP).

[REQ-342] A copy of the Delivery Report, which the IO owns, shall be kept by the Manufacturer.

9.1.5 Shipment, Transportation, and Delivery to the IO site

[REQ-343] The components shall exclusively be delivered to the IO site using the ITER Global Logistic Provider under the Supplier's responsibility.

Obtaining necessary clearance/interactions with statuary bodies for safe and authorized component transportation, if required, lies within the scope of the Manufacturer.

[REQ-344] Before the shipment, a Release Note shall be prepared following the "Contractor Release Note" [AD16] and approved by the IO.

[REQ-345] Upon receipt of the package, the IO shall open the package and make a visual inspection of its content to check the following:

- The integrity of the package, including identifying visible damage;
- The number and type of components contained in the shipment;
- The enclosed documentation;
- The reading of the accelerometers or other sensors;
- The integrity of the components;

- Cleanliness check;
- Accelerometer check.

[REQ-346] In the case of anomalies, the IO shall make any additional relevant remark on the inspection.

[REQ-347] If accelerometers record shocks observed above 5g, IO shall inspect the components thoroughly. Then, the IO will decide to accept the delivery of the components.

If the components are in an acceptable condition, the IO will sign the Delivery Report.

9.2 On-Site Activities

[REQ-348] The Manufacturer shall obey "Construction sign–off authority" [RD27].

9.3 Environment, Safety and Health

[REQ-349] The Manufacturer and its subcontractor shall observe all applicable environmental, safety, and health provisions for work on the IO site and specific requirements in this technical specification.

[REQ-350] Any activity by the Manufacturer and its subcontractors at the IO site shall be subject to the "Internal Regulations" [RD28].

[REQ-351] Any activity by the Manufacturer and its subcontractors on the ITER Construction Site shall be subject to the "General Safety Rules – Volume 0" [RD29] and resulting procedures.

[REQ-352] The IO shall communicate any additional applicable environmental, safety, and health provisions to the Supplier at least 30 calendar days before the activities are performed at the IO site.

10 QUALITY ASSURANCE

[REQ-353] Quality Requirements shall be in accordance with the "ITER Procurement Quality Requirements" [AD9].

[REQ-354] The ITER Quality Assurance Program shall be applied to all the work under this Contract. The ITER QA Program is based on IAEA Safety Standard GS-R-3 and conventional QA principles and integrates the requirements of the INB Order dated 7 February 2012 [AD22] on the quality of design, construction, and operation in Basic Nuclear Installation. For this purpose, the Supplier and Subcontractors carrying out contracts placed under this Contract shall be in compliance with the QA requirements under the relevant ITER QA classifications, the requirements of the INB Order, and shall have an IO-approved QA

Program or an ISO 9001 accredited quality system, complemented with the above-mentioned requirements.

[REQ-355] Prior to the commencement of any work under this Contract, a "Quality Plan" (QP) [AD10] shall be produced by the Supplier and Subcontractors and submitted to the IO for approval, describing how they will implement the ITER Procurement Quality Requirements.

[REQ-356] As part of the Quality plan, the manufacturer shall identify potential risks related to the contract and provide the associated Risk plan/register.

[REQ-357] Prior to the commencement of any manufacturing, a "Manufacturing and Inspection Plan" (MIP) [AD11] shall be produced by the Supplier and Subcontractors and approved by the IO, which will mark up any intended intervention point. MIPs are used to monitor Quality Control and acceptance tests during the execution of the Contract. It should be noted that interventions additional to those required in this Technical Specification may be included on the MIP by the IO.

[REQ-358] The right of the IO listed above shall apply in relation to any Subcontractor, and in this case, the IO will operate through the Supplier. The overseeing of the quality control operation by the IO shall not release the Supplier from his responsibility in meeting any aspect of this Technical Specification. Subcontractors not performing Critical Quality Activities (i.e. activities that, if not performed correctly, may affect safety, functionality, or reliability) may be exempted from the requirement to supply Quality Plans and Manufacturing & Inspection Plans, subject to agreement by the IO.

[REQ-359] All requirements of this Technical Specification and subsequent changes proposed by the Supplier during the execution of this Contract shall be subject to the Deviation Request process described in "Contractors Deviations and Non-conformities Procedure" [AD14].

[REQ-360] Documentation developed as the result of this Contract shall be retained by the Supplier for a minimum of 5 years and then may be discarded at the direction of the IO.

[REQ-361] The use of computer software to perform a safety-based task activity, such as analysis and/or modeling, etc. shall be reviewed and approved by the IO before its use following "Quality Assurance for ITER Safety Codes Procedure" [AD27].

[REQ-362] In case of Contracts concerning SIC components and/or a Safety Related Activity, or PIC and/or Protection Related Activities, the Quality Assurance Program of the Supplier shall comply with the requirements of the INB Order dated 7 February 2012 [AD22] and the subsequent ASN decisions linked to this Order. For this purpose, the Supplier and Subcontractors carrying out contracts placed under the Contract shall be in compliance with the QA requirements under the relevant QA classifications as defined in "Quality Classification Determination" [AD4] and additional requirements of the INB Order dated 7 February 2012 [AD22] and the subsequent ASN decisions linked to this Order.

[REQ-363] In particular for SIC, the IO, as the Nuclear Operator, will supervise the whole production cycle of the Supplier and Subcontractors in accordance with the document "Overall Supervision Plan of the Chain of Suppliers for Safety Important Components, Structures and Systems and Systems and Safety Related Activities" [AD28], which shall be identified in the MIP [AD11].

11 ASSOCIATED DOCUMENTS OF TECHNICAL SPECIFICATION

11.1 Appendices (mandatory requirements)

- Annexure 1: Raw Material Procurement
- Annexure 2: Welding and Welding Qualification Requirements
- Annexure 3: Welding and Welding Qualification for SIC Component
- Annexure 4: Pressure Testing
- Annexure 5: Leak testing
- Annexure 6: Cleaning and Cleanliness Requirements

11.2 Applicable Documents

[REQ-364] All applicable documents shall be considered as requirements of this technical specification and might be updated through the issue of a Deviation notice.

Document description		ITER Ref. No.
[AD1]	Development Requirement Document of DL	ITER_D_73XQHL v1.0
[AD2]	Codes and Standards for ITER Mechanical Components	ITER_D_25EW4K v4.0
[AD3]	Safety important function and components classification criteria and methodology	ITER_D_347SF3 v1.8

[AD4]	Quality Classification determination	ITER_D_24VQES v5.2
[AD5]	ITER Seismic Nuclear Safety Approach	ITER_D_2DRVPE v1.6
[AD6]	ITER Remote Maintenance Management System	ITER_D_2FMAJY v1.6
[AD7]	ITER Vacuum Handbook	ITER_D_2EZ9UM v2.5
[AD8]	NBI tritium classification of the components	ITER_D_34PRS4 v1.0
[AD9]	ITER Procurement Quality requirement	ITER_D_22MFG4 v5.1
[AD10]	Requirement for Producing a Quality Plan	ITER_D_22MFMW v4.0
[AD11]	Requirement for producing an inspection plan	ITER_D_22MDZD v3.7
[AD12]	ITER Vacuum Handbook attachments and appendices	
	Attachment 1: Inspection and Qualification of welded vacuum joints	ITER_D_2FMM4B v1.5
	Attachment 2: Cleanliness requirements relating to the assembly of vacuum equipment	ITER_D_MBXPP3 v1.7
	Appendix 2: Environmental cleanliness requirements pertaining to vacuum classification	ITER_D_2EL9Y6 v1.4
	Appendix 3: Accepted materials	ITER_D_27Y4QC v1.20
	Appendix 4: Accepted fluids	ITER_D_2ELN8N v1.14
	Appendix 12: Guide to leak testing	ITER_D_2EYZ5F v1.4
	Appendix 13: Guide to Cleaning and Cleanliness	ITER_D_2ELUQH v1.2
	Appendix 14: Guide to Passivation and Pickling	ITER_D_2F457S v1.2
	Appendix 15: Guide to Vacuum Baking	ITER_D_2DU65F v1.3
	Appendix 17: Guide to Outgassing Rates and their Measurement	ITER_D_2EXDST v2.2

[AD13]	Procedure for Identification and Control of Items	ITER_D_U344WG v2.2
[AD14]	Procedure for Management of Non-conformities	ITER_D_22F53X v9.1
[AD15]	Procedure for the management of deviation request	ITER_D_2LZJHB v8.1
[AD16]	Requirements for Producing a Contractor Release Note	ITER_D_22F52F v5.0
[AD17]	Delivery report template	ITER_D_WZPYVZ v2.6
[AD18]	Inspection plan template	ITER_D_QV7GQF v1.3
[AD19]	Working Instruction for Manufacturing Readiness Review	ITER_D_44SZYP v5.0
[AD20]	Working Instruction for the Delivery Readiness Review (DRR)	ITER_D_X3NEGB v2.0
[AD21]	Provision for implementation of the Generic safety requirements by the external actors/ interveners.	ITER_D_SBSTBM v2.2
[AD22]	Order dated 7th Feb 2012 relating to the general technical regulation applicable to INB.	ITER_D_7M2YKF v1.7
[AD23]	ITER Numbering System for Components and Parts.	ITER_D_28QDBS v5.0
[AD24]	DL BOM	Folder: uid=8ZVFE2
[AD25]	DL Welding Table	ITER_D_8ZVFFJ v2.5

[AD26] Justification des équipements du système de queusot du faisceau de neutre- hors ESPN	ITER_D_RB4NPL v1.2
[AD27] Working Instruction for the Qualification of ITER Safety Codes	ITER_D_258LKL v3.1
[AD28] Overall Surveillance Plan of the Chain of External Actors for Protection of Important Components, Structures and Systems, and Protection of Important Activities	ITER_D_4EUQFL v7.4

11.3 Reference Documents

Document description	ITER Ref. No.
[RD1] SRD-53-01, -02, -03 (NBHandCD)	ITER_D_28B37M v4.3.
[RD2] Load specification of HNB Duct Liner	ITER_D_4AMFEK v3.2
[RD3] Design Review Procedure	ITER_D_2832CF v6.4
[RD4] Tech Spec of the Cooling Water Coaxial Testbed	ITER_D_2FKKBB v1.2
[RD5] Tech Spec of the Module Bolting System Testbed	ITER_D_VAE2EW v1.9
[RD6] ITER System engineering management plan	ITER_D_2F68EX_v3.5
[RD7] IO/DA Documentation Exchange and Storage	ITER_D_35BVQR v5.0.
[RD8] ITER Document Breakdown Structure Overview	ITER_D_43327Q v1.1

[RD9]	ITER Plant Breakdown Structure (PBS).	ITER_D_28WB2P v2.0
[RD10]	PA monthly report template	ITER_D_2E346G v1.4
[RD11]	ICD-15-53 Interfaces Control Document (ICD) for Neutral Beam HandCD (PBS53) – Vacuum Vessel (PBS15)	ITER_D_2WJF4K v3.1
[RD12]	IS-15-53-001_HNB/DNB DL to VV interface	ITER_D_ 2FRHET v3.0
[RD13]	ICD-15.VV-22 Interfaces Control Document for Vacuum Vessel Systems (PBS 15.VV) and Assembly and Tooling (PBS 22)	ITER_D_ 32LVEM v2.1
[RD14]	ICD-15.VV-22 Interfaces Control Document for Vacuum Vessel Systems (PBS 15.VV) and Assembly and Tooling (PBS 22)	ITER_D_32LVEM v2.1
[RD15]	Interfaces Control Document (ICD) between Tokamak Cooling Water System (PBS 26-PH,-CV,-DR,-DY) - Vacuum Vessel (PBS 15)	ITER_D_ 2LEAEJ v1.1
[RD16]	IS-15-26-001 interface between CWS and the Vacuum Vessel	ITER_D_ 27YNGM v5.1
[RD17]	ICD-23-15 Interface Control Documents (ICD) for Vacuum Vessel (PBS 15) and Remote Handling Systems (PBS 23)	ITER_D_ 2FFPTY v5.7
[RD18]	IS-23-15-012 Neutral Beam RH system interface with the vacuum vessel	ITER_D_ AHBRRP v2.1
[RD19]	IS-23-15-013 Neutral Beam Duct Liner RH interfaces	ITER_D_ JE7SEW v2.2

[RD20]	ICD-16-53 Interface Control Document for Blanket System (PBS 16) and Neutral Beam HandCD system (PBS 53)	ITER_D_ 2MCUSN v1.1
[RD21]	IS-16-53-001 Interface between Blanket System and HNB System at Port Entrance	ITER_D_ 2MZTKG v1.3
[RD22]	Interface Control Document (ICD) between Neutral Beam HandCD System (PBS 53) and Cable Tray Systems (PBS 44)	ITER_D_ 3C4R9M v4.0
[RD23]	IS-44-53-001 Interface between Cable Tray System (PBS 44) and Neutral Beam HandCD System (PBS 53) for all types of cables	ITER_D_ MV3FRJ v1.2
[RD24]	Defined requirements for PBS53.	ITER_D_LAMFG2 v4.5
[RD25]	Surveillance plan for PBS 53 – Annex 2: Detailed List of PIAs	ITER_D_U65RWF v1.2
[RD26]	ITER Dimensional Metrology Handbook	ITER_D_46FN9B v2.1
[RD27]	Construction sign–off authority	ITER_D_VFY7GN 3.0
[RD28]	Internal Regulations	ITER_D_27WDZW v3.1
[RD29]	Health Protection and Safety General Coordination Plan - ITER Construction Site - Volume 0 - General Safety Rules	ITER_D_2NUEYG v5.7
[RD30]	DL Functional Reference	ITER_D_96RVVR v1.0
[RD31]	Fluid Acceptance request database	uid=VH2KDW
[RD32]	DL Manufacturing report	ITER_D_9GGSM4 v1.1

[RD33] DL welding table	ITER_D_8ZVFFJ v2.5
[RD34] DUCT LINER BLOWOUT SIMULATIONS - HNB1&HNB2	ITER_D_3LB372 v1.1

ANNEXURE 1.

RAW MATERIAL

12 ANNEXURE SCOPE

This annexure describes the requirements for the manufacture, procurement, testing, inspection, and supply of raw materials to manufacture Duct liners.

13 GENERAL REQUIREMENTS

[Annexure REQ 1] The following general technical requirements shall apply to all stages of raw material procurement for DL component manufacturing.

[Annexure REQ 2] All the materials, welding consumables, proprietary items, and bought-out items, including materials for trials, qualifications, production test coupons, testing, etc., as required for the manufacture of Duct liner shall be procured and tested following this Specification.

[Annexure REQ 3] The Supplier shall procure all the materials as per relevant applicable Specifications.

[Annexure REQ 4] The source of material procurement shall be notified to IO. IO can perform the quality audit of the selected supplier as and when required.

[Annexure REQ 5] All the materials used in manufacture shall be new and of specific quality.

[Annexure REQ 6] MIP, Quality Plan, testing procedure, Non-Destructive Examination (NDE) procedure, etc., submitted by the Supplier of raw materials shall be submitted to the IO for approval before material procurement.

[Annexure REQ 7] Approved MIP and QP shall be strictly followed after that during procurement.

13.1 Traceability and test certificate of material:

[Annexure REQ 8] The Supplier shall ensure that each material is adequately identified and that each block of material is assigned a unique traceable identification number.

[Annexure REQ 9] Identification and traceability of each material shall be maintained throughout all manufacturing processes.

[Annexure REQ 10] Traceability documentation (Test certificate for all the materials used in manufacturing), which cross-references parts to material certificates, shall be included in the final collective acceptance documentation.

[Annexure REQ 11] The Supplier shall ensure that all testing and characterization required by this Specification are conducted and adequately documented in test certificates and inspection reports.

13.2 Usage of Stock material

[Annexure REQ 12] Stock material from the Supplier's stock or the stockiest shall be used if traceability of the component is established, indicated by a stamp on the material and the relevant certificate.

[Annexure REQ 13] The Supplier shall ensure that the certificates of analysis and all test results of the stock material comply with the requirements of applicable Specifications.

[Annexure REQ 14] When traceability is established and test certificates are available, a 3.1 certificate of EN 10204, MIP, or QP from the raw material Manufacturer shall not be mandatory for submission. If the tests are unavailable, the material can be upgraded by performing the necessary tests in an accredited laboratory.

[Annexure REQ 15] The Supplier is responsible for the quality of the stock material used. All material shall be free from surface cracks and fissures, forge and other tool marks, burns, delamination, and other defects that would make it incompatible with a high vacuum environment.

13.3 Usage of Standard Items

[Annexure REQ 16] Supplier shall procure the standard items from recommended make (if applicable) as suggested in this Specification.

[Annexure REQ 17] Standard items of this document's required size, grade, and specification shall be procured.

[Annexure REQ 18] Supplier shall submit a Test certificate conforming to EN 10204 Type 3.1 for all the standard items procured.

[Annexure REQ 19] The dimensions mentioned in the drawings are finished dimensions, and the Supplier shall procure the materials in sufficient quantities and appropriate size, taking into account the necessary allowances required for manufacture, trials, qualification, production test coupons, and testing.

[Annexure REQ 20] Supplier shall issue a purchase order to raw material Supplier with the following minimum information:

- Form of Product
- Grade & Specification.
- Quantity ordered.
- Nominal Dimensions
- Technical specification reference
- Documentation requirement
- Inspection and Testing requirements
- Delivery Schedule

- Access for purchaser during manufacturing for examination, inspection & testing if desired.
- Commercial Terms & Conditions

[Annexure REQ 21] Supplier shall arrange for reasonable access for IO at Raw material Supplier's place for Progress monitoring activity during manufacturing for examination, inspection & testing if desired.

[Annexure REQ 22] When utilizing hot or cold rolled plate material, it shall be ensured that a surface parallel to the rolling direction forms the vacuum boundary to mitigate potential long leak paths caused by stratified inclusions.

[Annexure REQ 23] Hot or cold rolled plate material shall not be used where the transverse cross-section across the vacuum boundary is less than 25mm.

[Annexure REQ 24] Where hot or cold rolled plate material is used with the transverse cross-section crossing the vacuum boundary, a low inclusion rate material, which meets the inclusion limits specified in clause 5.3 of the IVH, shall be used.

13.4 Surface Finish

[Annexure REQ 25] After the above surface finishing operations, it shall be ensured that the remaining thickness is greater than the minimum specified thickness.

[Annexure REQ 26] All processes on vacuum surfaces shall be followed by appropriate surface cleaning.

14 QUALITY REQUIREMENTS

[Annexure REQ 27] The Supplier shall develop and operate a management system appropriate for all manufacturing stages based on a recognized Quality standard that meets the IO Quality program and complies with the ISO 9001 standard.

[Annexure REQ 28] The Supplier shall prepare a Quality plan (QP), which states the effective implementation of the contract.

[Annexure REQ 29] The Supplier shall ensure that all material produced is tested and the appropriate certificates issued.

[Annexure REQ 30] At the request of IO or his appointed representative, the Supplier shall provide objective evidence that the contractual requirements are met.

15 DOCUMENTATION REQUIREMENTS

[Annexure REQ 31] Supplier shall ensure that raw material Supplier has submitted the detail-manufacturing program to IO before the start of manufacturing.

[Annexure REQ 32] The Raw material Supplier shall submit the Manufacturing and inspection Plan (MIP) for raw material to the Supplier. The Supplier marks up its intended intervention points on the raw material Supplier's MIP, approves the plan, and sends it to the IO for acceptance and markup of any IO interventions.

[Annexure REQ 33] Supplier shall ensure that raw material Supplier has submitted material test report after completing all the manufacturing and inspection activity with supporting technical records (like Heat treatment record, NDE reports, Inspection reports, Lab test certificates, etc.) to the purchaser.

16 SS 316L(N)-IG PLATES

16.1 Scope

This annexure prescribes the requirements for the manufacture, inspection, testing, packing, and supplies of austenitic stainless steel plates of SS 316L(N)-IG.

16.2 Reference documents

- RCC-MR 2007; Section-2; RM 3331 Product procurement specification: class 1, 2 and 3 X2CrNiMo17-12-2 controlled nitrogen content austenitic stainless steel plate from 5 mm to 100 mm thick for use at high temperature
- Chemical composition & impurity requirements for materials (ITER_D_22KCMF v2.3)
- SDC-IC Appendix A: Materials design limits (ITER_D_222RLN v3.3)
- IVH Appendix 14 : Guide to passivation and pickling (ITER_D_2F457S v1.2)

General Information	ITER_D_222UYT
Composition	ITER_D_22KCMF
Ultimate Tensile Strength	ITER_D_222V3G
Yield Strength	ITER_D_222V5H
Elongation	ITER_D_222V8X
Reduction of Area	ITER_D_222VAU
Engineering and True Stress-Strain	ITER_D_222VBC
Poisson's Ratio	ITER_D_222VDD
Young's Modulus	ITER_D_222VES
Fatigue Strain Constant	ITER_D_222VQP
Fracture Toughness	ITER_D_222VWJ
Melting Point	ITER_D_222VX2
Specific Heat	ITER_D_222VYK
Emissivity	ITER_D_223FGA

Thermal Conductivity	ITER_D_222VZ3
Thermal Expansion	ITER_D_222W29
Electrical Resistivity	ITER_D_222W3R
Density	ITER_D_222W48

Table 12: Link to the 316L(N)-IG properties for information

16.3 Use of Plates in the construction of DL components and melting process (requirement from IVH)

[Annexure REQ 34] When using hot or cold rolled plate material for all vacuum classes, it shall be ensured that a surface parallel to the direction of rolling forms the vacuum boundary to mitigate the risk of long leak paths resulting from the stratification of inclusions.

[Annexure REQ 35] For components classified as VQC 1A, when using hot or cold rolled plate material with a transverse cross-section crossing the vacuum boundary (wall thickness less than 25 mm), the material shall be produced using Electro-slag remelting (ESR) or Vacuum arc remelting (VAR) methods.

[Annexure REQ 36] All VQC 1A components which are machined from steel, austenitic steel, or superalloys and which are of final thickness less than 5 mm shall be made from cross-forged material which is Electro-Slag Remelted (ESR) or Vacuum Arc Remelted (VAR).

[Annexure REQ 37] The rate of inclusions in such steels shall be checked in accordance with ASTM E-45 Method D (or equivalent) to be within the following inclusion limits:

- Inclusion Type A ≤ 1.0.
- Inclusion Type B ≤ 1.0.
- Inclusion Type C ≤ 1.0.
- Inclusion Type D ≤ 1.5.

These requirements are synopsised in Table 5-2 of IVH.

[Annexure REQ 38] The produced material shall adhere to the inclusion limits specified in Section 16.7.2, as summarised in Table 13.

Nominal thickness (of vacuum boundary)	Direction	Plate / Bar[1]			Forging[4]	Pipe[4]	Pipe, [4,5] (He, ≤ 2 mm)	HIP[3]	Casting [4]
		Crosses[2]		Parallel[2]					
	RH Class	3, N/A	1, 2	1, 2, 3, N/A	1, 2, 3, NA	1, 2, 3, NA	1, 2, 3, NA		
≤ 5 mm		X	L	NR	F + L	NR	L	X	A
>5 mm ≤ 25 mm		X	L	NR	F	NR	NR	A	A
> 25 mm		L	NR	NR	NR	NR	NR	A	A

[1]VQC 1A, VQC 2A cryogenic helium pipework (pipe & fittings) < 2 mm
[2]Transverse cross section w.r.t. vacuum boundary or parallel w.r.t vacuum boundary
[3]All VQC
[4] VQC 1A,2A &3A
[5] Helium coolant, thickness less than 2 mm.
X=Not Allowed
F=Cross or Upset Forged
L= Low inclusion in compliance with 5.3.1 and ESR/VAR remelting
A=requires *acceptance*
NR = No requirement
N/A – not applicable

Table 13: Specific requirements from the IVH

[Annexure REQ 39] For the component classified as VQC 1B, the material shall be produced using an electric arc furnace or another technically equivalent process.

16.4 Manufacturing program

[Annexure REQ 40] Before starting manufacturing operations, the Supplier shall create a manufacturing program.

[Annexure REQ 41] The manufacturing program shall encompass the following elements:

- Identification of the melting process,
- Ingot weight and type (not required for plate thk <80mm)
- Identification of main hot-working operations (not required for plate thk <80mm)
- In the case of continuous casting, the discard parameters, weight of blooms, etc.,
- Top and bottom end discard percentages (not required for plate thk <80mm)
- Position of the plate in the ingot, in particular the final rolling direction concerning the ingot axis,
- Indication of main rolling direction,
- Identification of main rolling directions
- Conditions for intermediate heat treatments and for solution heat treatment (in particular, temperature, holding time, and cooling method),
- Position of acceptance test samples on the plate,

- Dimensional drawing with the position of test specimens in these samples.

[Annexure REQ 42] The various heat treatment, sampling, and non-destructive examination operations shall be presented chronologically.

16.5 Delivery condition

[Annexure REQ 43] The material shall be supplied in the solution annealed, pickled, and passivated condition.

16.5.1 Solution heat treatment

[Annexure REQ 44] Solution heat treatment shall consist of holding between 1050°C and 1150 ºC followed by water cooling.

[Annexure REQ 45] The thermal cycle involved in the heat treatment shall be recorded, and the records will be kept at the disposal of the surveillance agent.

16.5.2 Pickling – passivation, surface condition

[Annexure REQ 46] The pickling-passivation treatment shall be performed in compliance with the technical specification in Section 6.5.14 and Appendix 14 of IVH.

[Annexure REQ 47] In its as-delivered condition, the metal shall adhere to the specifications outlined in Section 7.6.15 and Appendix 14 of IVH, ensuring no trace of oil or grease remains on its surface.

[Annexure REQ 48] When assessed per RMC 7200, the plates' surface condition shall meet or ensure a roughness of <6.3 µm, as determined using a stylus probe-type instrument.

16.6 Chemical analysis

[Annexure REQ 49] The chemical composition, as determined by ladle and product analysis, shall comply with the requirements specified in Table 14.

Element	**SS 316L(N)-IG** Alloying elements & impurities content, wt. %.
	max
C	0.030
Mn	1.60-2.00
Si	0.50

P	0.025
S	0.010
Cr	17.00 - 18.00
Ni	12.00 - 12.50
Mo	2.30 - 2.70
N	0.060 - 0.080
Cu	0.30
B	0.0010*
Co	0.05*
Nb*	0.01**
Ta*	0.01**
Ti*	0.10
*For parts that will be re-welded limit for B is 0.0010 wt.%. **Maximum Co, Nb, and Ta, content is based on radioprotection requirements in the ProductProcurement Specifications.	

Table 14: Chemical composition of SS 316L(N)-IG Plates

[Annexure REQ 50] The steelmaker shall provide a ladle analysis certified by the mill manager or his duly accredited representative.

[Annexure REQ 51] The steelmaker shall also supply a product analysis from each rolled sheet.

16.7 Structure

16.7.1 Microstructure

[Annexure REQ 52] A micrographic examination, with photographs, must be made parallel to the rolling direction on each rolled sheet. The structure shall be homogenous.

[Annexure REQ 53] The grain size number determined by EN ISO 643: Steels- Micrographic determination of the apparent grain size shall be greater than 2. The presence of a few grains with size numbers 1 and 0 is tolerated.

16.7.2 Non-metallic inclusion

The requirement applies if the material is used to construct a VQC 1A component (with wall thickness <25mm) and its transverse cross-section crosses the vacuum boundary.

[Annexure REQ 54] The rate of inclusion in the material shall be checked following ASTM E 45 method D (or equivalent) to be within the following inclusion limits;

- Inclusion Type A ≤ 1.0
- Inclusion Type B ≤ 1.0
- Inclusion Type C ≤ 1.0
- Inclusion Type D ≤ 1.5

[Annexure REQ 55] Magnetic materials with a relative permeability that is greater than 1.03 shall not be used within the cryostat boundary without formal project approval.

16.8 Ferrite Content

[Annexure REQ 56] As determined using the modified Schaeffler diagram by Pryce and Andrews and measured on a solution heat-treated product, the ferrite content shall be 0.5% which corresponds to magnetic permeability 1.03.

[Annexure REQ 57] The ferrite content shall be measured at the surface of each heat-treated rolling sheet, at one-quarter width at the top and bottom, close to the mechanical test specimen.

16.9 Intergranular Corrosion test

[Annexure REQ 58] Material shall pass intergranular corrosion test conducted following ASTM A262 Practice E or equivalent EN/ISO std.

16.10 Mechanical Properties

16.10.1 Sampling

[Annexure REQ 59] After solution heat treatment, test samples from the plate shall be procured, appropriately labeled, and oriented to display the final rolling direction.

[Annexure REQ 60] The size of the test samples shall be such that they can provide enough test specimens for all tests and retests.

[Annexure REQ 61] Test samples shall be taken halfway between the edge and the axis of the plate centreline, ensuring their distance from the sample's edge is at least equal to the plate's thickness.

[Annexure REQ 62] The longitudinal axis of these specimens shall align parallel to the rolling skins and be perpendicular to the final rolling direction.

[Annexure REQ 63] The longitudinal axis of test specimens shall be parallel to the rolling skins and perpendicular to the final rolling direction.

[Annexure REQ 64] The location of the longitudinal axis for tension test specimens is based on plate thickness:

- At mid-thickness for plates 30 mm thick or less.
- At quarter thickness for plates thicker than 30 mm.
- The specimen thickness matches the plate thickness for plates less than 10 mm, resulting in a specimen with a rectangular cross-section.

[Annexure REQ 65] The longitudinal axis of impact specimens shall be located at quarter thickness.

[Annexure REQ 66] The notch axis of the impact test specimen shall be perpendicular to the rolling skin.

For thicknesses less than 12 mm, the KV impact test is not performed.

16.10.2 Test conditions

[Annexure REQ 67] Tension test **shall** be performed in "Solution heat treated" condition.

[Annexure REQ 68] Charpy V notch Impact test **shall** be performed in "Solution heat treated" and "Solution heat treated + Aged" conditions.

16.10.3 Number & contents of tests

[Annexure REQ 69] The number of tests to be performed shall be as follows:

				Top end			Bottom end			Number of specimens	
Name of test	**Test temperature (°C)**	**Weight of plate or rolled strip**	**Thickness**	**Full thickness**	**Mid-thickness**	**Quarter thickness**	**Full thickness**	**Mid-thickness**	**Quarter thickness**	**Per heat**	**Per rolling sheet or strip**
Solution heat treated											
Tension	Room	≤ 3000 kg	< 10 mm	1							1
			10 mm ≤ e ≤ 30 mm		1						1
			> 30 mm			1					1
	Room	> 3000 kg	< 10 mm	1			1				2
			10 mm ≤ e ≤ 30 mm		1			1			2
			> 30 mm			1			1		2
	According to the Equipment Specification	Regardless of weight	< 10 mm	1						1	
			10 mm ≤ e ≤ 30 mm		1					1	
			> 30 mm			1				1	
Solution heat treated and aged											
Charpy V-notch impact Solution heat treated	Room	≤ 3000 kg	e ≥ 12 mm			1				2	
		> 3000 kg	e ≥ 12 mm			1			1	4	
Charpy V-notch impact Solution heat treated and aged	Room	≤ 3000 kg	e ≥ 12 mm			1				2	
		> 3000 kg	e ≥ 12 mm			1			1	4	

[Annexure REQ 70] For each rolled sheet or strip, tests shall be conducted at room temperature based on its mass:

- For sheets or strips with a mass of 3000 kg or less, one series of tests is performed at the end corresponding to the top of the ingot.
- Two tests are performed for sheets or strips with a mass exceeding 3000 kg, one at each end.

[Annexure REQ 71] The yield strength of each metal heat at 450°C shall be verified using the temperature specified in the Equipment Specification from table RM 3332.51. Ideally, the test specimen should come from the end corresponding to the ingot's top end.

16.10.4 Tension testing at room temperature

16.10.4.1 Test specimen

[Annexure REQ 72] Test specimens shall have a circular section with a standard diameter of 10mm, following the specifications given in RMC 1211.

[Annexure REQ 73] For plates with a thickness of less than 20mm, a rectangular section specimen shall be permissible as an alternative to the cylindrical one, as detailed in RMC 1211.

16.10.4.2 Test Method

[Annexure REQ 74] The tension test shall be conducted according to RMC 1211, with the subsequent values being documented:

- Yield strength at 0.2% offset in MPa,
- Yield strength at 1% offset in MPa,
- Ultimate tensile strength, in MPa,
- Percentage elongation after fracture,
- Percentage reduction of area after fracture

16.10.4.3 Test Results

[Annexure REQ 75] The results obtained shall meet the requirements given in Table 15.

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	220
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded for information
Ultimate Tensile Strength, in MPa, Rm	525-700
Percentage elongation after fracture, A%(5d)	45

Percentage reduction of area after fracture	To be recorded for information

Table 15: Tensile properties of SS 316L(N)-IG plates at room temperature

16.10.5 Tension testing at high temperature

16.10.5.1 Test specimen

[Annexure REQ 76] The normal diameter of test specimens shall be 10mm, and their dimensions as specified in RMC 1212. For Plates less than 20mm thick, the cylindrical test specimen could be replaced by a specimen with a rectangular section, as stipulated in RMC 1212.

16.10.5.2 Test Method

[Annexure REQ 77] The tension test shall comply with RMC 1212.

[Annexure REQ 78] The specimen shall be tested at 450°C.

16.10.5.3 Test Results

[Annexure REQ 79] Yield strength at 0.2% offset obtained shall meet the requirement given in Table 16.

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	112
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded for information
Ultimate Tensile Strength, in MPa, Rm	To be recorded for information
Percentage reduction of area after fracture	To be recorded for information

Table 16: Tensile properties of SS 316L(N)-IG plates at high temperature

16.10.6 Retesting of Tension test specimens

[Annexure REQ 80] If a test specimen demonstrates a physical defect (not impacting the product's usefulness) or unsatisfactory test results arise from incorrect specimen mounting or testing machine malfunction, another sample shall be retested.

[Annexure REQ 81] The rolled plate or strip shall be accepted upon satisfactory results from the second test.

[Annexure REQ 82] Two additional tests shall be conducted for each unsatisfactory result When unsatisfactory outcomes are not due to the previously mentioned reasons.

[Annexure REQ 83] The secondary test specimens shall be sourced near the original defective ones.

[Annexure REQ 84] The plate shall either be accepted or rejected based on the retest results.

16.10.7 Charpy V notch impact tests

[Annexure REQ 85] If the thickness of the plates does not allow for the manufacture of a standard sample, the test shall be skipped.

16.10.7.1 Test specimen and test method

[Annexure REQ 86] Four Charpy V-notch test blanks shall be taken from adjacent locations as specified in section 5.10.3. Two of them undergo the following aging treatment at the laboratory furnace.

- Holding to a temperature of 750C ± 5°C
- Holding for 100h
- Cooling in still air

[Annexure REQ 87] The shape and dimensions of the specimens shall follow the specification given in RMC 1221.

16.10.7.2 Results

[Annexure REQ 88] Impact test results shall meet the following requirements.

Name of test	Test temperature (°C)	Properties	Required value
Charpy V-notch impact – solution heat-treated	Room	Minimum individual value 12mm ≤ e ≤25mm	100 J
		e ≥ 25mm	112 J
Charpy V-notch impact – solution heat treated + aged 100 h at 750 °C	Room	Minimum individual value	80 J

Table 17: Impact properties of SS 316LN(IG)

16.10.7.3 Retesting

[Annexure REQ 89] If an individual value is lower than the required minimum value for each heat treatment condition, two series of retests shall be performed on two test specimens.

[Annexure REQ 90] These specimens are taken near the first series and tested in the same conditions.

[Annexure REQ 91] Each specimen must give satisfactory results; otherwise, the lot shall be rejected.

16.10.8 Retreatment

[Annexure REQ 92] Rolled strips or sheets rejected based on unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment as per section 16.5.1). Retreatment conditions shall be described in the test report.

[Annexure REQ 93] In such cases, test specimens shall be taken under the conditions specified in sections 16.10.1 to 16.10.3.

[Annexure REQ 94] The test performed shall be the same as in sections 16.10.4, 16.10.5, and 16.10.7.

16.11 Surface examination – Surface defects

[Annexure REQ 95] Plates shall undergo visual examination.

[Annexure REQ 96] The surfaces of the plates shall be flat, uniform, and devoid of wrinkles, buckles, blowholes, tears, cracks, and inclusions.

[Annexure REQ 97] After cutting to as-delivered dimensions, the edges shall be visually examined with RMC 7100. Check the absence of cleavage or lamination (for example, comprised of a fine layer of inclusions drawn out during rolling).

[Annexure REQ 98] A liquid penetrant examination shall be performed following RMC 4000 if in doubt.

16.11.1 Criteria

[Annexure REQ 99] Indications with one-dimension exceeding 1mm shall be considered a recordable indication.

[Annexure REQ 100] Plates 40mm thick or less shall not have linear indications of 8mm or less.

[Annexure REQ 101] Plates over 40mm thick shall not have linear indications of 10mm or less.

[Annexure REQ 102] For plates with operating conditions that could lead to a risk of lamellar tear, the cumulative length of indications over the most densely covered meter shall be:

- Less than 30mm for plates up to 40mm thick.
- Less than 40mm for plates over 40mm thick.

[Annexure REQ 103] The risk of lamellar tear shall be specified by the Manufacturer in the purchase order.

[Annexure REQ 104] Two separate indications shall be considered one if the distance between them is less than twice the length of the smaller two. The length of the combined indication is the sum of the lengths of the two indications plus the distance between them.

[Annexure REQ 105] If the above criteria are not respected, no repair welds shall be authorized, and the part will be rejected. However, if there are special and highly localized indications (which can be checked by shear wave ultrasonic examination), this zone can be eliminated by grinding, and the plate is accepted if its dimensions remain within acceptable tolerances.

[Annexure REQ 106] The plate shall be discarded if cleavage or lamination appears during use.

16.12 Volumetric examination

[Annexure REQ 107] An ultrasonic examination shall be performed in compliance with RMC 2400, which states the condition for the application of NF EN10307.

[Annexure REQ 108] The ultrasound examination shall only be carried out for parts at least 30mm thick, following the scanning plan and the S2 and E3 levels criteria in standard NFEN10307.

16.13 Removal of unacceptable areas

16.13.1 Removal by grinding

[Annexure REQ 109] The Supplier shall remove surface defects by grinding, with the following conditions:

- The remaining thickness is within the tolerance specified by the drawing or the purchase order.
- The cavity blends smoothly with the surrounding surface.
- After removal, the surface undergoes a liquid penetrant examination following RMC 4000.

[Annexure REQ 110] For the liquid penetrant examination, the following criteria shall be applied:

- Indications greater than 1mm are considered recordable indications.

- Unacceptable indications include:
- Linear indications.
- Indications that are rounded and have a dimension exceeding 2mm.

16.13.2 Repair by welding

[Annexure REQ 111] The rolling mill shall not be authorized to perform repair welding.

16.14 Dimensional check

[Annexure REQ 112] The dimensions of the plates shall comply with those specified on the drawings or in the purchase order.

16.15 Marking

[Annexure REQ 113] The Supplier shall specify the identification and marking methods used in compliance with RC 1300.

[Annexure REQ 114] Samples delivered with the part shall be marked following the provisions of the purchase order.

16.16 Test reports

[Annexure REQ 115] In addition to the inspection certificate type 3.1 following NF EN10204, the following reports shall be drawn up by the Supplier after each test and, in any case, before delivery of the part:

- Ladle and product analysis
- Intergranular corrosion test
- Heat treatment record
- Micrographic examination, grain size
- Ferrite contents
- Mechanical tests
- Non-destructive examinations
- Dimensional check
- Heat number and plate reference number
- Supplier's particular
- Purchase order number
- Name of the inspection agency, if applicable
- Test and retest

17 SS 316L(N)-IG FORGED

17.1 Scope

This annexure prescribes the requirements for manufacturing, inspection, testing, packing, and supplies of austenitic stainless-steel forgings of SS 316L(N)-IG.

17.2 Reference documents

- RCC-MR 2007; Section-2; RM 3321 Product procurement specification: class 1, 2, and 3 X2CrNiMo17-12-2 controlled nitrogen content austenitic stainless-steel forgings and drop forgings for use at high temperature.
- Chemical composition & impurity requirements for materials (ITER_D_22KCMF v2.3).
- SDC-IC Appendix A: Materials design limits (ITER_D_222RLN v3.3).
- IVH Appendix 14: Guide to passivation and pickling (ITER_D_2F457S v1.2).

General Information	ITER_D_222UYT
Composition	ITER_D_22KCMF
Ultimate Tensile Strength	ITER_D_222V3G
Yield Strength	ITER_D_222V5H
Elongation	ITER_D_222V8X
Reduction of Area	ITER_D_222VAU
Engineering and True Stress-Strain	ITER_D_222VBC
Poisson's Ratio	ITER_D_222VDD
Young's Modulus	ITER_D_222VES
Fatigue Strain Constant	ITER_D_222VQP
Fracture Toughness	ITER_D_222VWJ
Melting Point	ITER_D_222VX2
Specific Heat	ITER_D_222VYK
Emissivity	ITER_D_223FGA

Thermal Conductivity	ITER_D_222VZ3
Thermal Expansion	ITER_D_222W29
Electrical Resistivity	ITER_D_222W3R
Density	ITER_D_222W48

Table 18: Link to the 316L(N)-IG properties for information

17.3 Melting process

[Annexure REQ 116] The stainless steel shall be made using an electric furnace + Argon Oxygen Decarburization (AOD) or Vacuum Oxygen Decarburization (VOD) + Electroslag Remelting (ESR) or Vacuum Arc Remelting (VAR).

17.4 Specific requirements from IVH

17.4.1 Forging having Final Thickness between 5 mm and 25 mm

[Annexure REQ 117] VQC 1A machined components with a final thickness between 5 mm and 25 mm shall be manufactured in the form of stock that has been cross-forged (upset forged).

17.4.2 Forging having a Final Thickness < 5mm

[Annexure REQ 118] VQC 1A machined components with a final thickness of less than 5 mm shall be made from cross-forged material, which is electro-slag remelted (ESR) or vacuum arc remelted (VAR).

[Annexure REQ 119] Such material shall meet the non-metallic inclusion requirement specified in Section 17.8.2 of this Specification.

These requirements are synopsised in the following Table 19.

Nominal thickness (of vacuum boundary)	Direction	Plate / Bar[1]			Forging[4]	Pipe[4]	Pipe, [4,5] (He, ≤ 2 mm)	HIP[3]	Casting [4]
		Crosses[2]		Parallel[2]					
	RH Class	3, N/A	1, 2	1, 2, 3, N/A	1, 2, 3, NA	1, 2, 3, NA	1, 2, 3, NA		
≤ 5 mm		X	L	NR	F + L	NR	L	X	A
>5 mm ≤ 25 mm		X	L	NR	F	NR	NR	A	A
> 25 mm		L	NR	NR	NR	NR	NR	A	A

[1]VQC 1A, VQC 2A cryogenic helium pipework (pipe & fittings) < 2 mm
[2]Transverse cross section w.r.t. vacuum boundary or parallel w.r.t vacuum boundary
[3]All VQC
[4] VQC 1A,2A &3A
[5] Helium coolant, thickness less than 2 mm.
X=Not Allowed
F=Cross or Upset Forged
L= Low inclusion in compliance with 5.3.1 and ESR/VAR remelting
A=requires *acceptance*
NR = No requirement
N/A – not applicable

Table 19: Specific requirements from IVH

17.5 Manufacturing program

[Annexure REQ 120] The Supplier shall draw up a manufacturing program before the commencement of manufacturing operations.

[Annexure REQ 121] This program shall include the following:

- Identification of the melting process,
- Drawing of parts as-forged or drop forged, profiles for heat treatment, non-destructive examination and delivery,
- Conditions for intermediate heat treatments and final heat treatments for mechanical properties,
- Position of acceptance test samples on the par,
- Dimensional drawing with the position of test specimens on samples.

17.6 Delivery Condition

[Annexure REQ 122] Forged parts shall be delivered in the solution heat-treated condition and machined to the as-delivered profile.

17.6.1 Solution heat treatment

[Annexure REQ 123] Solution heat treatment shall consist of holding between 1050 °C and 1150 °C followed by water-quenching.

[Annexure REQ 124] The thermal cycle involved in the heat treatment shall be recorded, and the records kept at the disposal of the surveillance agents.

17.6.2 Machining Surface condition

[Annexure REQ 125] The parts shall be machined to their as-delivered profile.

[Annexure REQ 126] The surface condition determined following RMC 7200 shall meet the requirements of the various non-destructive examinations.

[Annexure REQ 127] Unless specified otherwise, the maximum average surface roughness shall be 6.3 µm Ra for all metallic components.

17.7 Chemical analysis

[Annexure REQ 128] The chemical composition, as determined by ladle and product analysis, shall comply with the requirements specified in Table 20.

[Annexure REQ 129] The steelmaker shall supply a ladle analysis certified by the mill manager or his duly accredited representative.

[Annexure REQ 130] The steelmaker shall also provide a product analysis taken from each heat.

Element	**SS 316L(N)-IG** Alloying elements & impurities content, wt. %.
	max
C	0.030
Mn	1.60-2.00
Si	0.50
P	0.025
S	0.010
Cr	17.00 - 18.00
Ni	12.00 - 12.50
Mo	2.30 - 2.70
N	0.060 - 0.080
Cu	0.30
B	0.0010*
Co	0.05*
Nb*	0.01**

Ta*	0.01**
Ti*	0.10
*For parts that will be re-welded limit for B is 0.0010 wt.%. **Maximum Co, Nb, and Ta, content is based on radioprotection requirements in the ProductProcurement Specifications.	

Table 20: Chemical properties of SS 316L(N)-IG forgings

17.8 Structure

17.8.1 Microstructure

[Annexure REQ 131] A micrographic examination, with photographs, shall be performed parallel to the main direction of the extension. The structure must be homogenous.

[Annexure REQ 132] The grain size number determined by EN ISO 643: Steels- Micrographic determination of the apparent grain size shall be greater than 2. The grain size is determined on a test sample close to the mechanical test specimens.

17.8.2 Non-metallic inclusion

[Annexure REQ 133] The amount and definition of non-metallic inclusions shall meet standard ASTM E45-05.

17.8.2.1 Forging (for VQC 1A component) having Final Thickness < 5mm

[Annexure REQ 134] Microstructural examination to determine the non-metallic inclusion content will follow ASTM E 45 - 95 Method D. Severity levels shall be as below.

- Type A ≤ 1
- Type B ≤ 1
- Type C ≤ 1
- Type D ≤ 1.5

17.8.2.2 Forging (for VQC 1A component) having Final Thickness > 5mm

[Annexure REQ 135] Micro inclusions (indigenous inclusions detectable by Micro Examination methods): Method D is applicable. The severity level number shall be at most 2 for types A, B, C, and D. The tolerance for acceptance may be a half-class above the set limit to the extent of 2% of the fields counted.

[Annexure REQ 136] Macro inclusions (exogenous inclusions from entrapped slag or refractories) shall be forbidden and cause rejection.

17.9 Delta Ferrite

[Annexure REQ 137] Magnetic materials with a relative permeability that is greater than 1.03 shall not be used within the cryostat boundary without formal project approval.

[Annexure REQ 138] The ferrite content evaluated using the Schaeffler diagram modified by Pryce and Andrews and measured on a solution heat-treated product shall be less than 0.5%.

17.10 Intergranular corrosion test

[Annexure REQ 139] Material shall pass the intergranular corrosion test following ASTM A262 Practice E or equivalent EN/ISO standards.

17.11 Mechanical properties

17.11.1 Sampling

[Annexure REQ 140] Test samples shall be obtained from the actual part, an extension, or surplus material integrally connected after the solution heat treatment.

[Annexure REQ 141] Each sample must be distinctly marked.

[Annexure REQ 142] The size of the test samples shall be such that they can provide enough test specimens for all tests and retests.

[Annexure REQ 143] Insofar as the shape of the parts so allows, test specimens shall be cut out in such a way that their axis is oriented perpendicular to the main forging direction (transverse direction) and that the distance between the axis and the nearest treated surface (skin) is:

- 20 mm if the thickness is > 40 mm,
- Mid-thickness if the thickness is <= 40 mm.

[Annexure REQ 144] The distance between the test-pertinent area of the test specimen and the other treated surfaces shall not be less than:

- 40 mm if the thickness is > 40 mm:
- The thickness if the thickness is <= 40 mm.

[Annexure REQ 145] If the shape of the parts does not permit this, values as close as possible to those given above shall be obtained.

[Annexure REQ 146] The notch root axis of the impact test specimen shall be perpendicular to the skins.

[Annexure REQ 147] For Drop forged parts, Mechanical test samples shall be cut out from one or more parts in a lot or, when this is impossible (for instance, very small parts) and

subject to the approval of the Contractor, from a test bar of the same heat of steel simultaneously treated in the same heat treatment charge.

[Annexure REQ 148] This test bar shall first have been subjected to forging operations considered representative of the parts' undergone.

17.11.2 Test conditions

[Annexure REQ 149] Tension test shall be performed in "Solution heat treated" condition.

[Annexure REQ 150] Charpy V notch Impact test shall be performed in "Solution heat treated" and "Solution heat treated + Aged" conditions.

17.11.3 Definition of a lot

17.11.3.1 General case

[Annexure REQ 151] A lot shall comprise parts of similar shape, cross-section, and diameter, as defined below:

$$\frac{\emptyset D_{max}}{\emptyset D_{min}} = \leq 1.1 \; ; \; \frac{e_{max}}{e_{min}} = \leq 1.1; \; \frac{S_{max}}{S_{min}} = \leq 1.25$$

$\emptyset D$: Diameter; e = Thickness; S = Area

17.11.3.2 Special case

[Annexure REQ 152] Hollow, circular parts that are 80 mm thick or less and have a mass of 500 kg or less shall be exempt from the dimensions above.

[Annexure REQ 153] All parts within a lot shall originate from the same steel heat and undergo identical processing cycles. These parts should either come from the same furnace batch or experience the same heat treatment session.

[Annexure REQ 154] A lot's mass limit shall be 5000 kg.

[Annexure REQ 155] Any part with an as-delivered unit mass of more than 1000 kg shall be categorized as its distinct lot.

17.11.4 Number & contents of tests

[Annexure REQ 156] One series of tests shall be performed per lot for parts weighing 500 kg or less.

[Annexure REQ 157] Two tests shall be performed for parts weighing more than 500 kg.

[Annexure REQ 158] A test shall comprise the following.

- Tensile testing at room temperature

- Tensile testing (checking of yield strength) at 450°C

17.11.5 Tensile testing at room temperature

17.11.5.1 Test specimen

[Annexure REQ 159] The Test specimen shall have a circular section.

[Annexure REQ 160] The normal diameter shall be 10mm, and their dimensions as specified in RMC 1211.

17.11.5.2 Test Method

[Annexure REQ 161] The tensile test shall comply with RMC 1211.

[Annexure REQ 162] The following values shall be recorded:

- Yield strength at 0.2% offset in MPa,
- Yield strength at 1% offset in MPa,
- Ultimate tensile strength in MPa,
- Percentage elongation after fracture,
- Percentage reduction of area after a fracture.

17.11.5.3 Test Results

[Annexure REQ 163] The results obtained shall meet the requirements given in Table 21.

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	220
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded for information
Ultimate Tensile Strength, in MPa, Rm	525-700
Percentage elongation after fracture, A%(5d)	45
Percentage reduction of area after fracture	To be recorded for information

Table 21 : Tensile properties of SS 316L(N)-IG forging at room temperature

17.11.6 Tensile testing at high temperature

17.11.6.1 Test specimen

[Annexure REQ 164] The normal diameter of test specimens shall be 10mm, and their dimensions as specified in RMC 1212.

17.11.6.2 Test Method

[Annexure REQ 165] The tensile test shall comply with RMC 1212.

[Annexure REQ 166] The specimen shall be tested at 450 °C.

17.11.6.3 Test Results

[Annexure REQ 167] Yield strength at 0.2% offset obtained shall meet the requirement given in Table 22.

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	112
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded for information
Ultimate Tensile Strength, in MPa, Rm	To be recorded for information
Percentage reduction of area after fracture	To be recorded for information

Table 22: Tensile properties of SS 316L(N)-IG forging at high temperature

17.11.7 Retesting of Tensile test specimens

[Annexure REQ 168] If the test specimen has a physical defect (which does not affect the product's usefulness) or unsatisfactory test results are due to incorrect mounting of the specimen or testing machine malfunction, the test shall be repeated using another specimen.

[Annexure REQ 169] The rolled plate or strip shall be accepted upon satisfactory results from the second test.

[Annexure REQ 170] In instances where the second test results are unsatisfactory, the stipulated follow-up process shall apply.

[Annexure REQ 171] Where unsatisfactory results cannot be attributed to the above causes, an NCR shall be raised

[Annexure REQ 172] Two retests shall be performed for each unsatisfactory result obtained after the NCR.

[Annexure REQ 173] The second set of test specimens shall be taken close to those that were defective.

[Annexure REQ 174] Based on the retest results, if satisfactory, the NCR will be closed and the plate shall be accepted; if not, it shall be rejected.

17.11.8 Charpy V notch impact tests

17.11.8.1 Test specimen and test method

[Annexure REQ 175] Four Charpy V-notch test blanks shall be taken from adjacent locations as specified in section 6.11.1.

[Annexure REQ 176] Two of the test blanks shall undergo the following aging treatment at the laboratory furnace:

- Holding to a temperature of 750°C ± 5°C
- Holding for 100h
- Cooling at ambient temperature

[Annexure REQ 177] The shape and dimensions of the specimens shall conform to specifications in RMC 1221.

[Annexure REQ 178] Impact test results shall meet the stipulated requirements.

Name of test	Test temperature (°C)	Properties	Required value
Charpy V-notch impact – solution heat-treated	Room	Minimum individual value	100 J
Charpy V-notch impact – solution heat treated + aged 100 h at 750 ◦C	Room	Minimum individual value	80 J

Table 23: Impact properties of SS 316L(N)-IG forging

17.11.8.2 Retesting

[Annexure REQ 179] If an individual value is below the required minimum for each heat treatment condition, two series of retests shall be conducted on two test specimens.

[Annexure REQ 180] These specimens shall be taken near the original specimens and tested under identical conditions.

17.11.9 Retreatment

[Annexure REQ 181] Lot rejected based on unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment). Retreatment conditions shall be described in the test report.

[Annexure REQ 182] In such cases, test specimens shall be taken under the conditions specified in sections 17.11.1 to 17.11.4.

[Annexure REQ 183] The test performed shall be the same as in sections 17.11.5, 17.11.6 and 17.11.8.

17.12 Surface examinations – Surface defects

[Annexure REQ 184] The surface shall be thoroughly inspected to assess the metal's integrity during all production and machining phases.

[Annexure REQ 185] The component shall be sound and free of defects such as scale, strings, tears, nicks, or other harmful imperfections.

[Annexure REQ 186] All parts shall undergo a visual examination.

[Annexure REQ 187] Following the visual check result, a Liquid penetrant examination shall be conducted in line with RMC 4000.

[Annexure REQ 188] Defects having a single dimension of 1 mm or more shall be treated as recordable conditions during the Liquid penetrant examination.

[Annexure REQ 189] Linear indications shall be deemed unacceptable during Liquid penetrant examination.

[Annexure REQ 190] Rounded indications with one dimension exceeding 3 mm shall be unacceptable during Liquid penetrant examination.

[Annexure REQ 191] If three or more indications are aligned with a spacing less than 3 mm apart from edge to edge, they shall be deemed unacceptable.

[Annexure REQ 192] Any set of 5 or more indications clustered within a 100 cm^2 rectangular region, where the larger dimension does not surpass 20 cm and is situated in the most disadvantageous location relative to the indications under review, shall be marked as unacceptable.

[Annexure REQ 193] For parts scheduled for deep machining, where more than 30% of wall thickness is to be removed, the criteria concerning grouped indications shall consider defects with dimensions greater than 0.5 mm.

17.13 Volumetric examination

[Annexure REQ 194] An ultrasonic volumetric examination shall be performed.

17.13.1.1 Degree and time of examination

[Annexure REQ 195] The examination shall be executed When the part's profile allows for satisfactory test performance. The preferred sequence for this examination is:

- Firstly, after the final machining,
- Secondly, after post-machining heat treatment is intended for mechanical properties, regardless of subsequent machining.

[Annexure REQ 196] If certain parts or sections are not examinable after heat treatment due to their geometry, they shall be examined at the most recent feasible intermediate phase.

[Annexure REQ 197] The examination shall be permissible on the semi-finished products for smaller formed components.

17.13.1.2 Procedures

[Annexure REQ 198] Ultrasonic examination procedures are specified in RMC 2310 and RMC 2320.

[Annexure REQ 199] Probe characteristics shall be as follows:

- Straight beam examination: frequency 2 MHz,
- Angle beam examination: frequency 1 MHz, refraction angle depends on the part geometry
- A lower frequency may be used for thick parts if the structure so requires.

17.13.1.3 Scanning plan and degree of examination

[Annexure REQ 200] Ultrasonic examination shall be carried out on parts with more than 500kg of mass.

[Annexure REQ 201] The entire volume of all the parts shall be subject to ultrasonic inspection.

[Annexure REQ 202] 100% scanning coverage defined in §12.4 of NF EN 10228-4 shall be performed. Part type is 1, 2, 3, or 4.

17.13.1.4 Evaluation of indications

[Annexure REQ 203] Indications following RMC 2310 and RMC 2320 requirements shall be evaluated.

17.13.1.5 Recordable conditions and examination criteria

[Annexure REQ 204] For the Straight beam examination:

1. The ranges considered and the acceptance criteria dependent on the thickness of the examined parts shall align with the standard NF EN 10228-4 stipulations for a regular probe. The classification to be utilized is quality class 2.
2. For parts with a thickness equal to or surpassing 75 mm, specifically concerning the loss of back echo, the recordable attenuation range shall be defined as R <=0.12 without a set acceptability threshold.

[Annexure REQ 205] Under the Angle beam examination:

3. Indications producing an echo amplitude of >=50% compared to the reference echo shall be documented.
4. Indications where the echo amplitude surpasses the amplitude of the reference echo shall be deemed unacceptable.

17.14 Removable of unacceptable areas

[Annexure REQ 206] The forged mill may eliminate surface defects by grinding, provided that the dimensional tolerances of the part in the as-delivered condition are respected.

[Annexure REQ 207] After grinding, A liquid penetrant examination shall be performed following RMC 4000. Examination criteria shall be those defined in section 6.12.

[Annexure REQ 208] No repairs by welding by the Forging mill shall be permissible.

17.15 Dimensional check

[Annexure REQ 209] The dimensions shall be checked following the requirements of the procurement drawings.

[Annexure REQ 210] The main dimensions shall be recorded.

[Annexure REQ 211] The values shall be within the tolerance given on the drawing.

[Annexure REQ 212] In the case of drop forging, this examination shall be performed by representative sampling.

17.16 Marking

[Annexure REQ 213] The Supplier shall specify the identification and marking method used in compliance with RC 1300.

17.17 Cleanliness – Packaging –Transportation

[Annexure REQ 214] Requirements shall be specified in the purchase order, considering the requirements of Annexure 6 (Cleaning requirement).

17.18 Test report

[Annexure REQ 215] In addition to the inspection certificate type 3.1 following NF EN10204, the following reports shall be drawn up by the Supplier after each test and, in any case, before delivery of the part:

- Ladle and product analysis, where applicable
- Intergranular corrosion test
- Heat treatment record
- Micrographic examination, grain size
- Ferrite contents
- Mechanical tests
- Non-destructive examinations
- Dimensional check
- Heat number and plate reference number
- Supplier's particular
- Purchase order number
- Name of the inspection agency, if applicable
- Test and retest

18 SS 316L SEAMLESS PIPES

18.1 Scope

This annexure covers weldable austenitic stainless steel (SS 316L) seamless pipes of thicknesses between 2.0 and 50.0 mm for piping or other uses.

[Annexure REQ 216] In all applications in VQC 1A VQC 2A and VQC 4A (process to insulation vacuum), pipes and fittings shall be seamless.

[Annexure REQ 217] Where pipes and fittings cannot be seamless, specific acceptance is required to use seamed components which shall conform to the testing requirements of Section 7.1.4 of IVH.

18.2 Reference

- RM 3342 Product procurement specification: class 1, 2, and 3 austenitic stainless steel seamless pipes
- Chemical composition & impurity requirements for materials (ITER_D_22KCMF v2.3).
- SDC-IC Appendix A: Materials design limits (ITER_D_222RLN v3.3).
- IVH Appendix 14: Guide to passivation and pickling (ITER_D_2F457S v1.2).

Coefficient of thermal Expansion	ITER_D_222U4R
Composition	ITER_D_222U38
Density	ITER_D_222UEJ
Electrical Resistivity	ITER_D_222UCM
General Information	ITER_D_222TZK
Magnetic Permeability	ITER_D_222UD5
Melting Point	ITER_D_222U8P
Poisson's Ratio	ITER_D_222UF2
Specific Heat	ITER_D_222U97
Table of Contents	ITER_D_222UH3
Thermal Conductivity	ITER_D_222UAL

Young modulus	ITER_D_222UB4
Tensile strength	ITER_D_22LQ9E
YIELD STRENGTH	ITER_D_22LQAV

Table 24: Link to the 316L properties for information

18.3 Melting Process

[Annexure REQ 218] The stainless steel shall be made using an electric furnace or any other technically equivalent process.

[Annexure REQ 219] Melting of the stainless steel shall be completed by a suitable secondary refining process like Argon oxygen decarburization (AOD) or Vacuum oxygen decarbonized (VOD).

18.4 Chemical requirements

[Annexure REQ 220] Chemical composition, as determined by the product analyses, shall comply with the following requirements (Table 1).

[Annexure REQ 221] The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative.

[Annexure REQ 222] Product analysis shall be performed on one tube per lot.

Element	**SS 316L** Alloying elements & impurities content, wt. %.
C	0.03
Mn	2.00
Si	0.75
Cr	16.00 – 18.00
Ni	10.00 – 14.00
P	0.045
Mo	2.00 – 3.00
S	0.03
N	0.10

Co	0.05
Nb	0.01
Ta	0.01

Table 25: Chemical composition of SS 316L seamless pipes

18.5 Intergranular corrosion test

[Annexure REQ 223] Intergranular corrosion test shall be performed following RMC 1310 on a test ingot made at the casting time.

[Annexure REQ 224] If this is impossible, one test per lot shall be performed on the product.

[Annexure REQ 225] The sensitizing treatment shall be performed at the heating temperature of 675°C ± 10°C.

[Annexure REQ 226] The test specimen shall produce a clear metallic sound during sound testing.

[Annexure REQ 227] No cracks or tears shall be detected during bend tests.

[Annexure REQ 228] In cases of uncertainty, the lack of intergranular corrosion shall be verified through micrographic examination.

18.6 Ferrite contents

[Annexure REQ 229] Magnetic materials with a relative permeability that is greater than 1.03 shall not be used within the cryostat boundary without formal project approval.

[Annexure REQ 230] The ferrite content shall be measured for each steel heat used to manufacture pipe thicker than 5mm.

[Annexure REQ 231] The ferrite content measured on a pipe part using the Schaeffler diagram modified by Pryce and Andrews shall be less than 0.5%.

18.7 Manufacturing program

[Annexure REQ 232] Before starting manufacturing operations, the pipe Manufacturer shall create a manufacturing program detailing, in chronological order, all manufacturing stages, including all intermediate and final heat treatments, finishing, and non-destructive examination operations.

[Annexure REQ 233] The rounds and/or billets used for manufacturing pipes shall come from ingots with sufficient top and bottom end discard removed.

[Annexure REQ 234] If necessary, all cracks shall be meticulously eliminated.

[Annexure REQ 235] The overall reduction ratio shall be no less than 3.

[Annexure REQ 236] The austenitic grain size number on the completed part shall be at least 2, as determined by EN ISO 643.

[Annexure REQ 237] Grain size uniformity shall be ±1 around the genuine average value.

[Annexure REQ 238] The Manufacturer shall ensure that their manufacturing processes do not weaken the steel's resistance to intergranular corrosion.

[Annexure REQ 239] Pipes shall be hot finished.

[Annexure REQ 240] Small diameter and thickness pipes may be cold drawn, which shall be noted in the manufacturing program.

18.8 Delivery condition – Heat Treatment

[Annexure REQ 241] Pipes shall be subjected to solution heat treatment between 1050°C and 1150°C before delivery.

[Annexure REQ 242] The manufacturing program shall specify the conditions for solution heat treatment and the furnace atmosphere.

[Annexure REQ 243] The holding temperature shall be documented.

[Annexure REQ 244] The feed speed shall be monitored continuously.

[Annexure REQ 245] Diagrams shall be available for inspection by the Surveillance Agents.

18.9 Surface condition

[Annexure REQ 246] Unless otherwise specified, the maximum average surface roughness for all metallic components shall be 6.3 µm Ra, as defined by ISO 4278:2000.

[Annexure REQ 247] A stylus probe-type instrument shall be used for the measurement.

18.10 Mechanical properties

18.10.1 Sampling

[Annexure REQ 248] Samples for testing shall be taken from pipes in the as-delivered condition, following solution heat treatment, and from the pipe ends.

[Annexure REQ 249] If the pipe dimensions allow, tension and impact test specimens shall be oriented perpendicular to the pipe axis.

[Annexure REQ 250] The test-relevant area of these specimens shall be as close as possible to the internal surface, and for impact test specimens, the notches shall be perpendicular to this surface.

[Annexure REQ 251] For other dimensions, tension, and impact test specimens shall be oriented longitudinally, aligned parallel to the pipe axis, with their test-relevant area as close as possible to the internal skin.

[Annexure REQ 252] Flattening and flare tests shall be conducted on tubular segments extracted from the pipe ends.

[Annexure REQ 253] For any retests, samples shall be collected near the initial samples.

18.10.2 Number and contents of tests

[Annexure REQ 254] Tests for mechanical properties shall be conducted per heat or per lot.

[Annexure REQ 255] The definition of a "lot" shall encompass pipes originating from the same heat, with identical diameter and wall thickness, undergoing the same manufacturing process, and belonging to either the same furnace charge or identical heat treatment set.

[Annexure REQ 256] Lot limitations shall be defined as:

- Up to 50 production lengths, not surpassing 1000 m, for pipes with a diameter > 150 mm and wall thickness > 9 mm.
- Up to 100 production lengths, not exceeding 2000 m, for pipes with a diameter <=150 mm and wall thickness <= 9 mm.

[Annexure REQ 257] Details regarding the number of tests, test specimen orientation, and test temperatures shall be provided in Table 26.

Name of test	Orientation of specimen	Test temperature (°C)	Number of specimens per type of test	
			Per heat	Per lot
Tension	(1)	Room	-	1
Tension (4)	(1)	According to the Equipment Specification	1	-
Charpy V-notch for thickness ≥ 12 mm (5)	(1)	Room	-	3
Flattening	-	Room	-	5 % (2)
Flare	-	Room	-	5 % (3)

(1) Transverse when the pipe is sufficiently thick, if not longitudinal (2) Limited to pipes whose external diameter is ≤ 400 mm or whose thickness is ≤ 15% of diameter. (3) Limited to pipes whose external diameter is ≤ 150 mm or whose thickness is ≤ 9 mm. (4) This test shall be performed at one of the temperatures given in table RM 3342.51. when specified in the equipment specification and the purchase order. This test shall be performed systematically for class 1 pipes. (5) Impact test is not performed when A% is determined at room temperature ≥45.

Table 26: Number and contents of tests

18.10.3 Tension testing at room temperature

18.10.3.1 Test specimen

[Annexure REQ 258] When the wall thickness of the pipe allows, a test specimen with a circular section measuring 10 mm in diameter, adhering to the standards of RMC 1211, shall be utilized.

[Annexure REQ 259] If the pipe's wall thickness prevents the use of test specimens with a 10 mm diameter circular section, strips extracted from the pipe or tubular sections removed as per RMC 1211 shall be employed for tension testing.

18.10.3.2 Test method:

[Annexure REQ 260] The tension test shall be carried out in alignment with RMC 1211. The data to be recorded includes:

- Yield strength at 0.2% offset, measured in MPa,
- Yield strength at 1% offset, measured in MPa,
- Ultimate tensile strength, measured in MPa,
- The percentage of elongation post-fracture.

18.10.3.3 Results

[Annexure REQ 261] The results derived shall comply with the criteria outlined in Table 27.

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	220
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded For Information
Ultimate tensile strength, in MPa, Rm	525-700
Percentage elongation after fracture, A% (5d)	45 (Longitudinal) | 30 (Transverse)
Percentage reduction of area after fracture	To be recorded For Information

Table 27: Tensile properties of SS416LN(IG) pipes

18.10.3.4 Test Re-evaluation and Acceptance Protocol:

[Annexure REQ 262] The test shall be retested using a different specimen if test results do not align with the set criteria and the discrepancy is not due to:

- A physical defect in the test specimen that doesn't impair the product's utility,
- Incorrect placement of the specimen, or
- Malfunction of the testing machine.

[Annexure REQ 263] If the retest is satisfactory, the component or lot shall be accepted.

[Annexure REQ 264] If the retest is unsatisfactory, the subsequent protocol shall be implemented.

[Annexure REQ 265] In situations where inadequate results aren't linked to the reasons stated in the first requirement, two more tests shall be permitted for every unsatisfactory finding.

[Annexure REQ 266] Retest specimens shall be sourced adjacent to the defective ones.

[Annexure REQ 267] If the retests are satisfactory, the lot shall be approved.

[Annexure REQ 268] If the retests are unsatisfactory, the lot shall be discarded.

18.10.4 Tension testing at high temperature

18.10.4.1 Test specimen:

[Annexure REQ 269] When the wall thickness of the pipe is sufficient, a test specimen with a circular section 10 mm in diameter whose dimensions conform to RMC 1212 shall be used.

[Annexure REQ 270] When the wall thickness of the pipe is such that test specimens with a circular section 10 mm in diameter cannot be used, strips cut out from the pipe or tubular sections removed following RMC 1212 shall be used for tension testing.

18.10.4.2 Test method

[Annexure REQ 271] The tensile test shall comply with RMC 1212.

18.10.4.3 Test Results

[Annexure REQ 272] The yield strength at 0.2% offset, Rp0.2, shall be 112 MPa at 450°C.

[Annexure REQ 273] The lot shall be discarded if the retests are unsatisfactory.

18.10.5 Charpy V notch impact tests

[Annexure REQ 274] If the tube thickness is low and standard samples cannot be manufactured, the test shall be skipped.

18.10.5.1 Test specimens and test method

[Annexure REQ 275] Charpy V-notch impact test specimens shall be sourced from an adjacent location.

[Annexure REQ 276] The specimens' shape, dimensions, and test conditions shall conform to RMC 1221.

[Annexure REQ 277] Three test specimens shall be broken for each test.

18.10.5.2 Results

[Annexure REQ 278] The average result of a three-specimen test shall be 100 J for (Longitudinal) and 60 J for (Transverse). Individual results shall be allowed to fall below the required value as long as they remain above 70% of it.

[Annexure REQ 279] If the criteria above aren't met, three additional specimens shall be extracted adjacent to the unsatisfactory specimen for testing.

[Annexure REQ 280] For a lot to be approved after testing the second set of three specimens, the following conditions shall be met:

- The average result of all six tests shall meet or exceed the designated minimum.
- No more than two of the six results shall fall below the specified minimum.
- Only one result out of the six shall be less than 70% of the set value.

[Annexure REQ 281] If these conditions aren't satisfied, the lot shall be rejected.

18.10.6 Flattening test

- **Test specimens and test method:**

[Annexure REQ 282] The specimen size and test procedure shall be specified in RMC 1272.

18.10.6.1 Results

[Annexure REQ 283] Following the first flattening stage, the pipe surface shall be free from cracks or tears.

[Annexure REQ 284] During the second flattening stage, the shell shall be devoid of delamination or significant heterogeneity.

[Annexure REQ 285] If a pipe fails the flattening test, it shall be retested.

[Annexure REQ 286] Additionally, two other pipes from the same batch shall also be tested.

[Annexure REQ 287] If any of these pipes are unsatisfactory, all defective ones shall be discarded.

[Annexure REQ 288] When more than 10% of the pipes in a lot are determined to be defective, the entire lot shall be rejected.

18.10.7 Flare test

18.10.7.1 Test specimens and test method:

[Annexure REQ 289] The specimen size and test procedure shall follow RMC 1271.

18.10.7.2 Results:

[Annexure REQ 290] There shall be no cracks or tears on the surface of the pipe after testing.

[Annexure REQ 291] The results shall be interpreted in the same way as for a flattening test.

18.10.8 Retreatment

[Annexure REQ 292] Lots rejected due to unsatisfactory mechanical test results shall be eligible for retreatment (solution heat treatment).

[Annexure REQ 293] The conditions for retreatment shall be detailed in the test report.

[Annexure REQ 294] Test samples and specimens for retreated lots shall be acquired following the specifications in sections 710.1 & 7.10.2. The tests conducted shall align with those detailed in sections 7.10.3 to 7.10.7.

[Annexure REQ 295] Only one retreatment shall be permitted for each lot.

18.11 Determination of austenitic grain size

[Annexure REQ 296] The grain size number shall be checked on one pipe per lot following RMC 1000.

[Annexure REQ 297] The grain size number shall equal at least 2.

[Annexure REQ 298] The grain size homogeneity shall be ±1 around the true average value.

18.12 Surface examination – Surface defects

[Annexure REQ 299] Internal and external surfaces of pipes shall be sound, i.e. free of any injurious defects.

[Annexure REQ 300] Straight pipes shall be delivered clean and free of oxidation.

[Annexure REQ 301] The maximum final roughness for piping shall be 6.3 µm for the inner and outer surfaces.

[Annexure REQ 302] In all cases, surface roughness shall be checked following the requirements of RMC 7231.

[Annexure REQ 303] Pipes shall be delivered pickled and passivated.

18.13 Volumetric examination

[Annexure REQ 304] Each straight pipe shall be subjected to ultrasonic examination as per RMC 2500, with additional criteria as follows:

[Annexure REQ 305] Ultrasonic examination shall be done on pipes in the solution-heat-treated state.

[Annexure REQ 306] The pipe's surface condition shall adhere to RMC 2100 requirements.

[Annexure REQ 307] An angle-beam examination shall detect longitudinal and transverse defects in pipes.

[Annexure REQ 308] An angle-beam examination shall identify longitudinal flaws in miscellaneous tubular components.

18.13.1 Results:

[Annexure REQ 309] Only defects with echo amplitudes less than the standard pipe's notch echo, as specified in RMC 2534, shall be deemed acceptable.

[Annexure REQ 310] Pipe ends that cannot undergo an effective examination on an automatic test bench shall either be discarded or manually inspected for at least 100 mm. The manual inspection technique shall match or exceed the automatic test bench's precision, using the same reference pipe for calibration.

18.14 Removal and repair of unacceptable areas

[Annexure REQ 311] Pipes with defects identified through visual or non-destructive methods shall be discarded.

[Annexure REQ 312] Surface defects shall be permitted to be removed by grinding, given that the residual thickness exceeds the minimum specified thickness after grinding.

[Annexure REQ 313] During grinding, overheating shall be avoided.

[Annexure REQ 314] Only iron-free corundum grinding wheels shall be used for grinding.

[Annexure REQ 315] The piping shall undergo a liquid penetrant examination after grinding.

[Annexure REQ 316] Indications measuring 1 mm or more shall be deemed recordable.

[Annexure REQ 317] Linear indications detected shall be considered unacceptable.

[Annexure REQ 318] Rounded indications that exceed 3 mm in one dimension shall be deemed unacceptable.

[Annexure REQ 319] Three or more indications clustered less than 3 mm apart (measured from edge to edge) shall be considered unacceptable.

[Annexure REQ 320] Five or more clustered indications within a 100 cm^2 rectangular area, where the longest side doesn't surpass 20 cm and is in a disadvantageous position relative to the indications, shall be deemed unacceptable.

[Annexure REQ 321] If significant defects emerge that cannot be rectified by grinding, the affected segment of the pipe shall be discarded.

18.15 Dimensional check

[Annexure REQ 322] Pipe dimensions and tolerances shall be as specified in the procurement drawings and must adhere to the standards set by NF EN 10216-5.

[Annexure REQ 323] The wall thickness tolerance of the pipes shall comply with class T2, and the outside diameter tolerance shall comply with class D2, as specified in NF EN 10216-5.

[Annexure REQ 324] For each lot, a minimum of five pipes shall undergo dimensional checks to evaluate thickness, diameter, and ovality.

18.16 Hydrostatic test

[Annexure REQ 325] Each pipe shall be subjected to hydrostatic testing during finishing operations following the requirements specified in the purchase order based on EN 10216-5. Alternative equivalent standards must be proposed to the IO for validation.

18.17 Marking

[Annexure REQ 326] The Supplier shall specify the identification and marking methods used in compliance with RC 1300.

18.18 Cleanliness – Packaging - Transportation

[Annexure REQ 327] Procedures shall be detailed in the purchase order and conform to the stipulations of Annexure 6.

[Annexure REQ 328] Pipe ends shall be cut squarely and capped with plastic.

[Annexure REQ 329] Every pipe shall be enclosed in watertight polythene packaging.

18.19 Test report

[Annexure REQ 330] In conjunction with the inspection certificate type 3.1 as per NF EN 10204, the Supplier shall prepare the subsequent reports after each unique test and before the pipe delivery:

[Annexure REQ 331] Reports shall encompass ladle and product analyses.

[Annexure REQ 332] Intergranular corrosion reports shall be created when relevant.

[Annexure REQ 333] A record of all heat treatments shall be maintained.

[Annexure REQ 334] Mechanical tests shall be documented.

[Annexure REQ 335] Visual examinations shall be recorded.

[Annexure REQ 336] Non-destructive examinations shall be reported.

[Annexure REQ 337] The grain size shall be determined and documented.

[Annexure REQ 338] Dimensional checks shall be performed and recorded.

[Annexure REQ 339] These reports above shall incorporate the heat and pipe reference numbers.

[Annexure REQ 340] Supplier details shall be included in the reports.

[Annexure REQ 341] The purchase order number shall be indicated in the reports.

[Annexure REQ 342] The name of the inspection agency shall be documented in the reports.

[Annexure REQ 343] Both test and retest results, along with the requisite values, shall be presented in the reports.

19 SS 660

19.1 Scope

This annexure covers the supply of grade X6NiCrTiMoVB25-15-2 (No. 1.4980) structural hardening austenitic stainless-steel hot rolled or forged bars with a diameter not greater than 160 mm for the ITER Duct Liner (i.e., for fasteners like the threaded inserts, screws, nuts, and other bolting. The bars are considered for mechanical parts (i.e. threaded inserts and bolting) which are not intended to be pressure-resistant.

19.2 Reference documents

[Annexure REQ 344] The following Codes and Standards shall be referred to.

EN 10269: 1999	Steel and Nickel Alloys for Fasteners with specified elevated and/or low-temperature properties.
EN 10228-4: 1999	Non-destructive testing of steel forgings, Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless-steel forgings
EN 10204: 2004	Metallic products: Type of inspection documents
EN 10221:1995	Surface quality classes for hot-rolled bars and rods – Technical delivery conditions
EN 10021: 2006	General technical delivery conditions for steel products EN 10002-1: 2001 Tensile testing at ambient temperature
EN 10002-5: 1991	Tensile testing at elevated temperature
EN ISO 643: 2003	Steels – Micrographic determination of the apparent grain size EN 10045-1: 1990 Charpy impact test. Part 1: test method
EN ISO 6506-1:2006	Metallic Materials – Brinell hardness test
EN ISO 377: 1997	Steel and steel products – Location and preparation of samples and test pieces for mechanical testing
EN ISO 14284: 2002	Sampling and preparation of samples for the determination of chemical composition
ASTM A342-14	Standard Test Methods for Permeability of Feebly Magnetic Materials ASTM E 45-10 Standard test methods for determining the inclusion content of steel.

[Annexure REQ 345] Other equivalent national or international standards and codes proposed by the Manufacturer may be acceptable with prior written IO approval, provided conformity assessment to all criteria is satisfied. Conformity assessment shall be submitted to the Agreed Notified Body for agreement.

General Information	ITER_D_223JJA
Composition	ITER_D_223JKS
Tensile Strength	ITER_D_223JLB
Yield Strength	ITER_D_223JMT
Elongation	ITER_D_223JNC
Reduction of Area	ITER_D_223JPU
Stress-Strain Curves	ITER_D_2EDQ3J
Young's Modulus	ITER_D_223JRV
Poisson's Ratio	ITER_D_223JQD
Fatigue - Constant Stress	ITER_D_223JSE
Fracture toughness	ITER_D_4ETQFY
Melting Point	ITER_D_223JTW
Specific Heat	ITER_D_223JUF
Thermal Conductivity	ITER_D_223JVX
Thermal Expansion	ITER_D_223JWG
Electrical Resistivity	ITER_D_223JXY
Density	ITER_D_223JYH

Table 28: Link to the SS 660 properties for information

19.3 Melting process

[Annexure REQ 346] The steel shall be made using an electric furnace or by any other technically equivalent process and shall be vacuum-re-melted or electro-slag-re-melted.

19.4 Chemical requirements and physicochemical characteristics

19.4.1 Required values

Chemical composition, as determined by ladle (cast) and product analyses, shall comply with the requirements given in Table 29.

Elements	*Content in wt.%*		*Tolerance wt. %*
	Min	**Max**	
Fe	balance		
C	0.030	0.080	±0.01
Si		1.0	±0.05
Mn	1.00	2.00	±0.04
P		0.025	±0.005
S		0.015	±0.003
Cr	13.50	16.00	±0.15
Mo	1.00	1.50	±0.05
Ni	24.00	27.00	±0.20
Ti	1.90	2.30	±0.10
V	0.10	0.50	±0.03
B	0.003	0.010	-
Al		0.35	-
Co		0.10	-
Nb+Ta		0.15	-
Cu		0.75	-
Nb		0.10	-

Note:
EN 10269:1999: If several product analyses are carried out on one cast, and the contents of an individual element determined lie outside the permissible range of the chemical composition specified for the cast analysis, then it is only allowed to exceed the permissible maximum value or to fall short of the permissible minimum value, but not both for one cast.

Table 29: Chemical composition

19.5 Chemical analysis

[Annexure REQ 347] The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative. A product analysis is made per heat.

[Annexure REQ 348] The chemical composition shall be within the limits specified in Table 1 (Content in wt. %). The product analysis shall not deviate from the values of the cast analysis by more than the values in Table 29 (Tolerance wt. %).

19.6 Magnetic permeability

[Annexure REQ 349] The relative magnetic permeability of the finished forgings shall be measured at room temperature after heat treatment.

[Annexure REQ 350] The value measured shall be equal to or lower than 1.03 as per applicable Test Methods of ASTM A342.

[Annexure REQ 351] Test Method Number shall be reported.

[Annexure REQ 352] Measurements made with other physical methods (e.g. permascope, magnetoscope, etc.) are accepted. Information about the type and trademark of the apparatus and their calibrations shall be provided.

[Annexure REQ 353] The test shall be performed per lot (test unit as for definition in EN 10269).

19.7 Structure

[Annexure REQ 354] A micrographic examination, with photographs, shall be performed parallel to the maximum direction of extension.

[Annexure REQ 355] The structure shall be homogeneous.

19.8 Grain size

[Annexure REQ 356] The grain size number determined in accordance with EN ISO 643 shall be no less than 3. The presence of a few grains of index 1 or 2 is tolerated.

[Annexure REQ 357] The test shall be performed per lot (test unit as for definition in EN 10269).

[Annexure REQ 358] The determination is performed on test samples taken from the immediate vicinity of the mechanical test samples.

19.9 Non-metallic inclusions

[Annexure REQ 359] The amount and definition of inclusions shall follow method D of ASTM E45-10.

[Annexure REQ 360] Micro inclusions (indigenous inclusions detectable by microscopic test methods): method D is applicable. The severity level number shall be at most 2 for types A, B, C, and D inclusions.

[Annexure REQ 361] Macro inclusions (exogenous inclusions from entrapped slag or refractories) shall not permitted.

[Annexure REQ 362] The test shall be performed per lot (test unit as for definition in EN 10269).

19.10 Manufacture

19.10.1 Manufacturing program

[Annexure REQ 363] Prior to the commencement of manufacturing operations, the material Supplier shall draw up a manufacturing program. This program shall include:

a) identification of the melting process,
b) the diameter of the bars during heat treatment and as delivered
c) conditions for intermediate heat treatments and final heat treatment
d) dimensional drawing with the position of test specimens on samples.

[Annexure REQ 364] The various heat treatments, sampling, and non-destructive examination operations shall be presented in chronological order.

[Annexure REQ 365] The program shall be agreed upon with DA and IO.

[Annexure REQ 366] After cutting some bars can be stamped or die forged to form heads. In this case, these operations and any prior cold working shall be indicated in the Manufacturing Program.

[Annexure REQ 367] The heat treatment for mechanical properties shall be performed after these operations.

19.10.2 Delivery condition

[Annexure REQ 368] Bars shall be delivered in the heat-treated condition compatible with further bolting manufacturing.

19.10.2.1 Heat treatment for mechanical properties

[Annexure REQ 369] The heat treatment for mechanical properties is given in Table 4 and Table B1 of the standard EN 10269 for grade X6NiCrTiMoVB25-15-2. Solution heat treatment shall consist of holding at a temperature of 970°C to 990°C for at least 1 hour. This is followed by oil quenching then precipitation treatment at a range of 710°C to730°C,

[Annexure REQ 370] The minimum time for precipitation treatment shall be 16 hours. Then air cooling.

[Annexure REQ 371] The thermal cycles shall be recorded.

[Annexure REQ 372] The records kept shall be presented in the test report.

19.10.2.2 Machining – surface conditions

[Annexure REQ 373] The parts shall be machined to their as-delivered profile.

[Annexure REQ 374] The surface condition shall meet the following requirement: roughness Ra shall not exceed 12.5 microns.

19.11 Mechanical properties

19.11.1 Required values

[Annexure REQ 375] Mechanical property requirements after heat treatment for mechanical properties shall comply with the values given in Table 2.

Test temperature, °C	Tensile Strength, Rm, MPa	Yield Strength (0.2%), min, Rp0.2, MPa	Elongation, (5d), A, min, %	Charpy V Notch Impact (J) min	Brinell Hardness (HBW)
Room	900 – 1150	600	15	50	248 – 341
200	Min. 815	560	–	–	–

Table 30: Mechanical properties

[Annexure REQ 376] Percentage reduction of area and yield strength at 1% offset at room temperature shall be given for information purposes.

[Annexure REQ 377] At elevated test temperature tensile strength, yield strength at 1% offset, and elongation shall be given for information.

19.11.2 Sampling

[Annexure REQ 378] Sampling and sample preparation shall be in accordance with the requirements of EN ISO 14284 (chemical composition) and EN ISO 377 (mechanical tests), in addition.

[Annexure REQ 379] If the product is not delivered in the heat-treated condition, the samples shall be treated to the usual delivery condition as per Section 19.10.2 prior to the test.

19.11.3 Testing

[Annexure REQ 380] The test shall be performed on specimens taken from samples subjected to no heat treatment after sampling.

19.11.3.1 Frequency of testing

[Annexure REQ 381] For the product analysis, one sample per cast shall be taken to determine the elements indicated within the numerical values of the chemical composition Table 29.

[Annexure REQ 382] The test unit for the other tests shall be the batch of products or part thereof coming from the same cast and having been treated in the same batch and the same heat treatment facility.

[Annexure REQ 383] Table 8 of EN 10269 shall be considered for the quantity of test samples and test pieces depending on batch size. Note additional requirements for Brinell Hardness Tests.

19.11.3.2 Test methods

19.11.3.2.1 Tension testing at room and elevated temperatures

[Annexure REQ 384] The EN 10269 shall be followed to perform tension testing.

19.11.3.2.2 Charpy V-notch impact tests

[Annexure REQ 385] The Charpy V-notch impact tests shall be performed following the EN 10269.

19.11.4 Retesting

[Annexure REQ 386] Retests shall follow the requirements of Clause 9.3 of EN 10269 (referred to as EN 10021).

19.12 Surface conditions

[Annexure REQ 387] The surface condition assessed in accordance with RMC 7200 shall correspond to the requirements relative to the various scheduled non-destructive examinations.

[Annexure REQ 388] Surfaces shall be thoroughly examined during all phases of production and machining to check the soundness of the metal.

[Annexure REQ 389] The part shall be sound and free of scale, strings, tears, nicks, or other injurious defects (class E as per NF EN 10221).

[Annexure REQ 390] A visual examination shall be performed on all parts and this shall be followed by a liquid penetrant examination in accordance with RMC 4000.

[Annexure REQ 391] The following recordable conditions and examination criteria shall be applied for liquid penetrant examination.

[Annexure REQ 392] Except in the particular case described below, any defects with one dimension of 1 mm or more shall be considered a recordable condition.

[Annexure REQ 393] The following indications shall be unacceptable:

- linear indications,
- rounded indications with one dimension greater than 3 mm,
- 3 or more indications aligned less than 3 mm apart edge to edge,
- 5 or more grouped indications within a rectangular area of 100 cm2, whose greater dimension shall not exceed 20 cm, taken in the most unfavorable location relative to the indication being evaluated.

[Annexure REQ 394] When the examination described above indicates the presence of unacceptable defects on the part, the instruction of chapter “Removal of unacceptable areas” shall apply.

19.12.1 Removal of unacceptable areas

[Annexure REQ 395] As the liquid penetrant examination is required on the finished part (bolting) it shall not be performed on the bar. The supplier can remove surface defects by grinding as long as the bars remain within the dimensional tolerances in the delivery condition.

[Annexure REQ 396] After grinding, a liquid penetrant examination shall be performed in accordance with RMC 4000. Examination criteria shall be those defined in chapter 8 “Surface examination – surface defects”.

[Annexure REQ 397] No repairs by welding by the Forging Mill shall be permissible.

19.13 Volumetric examination

[Annexure REQ 398] For products with a diameter equal to or more than 50 mm, internal defects shall be detected by ultrasonic examination.

19.13.1 Stage of examination

[Annexure REQ 399] This examination shall be performed on each bar in the treated and machined to delivery dimensions condition.

19.13.2 Procedures

[Annexure REQ 400] Ultrasonic examination procedures are specified in RMC 2310 and conditions specified in standard EN 10228-4 shall apply.

[Annexure REQ 401] The characteristics of the probe for straight beam examination shall normally have a frequency of 2 MHz.

19.13.3 Scanning plane and degree of examination

[Annexure REQ 402] The entire volume of the part shall be subject to ultrasonic examination. 100% scanning coverage defined in §12.4 of standard EN 10228-4 shall be performed. Part type is 1.

19.13.4 Assessment of indications

[Annexure REQ 403] Indications shall be evaluated in accordance with the requirements of RMC 2310.

19.13.5 Recordable conditions and examination criteria

[Annexure REQ 404] The ranges considered and the acceptance criteria which depend on the thickness of the parts examined, shall be those defined by the standard NF EN 10228-4 for normal probes. The quality class 2 shall be adopted. For thickness above or equal to 75 mm, concerning the loss of back echo, the recordable attenuation range is R < 0.12 with no acceptability limit.

19.14 Dimensional check - tolerances

[Annexure REQ 405] The dimensions shall be checked in accordance with the requirements of procurement drawings. The main dimensions shall be recorded.

[Annexure REQ 406] The values shall be within the tolerances given on the drawing.

19.15 Marking

[Annexure REQ 407] The Supplier is required to define and document the method of identification and marking employed, ensuring alignment with the requirements specified in Chapter 12 of NF EN 10269.

[Annexure REQ 408] Marking shall include:

- manufacturer name or symbol,
- the number of this EN standard
- steel name or number of materials,
- identification number (including heat number)
- nominal diameter

[Annexure REQ 409] Markings or codes that provide a clear reference to documents containing the information required for production control will always be acceptable.

[Annexure REQ 410] Samples delivered with the part shall be marked in accordance with the provisions of the purchaser order.

19.16 Cleanliness-Packaging-Transportation

[Annexure REQ 411] Requirements shall be specified in the purchase order, taking particular account of the requirements of RF 6000.

19.17 Acceptance

[Annexure REQ 412] Material Test Reports and certificates have to be provided to the Purchaser prior to delivery. Material and certification shall comply with this specification. Material cannot be accepted if it does not comply with this specification.

19.18 Documentation and Test Report

[Annexure REQ 413] The Supplier shall provide the Inspection Certificate type 3.1 in accordance with EN 10204:2004.

[Annexure REQ 414] The following reports shall be drawn up by the Supplier after each individual test and, in any case, prior to delivery of the part:

- ladle and product analyses of chemical composition, where applicable,
- melting process method,
- records of micrographic examination, inclusions and grain size,
- permeability,
- results of mechanical property tests,
- non-destructive examination,
- dimensional check,

- record of heat treatment.

[Annexure REQ 415] These reports shall include:

- the heat number and part reference number,
- identification of suppliers,
- identification of purchase order number,
- name of inspection agency, where applicable,
- test and retest results together with the required values.

[Annexure REQ 416] All documents shall be in the English language and all measures shall be given in the metric system SI.

[Annexure REQ 417] Each document shall be provided as an electronic file in PDF format.

20 COPPER CHROMIUM ZIRCONIUM ALLOY (TREATMENT B)

20.1 Scope

This annexure describes the requirements for manufacture, inspection, testing, packing, and supplies of Low alloyed copper plate of Type CuCrZr (Treatment B).

20.2 Reference

- ASME Section V, Article 9 – Visual Examination.
- ASME Section V, Article 5 – Ultrasonic Examination.
- ASTM E 112 – Standard test methods for Determining of Average Grain Size.
- ASTM E 21 – Standard Test Methods for Elevated Temperature tension test of metallic materials.
- ASTM E 8 – Test Method for Tension testing of metallic materials.
- ASTM E 478 – Test method for chemical analysis of copper alloys.
- ASTM E 118 – Test method for chemical analysis of copper chromium alloys.
- ASTM B 193 – Test method for resistivity of electrical conductor materials.
- ASTM B 248 – Standard Specification for General Requirements for Wrought copper and copper alloy plate, sheet, strip, and rolled bar.
- EN 12167 – Copper and Copper Alloys: Profile and Rectangular Bar for General Purpose.
- EN 10204 – Metallic products: Types of inspection documents.
- SDC-IC Appendix A: Materials design limits (ITER_D_222RLN v3.3).

General Information	ITER_D_22323N
Chemical Composition	ITER_D_223247
Creep Fatigue Interaction	ITER_D_256P2V
Density	ITER_D_2232VT
Electrical Resistivity	ITER_D_2232UB

Engineering and True Stress-Strain Curves	ITER_D_2232HM
Fatigue Stress-Strain Curves	ITER_D_256NZE
Fatigue-Constant Strain	ITER_D_2232PY
Melting point	ITER_D_256NWX
Poisson's ratio	ITER_D_256NUY
Specific Heat	ITER_D_2232QH
Stress Rupture and Creep Constant Stress	ITER_D_2232MX
Tensile properties, Solution annealed and Aged	ITER_D_256P4U
Thermal Conductivity	ITER_D_2232TS
Thermal Expansion	ITER_D_2232SA
Youngs Modulus	ITER_D_2232KW

Table 31: Link to the CuCrZr properties for information

20.3 Process

[Annexure REQ 418] The CuCrZr alloy shall be manufactured devoid of cuprous oxide and without employing metallic or metalloid deoxidizers.

20.4 Chemical compositions

[Annexure REQ 419] The material's chemical composition shall satisfy the requirements of the following table. The test method shall follow ASTM E 478 and ASTM E 118.

[Annexure REQ 420] The chemical analysis shall be performed for each material heat.

	Base Alloying Elements and Impurities (wt. %)*					
Alloy Designation	**Cu**	**Cr**	**Zr**	**O**	**Other elements**	**Total of Other Elements**
CuCrZr	base	0.6 – 0.8	0.1 – 0.2	≤ 25 E-4	H, ≤ 1E-3 Co < 0.05	≤ 0.15* Cd – to be controlled, < 5 ppm

Table 32: Chemical composition of CuCrZr -IG

[Annexure REQ 421] The sum of impurities (Al, Co, Fe, Ni, Pb, Si, Zn, As, P, Mn, B, Bi, Sn, Mg, Cd, Sb, S, O, etc) shall be less than 0.15%.

[Annexure REQ 422] The impurities shall be analyzed and recorded on the test certificate.

20.5 Delivery condition – Heat Treatment

[Annexure REQ 423] The CuCrZr plates shall be delivered under the following conditions.

[Annexure REQ 424] Treatment B shall consist of solution annealing at 980°C ± 10°C for 20 minutes, followed by water quenching and aging treatment at 475°C ±10°C for 3 hours.

[Annexure REQ 425] The thermal cycle involved in the heat treatment shall be recorded, and the records kept at the disposal of the surveillance agents.

[Annexure REQ 426] Its received heat treatment shall influence the CuCrZr alloy's properties.

[Annexure REQ 427] To counteract potential degradation in mechanical properties from manufacturing operations, like EB welding, components made from CuCrZr shall undergo an aging treatment at 475°C ±10°C for 3 hours during their manufacturing cycle.

[Annexure REQ 428] The CuCrZr material shall be provided in a "Solution-annealed condition".

[Annexure REQ 429] Despite being supplied in the "Solution annealed condition", the mechanical properties of the CuCrZr material shall be determined in the "Solution annealed + Aged condition".

[Annexure REQ 430] The "Solution annealed + Aged condition" shall be replicated by the CuCrZr material Supplier using simulated aging heat treatment on test coupons.

20.6 Mechanical properties

20.6.1 Sampling

[Annexure REQ 431] Test samples shall be drawn and tested in the following conditions: "Solution annealed (980°C ± 10°C) + Aged (475 C ±10°C for 3 hrs)".

[Annexure REQ 432] The frequency of test samples shall be as follows;

Test Description	Frequency of Test
Chemical	1 test per Each Heat
Tensile	1 test per lot

Grain Size	1 test per lot
Electrical conductivity	1 test per lot

[Annexure REQ 433] A "lot" shall consist of all material from the same Heat, Nominal Thickness, and heat treatment condition.

20.6.2 Tensile properties

[Annexure REQ 434] Tensile properties shall comply with the requirements given in Table 1.

[Annexure REQ 435] The following values shall be recorded:

- Yield strength at 0.2% offset in MPa
- Tensile strength in MPa
- Total Elongation after fracture

Temperature (◦C)	Ultimate Tensile Stress (Mpa) Min.	Yield Stress (Mpa) Min.	Elongation % (Min.)
20	369	241	11
350	238	171	11

Table 33: Tensile properties of CuCrZr-IG

20.6.3 Physical Characteristics

20.6.3.1 Electrical conductivity

[Annexure REQ 436] The electrical conductivity test shall be performed following ASTM B 193.

[Annexure REQ 437] The electrical conductivity at 20°C shall be no less than 75% IACS.

20.6.3.2 Grain size

[Annexure REQ 438] Samples shall be tested following ASTM E 112.

[Annexure REQ 439] Micrographs shall examine the material's structure and establish the grain size.

[Annexure REQ 440] The average grain size shall be less than 100µm. An occasional grain size as large as 200µm (<10% of grains) is acceptable after the completion of the manufacturing process.

20.7 Dimensions and permissible variations

[Annexure REQ 441] The tolerances shall follow ASTM B 248.

[Annexure REQ 442] The main dimensions shall be recorded.

[Annexure REQ 443] The values shall be within the tolerances given on the drawing.

20.8 Non-destructive examination

20.8.1 Visual examination

[Annexure REQ 444] All external surfaces of plates shall be examined visually following ASME Sec. V, Article 9 or equivalent EN/ISO standard.

[Annexure REQ 445] The surface shall be plane, uniform, and free from wrinkles, buckles, blowholes, tears, cracks, and inclusions.

20.8.2 Ultrasonic examination

[Annexure REQ 446] All plates shall be 100% ultrasonically examined following ASME Sec.V article 5 or equivalent EN ISO Standard.

[Annexure REQ 447] Acceptance criteria shall be mutually agreed upon between Supplier & IO in advance.

20.9 Test reports

[Annexure REQ 448] The Supplier shall provide the Inspection certificate type 3.1 following EN 10204.

[Annexure REQ 449] The above certificate shall include the following information:

- Material designation and Marking
- Heat Number
- Purchase order No.
- Identification of product
- Identification of Manufacturer
- Melting process
- Heat Treatment record
- Chemical & Mechanical Properties
- Microstructure and Grain Size Examination Result
- Result of Electrical conductivity test
- Record of non-destructive examination.

21 ALLOY 718

21.1 References

[Annexure REQ 450] Alloy 718 material shall be manufactured & tested following either ASTM B637 (UNS no. N07718) or EN 10302:2008 (NiCr19FeNB5Mo3, Number 2.4668).

Specific Heat	ITER_D_46AD75
Fracture Toughness irradiated	ITER_D_24DKVS
Stress-strain curve	ITER_D_24DKTT
Composition	ITER_D_222XGA
Density	ITER_D_223K4B
Electrical Resistivity	ITER_D_222XU4
Elongation	ITER_D_222XKR
Fatigue - Constant Stress	ITER_D_223K2A
Fatigue - Strain Constant	ITER_D_223JZZ
Fracture Toughness	ITER_D_223K3S
General Information	ITER_D_222XFT
Melting Point	ITER_D_222XRN
Poisson's Ratio	ITER_D_222XMQ
Reduction of Area	ITER_D_222XL8
Shear Modulus	ITER_D_222XPP
Table of Contents	ITER_D_222XVL
Thermal Conductivity	ITER_D_222XS5
Thermal Expansion	ITER_D_222XTM
Ultimate Tensile Strength	ITER_D_222XHS
Yield Strength	ITER_D_222XJ9

Young's Modulus	ITER_D_222XN7

Table 34: Link to the Alloy 718 properties for information

21.2 Chemical compositions

[Annexure REQ 451] The chemical composition of the material shall satisfy the requirement in Table 35.

[Annexure REQ 452] Sampling shall be done according to ASTM B 637 / EN10302.

[Annexure REQ 453] The test method shall follow ASTM E 1473.

Element	**Alloy 718** Alloying elements & impurities content, wt. %.
Fe	Balance
Ni	50 - 55.0
Cr	17 - 21.0
Ti	0.65 - 1.15
Mn	0.35
Mo	2.8 - 3.3
Si	0.35
Al	0.2 - 0.80
C	0.08
P	0.015
S	0.015
B	0.006
Co	0.10
Cu	0.3
Nb +Ta	4.75 - 5.5
Ta	0.05

Table 35: Chemical composition of Alloy 718

21.3 Heat Treatment

[Annexure REQ 454] Material shall subjected to the following heat treatments.

- **Solution Treatment:** Solution annealed at 924 to 1010 C, hold for ½ hour min, air cool or faster.
- **Precipitation hardening treatment:** Aging at 718°C ± 14°C, hold at temperature for 8 hours, then furnace cool to 621°C ± 14°C, hold until total precipitation heat treatment time has reached 18 hours, air cool.

21.4 Mechanical properties

[Annexure REQ 455] Sampling shall be done per ASTM B 637 / EN10302.

[Annexure REQ 456] The heat-treated material shall be capable of meeting the mechanical properties requirement, as mentioned in Table 36, and the stress rupture requirement, as mentioned in Table 37.

21.4.1 Tension and hardness requirements

[Annexure REQ 457] Test methods shall be following ASMT E8

Yield strength at 0.2% offset minimum, in MPa, $R_{p0.2}$	1034
Ultimate tensile strength minimum, in MPa, Rm	1275
Percentage elongation after fracture, minimum, % (4d)	12
Percentage reduction of area after fracture, Minimum %	15
Brinell Hardness, minimum	331

Table 36: Tensile & hardness properties of Alloy 718

21.4.2 Stress–rupture requirements

[Annexure REQ 458] Test methods shall be following ASMT E139

Heat treatment	Solution anneal+ precipitation harden.
Test temperature (°C)	649
Stress, MPa	690
Minimum hours	23

Elongation (4d), minimum, %	5

Table 37: Stress rupture properties of Alloy 718

21.5 Dimensions and permissible variations

[Annexure REQ 459] The permissible variations from the specified dimension of Alloy 718 product shall meet the ASTM B 637 / EN 10302 requirement.

[Annexure REQ 460] The Supplier shall provide the Inspection certificate type 3.1 following EN 10204.

22 ALLOY 625

22.1 References

[Annexure REQ 461] Alloy 625 material shall be manufactured & tested following ASTM B446 (UNS no. N06625).

Design Fatigue Curves of Alloy 625	ITER_D_M37KW9
Composition	ITER_D_222WXT
Electrical Resistivity	ITER_D_222XDU
Fracture Toughness, Irradiated	ITER_D_222X8E
General Information	ITER_D_222WWB
Impact Strength, Irradiated	ITER_D_222X7X
Melting Point	ITER_D_222X9W
Poisson's Ratio	ITER_D_222X5Y
Specific Heat	ITER_D_222XAD
Table of Contents	ITER_D_222XEB
Thermal Conductivity	ITER_D_222XBV
Thermal Expansion	ITER_D_222XCC
Ultimate Tensile Strength	ITER_D_222WYA
Ultimate Tensile Strength - irradiated	ITER_D_222WZS
Yield Strength	ITER_D_222X2H
Yield Strength vs DPA, Irradiated	ITER_D_222X3Z
Young's Modulus	ITER_D_222X6F

Table 38: Link to the Alloy 625 properties for information

22.2 Chemical compositions

[Annexure REQ 462] The chemical composition of the material shall satisfy the requirement given in Table 39.

Element	Alloy 625 Alloying elements & impurities content, wt. %.
C	0.10
Mn	0.50
Si	0.50
P	0.045
S	0.015
Cr	20 - 23.0
Cb+Ta* (Nb+Ta)	3.15 - 4.15
Co*	0.1
Mo	8.0 - 10.0
Fe	5.0
Al	0.40
Ti	0.40
Ni**	58.0 min
*: Depending on radioprotection requirements **: Element to be determined arithmetically by difference	

Table 39: Chemical composition of Alloy 625

[Annexure REQ 463] Sampling shall be done according to ASTM B 446.

[Annexure REQ 464] The test method shall follow ASTM E 354.

22.3 Heat Treatment

Grade 1, as specified in ASTM B 446, is selected for the application.

[Annexure REQ 465] The material shall be annealed with a solution at 871 °C minimum.

22.4 Mechanical properties

[Annexure REQ 466] Sampling shall be done per ASTM B 446.

[Annexure REQ 467] The heat-treated material shall be capable of meeting the mechanical properties requirement as mentioned in Table 40.

[Annexure REQ 468] Test methods shall be following ASMT E8

Yield strength at 0.2% offset minimum, in MPa, $R_{p0.2}$	414
Ultimate tensile strength minimum, in MPa, Rm	827
Percentage elongation after fracture, minimum, A% (4d)	30

Table 40: Tensile properties of Alloy 625

22.5 Dimensions and permissible variations

[Annexure REQ 469] The permissible variations from the specified dimension of the Alloy 625 product shall meet the requirement of ASTM B 446.

[Annexure REQ 470] The Supplier shall provide the Inspection certificate type 3.1 following EN 10204.

23 ALUMINIUM-NICKEL BRONZE

23.1 Scope

This annexure covers the supply of Aluminium bronze rods (Nickel-Aluminium, NiAl, bronze), UNS No.C63200.

The supply covers the following items:

a) Manufacture of Aluminium bronze rods.
b) Organization of quality at work. Elaboration of all procedures required for the manufacture, inspection (including analyses), packaging, storage, and delivery.
c) Perform all the inspections and tests during and after manufacturing envisaged.
d) Storage, packaging, and delivery.

23.2 Referenced Documents

[Annexure REQ 471] The following Codes and Standards shall be considered.

[Annexure REQ 472] Other equivalent national or international codes and standards may be acceptable subject to the IO'swritten acceptance through deviation request. To this aim, the supplier shall provide evidence that the proposed code and standard are equivalent to the specified one.

23.2.1 ASME Code Edition 2010

- Section V, Article 9 Visual Examination
- Section V, Article 5 Ultrasonic Examination Methods for Materials and Fabrication
- Section III, NB-2542 Examination procedure

23.2.2 ASTM Standards

- ASTM B150/B150M-12(2017)
  Standard Specification Aluminium Bronze, Rod, Bar and Shapes
- ASTM B249/B249M-09
  Standard Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes and Forgings
- ASTM E53-13
  Test Methods for Chemical Analysis of Copper

- ASTM E62-89(04)
  Test Methods for Chemical Analysis of Copper and Copper Alloys(Photometric Methods)
- ASTM E478-03
  Test Methods for Chemical Analysis of Copper Alloys ASTM E8/E8M:15
  Test Method for Tension Testing of Metallic Materials
- ASTM E21-09
  Standard Test Methods for Elevated Temperature Tension Tests of MetallicMaterials
- ASTM E165-12
  Standard Test Method for Liquid Penetrant Examination
- ASTM B150/B150M
  Standard Specification Aluminium Bronze, Rod, Bar and Shapes

23.2.3 EN Standard

- EN 10204:2004 Metallic products: Type of inspection documents
- EN 12163 Copper and copper alloys - Rod for general purposes

23.3 Ordering Information

[Annexure REQ 473] The supplier shall be responsible for specifying the requirements for the material purchase order.

23.4 Manufacturing Process

[Annexure REQ 474] The product shall be produced by hot working, cold working, or both and finished by such cold working, annealing, or heat treatment and straightening as necessary to meet the specified properties.

[Annexure REQ 475] A lot shall consist of bars or rods made from the same heat, produced with the same manufacturingconditions, size, and heat treatment.

[Annexure REQ 476] Lot mass shall be limited to 500 kg.

23.5 Heat Treatment

[Annexure REQ 477] All rods shall be delivered at the following heat-treated conditions:

- hold at 850°C minimum 1hour, quench in water or other suitable medium,

- temper anneal at 700 ± 15°C for 3 to 9 hours.

23.6 Chemical Requirements

[Annexure REQ 478] The chemical composition shall satisfy the requirement given in Table 41.

[Annexure REQ 479] The methods of testing shall follow ASTM E53. E62 and E458 or methods agreed between the Supplier and IO.

[Annexure REQ 480] The chemical analysis shall be performed for each heat and lot of material.

Element	Composition following ASTM B150 (range or maximum value),wt.%
Cu	Base
Al	8.7 – 9.5
Fe	3.5 – 4.3[A]
Ni	4.0 – 4.8
Mn	1.2 – 2.0
Si	0.10 max
Pb	0.02
Sn	(0.1)*
Zn	(0.02)*
Mg	-
Cd	(0.02)*
Co, Nb, Ta**	0.05; 0.10; 0.05**
Total impurities	(0.1)*

[A]: Iron content shall not exceed nickel content. (Nickel content is to be greater than iron content).

* Numbers in brackets are vacuum application requirements due to the high vapor pressures of these elements. These numbers in brackets are specific mandatory ITER requirements.

** Requirements on Co, Nb, and Ta depend on the particular application and shall be established in the radioprotection document.

Table 41: Chemical composition of Aluminium bronze C63200

23.7 Mechanical Properties

23.7.1 Tensile Properties

[Annexure REQ 481] The tensile test shall be performed according to ASTM E 8/8M and ASTM E 21.

[Annexure REQ 482] After heat treatment as defined in Section 23.5, the minimum tensile properties shall meet the requirements given in the following Table: 2 samples per lot at temperature (RT and 250C) shall be tested.

Tensile Properties	Test temperature	
	Room	250°C
Tensile Strength, min	620 MPa	530 MPa
Yield Stress (0.5 %), min, under load	345 MPa	-
Yield Stress (0.2 %), min, offset	300 MPa	260 Mpa
Total Elongation, min	15 %	8 %

Table 42: Tensile properties for rod or bar with diameter <80 mm

Tensile Properties	Test temperature	
	Room	250°C
Tensile Strength, min	620 Mpa	530 Mpa
Yield Stress (0.5 %), min, under load	310 Mpa	-
Yield Stress (0.2 %), min, offset	300 MPa	260 MPa
Total Elongation, min	15 %	8 %

Table 43: Tensile properties for rod or bar with diameter 80-125 mm

23.8 Dimensions and Permissible Variations

[Annexure REQ 483] Dimensions and permissible variations are defined in the purchase order. The straightness requirement of ASTM B249 and those specified in the purchase order shall be fulfilled.

23.9 Non-Destructive Examination

23.9.1 Visual Examination

[Annexure REQ 484] A visual examination shall examine all external surfaces of rods following ASME Section V, Article 9.

[Annexure REQ 485] The surfaces shall be plane, uniform, and free from wrinkles, buckles, laps,burrs, blowholes, tears, cracks, and inclusions.

23.9.1.1 Ultrasonic Examination

[Annexure REQ 486] 100% of each product's ultrasonic inspection shall be provided per ASME SectionV, Article 5.

[Annexure REQ 487] The acceptance standard shall be following Section III, NB-2542.

[Annexure REQ 488] Compression wave examination of any material containing defects that cause a signal equalto or greater than the signal produced by the calibration standard, having made allowance for the differences in attenuation between the test block and the material under test, shall be rejected.

23.9.1.2 Liquid penetrant examination

[Annexure REQ 489] 100% liquid penetrant inspection of each product shall be provided following ASTM E 165. Indicationsof cracks, tears, laps, seams, or chain-like porosity are unacceptable.

23.10 Number and Content of Tests / Sampling

23.10.1 Tests on base material - frequency

Test	Number of test samples/lot
Chemical analysis	1 test per heat and 1 test per lot
Tensile test	2 tests per lot and per temperature

23.10.2 Non-destructive tests – frequency

Test	Inspection in [%]
Visual examination	100
Ultrasonic test	100
Liquid penetrant examination	100

23.11 Acceptance

[Annexure REQ 490] Material Test Reports have to be provided to the Purchaser before delivery.

[Annexure REQ 491] Material and certification shall comply with this annexure.

[Annexure REQ 492] The material shall not be accepted if it does not comply with this specification.

23.12 Documentation

[Annexure REQ 493] The Supplier shall provide the Inspection Certificate type 3.1 following EN 10204:2004,which includes at least the following information:

- Description of the material designation and marking,
- Lot number,
- Identification of Supplier,
- Melting process,
- Dimensional check,
- Heat treatment,
- Result of chemical analysis,
- Results of mechanical property tests at specified heat treatment,
- Results of non-destructive examination.

23.13 Packaging and marking

[Annexure REQ 494] Each rod shall be legibly identified with the following information. The marking shall be performedby impression stamping or other acceptable means specified by the purchaser.

- Supplier name or symbol,
- Grade of material,
- Dimensions: rod diameter, width and length,
- Rod number or unique identification number related to production history.

[Annexure REQ 495] The supplier shall ensure that consignments comply with regulatory requirements applicable totransport and the destination country.

[Annexure REQ 496] Requirements for packaging shall be specified in the purchase order.

24 TUNGSTEN

[Annexure REQ 497] Tungsten material shall be manufactured & tested following ASTM B 760.

24.1 References

Pure Tungsten - Chemical Composition	ITER_D_22376H
Pure Tungsten - Density	ITER_D_22382P
Pure Tungsten - Electrical Resistivity	ITER_D_2237VJ
Pure Tungsten - Elongation	ITER_D_22379Y
Pure Tungsten - Emissivity	ITER_D_2237PR
Pure Tungsten - General Information	ITER_D_22374E
Pure Tungsten - Poisson's Ratio	ITER_D_2237DS
Pure Tungsten - Reduction of Area	ITER_D_2237BT
Pure Tungsten - Specific Heat Capacity	ITER_D_2237KP
Pure Tungsten - Thermal Conductivity	ITER_D_2237RQ
Pure Tungsten - Thermal Expansion	ITER_D_2237TK
Pure Tungsten - True Stress-Strain	ITER_D_2237CA
Pure Tungsten - Ultimate Tensile Strength	ITER_D_22377Z
Pure Tungsten - Yield Strength	ITER_D_22378G
Pure Tungsten - Young's Modulus	ITER_D_2237ED

24.2 Chemical composition

[Annexure REQ 498] The chemical composition of the material shall satisfy the requirement given in the following Table 44.

Element	Composition max, wt. %	Permissible variation in Check analysis, wt. %
C	0.010	±0.002
O	0.010	+10% relative

N	0.010	+0.0005
Fe	0.010	+0.001
Ni	0.010	+0.001
Si	0.010	+0.001

Table 44: Chemical composition of Tungsten

24.3 Mechanical properties

[Annexure REQ 499] Mechanical properties are strongly dependent on the production history and thermal treatment. The mechanical properties of Tungsten material in various conditions shall be as tabulated below :

Properties	Stress relieved condition	Annealed (recrystallized) condition
Ultimate tensile strength, MPa (Ref. SDC-IC Appendix A, ITER MPH _22377Z v1.0)	1432	380
Yield Strength, 0.2% offset, MPa (Ref. SDC-IC Appendix A, ITER MPH)	1360	94

Table 45: Mechanical properties of Tungsten

24.4 Thermal properties

The primary function of tungsten is to emit the energy absorbed by it, making emissivity a crucial characteristic of its properties.

The emissivity of the tungsten needs to be at least equal to the curve provided in Table 46.

Temperature °C	Emissivity
20	0.01
200	0.04
400	0.07
600	0.10
800	0.13
1000	0.16
1200	0.19

1400	0.21
1600	0.24
1800	0.26
2000	0.28
2200	0.30
2400	0.31
2600	0.33
2800	0.34
3000	0.35

Table 46: Tungsten emissivity depending on temperature

25 CUSTOMIZED AND "OFF THE SHELF" ITEMS USED IN DUCT LINER

[Annexure REQ 500] For the construction of the Duct Liner, the Supplier shall provide test certificates compliant with EN 10204 Type 3.1 for all customized and standard off-the-shelf items, ensuring compliance with the specifications detailed in the Technical Specification and its annexure, and the relevant codes/standards listed in the bill of materials.

End of:

ANNEXURE 1
Raw
Material

ANNEXURE 2.

WELDING AND WELDING QUALIFICATION

26 ANNEXURE SCOPE

This annexure describes the technical requirements related to welding qualification (including preparation of Welding procedure specification (WPS), qualification of welding procedure (WPQR) and welder/welding operators (WPQ), and production welding of DL components classified as “VQC 1A” and “non-SIC”.

[Annexure REQ 501] Qualification of welds, which form the vacuum boundaries, shall be compliant with this specification.

[Annexure REQ 502] Welding Qualification of other welds (i.e., those that do not form vacuum boundary) shall be done as per the relevant EN ISO / ASME code.

27 REFERENCE DOCUMENTS

- ITER Vacuum Handbook [AD7], and the IVH Attachment 1
- EN ISO 15607: Specification for the Qualification of welding procedures for metallic material – General rules.
- EN ISO 15614: Specification and Qualification of welding procedures for metallic material- Welding procedure test.
- EN ISO 15609: Specification and Qualification of welding procedures for metallic material – Welding procedure specification.
- EN 287-1: Qualification test of welders.
- EN 473: Qualification and Certification of NDT Personnel
- EN 895: Destructive Tests on welds in metallic material – Transverse Tensile Test
- EN 910: Destructive Tests on welds in metallic materials. Bend tests.
- EN1043: Destructive Tests on welds in metallic materials. Hardness Test
- EN 970: Non-Destructive Examination of Fusion Welds – Visual Examination
- EN 1435: Non-Destructive Examination of Fusion Welds – Radiographic Examination.
- EN 1714: Non-Destructive Examination of Fusion Welds – Ultrasonic Examination
- ISO 17637: Non-Destructive Examination of Welds – Visual Examination of Fusion welded joints.
- ISO 17636: Non-Destructive Examination of welds – Radiography Examination of welded joints.
- ISO 17640: Non-Destructive Examination of welds –Ultrasonic Examination of Fusion-welded joints.
- ISO 22825: Non-destructive testing of welds – Ultrasonic testing - Testing of welds in austenitic steels and nickel-based alloys.
- EN ISO 5817: Welding. Fusion welding joints are in steel, nickel, titanium, and their alloys (beam welding excluded). Quality levels for imperfections.
- ISO 9606: Qualification of welders – Fusion welding

- ISO 9712: Non-Destructive Testing – Qualification and certification of personnel.
- EN 1418: Welding personnel. Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials.
- ISO 6947: Welds – working positions – Definition of angles of slope and rotation.
- ISO 14344: Welding consumables – Procurement of filler materials and fluxes.
- ASME Sec. II Part C: Specification for welding rods, electrodes, and filler metals.

28 WELD JOINT CONFIGURATION

[Annexure REQ 503] The use of welds from both sides makes leak testing difficult and enhances the risk of trapped volumes forming virtual leaks or contaminant traps that are to be avoided. Thus, vacuum sealing welds shall be either internal (i.e. facing the vacuum) or external.

[Annexure REQ 504] Stitch welds shall not be used on the vacuum-facing side.

[Annexure REQ 505] All air, water, and vacuum boundaries shall have full penetration welds.

[Annexure REQ 506] Welds shall normally be made in such a way that they can be leak-tested at the time of completion. For all VQC 1A, and VQC 2A water boundaries, and vacuum boundary welds that become inaccessible, 100% volumetric examination of production welds shall be performed unless a method of preproduction proof sampling is approved.

29 WELD PLAN

[Annexure REQ 507] The Weld plan shall include the details of weld joint mapping (i.e. identification of all the welds by proper numbering system), applicable WPS, process used, type of joint with sketch, NDT requirements, and welds requiring production proof samples.

[Annexure REQ 508] The Weld Plan, in conjunction with the following documents, shall be submitted to IO before the start of welding activity.

- Welding Procedure Specification (WPS)
- Procedure Qualification Record (PQR)
- Welder Performance Qualification Record (WPQ)

[Annexure REQ 509] IO shall approve the welding plan before initiating welding/fabrication activity.

30 ACCEPTABLE WELDING PROCESSES

TIG welding and Electron Beam Welding are authorized. The BtP drawing describes each weld to be done.

[Annexure REQ 510] The selected welding technique shall produce a clean, pore-free weld with minimal oxidation.

[Annexure REQ 511] The Manufacturer shall choose any welding process other than that given in the BtP drawings after the IO approval.

[Annexure REQ 512] The Manufacturer shall demonstrate that the selected process meets the qualification and quality requirements. In such a case, the Manufacturer has to submit such records and get approval.

31 WELDING QUALIFICATION

31.1 Qualification of Welding Procedure Specification (WPS)

The Qualification of the WPS provides proof that the defined welding process will achieve a weld of acceptable quality following the applicable code.

[Annexure REQ 513] The Qualification of the WPS shall be performed following this annexure.

[Annexure REQ 514] The welding & testing of this Qualification shall be witnessed by an ITER / ITER-recognized independent inspection agency.

[Annexure REQ 515] All welding data and required non-destructive and destructive testing results shall be documented using a Procedure Qualification Record (PQR).

[Annexure REQ 516] An existing Welding Procedure Qualification Record (WPQR or WPAR) shall be deemed acceptable if the test was performed in the same environment as proposed for production, utilizing identical welding techniques, processes, joint configurations, and welding equipment (for mechanized welds).

[Annexure REQ 517] The allowable ranges for the WPQR or WPAR shall match concerning essential variables.

[Annexure REQ 518] The associated Preliminary Welding Procedure Specification (pWPS) shall have been qualified in line with ISO 15614.

[Annexure REQ 519] The test for the WPQR or WPAR shall have been overseen by an ITER / ITER recognized Independent Inspection Authority.

31.1.1 Qualification tests

[Annexure REQ 520] The preparation, execution, and testing of the test piece shall reflect the conditions intended for the preparation, execution, and testing of production welds.

31.1.2 Test pieces

31.1.2.1 Number and type of test piece

[Annexure REQ 521] The number and type of test pieces for welding procedure approval depends on the welding operation to be performed and shall be determined by:

- The essential variable governing the range of approval of the Qualification.
- The working conditions.

31.1.2.2 Dimension of the test piece

[Annexure REQ 522] The dimension of the qualification coupon shall be determined as follows:

- The welding process
- The plan for the removal of specimens for tests and retests
- The non-destructive examination to be performed
- If necessary, the Qualification of a welding procedure for repairs

[Annexure REQ 523] The minimum dimension of the test piece shall be as per Figures 1, 2, and 3 of ISO 15614-1 for arc and gas welding and as per Figures 1, 2, 3, and 4 of ISO 15614-11 for electron beam welding.

31.1.3 Acceptance of base material and filler material

[Annexure REQ 524] The filler material and base material used shall be acceptance tested as per relevant applicable specifications.

[Annexure REQ 525] The acceptance test report shall be available before the welding operations of the test piece.

[Annexure REQ 526] These documents shall be submitted to the IO on request.

31.1.4 Position

[Annexure REQ 527] The Manufacturer shall refer to ISO 6947 for the basic welding position used during Qualification and production welding.

31.1.5 Pre Heating, Interpass, and Post Heating temperature

[Annexure REQ 528] If applicable, the requirements shall be specified in pWPS.

[Annexure REQ 529] Qualification shall follow the preheating, interpass, and post-heating temperature needs per that pWPS.

31.1.6 Post weld Heat Treatment

[Annexure REQ 530] If applicable, once the weld is performed, the test piece shall be subjected to a heat treatment simulating all the stress-relieving heat treatments applied in production to welds.

[Annexure REQ 531] When a production weld is subjected to successive stress-relieving heat treatments at different holding temperatures, the corresponding qualification weld shall be treated at each.

[Annexure REQ 532] The qualification test piece shall be subjected to the same thermal cycle corresponding to the heat treatments performed on production joints.

31.1.7 Records

[Annexure REQ 533] Each WPS shall have minimum information as required by Attachment 1 of the ITER Vacuum Handbook (ITER_D_2FMM4B v1.5).

[Annexure REQ 534] PQR results shall be recorded in the suggested format as defined in Annexure A of ISO 15614 -1 & 11. The contractor may use the other format, provided all the required content of Annexure A of ISO 15614 -1 is incorporated

31.1.8 Extent of approval (Essential Variables)

31.1.8.1 Related to Manufacturer

[Annexure REQ 535] A qualification of a WPS by a welding procedure test obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of the Manufacturer.

31.1.8.2 Material groups

[Annexure REQ 536] For stainless steel grades 304, 304L, 316, 316L, and 316L(N)-IG, cross qualification shall be accepted when using a 316L filler.

[Annexure REQ 537] Cross qualification shall not be accepted for automatic welds that are performed without filler metals.

[Annexure REQ 538] Transition welds joining dissimilar materials not listed above shall undergo specific qualification tests.

31.1.8.3 Base Material

[Annexure REQ 539] There shall be no requirement to use material from the production heat number for the Qualification of WPS.

[Annexure REQ 540] For special processes such as automatic or mechanized gas tungsten arc welding, electron beam welding, and laser beam welding, PPS shall be welded using material from the same production heat number.

31.1.8.4 Welding position

[Annexure REQ 541] Welds for Qualification shall be performed under local conditions similar to the production weld conditions.

[Annexure REQ 542] Welder's access to the test piece shall be similar to their access to the production weld they qualify for.

[Annexure REQ 543] The orientation of the test piece, relative to the welder, shall be similar to that of the production weld for which they qualify.

31.1.8.5 Thickness range

[Annexure REQ 544] The Qualification of a welding procedure test on thickness "t" shall include Qualification for thickness in the following ranges in Table 47 and Table 48.

Thickness of Test piece t (mm) **Where "t" is the thk of thinner material**	**Range of Approval*# (Dimensions in mm) (ISO 15614-1)**		
	Parent metal thickness		**Deposited weld metal thickness for each process "s"**
	Single Run	**Multi Run**	
t≤ 3	0.5 t to 2 t		Max 2s
3 < t ≤ 12	0.5t (3mm min) to 1.3 t	3 mm to 2t	Max 2s
12 ≤ t ≤ 20	0.5 t to 1.1 t	0.5 t to 2t	Max 2s
20 < t ≤ 40	0.5 t to 1.1 t	0.5 t to 2t	Max 2s when s <20, Max 2t when s ≥20
40 < t ≤ 100		0.5 t to 2t	Max 2s when s <20, Max 200 when s ≥20

100 < t ≤ 150		50 mm to 2t	Max 2s when s <20, Max 300 when s ≥20
t >150	Not Applicable	50 mm to 2t	Max 2s when s <20, Max 1.33t when s ≥20

Table 47: Range of approval for material thickness and weld deposit thickness for butt welding qualification of arc welds

Thickness of Test piece t (mm)	Range of Approval (Dimensions in mm) (ISO 15614-1)		
	Material Thickness	Throat Thickness	
		Single Run	Multi Run
t≤ 3	0.7 t to 2 t	0.75a to 1.5a	No restriction
3 < t ≤ 30	3 to 2 t	0.75a to 1.5a	No restriction
t≥ 30	≥ 5	*	No restriction
Note 1: "a" is the throat thickness of the test piece. Note 2: Butt welds cannot qualify as fillet welds. * For special applications only. Each throat thickness has to be proofed separately by a welding procedure test.			

Table 48: Range of approval for material thickness and throat thickness of fillet welds by arc & gas welding

[Annexure REQ 545] For Electron beam welding, a procedure test carried out on a thickness "t" for a depth of penetration "s" shall qualify the thicknesses for the range of Qualification given in Table 49.

Depth of Penetration	Range of Approval
s < 5	t ± 20%
5 < s ≤ 25	t ± 15%
s >25	t ± 10%
s: Depth of Penetration t: Thickness of Test Piece	

Table 49:Range of approval for the material thickness of butt weld qualification by Electron beam welding

31.1.8.6 Diameter range

[Annexure REQ 546] The Qualification of a welding procedure test on diameter D shall include Qualification for diameters in the ranges given in Table 50 and Table 51.

Diameter of test piece D *# (in mm)	Range of Approval (in mm)
D ≤ 25	0.5 D to 2D
D > 25	0.5D up to plates (25mm min)
*D is the pipe's outside diameter or the set's outside diameter – on the branch pipe. # Approval given for plates also covers pipes when the outside diameter is >500mm.	

Table 50: Range of approval for pipe diameter (Arc welding qualification)

"D" Diameter of Test Piece	Range of Qualification
D	≥ 0.75 D

Table 51: Range of approval for pipe diameter (EB welding qualification)

31.1.8.7 Type of joint: range of approval

Type of Joint in Approval Test Piece			Range of Approval											
			Butt welds on plate				T Butt welds on plate		Fillet weld on plate	Butt welds on pipe		Fillet weld on pipe	Branch welds on pipe	
			Welded from one side		Welded from bothsides		Welded from one side	Welded from both sides		Welded from one side			Seton	Set through
			With backing	No backing	With gouging	No gouging				With backing	No backing			
Butt weld on plate	Welded from one side	With Backing	✓	x	Δ	Δ	x	x	x	x	x	x	x	x
		No Backing	Δ	✓	Δ	Δ	x	x	x	x	x	x	x	x
	Welded from both sides	With gouging	x	x	✓	Δ	x	x	x	x	x	x	x	x
		No gouging	x	x	x	✓	x	x	x	x	x	x	x	x
Butt weld on pipe	Welded from one side	With backing	Δ	x	Δ	Δ	x	Δ	x	✓	x	x	x	x
		No backing	Δ	Δ	Δ	Δ	Δ	Δ	x	Δ	✓	x	x	x
T Butt weld on plate	Welded from one side		x	x	x	x	Δ	Δ	x	x	x	x	x	x
	Welded from both sides		x	x	x	x	x	✓	x	x	x	x	x	x
Fillet weld	Plate		x	x	x	x	x	x	✓	x	x	x	x	x
	Pipe		x	x	x	x	x	x	Δ	x	x	✓	x	x
Branch weld in pipe	Set on		x	x	x	x	x	x	x	x	x	x	✓	x
	Set through		x	x	x	x	x	x	x	x	x	x		✓

Key:
✓ Indicates the weld for which the WPS is approved in the approval test
Δ Indicates those welds for which the WPS is also approved
x Indicates those welds for which the WPS is not approved

(Extracted from IVH Attachment 1)

31.1.8.8 Welding process

[Annexure REQ 547] Any change in the welding process shall necessitate a requalification of the process.

[Annexure REQ 548] For automatic welding, any change of the welding equipment shall require requalification.

31.1.8.9 Welding consumables

These requirements are given in the chapter 38.4.4.9.

31.1.8.10 Type of current

[Annexure REQ 549] The qualification shall be specified for the current type (alternating current, Direct current, pulsed current) used in the welding procedure test.

31.1.8.11 Heat input (if applicable)

[Annexure REQ 550] When impact requirements apply, the upper limit of heat input shall be 25% greater than that used in welding the test piece.

[Annexure REQ 551] When hardness requirements apply, the lower heat input limit shall be 25% lower than that used in welding the test piece.

31.1.8.12 Preheat temperature (if applicable)

[Annexure REQ 552] When preheating is required, the lower limit of Qualification shall be the nominal preheat temperature applied at the start of the welding procedure test.

[Annexure REQ 553] Where a gas shield is used, the introduction of preheating at above 50°C into a welding procedure for which it was not specified shall be prohibited.

31.1.8.13 Post heating (if applicable)

[Annexure REQ 554] The temperature range validated shall be the holding temperature used in the welding procedure test ±20ºC unless otherwise specified.

31.1.8.14 Post Weld Post heat treatment (if applicable)

[Annexure REQ 555] The addition or deletion of post-weld heat treatment shall not be permitted.

[Annexure REQ 556] The temperature range validated shall be the holding temperature used in the welding procedure test ±20°C unless otherwise specified.

31.1.8.15 Specific to process (TIG welding)

[Annexure REQ 557] A welding procedure test without a backing gas shall qualify as a welding procedure with a backing gas.

[Annexure REQ 558] Welding with filler material shall not qualify for welding without filler material or vice versa.

31.1.8.16 Initial heat treatment

[Annexure REQ 559] A change in the initial heat treatment condition before welding precipitation-hardened materials shall not be permitted.

31.1.8.17 Jigs, Fixtures & tooling (applicable for EBW)

[Annexure REQ 560] A qualified WPS shall only be valid for Jigs, Fixtures, and tooling as specified in the WPS.

31.1.8.18 Joint geometry (applicable for EBW)

[Annexure REQ 561] The welding procedure shall cease to be qualified if there is a modification of the joint geometry, alignment tolerance, or clearance or separation between the two parts welded.

[Annexure REQ 562] The welding procedure shall cease to be qualified if an addition, removal, or welding position change of a temporary or permanent backing strip exists.

[Annexure REQ 563] If tack or clamp weld is added, overlapping, or smoothing pass, the welding procedure shall cease being qualified.

[Annexure REQ 564] The welding procedure shall cease to be qualified if there is a shift from welding from both sides to welding from one side or conversely.

31.1.8.19 Weld baking (applicable for EBW)

[Annexure REQ 565] The qualified WPS shall be valid only if no backing is added or removed.

31.1.8.20 Weld type (applicable for EBW)

[Annexure REQ 566] The Qualification of a WPS shall be valid only for the weld type used during the procedure test, i.e., “Full penetration” or “Partial Penetration”.

31.1.8.21 Welding parameters (applicable for EBW)

[Annexure REQ 567] The Qualification of a WPS shall be valid only insofar as the specified range of welding parameters defined in the WPS (See. 4.13 in ENISO 15609 -11) and the specified tolerances are met.

31.1.8.22 Number of weld passes (applicable for EBW)

[Annexure REQ 568] The Qualification of a WPS shall be valid only insofar as the number of passes is the same as the one used for the procedure test.

31.1.9 Examination & Testing

31.1.9.1 Destructive examination

31.1.9.1.1 Number of test specimens

Test Specimen	No. of tests
Butt Weld	
❖ Transverse Tensile (Room Temp)	2
❖ All Weld Tensile (for t≥ 30mm)	1
❖ Root Bend (for t< 12 mm)	2
❖ Face Bend (for t< 12 mm)	2
❖ Side Bend (for t> 12mm)	4
❖ Macro Examination (With Photograph)	1
❖ Micro Examination at 200X	1
❖ Hardness testing	1
❖ Ferrite Content (In SS Material)	1
❖ Longitudinal Bend Test (for EBW only) (1 Root bend + 1 Face bend) applicable for flat heterogeneous assemblies	2
❖ Transverse Tensile at Elevated temp. *(If applicable in parent metal –refer to ANNEXURE 1.)*	1

❖ Impact test (for t> = 12 mm one set from weld metal and one set from HAZ, if required by tech. specs.)	2
Fillet Weld	
❖ Fracture Test	1
❖ Macro Examination (with the photograph)	4
❖ Micro Examination at 200x	2
❖ Hardness Survey	2
T –Butt / Branch Weld	
❖ Macro Examination (With Photograph)	4
❖ Micro Examination at 200x	2
❖ Hardness Survey	2
Socket /Lip Weld	
❖ Macro Examination (With Photograph)	4
❖ Micro Examination at 200x	2
❖ Hardness Survey	2

Table 52: No. of the test specimen for weld qualification

31.1.9.1.2 Location of the test specimen

[Annexure REQ 569] Test specimens for destructive testing shall be taken as per EN ISO 15614-1 & EN ISO 15614-11 for Arc and Electron Beam welding, respectively.

[Annexure REQ 570] For orbital TIG welding, transverse tensile test specimen shall be taken for both welding directions (i.e., upward vertical and downward vertical).

31.1.9.1.3 Methods and Acceptance Criteria

- **Transverse tensile test**

[Annexure REQ 571] Specimen and transverse tensile testing for butt joints shall follow EN895 or equivalent std.

[Annexure REQ 572] The tensile strength of the test specimen shall not be less than the corresponding specified minimum value for the parent metal unless otherwise specified before testing.

[Annexure REQ 573] The tensile strength for dissimilar parent metal joints shall not exceed the minimum value specified for the parent material with the lowest tensile strength.

- **Bend Test:**

[Annexure REQ 574] Specimen and bending testing for butt joints shall follow EN 910 / ISO 5173 or equivalent standards.

- **For SS and Ni alloy:**

[Annexure REQ 575] Each bend test specimen shall be bent at 180° round a former of diameter 2t, where t is the thickness of the test specimen.

[Annexure REQ 576] The bend test specimen shall have no open defects exceeding 2mm measured in any direction on the convex surface after bending.

- **For material other than SS and Ni alloys:**

[Annexure REQ 577] Each bend test specimen shall be bent at 180° around a former diameter as per recommendations of EN/ISO, with the acceptance criteria following EN/ISO standards.

- **Ferrite content (for SS only)**

[Annexure REQ 578] Ferrite content in the weld shall be 3 to 8 %.

- **Hardness testing**

[Annexure REQ 579] Vickers hardness testing with a load of HV10 shall be performed following EN1043.

[Annexure REQ 580] Hardness measurements shall be taken in the weld, the heat-affected zones, and the parent metal to evaluate the range of hardness values across the welded joint.

[Annexure REQ 581] For materials with a thickness of 5mm or less, a single row of indentations shall be made up to 2mm below the top surface of the welded joint.

[Annexure REQ 582] For material thickness over 5mm, two rows of indentations shall be made at a depth of up to 2mm below the upper and lower surface of the welded joint.

[Annexure REQ 583] For double-sided welds, fillet, and T butt welds one additional row of indentation shall be made through the root area.

[Annexure REQ 584] Each row of indentation shall have a minimum of three indentations in the weld, both heat-affected zones, and both parent metals.

[Annexure REQ 585] The hardness value shall conform to the specifications of EN ISO 15614-1. The hardness value for EBW welded joints shall be documented in the test report for reference.

- **Macro examination**

[Annexure REQ 586] All fillet welds shall have penetration at the root.

[Annexure REQ 587] For lip welds, penetration shall be 0.7t, where t is the thickness of the thinner material.

[Annexure REQ 588] The test specimen shall be prepared and etched in accordance with ISO 17639 on one side to reveal the fusion line, the HAZ, and the build-up of the runs.

- **Tensile test at Elevated temperature (if required for parent material)**

[Annexure REQ 589] The tensile test shall be done at a temperature defined in the Parent material specification.

[Annexure REQ 590] The tensile strength of the test specimen shall not be less than the corresponding specified minimum value for the parent metal as defined in the Material Specification.

31.1.9.2 Non-Destructive examination

31.1.9.2.1 Personnel Qualification

[Annexure REQ 591] The NDE operators, inspectors, and engineers shall be trained and qualified to the appropriate level to meet the requirements of ISO 9712 or ASNT Level 2 before performing or evaluating the examinations.

[Annexure REQ 592] Training and certification shall be the Manufacturer's responsibility.

[Annexure REQ 593] Certification validity shall be as per relevant standards.

31.1.9.2.2 Examination

[Annexure REQ 594] After post-weld heat treatment (if applicable) and before cutting the test specimen for further destructive testing, all test pieces shall be examined for following non-destructive examinations.

- Visual Examination ISO 17637
- Radiographic Examination ISO 17636
  and/or
- Ultrasonic Examination ISO17640 or ISO22825

[Annexure REQ 595] The examination method shall be agreed upon before inspection for a pipe or plate with a wall thickness of 2mm or less.

31.1.9.2.3 Acceptance Criteria (taken form IVH attachment 1)

[Annexure REQ 596] Defects detected by the relevant non-destructive examination method shall be assessed w.r.t criteria given in Table 53.

[Annexure REQ 597] The defect criteria shall be considered to evaluate results for weld qualification and production welding NDEs.

Defect Type	Permitted Maximum

Planar Defects	Crack or lamellar tears	Not Permitted
	Lack of Root Fusion	
	Lack of Side Fusion	
	Lack of inter-run fusion	
	Lack of root Penetration	
Solid Inclusion	Slag inclusion – Individual	20% of t or 2 mm, whichever is smaller
	Slag inclusion –Group	Aggregate length not to exceed t in a length of 12t, except when the distance between successive indications exceeds 6L, where L is the length of the longest indication in the group.
	Inclusion – Tungsten or Copper	Not Permitted
Cavities	Isolated pores – round	Diameter < 20% t or 2 mm, whichever is smaller
	Gas pore uniformly distributed porosity	1% for single layer (2% for multi-layer) by area where the area of the radiograph to be considered is the length of the weld affected by the porosity times the maximum thickness of the weld.
	Elongated pores - Wormholes	Not Permitted
	Linear Porosity	Not Permitted
Profile Defects	Undercut	Some intermittent undercut is Permitted. Depth not to exceed 0.5mm for t > 3 mm or 10% for t < 3mm. Undercut to blend smoothly with the parent material.
	Incompletely filled groove, sagging. Root concavity, shrinkage groove	0.05 t or 0.5 mm, whichever is smaller. Weld thickness shall not be less than the parent plate thickness
	Excess penetration – pipe	Not greater than 5% of the pipe's Internal diameter up to 2 mm max.
	Excess penetration – plate	t = 0.5 to 3 mm: h ≤1 mm+10% b t > 3mm: h ≤1 mm+20% b max 3mm

		h = height of excess penetration on the backside of the plate and b the width
	Excess weld material	Not greater than 10% weld width
	Misalignment	Not greater than 10% of the parent material thickness
	Fillet leg length (asymmetry)	Unequal leg length should not exceed 20% of the fillet throat thickness
	Burn through	Not Permitted
Other	Root Oxidation	Not permitted where a backing gas purge is specified in the WPS

Table 53: Acceptance criteria to evaluate NDE results

32 WELDER/WELDING OPERATOR PERFORMANCE QUALIFICATION

[Annexure REQ 598] Welder Qualification is intended to show the competence of the welder /operator in depositing sound welded material when following a qualified WPS. Welder Qualification shall follow ISO 9606 /ASME Sec. IX or equivalent standards were agreed upon in advance with IO.

[Annexure REQ 599] ISO 1418 shall be used for welding operators. IO may approve other standards on submission of documentation detailing the equivalence between the proposed standards and those quoted herein.

[Annexure REQ 600] The Manufacturer shall establish and maintain a list of qualified welders and operators.

[Annexure REQ 601] The list shall include their identification and the range of welds for which they are qualified.

[Annexure REQ 602] The welding and testing of the welder qualification test coupon shall be witnessed by an IO / ITER-recognized independent agency.

33 PRODUCTION WELDS

33.1 General requirements

[Annexure REQ 603] Welding shall be done on the job, strictly following the approved welding procedures using approved welding consumables and qualified welders.

[Annexure REQ 604] Suitable sequencing of welds shall be carried out to avoid the buildup of residual stresses and distortions.

[Annexure REQ 605] The Manufacturer shall ensure that procedures are in place to ensure that welding parameters specified on the WPS are adhered to during production welding.

[Annexure REQ 606] The Manufacturer shall perform regular audits to monitor the implementation of the welding parameters specified on the WPS.

[Annexure REQ 607] All welding equipment shall be suitably calibrated.

[Annexure REQ 608] Welding equipment shall be checked on a regular basis during production.

[Annexure REQ 609] Safety measures for welding and cutting operations workers shall comply with all local and national regulations.

[Annexure REQ 610] All welding processes shall prescribe protection from adverse weather conditions that could affect weld quality.

[Annexure REQ 611] When welding is performed outdoors in adverse weather conditions, temporary shelters shall be erected to enclose the work area completely.

33.2 Non-destructive examination of production welds

[Annexure REQ 612] Non-destructive examination of production weld shall follow Section 7.1.7 of technical specifications.

33.3 Production proof sample (PPS)

[Annexure REQ 613] Production welds where radiography or ultrasonic testing is impractical, such as welds that are not full penetration butt welds, shall be covered by production proof sampling (PPS).

[Annexure REQ 614] Production proof samples shall be welded and examined as per section 7.1.8 of the technical specification.

33.4 Leak testing of production welds

[Annexure REQ 615] All vacuum sealing welds in each VQC shall be subject to helium leak testing in accordance with the procedures of Section 25 of IVH.

[Annexure REQ 616] Leak testing shall be done as per Annexure 5.

[Annexure REQ 617] Where multi-pass welding is required in the production of components of VQC 1A, it is recommended that leak testing of the root weld pass shall be performed with only this pass completed.

33.5 Weld finish

[Annexure REQ 618] Production welds used on all vacuum systems shall be left clean and bright, but there is no vacuum requirement to machine the weld zone to match the surface finish of the parent material.

[Annexure REQ 619] All weld regions shall be free from scale, voids, blowholes, etc.

[Annexure REQ 620] All weld regions shall have no visible evidence of inclusions.

33.6 Repair of production welds

[Annexure REQ 621] The size and magnitude of all leaks detected on welds forming a vacuum boundary shall be reported to the IO.

[Annexure REQ 622] Weld repairs on these boundaries shall not be carried out without the prior agreement of the IO.

[Annexure REQ 623] Weld repairs shall not be performed unless the welding procedure used has been qualified.

[Annexure REQ 624] Welding procedures utilized for weld repairs shall adhere to the standards set in this specification.

[Annexure REQ 625] Any repair process that involves grinding or a combination of grinding and welding shall undergo a re-examination using all the non-destructive tests applicable to the respective joint.

[Annexure REQ 626] The acceptance criteria for repair welds shall remain consistent with the original standards.

[Annexure REQ 627] All repair welds on vacuum boundaries shall undergo a comprehensive vacuum leak test executed according to the approved procedure detailed in Annexure 5.

End of:
ANNEXURE 2
Welding
and
Welding qualification

ANNEXURE 3.

SIC WELDING AND WELDING QUALIFICATION

34 ANNEXURE SCOPE

This Annexure outlines the technical requirements for DL feedthrough box components (SIC) fabrication following the RCC-MR. The requirements cover 1) workshop qualification, 2) welding procedure and qualification of welders/welding operators, 3) acceptance and qualification of filler material, and 4) production welding of DL feedthrough box components.

35 REFERENCE DOCUMENTS

- RCC-MRx:2022; Section 4 Welding; RS 3000 Welding Procedure Qualification
- ITER Vacuum Handbook: Attachment 1 Welding_2FMM4B_v1_5
- ISO 15607: Specification and qualification of welding procedures for metallic materials
- ISO 15609-1: Specification and qualification of welding procedures for metallic materials —Welding procedure specification — Part 1: Arc welding
- ISO 15609-2: Specification and qualification of welding procedures for metallic materials - Welding procedure specification — Part 2: Gas welding
- EN 15614-1: Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys

36 ACCEPTANCE AND QUALIFICATION OF FILLER MATERIAL

[Annexure REQ 628] The filler material used in the fabrication & welding qualification of the DL Feedthrough box component shall be procured according to RS 2000 Section 4 of RCC-MR.

[Annexure REQ 629] The filler material's composition shall comply with ITER radioprotection requirements.

[Annexure REQ 630] Ferrite contents in the filler material shall be restricted to 3 to 10 %.

[Annexure REQ 631] Co in the filler material shall be less than 0.05%.

[Annexure REQ 632] Nb in the filler material shall be less than 0.01%.

[Annexure REQ 633] Ta in the filler material shall be less than 0.01%.

[Annexure REQ 634] The filler material shall be qualified according to RS 5000 Section 4 of RCC MR.

[Annexure REQ 635] If the proposed filler material is not referenced in RS 2700 and RS 2900 of section 4 RCC MR, the Manufacturer shall submit a specification data sheet mentioning the results to IO for approval.

[Annexure REQ 636] The filler material qualification report shall be submitted to IO.

[Annexure REQ 637] The filler material certificate shall be submitted to IO for approval.

[Annexure REQ 638] Welds shall normally be made so that they can be leak-tested at the time of completion.

[Annexure REQ 639] Welds that cannot be inspected shall not be permitted for the component classified as VQC 1A.

37 QUALIFICATION OF WORKSHOP

[Annexure REQ 640] For the DL feedthrough box fabrication, a production workshop's technical qualification shall comply with RS 6000 section 4 requirements of RCC MR.

38 WELDING QUALIFICATION

38.1 The purpose of welding procedure qualification

The primary purpose of the welding procedure qualification is to demonstrate that the joining process proposed for the construction can produce joints with the required mechanical properties for the intended application.

38.2 Document to be established

[Annexure REQ 641] Every welding procedure qualification shall follow the provisions set out in this section.

[Annexure REQ 642] All qualifications shall comply with the requirements of the relevant paragraphs.

[Annexure REQ 643] Each qualification shall comprise the p-WPS (preliminary Welding Procedure Specification) prepared following ISO 15609-1 or ISO 15609-2.

[Annexure REQ 644] The p-WPS shall be included in the welding data package.

[Annexure REQ 645] Each qualification shall define the range of its approval.

[Annexure REQ 646] Each qualification shall specify the tests to be carried out and the associated criteria concerning the qualification level.

[Annexure REQ 647] Every qualification shall provide the basic sketch for removing test specimens.

[Annexure REQ 648] Qualifications shall detail bead distribution and the welding process used for each bead.

[Annexure REQ 649] Qualifications shall define the unwinding speed if applicable.

38.3 Welding Procedure specification

[Annexure REQ 650] The welding procedure specification (WPS) shall be a document qualified by the subjected welding process intended for use in production.

[Annexure REQ 651] The WPS shall provide the required variables of the welding procedure to ensure repeatability during production welding.

[Annexure REQ 652] Each WPS shall detail each type of weld.

[Annexure REQ 653] The WPS shall include necessary information as required by section 4 of ISO 15609.

[Annexure REQ 654] Additionally, the WPS shall adhere to section 5 of Attachment 1 ITER Vacuum Handbook requirements.

38.3.1 **WPS format**

The Manufacturer can use the format provided in Annex A of ISO 15609 to prepare the pWPS and WPS. Note that the format does not contain an exhaustive list of all the variables. The Manufacturer has to expand it to cover all the applicable information as required by section 4 ISO 15609.

38.4 Welding Procedure Qualification Record (WPQR)

38.4.1 **General requirements**

The qualification of the welding procedure provides proof that the defined welding process will achieve a weld of acceptable quality following the applicable code.

[Annexure REQ 655] The Qualification of the WPS shall be performed following this Annexure.

[Annexure REQ 656] ITER / ITER-recognized independent shall witness the welding & testing of the qualification coupon inspection agency.

[Annexure REQ 657] All welding data and required non-destructive and destructive testing results shall be documented using a Welding Procedure Qualification Record (WPQR).

An existing Welding Procedure Qualification Record (WPQR or WPAR) is acceptable if the following conditions are met:

- The test was performed in the same environment as proposed for production, using the same welding technique, process, joint configuration, and welding equipment (for mechanized welds)
- The allowable ranges are the same concerning essential variables.

- The related Preliminary Welding Procedure Specification (pWPS) was qualified following ISO 15614.
- The test was witnessed by an ITER / ITER-recognized Independent Inspection Authority.

[Annexure REQ 658] The preparation, execution, and testing of the test piece shall consider the conditions applied to the preparation, execution, and testing of production welds.

[Annexure REQ 659] The filler material and base material used in qualification shall be acceptance tested as per relevant applicable specifications.

[Annexure REQ 660] The acceptance test report shall be available before the welding operations of the test piece.

[Annexure REQ 661] The acceptance test report shall be submitted to the IO on request.

[Annexure REQ 662] The requirements of preheating, interpass, and post-heating (as applicable) shall be specified in pWPS and followed for the qualification.

[Annexure REQ 663] If applicable, once the weld is performed, the test piece shall be subjected to a heat treatment simulating all the stress-relieving heat treatments applied in production to welds.

[Annexure REQ 664] When a production weld is subjected to successive stress-relieving heat treatments at different holding temperatures, the corresponding qualification weld shall be treated at each.

[Annexure REQ 665] The qualification test piece shall be subjected to the same thermal cycle corresponding to the heat treatments performed on production joints.

[Annexure REQ 666] WPQR results shall be recorded in the suggested format as defined in Annexure A of ISO 15614 -1. The contractor may use the other format, provided all the required content of Annexure A of ISO 15614 -1 is incorporated.

38.4.2 Test pieces

38.4.2.1 Number and type of test piece

The number and type of test pieces for welding procedure approval depends on the welding operation to be performed and are determined by:

- The essential variable governing the range of approval of the qualification.
- The working conditions.

38.4.2.2 Dimension of the test piece

[Annexure REQ 667] The dimension of the qualification test piece shall be determined as follows:

- The welding process

- The plan for the removal of specimens for tests and retests
- The non-destructive examination to be performed
- If necessary, the qualification of a welding procedure for repairs
- In any event, the width of each part (or each section of the tube) to be welded must not be less than 150 mm or 2t (where “t” is the thickness of the test coupon)

[Annexure REQ 668] The minimum dimension of the qualification test piece shall be as per figures 1,2 & 3 of ISO 15614-1 for Arc and gas welding.

38.4.2.3 Type of Groove

[Annexure REQ 669] Grooves shall be machined, gouged, or ground by the same processes as those used in production (thermal, mechanical, etc.). Where production grooves are to be prepared by oxygen cutting, the requirements of RF 3300.d Section 5 RCC-MR shall be met.

[Annexure REQ 670] The groove shape shall correspond to one of the joints used in fabrication. Grooves shall be subjected to the same examinations and tests before welding as those required in fabrication.

[Annexure REQ 671] The test piece shall be prepared with clearances and fit-up corresponding to the limit tolerances required in fabrication / Manufacturing drawing.

38.4.3 Welding of test pieces

[Annexure REQ 672] Preparation and welding of qualification test pieces shall meet the requirement of RS 3221 Section 4 RCC MR.

38.4.4 Extent of approval (Essential Variables)

38.4.4.1 Related to Manufacturer

[Annexure REQ 673] A qualification test shall be performed in the same workshop as the production welds, subject to RS 6000 section 4 RCC MR provisions.

38.4.4.2 Material groups

[Annexure REQ 674] For stainless steel grades 304, 304L, 316, 316L, and 316LN-IG, cross qualification shall be permissible when using a 316L filler.

[Annexure REQ 675] Cross qualification shall not be acceptable for automatic welds executed without filler metals.

[Annexure REQ 676] Transition welds joining dissimilar materials not listed above shall undergo specific qualification tests.

38.4.4.3 Base Material

[Annexure REQ 677] Qualification on the production metal type and grade shall be mandatory.

[Annexure REQ 678] There shall be no requirement to use material from the production heat number for the qualification of WPS.

[Annexure REQ 679] The Production Proof Sample (PPS) shall be welded from the same production heat number for special processes like automatic or mechanized gas tungsten arc, electron beam welding, and laser beam welding.

38.4.4.4 Welding position

[Annexure REQ 680] Welds for qualification shall be conducted in local conditions mirroring the intended production weld.

[Annexure REQ 681] The welder's access to the test piece and the orientation of the test piece (relative to the welder) shall align with those of the production weld for which they qualify.

38.4.4.5 Thickness range

[Annexure REQ 682] Qualification limits for both the parent material and deposited metal shall adhere to the guidelines presented in Table 54 and Table 55.

[Annexure REQ 683] The thickness limits of the deposited metal qualified shall not surpass those set for production welds, except that fillet weld thickness is exempted.

[Annexure REQ 684] Both sections of the parent material intended for welding shall remain within the qualified thickness boundaries, except for dissimilar thickness parent materials; there's no restriction on the thickest section if the qualification was done on a parent material measuring 30 mm or more.

[Annexure REQ 685] For multi-process qualifications, the documented thickness of each process's deposited metal shall determine the qualification range for that specific welding process.

[Annexure REQ 686] Precise measurements of deposited metal thickness, base metal thickness, or outside pipe diameters are not required, but the overarching principles represented in Table 54, Table 55, and Table 56 shall be adhered to.

[Annexure REQ 687] A welding procedure test qualification on a thickness' t' shall cover qualifications for thickness ranges specified in Table 54 and Table 55.

Thickness of Test piece t (mm) Where "t" is the thk. of thinner material	Range of Approval*#(Dimensions in mm) (ISO 15614-1)		
	Parent metal thickness		Deposited weld metal thickness for each process "s"
	Single Run	Multi Run	
t≤ 3	0.5 t to 2 t		Max 2s
3 < t ≤ 12	0.5t (3mm min) to 1.3 t	3 mm to 2t	Max 2s
12 ≤ t ≤ 20	0.5 t to 1.1 t	0.5 t to 2t	Max 2s
20 < t ≤ 40	0.5 t to 1.1 t	0.5 t to 2t	Max 2s when s <20, Max 2t when s ≥20.
40 < t ≤ 100		0.5 t to 2t	Max 2s when s <20, Max 200 when s ≥20.
100 < t ≤ 150		50 mm to 2t	Max 2s when s <20, Max 300 when s ≥20.
t >150	Not Applicable	50 mm to 2t	Max 2s when s <20, Max 1.33t when s ≥20.

Table 54: Range of approval for material thickness and weld deposit thickness for butt welding qualification

Thickness of Test piece t (mm)	Range of Approval (Dimensions in mm) (ISO 15614-1)		
	Material Thickness	Throat Thickness	
		Single Run	Multi Run
t ≤ 3	0.7 t to 2 t	0.75a to 1.5a	No restriction
3 < t ≤ 30	3 t to 2 t	0.75a to 1.5a	No restriction
t ≥ 30	≥ 5	*	No restriction
Note 1: "a" is the throat thickness of the test piece. Note 2: Butt welds cannot qualify as fillet welds.			

*: For special applications only. Each throat thickness has to be proofed separately by a welding procedure test.

Table 55: Range of approval for material thickness and throat thickness of fillet welds

38.4.4.6 Thickness range for Branch pies (Diameter Range)

[Annexure REQ 688] The qualification of a welding procedure test on diameter D shall include qualification for diameters in the following ranges given in Table 56.

Diameter of test piece D * (mm)	Range of Approval (mm)
D ≤ 25	0.5 D to 2D
D > 25	0.5D up to plates (25mm min)
*: D is the pipe's outside diameter or the set's outside diameter – on the branch pipe. # Approval given for plates also covers pipes when the outside diameter is >500mm.	

Table 56: Range of approval for pipe & branch connections

38.4.4.7 Type of joint: Range of Approval

Type of Joint in Approval Test Piece			Range of Approval											
			Butt welds on plate				T Butt welds on plate		Fillet weld on plate	Butt welds on pipe		Fillet weld on pipe	Branch welds on pipe	
			Welded from one side		Welded from bothsides		Welded from one side	Welded from both sides		Welded from one side			Seton	Set through
			With backing	No backing	With gouging	No gouging				With backing	No backing			
Butt weld on plate	Welded from one side	With Backing	✓	x	Δ	Δ	x	x	x	x	x	x	x	x
		No Backing	Δ	✓	Δ	Δ	x	x	x	x	x	x	x	x
	Welded from both sides	With gouging	x	x	✓	Δ	x	x	x	x	x	x	x	x
		No gouging	x	x	x	✓	x	x	x	x	x	x	x	x
Butt weld on pipe	Welded from one side	With backing	Δ	x	Δ	Δ	x	Δ	x	✓	x	x	x	x
		No backing	Δ	Δ	Δ	Δ	Δ	Δ	x	Δ	✓	x	x	x
T Butt weld on plate	Welded from one side		x	x	x	x	Δ	Δ	x	x	x	x	x	x
	Welded from both sides		x	x	x	x	x	✓	x	x	x	x	x	x
Fillet weld	Plate		x	x	x	x	x	x	✓	x	x	x	x	x
	Pipe		x	x	x	x	x	x	Δ	x	x	✓	x	x
Branch weld in pipe	Set on		x	x	x	x	x	x	x	x	x	x	✓	x
	Set through		x	x	x	x	x	x	x	x	x	x		✓

Key:
✓ Indicates the weld for which the WPS is approved in the approval test.
Δ Indicates those welds for which the WPS is also approved.
x Indicates those welds for which the WPS is not approved.

(Extracted from IVH Attachment 1)

38.4.4.8 Welding process

[Annexure REQ 689] Any alteration in the welding process shall necessitate process requalification.

[Annexure REQ 690] Any change to the welding equipment for automatic welding shall also require requalification.

[Annexure REQ 691] Qualification of a multi-pass welding procedure shall not validate the single-pass welding procedure, and the reverse also holds true.

[Annexure REQ 692] Each level of mechanization, including manual, partly mechanized, fully mechanized, and automatic, shall undergo separate qualifications.

[Annexure REQ 693] If a test piece is welded using multiple welding processes, the procedure shall only be valid for the sequence of processes executed on the test piece.

[Annexure REQ 694] Test specimens shall encompass deposited material from every welding process employed.

38.4.4.9 Welding consumables

[Annexure REQ 695] All welding consumables shall be certified to a standard recognized by the ITER IO, such as ISO 14344 or ASME sec. II Part C.

[Annexure REQ 696] For manual welding processes, the approval scope for filler materials shall include other filler metals, provided they fall within the same range and possess the same chemical composition.

[Annexure REQ 697] For automatic and semi-automatic welding processes, the welding consumables used for qualification shall originate from the same batch as those chosen for production welds.

[Annexure REQ 698] If there is any change in consumables during production, weld samples shall be created and inspected before proceeding with the new batch of consumables in production.

[Annexure REQ 699] RS3243.4 Section 4 RCC MR guidelines regarding the range of approval for filler metal shall be adhered to.

[Annexure REQ 700] Qualifying with filler shall not validate autogenous welds; the reverse is also true.

38.4.4.10 Type of current

[Annexure REQ 701] The welding qualification shall be specific to the current type (alternating current, Direct current, pulsed current) used during the welding procedure test.

[Annexure REQ 702] Qualification shall adhere to the parameters outlined in the p-WPS (preliminary Welding Procedure Description), which includes:

- The ranges for the electrical parameters: I (amp) in all scenarios and U (volts) for automatic welding only
- The range of welding speeds, v, for automated welding only

38.4.4.11 Heat input

[Annexure REQ 703] Arc energy and heat input shall be considered measures of the heat generated by the arc.

[Annexure REQ 704] The arc energy shall be calculated following the guidelines set out in ISO/TR 18491.

[Annexure REQ 705] In calculations related to heat input, the k-factor, as prescribed by ISO/TR 17671-1, shall be considered.

[Annexure REQ 706] Whether heat input or arc energy, the chosen calculation method shall be duly documented.

[Annexure REQ 707] If impact requirements are relevant, the qualified heat input's upper limit shall be 25% more than used for the test piece's welding.

[Annexure REQ 708] If hardness requirements are in place, the qualified heat input's lower limit shall be 25% less than used while welding the test piece.

[Annexure REQ 709] In cases where a welding procedure test was conducted at high and low heat input levels, all intermediate heat input levels shall be deemed qualified.

[Annexure REQ 710] The average heat input for each used diameter shall be calculated to establish the qualified heat input for covered electrodes.

[Annexure REQ 711] For the 111 processes, heat input can also be gauged by the run-out length per unit length of the electrode.

[Annexure REQ 712] When welding times are exceptionally short, or the weld length is insignificant (e.g., for minor repairs or tack welds), verifying heat input is not mandatory; only adjustable parameters like amperage and/or voltage shall be inspected.

38.4.4.12 Preheat temperature

[Annexure REQ 713] A decrease in the preheat temperature from the recorded preheating temperature on the WPQR shall necessitate requalification.

[Annexure REQ 714] When using a gas shield, introducing preheating above 50ºC for a welding procedure where it was not previously specified shall be prohibited.

38.4.4.13 Interpass temperature

[Annexure REQ 715] The interpass temperature shall be consistent with the value specified in the p-WPS during the qualification process.

[Annexure REQ 716] Any increase in interpass temperature beyond what was achieved during the WPQR shall necessitate requalification.

[Annexure REQ 717] The above limitation shall not apply to a qualified WPS when an austenitic material undergoes solution annealing post-welding.

38.4.4.14 Post-heating (when applicable)

[Annexure REQ 718] The post-heating temperature shall be as specified in the p-WPS.

[Annexure REQ 719] The temperature and duration of post-heating shall not be reduced.

38.4.4.15 Post Weld Post heat treatment (when applicable)

[Annexure REQ 720] The addition or deletion of post-weld heat treatment shall not be permitted.

[Annexure REQ 721] The test piece shall undergo the same thermal cycles corresponding to the heat treatments performed on production joints.

[Annexure REQ 722] If there is any modification to the temperature cycles for post-weld heat treatment, the welding procedure qualification shall be invalidated.

38.4.4.16 Welding technique

[Annexure REQ 723] Changes invalidating approval of the welding procedure:

- Change from a narrow-run to a wide-run deposit (oscillation more than 3 times the diameter of the core wire),
- Change from a spray, droplet, or pulsed arc to a short-circuit arc, or vice-versa,

- Modification of the width, frequency, or dwell time of oscillation,
- Change in the trade designation of the welding automation equipment,
- Reduction, during manufacture, by 10% or more of the front shield gas flow concerning the minimum specified value,
- Change in the root shield: method used (global or local),
- Change from a single-electrode to a multiple-electrode process and vice-versa.

38.4.4.17 Specific to process: Additional rules

38.4.4.17.1 *Processes 111 (manual shielded metal arc welding) and 114 (self-protecting flux cored wire welding)*

[Annexure REQ 724] As outlined in session 38.4.4.9, the equivalence shall only be permissible if the current ranges used in production match those defined in the qualification certificate or the qualification technical data sheet as stipulated by RS 5000.

[Annexure REQ 725] The welding procedure qualification shall encompass this diameter if the specified ranges are not adhered to for a given diameter.

[Annexure REQ 726] No equivalence shall be considered for a diameter that does not adhere to the specified ranges.

38.4.4.17.2 *Process 15 (Plasma arc welding)*

[Annexure REQ 727] The welding procedure shall be qualified solely for the ranges outlined in the p-WPS concerning the distance between edges designated for welding.

[Annexure REQ 728] The welding procedure qualification shall be limited to the nominal composition of the plasma gas utilized during the welding procedure test.

[Annexure REQ 729] Qualification shall only pertain to the nominal composition of the shielding gas employed in the procedure test.

[Annexure REQ 730] Welding with filler material shall not be considered qualified for welding without such material, and vice versa.

[Annexure REQ 731] Any alteration in the type of joint preparation (groove) shall necessitate a requalification.

38.4.4.17.3 *Process 12 (Submerged arc welding)*

[Annexure REQ 732] Each variant of process 12 (from 121 to 126) shall be qualified individually.

[Annexure REQ 733] A change in the number of electrodes shall necessitate requalification.

[Annexure REQ 734] Any addition or removal of wires, whether cold or hot, shall require requalification.

[Annexure REQ 735] An alteration exceeding ±10% in the ratio of supplementary filler material to the electrode shall lead to requalification.

[Annexure REQ 736] The welding procedure test qualification shall be confined to the Manufacturer, trade name, and designation of the flux utilized in the test.

[Annexure REQ 737] When employing flux from re-crushed slag, every batch or mixture shall necessitate a fresh qualification test.

38.4.4.17.4 *Process 13 (Gas shielded metal arc welding)*

- **Shielding gases:**

[Annexure REQ 738] The qualification shall be restricted to the nominal composition of the shielding gas used in the procedure test, with the ISO 14175 designation being an acceptable specification for the shielding gas composition, e.g. ISO 14175:2008-M21-ArC-18.

[Annexure REQ 739] A deviation of up to ±20% (relative) from the nominal composition of the CO_2 content shall be permissible.

[Annexure REQ 740] Intentional additions or deletions of up to 0.1% of any gas component shall not necessitate a new welding procedure test.

- **Process variants:**

[Annexure REQ 741] The qualification shall be limited to the wiring system utilized in the welding procedure test (e.g. single-wire or multiple-wire system).

- **Transfer mode**
  - **General**

[Annexure REQ 742] Qualification using short-circuiting transfer for solid, and metal cored wires shall only qualify short-circuiting transfer, while qualification using a spray, pulse, or globular transfer shall qualify spray, pulse, and globular transfer.

  - **Waveform-controlled welding**

[Annexure REQ 743] When a power source featuring waveform control (as defined in ISO/TR 18491) is used, both the power source manufacturer and waveform control mode shall be documented on the WPQR, along with any other relevant details. Switching from one power source manufacturer to another or altering the waveform control mode shall require a new qualification test.

- **Welding with pulsed mode (without waveform control)**

[Annexure REQ 744] When employing a power source in pulsed mode, the Manufacturer's identification shall be documented on the WPQR, including all pertinent details. Transitioning from one power source manufacturer to another shall not require a new qualification test.

- **Welding without pulsed mode and without waveform control**

[Annexure REQ 745] In cases where the power source qualifying a WPQR operates without waveform control, the power source manufacturer's identification shall be necessary. Transitioning from one power source manufacturer to another shall not require a new qualification test.

38.4.4.17.5 *Process 14 (Gas shielded arc welding with non-consumable electrode)*

- **Shielding gases**

[Annexure REQ 746] The qualification shall be restricted to the nominal composition of the shielding gas used in the procedure test, with the designation of ISO 14175 being an acceptable method to specify the shielding gas composition, e.g. ISO 14175:2008-13 ArHe-30.

[Annexure REQ 747] A maximum deviation of ±10% (relative) from the nominal composition of the helium content shall be permissible.

[Annexure REQ 748] Intentional additions or deletions of up to 0.1% of any gas component shall not necessitate a new welding procedure test.

- **Filler material**

[Annexure REQ 749] Welding with filler material does not qualify for welding without filler material or vice versa.

38.4.5 Destructive examination

38.4.5.1 Extent of destructive examination

Test Piece	Type of Test	No. of tests	Applicable standard
1. Butt Joint with full penetration (Pipe and Plate)	Longitudinal Tensile test (if applicable)	See Chapter 38.4.5.3	
	Transverse Tensile test	See Chapter 38.4.5.4	
	Transverse bend test	See Chapter 38.4.5.5	

	Impact Test	See Chapter 38.4.5.6	
	Hardness test	1	Chapter 38.4.5.9
	Macroscopic Examination	1	Chapter 38.4.5.8
	Microscopic examination	1	Chapter 38.4.5.8
	Ferrite contents	1	Chapter 38.4.5.10
2. T-Joint with full penetration 3. Branch connection with full penetration	Hardness test	2	Chapter 38.4.5.9
	Macroscopic Examination with photos	4	Chapter 38.4.5.8
	Microscopic Examination at 200X with photos	2	Chapter 38.4.5.8
4. T-joint Fillet weld 5. Branch connection Fillet weld	Hardness test	2	Chapter 38.4.5.9
	Macroscopic Examination with photos	4	Chapter 38.4.5.8
	Microscopic Examination at 200X with photos	2	Chapter 38.4.5.8
	Fracture test	1	
*Inspection using a Photothermal camera is permitted in the case where the Manufacturer has qualified the method/acceptance criteria before the weld qualification			

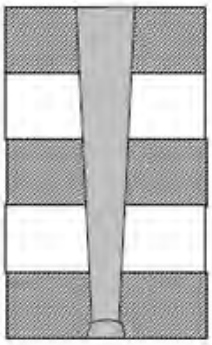
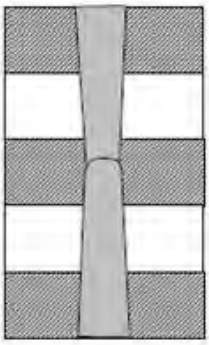
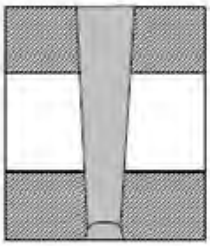
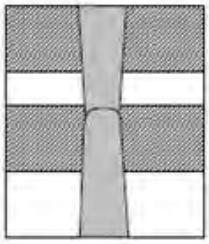
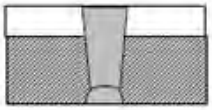
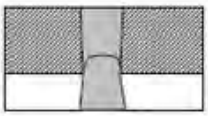
Table 57: No. of the test specimen for weld qualification

38.4.5.2 Location and cutting of test specimen

38.4.5.2.1 *Location of test specimen in butt joints*

[Annexure REQ 750] Test specimens sampling areas and positioning in the thickness for butt welds of plates and pipes shall be as per Table 58.

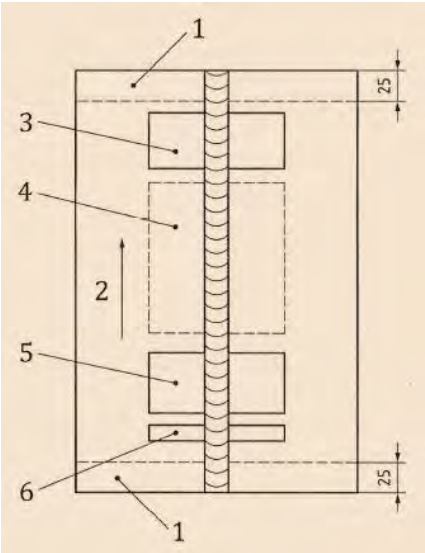
Table RS3231.21c : test specimen sampling areas, positioning in the thickness

Welding of one side only	Sampling area		Welding of both sides
t > 100 mm 	P A R	P R A	t > 200 mm 
30 < t ≤ 100 mm 	P R	P R	30 < t ≤ 200 mm 
t ≤ 30 mm 	P	P	t ≤ 30 mm 

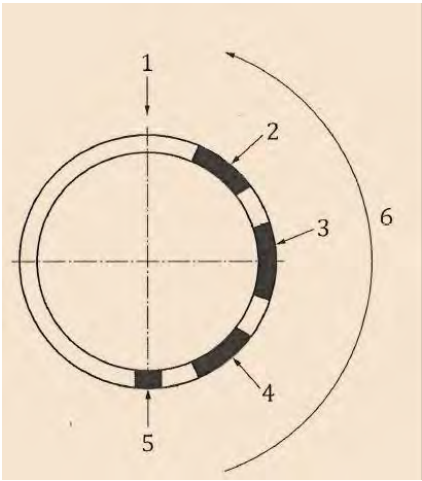
t : thickness of qualification test piece
the sampling areas (P on the skin, R at the root, A additional) are not localized in the same section and shall be distributed to comply with positioning specified in figures 5 and 6 of standard *NF EN ISO 15614-1*

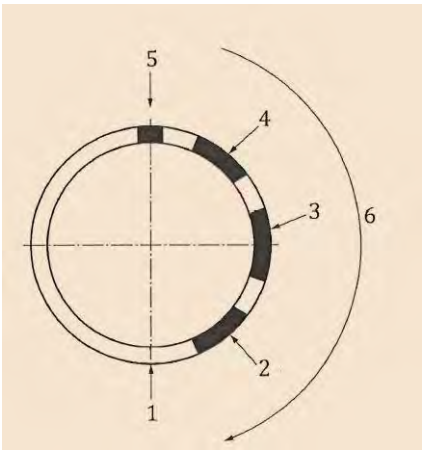
Table 58: Location of test specimen in butt welds

[Annexure REQ 751] The sampling areas (P on the skin, R at the root, and A additional) are not localized in the same section and shall be distributed as described in Figure 22.



1 discard 25 mm
2 welding direction
3 area for:
- 1 tensile test specimen
- bend test specimens
4 area for:
- impact and additional test specimens if required
5 area for:
- 1 tensile test specimen
- bend test specimens
6 area for:
- 1 macro test specimen
- 1 hardness test specimen
NOTE: Not to scale.

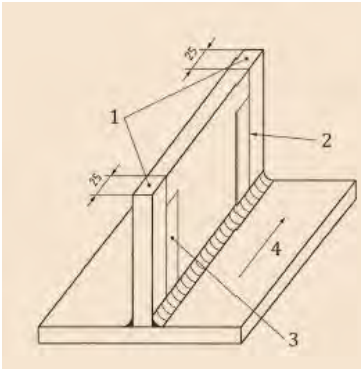




1 end of weld
2 area for:
- 1 tensile test specimen
- bend test specimens
3 area for:
- impact and additional test specimens if required
4 area for:
- 1 tensile test specimen
- bend test specimens
5 starts of weld, area for:
- 1 macro test specimen
- 1 hardness test specimen (taken from the start of weld)
6 weld direction
NOTE: Not to scale.

Figure 22: Location of the test specimen for the butt joint in the plate (top view) and pipe

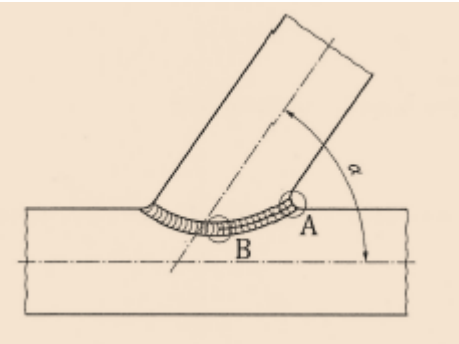
38.4.5.2.2 *Location of test specimen in T-joint*



1: discard 25 mm
2: macro test specimen
3: macro and hardness test specimen
4: welding direction

Figure 23: Location of test specimen in T joint

38.4.5.2.3 *Location of test specimen in branch joint on pipe*



A: macro and hardness test specimen to be taken
B: macro test specimen to be taken a branch angle

Figure 24: Location of the test specimen for the branch joint in the pipe

Taking the test specimens from the locations is acceptable, avoiding areas with imperfections within the acceptable limits for the NDT methods.

38.4.5.3 Longitudinal Tensile Test (if t>=15mm) on deposited weld metal

Temperature	Room	200 °C
Procedure	RS1.0120	RS1.0120
Measurement	Rm, Rp0.2, A%, Z	Rp0.2 and for information Rm, A%, Z
Sampling conditions	RS1.0121	RS1.0121

Area Table 58	P*	R*	A*	P*
Number of tests	1	1	1	1
Acceptance criteria	[Annexure REQ 752] The tensile and yield strength shall be equal to those specified for the base metal. Where base metals are joined for which, different minimum values are specified for these two characteristics, the values to be guaranteed shall be the lower for each characteristic. [Annexure REQ 753] The tensile strength of the deposited metal shall not exceed 800 MPa. [Annexure REQ 754] Elongation shall be at least 25%, and the reduction in area shall be recorded for information. [Annexure REQ 755] If the fracture occurs outside the middle third with an unsatisfactory value in the case of tubular butt-welded qualification coupons, a retest may be performed at the 12 o'clock position on a test specimen prepared following the requirements of annex E of standard EN ISO 6892. The retest shall give a value greater than or equal to 25%.			
***:**	The sampling areas (P, R, A) are not localized in the same section and shall be distributed to comply with the positioning specified in Figure 22.			

*

38.4.5.4 Transverse tensile tests

Temperature	Room		200 °C	
Procedure	RS 1.0110			
Measurement	Rm + Location of the break			
Sampling conditions	RS 1.0111 ISO 4136			
Area Table 58	P	R	P	R
Number of tests	1*	1	1	1
Acceptance Criteria	[Annexure REQ 756] The tensile strength and the yield strength shall be equal to those specified for the base metal unless otherwise specified before the testing.			

	[Annexure REQ 757] Where base metals are joined for which different minimum values are specified for these two characteristics, the values to be guaranteed shall be the lower of the two for each of the characteristics.
Additional Note	[Annexure REQ 758] The test shall represent the whole thickness except as necessary to obtain parallel sides on the specimens. [Annexure REQ 759] Tensile testing shall ensure all welding processes used and the associated essential variables are tested. It is not essential to overlap the specimens as identified in ISO 4136. [Annexure REQ 760] For pipes >50 mm outside diameter, the excess weld metal shall be removed on both faces to give the test specimen a thickness equal to the wall thickness of the pipe. [Annexure REQ 761] For pipes ≤50 mm outside diameter, for which the transverse tensile test is performed on the entire pipe, the excess weld metal may be left undressed on the inside surface of the pipe.
***:**	[Annexure REQ 762] For thickness less than 30 mm, 2 test specimens shall be sampled, each covering the entire thickness.

38.4.5.5 Bend tests

	Root Bend	**Face Bend**	**Side Bend** **(if thickness >20mm)**
Temperature	Room		
Procedure	RS 1.0220 ISO 5173:2002		RS 1.0220 ISO 5173:2002
Measurement	Ductility (Qualitative assessment)		Ductility (Qualitative assessment)
Sampling conditions	RS 1.0211		RS 1.0213

Area Table 58	Internal Skin	External Skin	Through Thickness
Number of tests	2	2	2
Bend angle and Former diameter	The bend angle shall be 180° round a former of diameter 2t, where t is the thickness of the specimen.		
Acceptance Criteria	[Annexure REQ 763] The bend test specimen shall have no open defects exceeding 2 mm measured in any direction on the convex surface after bending. [Annexure REQ 764] Defects located in the test specimen's angles shall be considered. [Annexure REQ 765] If localized de-cohesions occur, the method described in RS1.0240 shall be used to identify its origin. If the results obtained using this method demonstrate that the metal's deformation capacity has been exceeded in a localized area, these results shall be deemed acceptable. [Annexure REQ 766] Imperfections appearing at the corners of a test specimen during testing shall be ignored in the evaluation.		

38.4.5.6 KV impact test (if t>=12mm)

	Weld			HAZ	
Temperature	Room			Room	
Procedure	RS 1.0310 ISO 9016			RS 1.0320	
Measurement	Energy			Energy	
Sampling conditions	RS 1.0310			RS 1.0320 (notch on the fusion line)	
Area Table 58	P	R	A	P	A
Number of tests	3	3	3	3	3
Acceptance Criteria	[Annexure REQ 767] At room temperature, each series of impact tests, consisting of three test specimens in the weld metal and HAZ, shall achieve a KV impact test with a minimum individual value of 60 J,				

	which can be reduced to 50 J for welding steels in group 8 undergoing stress-relieving heat treatment.
Additional Note	[Annexure REQ 768] The type VWT specimen (V: Charpy V-notch - W: a notch in weld metal - T: notch through the thickness) shall be utilized for weld metal. [Annexure REQ 769] The type VHT specimen (V: Charpy V-notch - H: notch in heat affected zone - T: notch through the thickness) shall be employed for the HAZ. [Annexure REQ 770] Specimens shall be extracted no more than 2 mm below the top surface of the parent metal and transverse to the weld. [Annexure REQ 771] The notch's mid-point in the HAZ shall be positioned 1 mm to 2 mm from the fusion line, whereas in the weld metal, it shall be at the centerline of the weld. [Annexure REQ 772] For butt joints with material thickness greater than 50 mm, two extra sets of specimens shall be taken from the root area, one set from the weld and one from the HAZ. [Annexure REQ 773] When multiple welding processes or types of coverings and fluxes are qualified within a single test piece, additional impact test specimens shall be sampled from the weld metal and HAZ for each process and type of covering and fluxes used.

38.4.5.7 Chemical analysis

[Annexure REQ 774] A sample for chemical analysis shall be taken in a zone outside the dilution area. In addition, the chemical analysis shall be performed for each process used in combination, except for TIG root passes.

If the thickness of the test piece makes it impossible to perform analysis in a zone outside the dilution area, the examination shall be performed on the surface of a separate deposit of sufficient thickness.

[Annexure REQ 775] Where a longitudinal tensile test is required, the sample shall be taken from the end extension of a tensile specimen chosen so as not to lie within the dilution zone.

[Annexure REQ 776] The quantities of all elements analyzed during acceptance tests of filler materials shall be determined.

[Annexure REQ 777] The required results are those defined in the acceptance specification (RS 2120).

38.4.5.8 Metallographic examination

[Annexure REQ 778] These are performed following Annex RSI 400 on a complete transverse section of the weld.

[Annexure REQ 779] In the case of pipe welds, the section examined shall preferably lie in the overlap zone.

[Annexure REQ 780] The micrographic and macrographic criteria specified in RSI 400 shall also be satisfied.

[Annexure REQ 781] The test specimen shall be prepared and etched per ISO 17639 on one side to reveal the fusion line, the HAZ, and the build-up of the runs.

[Annexure REQ 782] The test specimen shall include unaffected parent metal and shall be recorded by at least one photograph of a macro cross-section per procedure test.

[Annexure REQ 783] The acceptance levels shall be following 38.4.6.3.

38.4.5.9 Hardness measurement

[Annexure REQ 784] Vickers hardness testing with a load of HV 10 shall be performed following ISO 9015-1.

[Annexure REQ 785] Hardness measurements shall be conducted in the weld, the heat-affected zones, and the parent metal.

[Annexure REQ 786] For double-sided welds, one additional row of indentations shall be executed through the root area.

[Annexure REQ 787] Examples of indentation patterns can be referenced in ISO 9015-1.

[Annexure REQ 788] When multiple welding processes are applied, each process shall be represented by at least one row of indentation.

[Annexure REQ 789] In each row of indentation, a minimum of three individual indentations shall be made in the weld, both heat-affected zones, and both parent metals.

[Annexure REQ 790] The initial indentation in the heat-affected zones shall be positioned as close to the fusion line as feasible.

[Annexure REQ 791] All results from the hardness test shall be documented and provided for informational purposes.

38.4.5.10 Determination of delta ferrite contents

[Annexure REQ 792] The delta ferrite content of the deposited metal, as determined using Delong or Mc Kay's modified Schaeffler diagram, shall lie between 5% and 15% (preferably not exceeding 12% max.)

In case of doubt, an additional test may be performed by a magnetic saturation method or direct magnetic measurement (the apparatus having been calibrated beforehand).

38.4.6 Non-Destructive examination

38.4.6.1 Personnel qualifications

[Annexure REQ 793] The NDE operators, inspectors, and engineers shall be trained and qualified to ISO 9712 or ASNT Level 2 standards before conducting or assessing the examinations.

[Annexure REQ 794] Training and certification of these personnel shall be the Manufacturer's responsibility.

[Annexure REQ 795] The validity of the certification shall align with the stipulations of the relevant standards.

38.4.6.2 Examinations

[Annexure REQ 796] After post-weld heat treatment (if applicable) and before the cutting of the test specimen for further destructive testing, all test pieces shall be examined for following non-destructive examinations.

Test Piece	Type of Test	Extent of Testing	Applicable standard
1. Butt Joint with full penetration (Pipe and Plate) 2. T-Joint with full penetration 3. Branch connection with full penetration	Visual Examination	100%	ISO 17637
	Surface Crack Detection on the accessible weld surfaces (Penetrant testing*)	100%	ISO 3452
	Radiographic examination OR Ultrasonic examination	100%	ISO 17636 ISO 17640 and ISO 22825

4. T-joint Fillet weld 5. Branch connection Fillet weld	Visual Examination	100%	ISO 17637
	Surface Crack Detection on the accessible weld surfaces (Penetrant testing*)	100%	ISO 3452
*Inspection using a Photothermal camera is permitted in the case where the Manufacturer has qualified the method/acceptance criteria before the weld qualification			

Table 59: Type and extent of NDE

[Annexure REQ 797] The examination method shall be agreed upon before inspection for a pipe or plate with a wall thickness of 2mm or less.

38.4.6.3 Acceptance criteria (taken from IVH attachment 1)

[Annexure REQ 798] Defects detected by the relevant non-destructive examination method shall be assessed w.r.t criteria in the following table for evaluating results for weld qualification NDEs.

Defect Type		Permitted Maximum
Planar Defects	Crack or lamellar tears	Not Permitted
	Lack of Root Fusion	
	Lack of Side Fusion	
	Lack of inter-run fusion	
	Lack of root Penetration	
Solid Inclusion	Slag inclusion – Individual	20% of t or 2 mm, whichever is smaller
	Slag inclusion – Group	Aggregate length not to exceed t in a length of 12t, except when the distance between successive indications exceeds 6L, where L is the length of the longest indication in the group.
	Inclusion – Tungsten or Copper	Not Permitted

Cavities	Isolated pores – round	Diameter < 20% t or 2 mm, whichever is smaller
	Gas pore uniformly distributed porosity	1% for single layer (2% for multi-layer) by area where the area of the radiograph to be considered is the length of the weld affected by the porosity times the maximum thickness of the weld
	Elongated pores - *Wormholes*	*Not Permitted*
	Linear Porosity	*Not Permitted*
Profile Defects	*Undercut*	*Some intermittent undercut is Permitted. Depth not to exceed 0.5mm for t > 3 mm or 10% for t < 3mm. Undercut to blend smoothly with the parent material.*
	Incompletely filled groove, sagging. Root concavity, shrinkage groove	0.05 t or 0.5 mm, whichever is smaller. Weld thickness shall not be less than the parent plate thickness
	Excess penetration – pipe	Not greater than 5% of the pipe's Internal diameter up to 2 mm max.
	Excess penetration – plate	t = 0.5 to 3 mm: , h ≤1 mm+10% b t > 3mm: h ≤1 mm+20% b max 3mm. h =height of excess penetration on the backside of the plate and b the width
	Excess weld material	Not greater than 10% weld width
	Misalignment	*Not greater than 10% of the parent material thickness*
	Fillet leg length (asymmetry)	Unequal leg length should not exceed 20% of the fillet throat thickness
	Burn through	Not Permitted
Other	Root Oxidation	Not permitted where a backing gas purge is specified in the WPS

38.4.7 Retesting procedure

[Annexure REQ 799] If an unsatisfactory result arises from poor test execution, the relevant results shall be disregarded, and the test repeated.

38.5 Welder /Welding operator performance qualification (WPQ)

[Annexure REQ 800] Welder Qualification is intended to show the competence of the welder /operator in depositing sound welded material when following a qualified WPS. Welder Qualification shall follow RS 4000 of RCC MR.

[Annexure REQ 801] ISO 1418 shall be used for welding operators. IO may approve other standards on submission of documentation detailing the equivalence between the proposed standards and those quoted herein.

[Annexure REQ 802] The Manufacturer shall establish and maintain a list of qualified welders and operators. This list shall include their identification and range of welds for which they are qualified.

[Annexure REQ 803] The welding and testing of the welder qualification test coupon shall be witnessed by an IO / ITER-recognized independent agency.

39 PRODUCTION WELDS

This section covers the requirements for the welding operations to be carried out while manufacturing SIC components. By “welding operations” are meant.

- The preparation of the surfaces to be welded,
- The use of filler materials,
- The use of the welding processes for the production welds & equipment repairs,
- The finishing of production welds and repairs,
- The associated heat treatments (preheating, post-heating, stress-relieving heat treatments),
- The conditions governing the preparation of production weld test coupons.

39.1 Document requirement

[Annexure REQ 804] All welding operations, including joints and repairs, shall be executed in alignment with a set of identified documents that meet the technical specification requirements, including:

- The Welding Procedure Specification (WPS) used,
- Welding procedure & welder qualification records,

- Instructions were provided by the Manufacturer for workshop staff, especially welders and welding operators, for effective welding operations completion.

[Annexure REQ 805] The production weld data sheet shall be released after welding operations.

39.2 Preliminary verification, qualifications, acceptance for welding

[Annexure REQ 806] Before implementing a welding procedure, the necessary qualifications and acceptances shall include the following:

- Preliminary verification of weldability of materials,
- Acceptance/Qualification of filler material lots as per Chapter 36,
- Welding procedure qualification, as described in Chapter 38.4,
- Qualification of welders and operators specific to the welding procedure, as detailed in Chapter 38.5,
- Workshop qualification is outlined in Chapter 37.

[Annexure REQ 807] Production welds shall be conducted using qualified procedures and executed by certified welders.

[Annexure REQ 808] For reference purposes, the WPS shall be accessible to welders, welding operators, the responsible welding engineer, and the authorized inspector.

[Annexure REQ 809] The Manufacturer shall ensure the welding equipment and plant undergo regular maintenance and calibration as per relevant operation and maintenance schedules.

39.3 Storage and use of welding materials

[Annexure REQ 810] Storage and use of welding material shall meet the requirements of RS 7200 of RCC MR.

39.4 Preparation and Examination of Edge and surface for welding

[Annexure REQ 811] Weld edge preparation shall meet the requirements of RS 7310, RS 7320, RS 7340, and RS 7350 of RCC MR.

[Annexure REQ 812] Weld edge & welding surface shall be examined per RS 7361. RS7362. RS7363, RS 7364, RS 7370, RS7381, and RS 7382 of RCC MR.

39.5 Execution of production welds

[Annexure REQ 813] Take welding during the execution of production welds shall meet the requirements of RS 7410 of RCC MR.

[Annexure REQ 814] Welding of all permanent & temporary attachments for the execution of production weld shall meet the requirements of RS 7420 of RCC MR.

[Annexure REQ 815] Production weld shall be executed per RS 7430 of RCC MR.

[Annexure REQ 816] The surface finishing of the production weld shall meet the requirements of RS 7450 of RCC MR.

[Annexure REQ 817] After completion, the production weld shall be subjected to visual & dimensional examination per RS 7461 of RCC MR.

[Annexure REQ 818] [REQ-W-SIC 167] After concluding a welding operation, whether individual or grouped operations using the same welding procedure, a production weld data sheet shall be generated that specifies the following:

- The equipment reference number to which the joint or the repair belongs,
- The reference number of the joint, the group of joints or repair,
- The reference to the welding procedure used,
- The reference number of the lot or lots of filler materials used,
- For each operation, the name (identifying symbol) or the welding operator(s) responsible,
- For automatic welding, the reference of the machine used.

39.6 Weld-related heat treatments

39.6.1 **Preheat**

Austenitic stainless steel is not preheated. Therefore, this session is not applicable.

39.6.2 **Interpass temperature**

[Annexure REQ 819] Regular checks shall ensure that the interpass temperature remains within the range required by the welding procedure.

[Annexure REQ 820] The specified temperature shall be monitored utilizing:

- Thermocouples (RF 8140a),
- Pyrometers or contact thermometers,

[Annexure REQ 821] Using heat-sensitive pens is forbidden for welding austenitic stainless steels to prevent the introduction of low-melting point products.

[Annexure REQ 822] The measurement points shall be chosen to ensure that the specified temperature is reached throughout the thickness and the entire area to be welded.

39.6.3 Post heating

Austenitic stainless steel is not preheated. Therefore, this session is not applicable.

39.6.4 Stress-relieving heat treatment

Stress-relieving heat treatment is not required for austenitic stainless-steel welds.

39.7 Repair by welding

[Annexure REQ 823] No weld repair shall be performed without qualification of the welding procedure.

[Annexure REQ 824] The welding procedure used for welding repair shall be qualified following this technical specification.

[Annexure REQ 825] Repair of production weld shall satisfy the requirement of RS 7600 of RCC MR.

39.8 Non-destructive examination (NDE) of production welds

[Annexure REQ 826] Criteria for Class 2 welds as specified in RS 7720 of RCC MR shall be applied for the NDE examination of production welds.

[Annexure REQ 827] Besides the criteria defined in RS 7720, production welds classified as VQC 1A shall adhere to the subsequent criteria.

[Annexure REQ 828] All VQC 1A welds shall undergo a 100% volumetric examination.

[Annexure REQ 829] Volumetric examination results shall be evaluated following section 6.3.2 of the ITER Vacuum Handbook attachment 1.

[Annexure REQ 830] VQC 1A welds, where either radiography or ultrasonic examination is not feasible, shall be subjected to production proof sampling (PPS) that represents a specific type of weld and utilizes identical materials, thickness, and set-up as the production weld.

[Annexure REQ 831] PPS shall be welded within the same shift as the production welds by the same welder using identical equipment to mirror the production welding process.

[Annexure REQ 832] The sectioned PPS shall be macro-examined at four distinct locations, including the start/stop area.

[Annexure REQ 833] Documentation shall feature a photograph of the macros, specifying the PPS weld date and the welder's identity and pinpointing the corresponding production welds covered.

[Annexure REQ 834] If the PPS is deemed non-conformant based on the macro examination, all welds represented by this PPS shall be rejected.

39.9 Repair of production welds

[Annexure REQ 835] All detected leaks in welds forming a vacuum boundary shall be reported to the IO regarding size and magnitude.

[Annexure REQ 836] Prior agreement shall be secured before performing any weld repairs.

[Annexure REQ 837] All welding repair procedures shall be qualified per this Annexure.

[Annexure REQ 838] In case a non-destructive examination exposes an unacceptable defect in a welded joint, a weld repair shall be executed following the stipulations of RS 7600 of RCC-MR.

[Annexure REQ 839] Repair welds on vacuum boundaries shall undergo comprehensive vacuum leak testing per the endorsed procedure detailed in ANNEXURE 5.

39.10 Helium leak testing of production welds

[Annexure REQ 840] All vacuum sealing welds shall undergo helium leak testing as per the criteria outlined in ANNEXURE 5.

[Annexure REQ 841] For components of VQC 1A that require multi-pass welding, testing for leaks in the root weld pass shall be performed after completing just that pass.

39.11 Destructive testing of production welds: Production weld test coupons

[Annexure REQ 842] During manufacturing, the Manufacturer shall produce production weld test coupons that indicate the consistency and quality of the production welds in line with the requirements established by the welding procedure qualification tests.

[Annexure REQ 843] Production weld test coupons shall represent the production welds they reference.

[Annexure REQ 844] Production weld test coupons shall be welded and examined following RS 7800 of RCC MR.

End of:

ANNEXURE 3
SIC Welding
and
Welding Qualification

ANNEXURE 4.

PRESSURE TESTING

40 ANNEXURE SCOPE

This annexure provides the technical requirements related to pressure testing of cooling passages (including connections) of DLMs, NS, NSA, NSE-LDLM, and CW main pipes, of the Duct Liner.

The preliminary manufacturing report describes the pressure test and the vacuum He leak test for each of the components.

41 REFERENCE CODE/ STANDARDS

ASME BPVC Sec.VIII Div.2	Pressure Vessels
ASME B 31.3	Process Piping

42 DOCUMENTATION

[Annexure REQ 845] The Manufacturer shall prepare the pressure testing procedure (which describes the applied test pressure, duration, test procedures, acceptance criteria, and the records to be generated after completion of the test) and submit it to IO for approval.

[Annexure REQ 846] The Manufacturer shall submit the pressure test records (along with the calibration records of measuring instruments) after the completion of each test.

43 VERIFICATION PRIOR TO PRESSURE TESTING

[Annexure REQ 847] Prior to initiating the pressure test of the subjected component, the manufacturer shall ensure the following:

- All fabrication activities have been completed, except for operations that could not be performed prior to the test.
- All applicable examinations, inspections, and tests, including NDE and Post Weld Heat Treatment (If applicable), are satisfactorily completed and accepted.

44 SAFETY PRECAUTIONS

[Annexure REQ 848] Pressure Tests shall be carried out in an isolated place from the work area/pit with appropriate safety precautions and equipment.

45 TECHNICAL REQUIREMENTS

45.1 Preparation for testing

[Annexure REQ 849] Before applying Test pressure, the test equipment shall be inspected to see that it is tight and that all low-pressure filling lines and other appurtenances that should not be subjected to the test pressure have been disconnected or isolated by valves or other suitable means.

[Annexure REQ 850] All the cooling openings must be sealed before conducting the pressure test.

[Annexure REQ 851] A design addressing the closure of cooling openings for the pressure test shall be submitted for the MRR.

45.2 Methodology

45.2.1 Components to be tested

[Annexure REQ 852] All cooling passages of the DLMs (including their connection with plugs & connectors), NS, NSA, NSELD, and CW main pipes of the Duct liner assembly shall be tested as described in the manufacturing report [RD32].

DLMs, NS, NSA, and NSELD are considered as pressure vessels/heat exchangers, taking into account their primary function of cooling and not transporting the fluid.

The CW main piping is considered “Piping” as it primarily supplies water to DLM Panels.

[Annexure REQ 853] In view of the above consideration, the applicable code for pressure testing shall be as follows.

- DLMs, NS, NSA, and NSELD: ASME Sec.VIII Div. 2 / Equivalent EN/ISO code.
- Main Piping: ANSI B 31.3 / Equivalent EN/ISO code to be followed for its pressure testing. And manifold piping as a “Pipe for transporting water”.

45.2.2 Test procedure

[Annexure REQ 854] The test procedure shall comply with the applicable codes as mentioned in section 45.2.1.

[Annexure REQ 855] If the manufacturer intends to use the equivalent code mentioned in section 45.2.1, they shall obtain an IO agreement in advance.

[Annexure REQ 856] The technical specification requirement shall take precedence in cases of contradiction with requirements from other codes and standards.

[Annexure REQ 857] The manufacturer shall submit the test procedure for IO approval before the test is performed.

45.2.3 Test fluids

[Annexure REQ 858] Pressure Test shall be done with Deionized Water.

45.2.4 Test pressure & duration

The design pressure is set at P_{design} = 5MPa to accommodate dynamic pressure during baking, which may arise from the potential rapid closure of valves and pressure measurement errors.

[Annexure REQ 859] According to the ASME VIII div. 2, the test pressure shall be set at PT = 7.15MPa for the pressure vessels.

[Annexure REQ 860] Test pressure shall be held for a duration of not less than one hour.

[Annexure REQ 861] All water-cooling circuits shall be subject to a series of cycles of pressure tests at the completion of assembly.

[Annexure REQ 862] The system shall be subjected to 10 pressure cycles, alternating between the test pressure (P_{TEST}), held for one minute, and atmospheric pressure (P_{ATM}). This procedure is in accordance with the ANSI/ASME B31.3 Code for Process Piping.

[Annexure REQ 863] The test temperature shall be room temperature.

45.2.5 Test gauges

45.2.5.1 Location

[Annexure REQ 864] The pressure gauges used in testing shall be connected directly to the test component.

[Annexure REQ 865] If the indicating gauge is not readily visible to the operator controlling the pressure from a safe location, an additional indicating gauge shall be provided where it is visible to both the operator and inspector throughout the duration of the test.

[Annexure REQ 866] A recording gauge shall be used in addition to the indicating gauge.

45.2.5.2 Range

[Annexure REQ 867] Dial-indicating pressure gauges used for testing shall be graduated over a range of about two times the maximum intended test pressure.

[Annexure REQ 868] The range of these gauges shall not be less than one and one-half times nor more than four times the intended test pressure.

Digital reading pressure gauges with a wider range may be used, provided the readings have the same or greater accuracy than those obtained with dial pressure gauges.

45.2.5.3 Calibration

[Annexure REQ 869] All gauges shall be calibrated against a standard deadweight tester or a calibrated master.

[Annexure REQ 870] The supplier shall be able to show the calibration certificate if requested.

45.2.6 Pressurization and Preliminary check

[Annexure REQ 871] Test pressure shall gradually be increased until the lower gauge reaches half of the test pressure.

[Annexure REQ 872] At this stage, a preliminary check shall be made to ensure the integrity of installation, sealing, openings, etc.

[Annexure REQ 873] After a satisfactory check, the pressure shall gradually increase until the test pressure is reached.

[Annexure REQ 874] Once the test pressure is reached, it shall be held for the prescribed duration.

45.3 Inspection & testing

[Annexure REQ 875] The visual examination shall check leakage and permanent deformation for all joints and connections.

[Annexure REQ 876] All present leakages shall be satisfactorily repaired and retested, except for those that may occur at temporary test closures.

[Annexure REQ 877] The inspector shall reserve the right to reject the pressure test program if there are any visible signs of permanent distortion and deformations.

45.4 Acceptance criteria

[Annexure REQ 878] After pressure testing, the component shall not have:

- Permanent deformation of the component,
- Leakage (may be conducted using the bubble test method to identify any leaks effectively).

45.5 Pressure test record

[Annexure REQ 879] The Manufacture shall record the following data in the pressure test report.

- Identification of parts being tested,
- Calibration status of measuring instrument,
- Reference of the approved test procedure,
- Test condition, test pressure & test duration,
- Test fluid,
- Test results,
- Date of pressure test,
- Details of witnessing authority,

45.6 Blowout

[Annexure REQ 880] A blowout of the NSA and the NSELD shall be performed following the parameters defined in the analysis report [RD34].

End of:

ANNEXURE 4
Pressure
Testing

ANNEXURE 5.

LEAK TESTING

46 ANNEXURE SCOPE

Technical requirements provided in this specification apply to check the leak tightness of duct liner components and assembly at various stages of contract execution.

47 REFERENCE

ITER Vacuum Handbook	ITER_D_2EZ9UM v2.5
Appendix 12 ITER Vacuum Handbook	ITER_D_46FN9B v2.1
Appendix 13 of the ITER Vacuum Handbook	ITER_D_2ELUQH v2.1
Appendix 15 ITER Vacuum Handbook	ITER_D_2DU65F v1.3
Non-Destructive Testing – General requirements	ASME Sec. V Article 1
Leak testing	ASME Sec. V Article 10
Non-destructive testing - Qualification and certification of NDT personnel - General principles	EN 473
Non Destructive Testing –Leak Testing Tracer gas	EN 13185

48 DOCUMENTATION

[Annexure REQ 881] The Manufacturer shall prepare the leak testing procedure as specified in the ITER Vacuum Handbook.

[Annexure REQ 882] A test plan shall describe the configuration arrangement and the type of equipment, as well as the test procedures.

[Annexure REQ 883] Chart recording of the mass spectrometer signal shall be made through the identified test amplifier range.

[Annexure REQ 884] The recording shall cover the whole test duration and identify the standard leak signal, Helium introduction, and termination.

[Annexure REQ 885] The standard leak signal, Helium introduction, and termination shall be identified on the recording.

[Annexure REQ 886] For each test, a document shall be prepared to show the mechanical setup, the number of assemblies, base pressure, calibration & measured leak rate.

[Annexure REQ 887] The leaks shall be localized and marked if the specification is unmet.

[Annexure REQ 888] Any event shall be reported using the ITER NCR database.

[Annexure REQ 889] After repair, the test subject shall be re-tested, and the repairs documented.

[Annexure REQ 890] The leak test procedure shall be submitted to IO for approval before initiating DL components/assembly leak testing.

49 TECHNICAL REQUIREMENTS

[Annexure REQ 891] Before and after leak testing, components shall be cleaned, dried, or baked following the technical specifications.

[Annexure REQ 892] Helium leak tests shall be carried out to check the leak tightness of all welded & bolted joints of the Duct Liner.

[Annexure REQ 893] The Manufacture shall perform the He leak test at various stages of contract execution, i.e. During manufacturing (sub-component / sub-assemblies) as described in the manufacturing report [RD32].

[Annexure REQ 894] After the final assembly, the leak test plan shall be integrated into the MIP.

[Annexure REQ 895] Where multi-pass welding is required to produce vacuum boundary components, leak testing of the weld shall be performed after the root pass welding is completed and again after the last multi-pass weld is completed.

[Annexure REQ 896] All required examinations, like Non-Destructive Examination and Pressure Testing, shall be done before final vacuum leak testing.

[Annexure REQ 897] All repaired vacuum boundary welds shall be subject to complete vacuum leak testing following this specification.

[Annexure REQ 898] Leak testing shall be performed at several stages of the manufacturing process, i.e., for all the DLMs, the NS, and during the different assembly stages of the DL as described in the manufacturing report [RD32].

[Annexure REQ 899] No vacuum component shall be installed, nor assembled if the leak testing shows a leak above the specified maximum acceptable leak rate.

49.1 Test condition

[Annexure REQ 900] All components shall be vacuum-baked prior to testing, according to IVH [3].

[Annexure REQ 901] Leak tests shall be performed at ambient temperature.

[Annexure REQ 902] Components, including joints of dissimilar materials, shall be subjected to at least three thermal cycles from ambient to maximum operating temperature before leak testing.

[Annexure REQ 903] The time taken for any component to reach the specified bake temperature from ambient shall be less than 100 hours.

[Annexure REQ 904] Before Leak testing, all components and systems subjected to leak testing shall be cleaned according to Appendix 13 of the IVH and drained/dried after the hydraulic pressure test in compliance with section 27 of the IVH.

[Annexure REQ 905] A Vacuum chamber shall be used and pre-tested in advance to measure the He leak rate lower than 10^{-10} Pa m^3/s, with pressure kept lower than 10^{-5} Pa.

50 CERTIFICATE OF PERSONNEL

[Annexure REQ 906] The Manufacturer shall ensure that the personnel performing & evaluating the non-destructive examinations (NDEs) is qualified & certified following EN 473, ISO 9712, or ASNT Level 2.

51 CHOICE OF UNITS

[Annexure REQ 907] The measured leak shall be reported in SI units. i.e. Pascal cubic meter per second ($Pa.m^3/s$).

52 SENSITIVITY OF HE DETECTOR

[Annexure REQ 908] The helium detector's minimum sensitivity shall comply with the specifications outlined in Section 25.7 of the IVH.

53 LEAK TEST METHODS & PROCEDURES

[Annexure REQ 909] Leak testing methods used by the supplier shall comply with section No.12.3 of Appendix 12 of the IVH and section 25 of the IVH.

[Annexure REQ 910] The leak testing procedure shall meet the requirements of section No.12.4 of Appendix 12 of the ITER Vacuum Handbook.

Other methods & procedures may be used, but only with the prior approval of the IO vacuum RO.

54 ACCEPTANCE CRITERIA

Acceptance of leak testing of components is subject to the successful completion of all stages.

[Annexure REQ 911] The leak detector used in the test configuration shall be calibrated within the limits of ±5% of the nominal value of the standard leak rate value, taking into account the ambient temperature and the age of the standard leak.

[Annexure REQ 912] The background level of the leak test shall be below the acceptance leak rate without electronic correction prior to the test.

[Annexure REQ 913] The reading from the leak detector shall not increase in value above the measured background by more than the specified leak rate, as defined for the item under test, throughout the entire duration of the leak test procedure.

[Annexure REQ 914] The qualified personnel following chapter 50 shall carry out the test.

[Annexure REQ 915] The maximum acceptable leak rate for DL components/assembly shall be $1 \cdot 10^{-10}$ Pa·m^3/s air equivalent.

55 TEST REPORT

[Annexure REQ 916] Complete records of the tests carried out on any component shall be completed to maintain traceability of the leak test history of a particular item.

[Annexure REQ 917] The records shall consist of the following as a minimum.

- Identification of the Manufacturer, the purchase order, and the equipment.
- Identification of the part, weld, or area subjected to examination.
- Time of Examination.
- Reference of approved procedures
- Surface condition and cleanliness.
- Examination condition and, in particular, calibration details.
- Data records of the output of the leak detector for all the global tests specified, including the standard leak calibration and response time determination.
- A record of the helium concentration during the leak test where that is required.
- The make, model, and manufacturing date of the helium mass spectrometer leak detector used in the tests.
- The nominal value of all standard leaks used, their date of calibration, aging and temperature characteristics, and the ambient temperature(s) experienced during the tests.
- The results of all tests showing whether it is a pass or fail, and, if a failure, the measured leak rate and the location of the leak, together with the steps taken for any repair or elimination.
- A complete record of any residual gas scans taken with appropriate time markers to identify the scans to the position in the component leak test cycle.
- Interpretation results.
- Name and qualification of the inspector.
- Identification of the subcontractor conducting the examination (if applicable).
- Date of examination and inspector’s signature.

[Annexure REQ 918] The data records of the output of the leak detector shall include the date and time of all tests and anything else of relevance, such as the start and finish time of helium gas applied to the item under test.

[Annexure REQ 919] The magnitude and location (if applicable) of all leaks identified during testing shall be recorded. It includes leaks of magnitude lower than the acceptance criteria for which no remedial action may have been taken.

End of:

ANNEXURE 5
Leak
Testing

ANNEXURE 6.

CLEANING AND CLEANLINESS

56 SCOPE

This annexure provides the cleanliness requirements to be followed during the manufacturing of Duct Liners and post-cleaning handling requirements to maintain the required cleanliness.

These requirements are taken from the ITER Vacuum Handbook, Appendix_13, and are intended to assist the supplier in preparing a clean work plan & cleaning procedures to be submitted to IO for acceptance.

57 APPLICABILITY OF THIS SPECIFICATION

[Annexure REQ 920] The Requirement specified in this technical specification applies to all duct liner components, sub-assemblies, and final assembly during all phases of manufacturing, testing & delivery of components.

[Annexure REQ 921] The DL Feedthrough Box that has to follow RCC-MR, cleanliness class B requirements from chapter RF 6000, and Level II work area requirements from RF 6240 shall apply in addition to the requirement of this specification.

[Annexure REQ 922] Where the requirements of RCC MR and what is described in this specification are contradictory, the specification requirement shall prevail.

58 REFERENCE

ITER_D_2EL9Y6	Appendix 2 Environmental Cleanliness of IVH
ITER_D_2ELN8N	Appendix 4 Accepted Fluids of IVH
ITER_D_2ELUQH	Appendix 13 Cleaning and Cleanliness of the IVH
ISO 14644	Clean room and associated controlled environments Part 1: Classification of air cleanliness
RCC-MR	RF 6000, RF 6240

59 GENERAL REQUIREMENTS

[Annexure REQ 923] All components classified as VQC1 will need cleaning to Ultra High Vacuum standards. It is the responsibility of the manufacturer to ensure that they understand fully the implications of cleaning to the required standard.

[Annexure REQ 924] For all discrete components, sub-assemblies, or main assemblies, the manufacturer shall propose a specific cleaning procedure to IO for approval. The clean procedure has to be consistent with the vacuum classification of the particular component/assembly.

[Annexure REQ 925] During the execution of all the tests, all necessary precautions to preserve the cleanness of the involved parts shall be taken.

[Annexure REQ 926] After tests, the components or sub-assemblies shall be visually clean and free from chemical deposition and corrosion products.

[Annexure REQ 927] The Supplier shall define and submit for F4E approval the acceptance criteria for this requirement during contract implementation.

[Annexure REQ 928] The manufacturer shall submit a detailed Clean Work Plan for prior approval to ITER before any cleaning operations are undertaken.

[Annexure REQ 929] The plan shall specify how cleanliness will be maintained throughout the manufacturing process.

[Annexure REQ 930] It shall state when specific cleaning procedures will be applied and controls put in place to maintain cleanliness, including handling.

[Annexure REQ 931] Parts and sub-components shall be degreased using solvents or alkaline detergents, rinsed with demineralized water, and dried in hot gas or an oven to accepted procedures.

[Annexure REQ 932] The use of halogenated solvents is forbidden at any stage. Lists of accepted cleaning fluids can be found in the ITER Vacuum Handbook: Appendix_4.

[Annexure REQ 933] Any proposed deviation from the procedures and processes described in this annexure shall be accepted in writing by IO. The use of any chemical product (solvent, etchant, detergent, etc.) other than those approved in ITER IVH appendix 4, shall require a fluid acceptance request to IO.

60 HEALTH AND SAFETY

Some chemicals or equipment used in cleaning processes may be classified as hazardous.

[Annexure REQ 934] It is the responsibility of the supplier to satisfy themselves that any cleaning procedure complies fully with local legislative and regulatory standards regarding the health and safety of any or all processes used and that all operatives have received the necessary training.

[Annexure REQ 935] The manufacturer shall ensure that all staff fully understand all health and safety information issued by the manufacturer or supplier of any chemical or equipment used.

61 PROPRIETARY ITEMS AND TRADEMARKS

Where propriety items from particular manufacturers or suppliers are mentioned in this specification / IVH, any or all trademarks are duly acknowledged. Manufacturers can suggest

alternative items from other manufacturers if they are chemically identical. Any such substitutions need to be accepted in writing by IO.

62 INITIAL INSPECTION AND PREPARATION

Before cleaning any item, the following inspections are mandatory:

[Annexure REQ 936] All vacuum flanges or covers shall be removed.

[Annexure REQ 937] Each item shall be distinctly marked with a durable identification tag on an external, non-vacuum surface, typically using a drawing number and component identifier.

[Annexure REQ 938] For small items or those exposed to vacuum, a metal label of the same material with a scribed identifier shall be attached using clean bare wire.

[Annexure REQ 939] If marking is not feasible, items shall be stored and transported in a suitably marked container to maintain identification throughout the cleaning process.

[Annexure REQ 940] After cleaning, items shall be packaged to prevent re-contamination from the container.

[Annexure REQ 941] Each item shall be visually inspected to identify potential traps or issues affecting vacuum performance, considering the intended cleaning process and environment.

[Annexure REQ 942] All vacuum sealing faces shall be examined for damage such as scratches, pitting, or other defects that could impair sealing integrity.

[Annexure REQ 943] The edge shall be inspected meticulously for any damage for knife-edge seal types.

[Annexure REQ 944] Adhesive tapes on any item's surface shall be removed, as well as any residues using solvents such as isopropyl alcohol or ethanol.

[Annexure REQ 945] Marks from pens, paint, or similar substances on any part of the item shall be eradicated by scraping if needed, followed by solvent cleaning and a rinse with demineralized water.

[Annexure REQ 946] Threaded holes and similar features shall be inspected for lubricants, cutting fluids, or swarf.

[Annexure REQ 947] Identified contaminants shall be removed with brushing, clean compressed air or nitrogen, and solvent washing, followed by a final rinse with demineralized water to prevent contamination of vacuum surfaces.

63 MECHANICAL PROCESS ON VACUUM SURFACE

[Annexure REQ 948] Abrasive techniques shall be kept to an absolute minimum for cleaning or improving the appearance of vacuum components and are preferably avoided.

[Annexure REQ 949] Stainless steel wire brushes, which have been cleaned in accordance with the standards specified in this document, shall only be used when deemed necessary.

[Annexure REQ 950] If grinding on VQC 1 systems is essential, the grinding wheel shall be free of organic components and manufactured in an oil-free, clean environment, with its material and manufacturing process accepted by ITER before use.

[Annexure REQ 951] The use of grinding wheels, wire brushes, files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes, and similar tools shall be prohibited under normal circumstances without prior acceptance by ITER.

[Annexure REQ 952] Accepted surface finish techniques shall include slurry blasting with alumina or glass beads in a water jet; gentle hand use of a dry fine stone or a fine stone lubricated with isopropyl alcohol or ethanol; hand polishing with fine mesh alumina in an isopropyl alcohol or ethanol carrier on a lint-free cloth; and hand polishing with ScotchBrite (Alumina loaded, Grade A).

[Annexure REQ 953] If any surface finish technique is employed, care shall be taken to remove any powder or residues by copious washing in hot water.

[Annexure REQ 954] Any other such operations shall be carried out only with prior acceptance.

64 USE OF ACIDS

[Annexure REQ 955] Acid treatment of any sort shall be avoided wherever possible and may only be carried out with specific prior acceptance by ITER, as most acid treatments are for cosmetic purposes and may result in degradation of vacuum performance.

[Annexure REQ 956] Where the use of acids is accepted, exposure of the component shall be kept to a minimum and must be followed by copious washing in hot demineralized water.

65 ELECTRO-POLISHING FOR VQC 1 APPLICATIONS

- Electro-polishing should only be carried out where it is necessary to produce a smooth surface for electrical discharge or field emission minimization, emissivity, or similar purposes. It is usually unnecessary from a pure vacuum point of view and, indeed, can be detrimental to vacuum performance.
- Electro-polishing should be carried out in clean polishing tanks using fresh electrolytes.

- Local electro-polishing can be carried out with tampons. Fresh pads dipped in clean electrolytes should be used, and excessive pressure should be avoided.
- After electro-polishing, the item should be washed with copious quantities of hot demineralized water.
- If required, vacuum Items for use in Class VQC 1 may be baked to 450°C for at least 24 hours to remove the residual hydrogen and other contaminants introduced into the surface layers by electro-polishing.

66 HANDLING AND PACKING

[Annexure REQ 957] Handlers shall use powder-free latex or nitrile gloves, possibly over cotton or linen, after components have completed the initial rough cleaning to prevent bare skin from touching vacuum surfaces.

[Annexure REQ 958] Colored gloves shall not be used when handling components post-cleaning.

[Annexure REQ 959] Components shall complete the cleaning cycle without interruption once started.

[Annexure REQ 960] In case of an inevitable delay between cleaning stages, the component shall be thoroughly dried before storage.

[Annexure REQ 961] All seal faces and ports of the component shall be protected as specified if a delay occurs between cleaning stages.

[Annexure REQ 962] There shall be no break between chemical cleaning and subsequent water washing stages.

[Annexure REQ 963] After cleaning and drying, each component shall be packed carefully to ensure it remains clean and undamaged.

[Annexure REQ 964] Vacuum sealing faces of the component shall be protected with a clean metal plate or a fiber-free board covered with clean aluminum foil and secured by bolts.

[Annexure REQ 965] Knife edges of the component shall be protected with clean, scale-free metal gaskets.

[Annexure REQ 966] All ports of the component shall be covered with strong, clean, new aluminum foil and plastic covers.

[Annexure REQ 967] After cleaning and drying, small items shall be wrapped in clean aluminum foil and sealed in a polyethylene bag, preferably under dry nitrogen.

67 SPRAY WASHING

[Annexure REQ 968] Where an item is cleaned by spray washing, it shall be ensured that all hoses, lances, spray heads, etc, are thoroughly cleaned out with clean hot water before the cleaning process starts.

[Annexure REQ 969] Washing shall start at the top of the item and the spray work down to the bottom, ensuring good run-off.

68 STANDARD CLEANING PROCEDURE FOR STAINLESS STEEL COMPONENTS

68.1 Preclean

[REQ-365] All debris, such as swarf, shall be removed physically by blowing out with a high-pressure airline, observing standard safety precautions.

[REQ-366] Gross contamination, e.g., greases or cutting oils, shall be removed by washing, swabbing, and rinsing with any non-halogenated general-purpose solvent.

[REQ-367] Scrubbing, wire brushing, grinding, filing, or other mechanically abrasive methods shall not be used.

68.2 Wash

[Annexure REQ 970] The item shall be washed down using a high-pressure jet of hot town water (at approximately 80°C) with a simple mild alkaline detergent.

[Annexure REQ 971] Following the previous requirement, the detergent shall be switched off, and the item rinsed thoroughly with hot water until all visible traces of detergent are eliminated.

[Annexure REQ 972] If necessary, any scaling or deposited surface films shall be removed by stripping with alumina or glass beads in a water jet in a slurry blaster.

[Annexure REQ 973] After any stripping process, the item shall be washed down with a high-pressure hot demineralized water jet (at approximately 80°C), without detergent, to ensure that any residual beads are washed away. Special attention needs to be paid to any trapped areas or crevices.

[Annexure REQ 974] The item shall be dried using an air blower with clean, dry air; hot air is preferable if available.

69 CHEMICAL CLEANING FOR STAINLESS STEEL OR SIMILAR ITEMS

[Annexure REQ 975] Where possible, the item shall be entirely immersed in an ultrasonically agitated bath of hot, clean liquid solvent for at least 15 minutes or until it reaches the temperature of the bath, whichever is longer. The temperature should be the maximum specified by the solvent supplier.

[Annexure REQ 976] ITER shall accept suitable solvents using the ITER fluid acceptance request database. Approved solvents include Isopropyl Alcohol, Ethyl Alcohol, Acetone, Axarel 9100TM, Citrinox TM, P3 Almeco TM P36, or T5161.

[Annexure REQ 977] Where technically feasible, after liquid immersion, the item shall be immersed in the solvent's vapor for at least 15 minutes or until it reaches the temperature of the hot vapor, whichever is longer.

[Annexure REQ 978] It shall be ensured that all liquid residues are entirely drained off, with particular attention to trapped areas, blind holes, etc.

[Annexure REQ 979] The item shall then be washed down with a high-pressure hot (approximately 80°C) water jet using clean demineralized water without using detergent.

[Annexure REQ 980] If the item is too large for immersion cleaning, it shall be cleaned by washing it down with a high-pressure jet of P3 Almeco TM P36 or T5161.

[Annexure REQ 981] After cleaning, the item shall be cooled to room temperature in a dry, dust-free area conforming to clean conditions as defined in the ITER Vacuum Handbook/this specification.

[Annexure REQ 982] The item shall be inspected for contamination, faulty cleaning, or damage.

[Annexure REQ 983] The item shall be baked to a temperature of 300°C or the specified alternative temperature for at least 24 hours as per Annexure 2 of the IVH.

70 CHEMICAL CLEANING FOR COPPER AND COPPER ALLOYS

[Annexure REQ 984] Items manufactured from copper or copper alloys shall be cleaned using the procedures for stainless steel, except that Almeco P3-36 is not acceptable. Alternatively, copper surfaces shall be cleaned using light chromic acid or citric acid etches, followed by thorough washing in hot, clean, demineralized water.

71 CLEANING CONDITION

71.1 Airborne particles count in a clean area

[Annexure REQ 985] The airborne particulate count shall not exceed 5 x 10^6 particles of size > 0.5µm per m^3 inside the clean area.

[Annexure REQ 986] Manufacturers without a certified clean room facility but with an appropriate assembly enclosure shall provide detailed information, including the size of the enclosure and equipment handling capabilities.

[Annexure REQ 987] In situations where assembly occurs in an enclosure rather than a certified clean room, a measurement of air quality shall be performed as a prerequisite to assembly.

71.2 Clean area

[Annexure REQ 988] The clean area shall be located in an independent building or in a workshop zone suitably segregated from other areas not fulfilling the cleanliness conditions.

[Annexure REQ 989] The Clean Area is a controlled area that shall satisfy the following conditions:

- Temperature and humidity control.
- Control of cleanliness to avoid contaminations from powders.
- Suitable floors (e.g. concrete slab suitably sealed and painted).
- Sufficient lighting for operations to be carried out.
- Adequate heating of the working area, avoiding equipment that could cause smoke or fires, such as gas stoves, etc.
- Access controls.
- Regular and frequent cleaning of the floor.
- Optimum number of entrances and exits.

71.3 Working inside the clean area

71.3.1 General requirements

The initial part of the work (e.g., storage of semi-finished products, marking of the pieces, and some machining operations) can be carried out in a regular workshop area unless specified in the technical specifications or procedures approved for manufacturing.

[Annexure REQ 990] The materials shall be transferred to the Clean Area following the initial works.

[Annexure REQ 991] In cases where transferring the component to the Clean Area is not possible, the same cleanliness conditions shall be guaranteed both in the area around the component and around the assembly areas.

71.3.2 Environmental condition and monitoring

[Annexure REQ 992] Smoking shall be forbidden.

[Annexure REQ 993] Storage and preparation of foods and drinks shall be forbidden, as well as eating and drinking.

[Annexure REQ 994] Daily Cleaning of area, including floors and surfaces. Sticky mats at the area entry

[Annexure REQ 995] Daily air quality checks.

[Annexure REQ 996] Weekly cleanliness test of the area with results stored in the component document package

71.3.3 Conditions for operator/personnel

[Annexure REQ 997] Access shall involve only trained personnel.

[Annexure REQ 998] Access shall be limited to authorized personnel only.

[Annexure REQ 999] Protective hair nets shall be used.

[Annexure REQ 1000] Powder-free latex or nitrile outer gloves shall be worn.

[Annexure REQ 1001] Clean white coveralls shall be worn.

[Annexure REQ 1002] Overshoes and clean job-specific footwear shall be used.

71.3.4 Other apparatus inside the clean room

[Annexure REQ 1003] The use of sulfur-bearing fluids shall be strictly controlled to minimize the risk of corrosion in stainless steel.

[Annexure REQ 1004] All items (components, tools, jigs, fixtures, etc.) shall be thoroughly degreased, cleaned, and sealed in a suitable envelope (polythene, etc.) before being introduced into the clean conditions assembly area.

[Annexure REQ 1005] An inventory of all items entering or leaving the clean area shall be maintained, including tools, welding machines, protective clothing (welding gloves, overshoes, etc.), and containers for transporting tools or components.

[Annexure REQ 1006] Surfaces of jigs, fixtures, and tools that contact the component/assembly shall generally be made of stainless steel and never be constructed of carbon steel.

[Annexure REQ 1007] Direct contact with carbon steel or zinc-coated slings, chains, and tools containing lead, bronze, copper, or zinc shall not be permitted.

[Annexure REQ 1008] Lead or other low-melting metals (tin, antimony, mercury, zinc, arsenic, cadmium, etc.), their compounds, or materials containing low-melting metals as an essential chemical constituent shall not be used in direct contact with surfaces of the component to be exposed to vacuum at any time. It includes tooling, fixtures, marking materials, dyes, fluxes, paints, coating, and sealing compounds used during fabrication and installation operations.

[Annexure REQ 1009] Tooling or equipment producing oil, grease, flux, or any harmful contaminant shall not be permitted.

[Annexure REQ 1010] Overhead cranes and lifting equipment shall be arranged to avoid oil dripping in the clean conditions assembly area.

[Annexure REQ 1011] Machinery/vacuum pumps shall not exhaust into the clean area.

[Annexure REQ 1012] Cutting operations in the clean area shall be minimized, and the swarf generated by such operations shall be collected.

[Annexure REQ 1013] After cleaning, all surfaces shall be "metal clean" and free from oil, grease, ink, paint, dust, rust spots, abrasive particles, chips, and any other gross discontinuities, showing a uniform metallic color without evaporation patches from cleaning agents. Stainless steel surfaces shall be protected to avoid further contamination.

71.3.5 Inspection for clean area

[Annexure REQ 1014] The supplier shall be asked to demonstrate the fulfillment of clean area requirements of this specification and other references mentioned in this specification at any stage of the contract execution.

[Annexure REQ 1015] Calibrated instruments shall be used to measure various parameters during the inspection of a clean area.

72 CLEANLINESS CHECK

72.1 Wipe test for cleanliness

[Annexure REQ 1016] Gross contamination of a vacuum component shall be assessed utilizing a wipe test.

It may be carried out “dry” or “wet”. Gross contamination may also manifest as an “oily” or “solvent-like” smell. Note that these tests are somewhat subjective and may not be conclusive and, therefore, should only be used as a guide to cleanliness and as a marker for subsequent cleaning operations should the tests result in a cleanliness failure.

72.1.1 Dry test

[Annexure REQ 1017] A clean, lint-free cloth shall wipe the component's surface gently.

[Annexure REQ 1018] If a stain or color change is evident on the cloth after wiping, the component shall be considered unclean.

[Annexure REQ 1019] If the component's surface exhibits a change in color or reflectivity of light after wiping, it shall be considered unclean.

72.1.2 Wet test

[Annexure REQ 1020] A clean, lint-free cloth dipped in a solvent that evaporates at room temperature, such as isopropanol, ethanol, or acetone, shall be used.

[Annexure REQ 1021] Appropriate safety precautions against fire hazards, inhalation of solvent fumes, and protection of eyes and skin shall be taken while using solvents.

[Annexure REQ 1022] The cloth, after being dipped in the solvent, shall be allowed to evaporate safely, ensuring no change in the appearance of the surface of the dry cloth.

[Annexure REQ 1023] The component's surface shall be wiped gently with the cloth while still wet with the solvent.

[Annexure REQ 1024] The solvent shall be allowed to evaporate from the cloth and the component's surface until dry.

[Annexure REQ 1025] If evidence of a deposit (such as a stain or a color change) is found on the cloth, the item shall be considered unclean.

[Annexure REQ 1026] If required, the deposit on the cloth shall be analyzed by suitable means to determine the chemical nature of the contamination.

73 POST-CLEANING HANDLING OF THE DUCT LINER

[Annexure REQ 1027] After final cleaning, the handling of the Duct Liner shall be strictly controlled to preserve cleanliness. General area cleanliness requirements for Vacuum Classifications are summarized in the table below.

[Annexure REQ 1028] The continuing suitability of any given area used for handling Duct liner shall be checked on a regular basis by monitoring the airborne particulate count, which should not exceed 5×10^6 particles of size > 0.5 µm.

Cleanliness requirements	Personnel	Area Cleanliness	Monitoring
• Segregated clean area. • Limited Access to authorised personnel. • Authorised equipment operated to approved procedures. • Management of equipment (e.g. no vacuum pumps exhausting into clean area)	• Trained personnel. • Protective hair nets. • Powder free latex or nitrile outer gloves. • Clean white overalls. • Overshoes. • Clean job specific footwear	• Daily Cleaning of area Including floors and surfaces. • Sticky mats at area entry	• Daily air quality checks. • Results stored in Component document package. • Weekly cleanliness test of area with results stored in component document package

End of:

ANNEXURE 6
Cleaning and cleanliness

End of the technical specification