別添－１『イーター調達取決めに係る契約の品質保証に関する特約条項』

本契約については、契約一般条項によるほか、次の特約条項（以下「本特約条項」という。）による。

（定義）

第１条　本契約において「協定」とは、「イーター事業の共同による実施のためのイーター国際核融合エネルギー機構の設立に関する協定」をいう。

２　本契約において「イーター機構」とは、協定により設立された「イーター国際核融合エネルギー機構」をいう。

３　本契約において「加盟者」とは、協定の締約者をいう。

４　本契約において「国内機関」とは、各加盟者がイーター機構への貢献を行うに当たって、その実施機関として指定する法人をいう。

５　本契約において「フランス規制当局」とは、イーター建設地であるフランスの法令に基づき契約物品に関して規制、許認可を行う権限を有する団体をいう。

（品質保証活動）

第２条　乙は、本契約書及びこの契約書に附属する仕様書（以下「契約書等」という。）の要求事項に合致させるため本契約内容の品質を管理するものとする。

（品質保証プログラム）

第３条　乙は、本契約の履行に当たっては、乙の品質保証プログラムを適用する。このプログラムは、国の登録を受けた機関により認証されたもの（ISO9001-2015 等）で、かつ、本特約条項に従って契約を履行することができるものとする。ただし、これによることができないときは、甲により承認を得た品質保証プログラムを適用することができる。

（品質重要度分類）

第４条　乙は、適切な製品品質を維持するため、安全性、信頼性、性能等の重要度に応じて甲が定める本契約内容の等級に従って管理を実施しなければならない。契約物品の等級及び等級に応じた要求事項は、仕様書に定める。

（疑義の処置）

第５条　乙は、本契約書等に定める要求事項に疑義又は困難がある場合には、作業を開始する前に甲に書面にて通知し、その指示に従わなければならない。

（逸脱許可）

第６条　乙は、契約物品について、契約書等に定める要求事項からの逸脱許可が必要と思われる状況が生じた場合は、当該逸脱許可の申請を速やかに甲に提出するものとする。甲は、乙からの申請に基づき、当該逸脱許可の諾否について検討し、その結果を乙に通知するものとする。

（不適合の処理）
第７条 乙は、契約物品が契約書等の要求事項に適合しないとき又は適合しないことが見込まれるときは、遅滞なくその内容を甲に書面にて通知し、その指示に従わなければならない。

（重大不適合の処置）
第８条 乙は、重大不適合が発生した場合、直ちにその内容を甲に報告するとともに、プロジェクトへの影響を最小限に抑え、要求された品質を維持するため、その処置方法を検討し、速やかに甲に提案し、その承認を得なければならない。

（作業場所の通知）
第９条 乙は、本契約締結後、本契約の履行に必要なすべての作業場所を特定し、本契約に係る作業の着手前に、甲に書面にて通知するものとする。当該通知には、本契約の履行のために、乙が本契約の一部を履行させる下請負人の作業場所を含む。

（受注者監査）
第１０条 甲は、乙に対して事前に通知することにより、乙の品質保証に係る受注者監査を実施できるものとする。

（立入り権）
第１１条 乙は、本契約の履行状況を確認するため、甲、イーター機構、本契約の活動に関連する日本以外の加盟者の国内機関、フランス規制当局及びそれらから委託された第三者が、第９条に基づき特定した作業場所に立ち入る権利を有することに同意する。
２ 前項に定める立入り権に基づく作業場所への立入りは、契約書等に定める中間検査等への立会い及び定期レビュー会合への参加の他、乙に対して事前に通知することにより、必要に応じて実施することができるものとする。

（文書へのアクセス）
第１２条 乙は、甲の求めに応じ、本契約の適切な管理運営を証明するために必要な文書及びデータを提供するものとする。

（作業停止の権限）
第１３条 甲は、乙が本契約の履行に当たって、契約書等の要求事項を満足できないことが認められる等、必要な場合は、乙に作業の停止を命じることができる。
２ 乙は、甲から作業停止命令が発せられた場合には、可及的速やかに当該作業を停止し、甲の指示に従い要求事項を満足するよう必要な措置を講ずるものとする。

（下請負人に対する責任）
第１４条 乙は、下請負人に対し、本契約の一部を履行させる場合、本特約条項に基づく乙の一切の義務を乙の責任において当該下請負人に遵守させるものとする。

（情報のイーター機構等への提供）

第１５条 乙は、本契約の履行過程で甲に伝達された情報が、必要に応じてイーター機構及びフランス規制当局に提供される場合があることにあらかじめ同意するものとする。

以上

別添－２『本契約において遵守すべき「情報セキュリティの確保」に関する事項』

1　受注者は、契約の履行に関し、情報システム（情報処理及び通信に関わるシステムであって、ハードウェア、ソフトウェア及びネットワーク並びに記録媒体で構成されるものをいう。）を利用する場合には、量研機構の情報及び情報システムを保護するために、情報システムからの情報漏えい、コンピュータウィルスの侵入等の防止その他必要な措置を講じなければならない。

2　受注者は、次の各号に掲げる事項を遵守するほか、量研機構の情報セキュリティ確保のために、量研機構 が必要な指示を行ったときは、その指示に従わなければならない。

(1)　受注者は、契約の業務に携わる者（以下「業務担当者」という。）を特定し、それ以外の者に作業をさせてはならない。

(2)　受注者は、契約に関して知り得た情報（量研機構に引き渡すべきコンピュータプログラム著作物及び 計算結果を含む。以下同じ。）を取り扱う情報システムについて、業務担当者以外が当該情報にアクセス可能とならないよう適切にアクセス制限を行うこと。

(3)　受注者は、契約に関して知り得た情報を取り扱う情報システムについて、ウィルス対策ツール及びファイアウォール機能の導入、セキュリティパッチの適用等適切な情報セキュリティ対策を実施すること。

(4)　受注者は、P2P ファイル交換ソフトウェア（Winny、WinMX、KaZaa、Share 等）及び SoftEther を導入した情報システムにおいて、契約に関して知り得た情報を取り扱ってはならない。

(5)　受注者は、量研機構の承諾のない限り、契約に関して知り得た情報を量研機構又は受注者の情報システム 以外の情報システム（業務担当者が所有するパソコン等）において取り扱ってはならない。

(6)　受注者は、委任をし、又は下請負をさせた場合は、当該委任又は下請負を受けた者の契約に関する 行為について、量研機構に対し全ての責任を負うとともに、当該委任又は下請負を受けた者に対して、 情報セキュリティの確保について必要な措置を講ずるように努めなければならない。

(7)　受注者は、量研機構が求めた場合には、情報セキュリティ対策の実施状況についての監査を受け入れ、 これに協力すること。

(8)　受注者は、量研機構の提供した情報並びに受注者及び委任又は下請負を受けた者が契約業務のために収集した情報について、災害、紛失、破壊、改ざん、き損、漏えい、コンピュータウィルスによる 被害、不正な利用、不正アクセスその他の事故が発生、又は生ずるおそれのあることを知った場合は、直ちに量研機構に報告し、量研機構の指示に従うものとする。契約の終了後においても、同様とする。

なお、量研機構の入札に参加する場合、又は量研機構からの見積依頼を受ける場合にも、上記事項を遵守していただきます。

以上

別添－3

知的財産権特約条項

（知的財産権等の定義）

第１条　この特約条項において「知的財産権」とは、次の各号に掲げるものをいう。

一　特許法（昭和34年法律第121号）に規定する特許権、実用新案法（昭和34年法律第123号）に規定する実用新案権、意匠法（昭和34年法律第125号）に規定する意匠権、半導体集積回路の回路配置に関する法律（昭和60年法律第43号）に規定する回路配置利用権、種苗法（平成10年法律第83号）に規定する育成者権及び外国における上記各権利に相当する権利（以下総称して「産業財産権等」という。）

二　特許法に規定する特許を受ける権利、実用新案法に規定する実用新案登録を受ける権利、意匠法に規定する意匠登録を受ける権利、半導体集積回路の回路配置に関する法律に規定する回路配置利用権の設定の登録を受ける権利、種苗法に規定する品種登録を受ける地位及び外国における上記各権利に相当する権利

三　著作権法（昭和45年法律第48号）に規定する著作権（著作権法第21条から第28条までに規定する全ての権利を含む。）及び外国における著作権に相当する権利（以下総称して「著作権」という。）

四　前各号に掲げる権利の対象とならない技術情報のうち、秘匿することが可能なものであって、かつ、財産的価値のあるものの中から、甲乙協議の上、特に指定するもの（以下「ノウハウ」という。）を使用する権利

２　この特約条項において「発明等」とは、次の各号に掲げるものをいう。

一　特許権の対象となるものについてはその発明

二　実用新案権の対象となるものについてはその考案

三　意匠権、回路配置利用権及び著作権の対象となるものについてはその創作、育成者権の対象となるものについてはその育成並びにノウハウを使用する権利の対象となるものについてはその案出

３　この契約書において知的財産権の「実施」とは、特許法第２条第３項に定める行為、実用新案法第２条第３項に定める行為、意匠法第２条第２項に定める行為、半導体集積回路の回路配置に関する法律第２条第３項に定める行為、種苗法第２条第５項に定める行為、著作権法第21条から第28条までに規定する全ての権利に基づき著作物を利用する行為、種苗法第２条第５項に定める行為及びノウハウを使用する行為をいう。

（乙が単独で行った発明等の知的財産権の帰属）

第２条　甲は、本契約に関して、乙が単独で発明等行ったときは、乙が次の各号のいずれの規定も遵守することを書面にて甲に届け出た場合、当該発明等に係る知的財産権を乙から譲り受けないものとする。

一　乙は、本契約に係る発明等を行った場合には、次条の規定に基づいて遅滞なくその旨を甲に報告する。

二　乙は、甲が国の要請に基づき公共の利益のために特に必要があるとしてその理由を明らかにして求める場合には、無償で当該知的財産権を実施する権利を国に許諾する。

三　乙は、当該知的財産権を相当期間活用していないと認められ、かつ、当該知的財産権を相当期間活用していないことについて正当な理由が認められない場合において、甲が国の要請に基づき当該知的財産権の活用を促進するために特に必要があるとしてその理由を明らかにして求めるときは、当該知的財産権を実施する権利を第三者に許諾する。

四　乙は、第三者に当該知的財産権の移転又は当該知的財産権についての専用実施権（仮専用実施権を含む。）若しくは専用利用権の設定その他日本国内において排他的に実施する権利の設定若しくは移転の承諾（以下「専用実施権等の設定等」という。）をするときは、合併又は分割により移転する場合及び次のイからハまでに規定する場合を除き、あらかじめ甲に届け出、甲の承認を受けなければならない。

イ　子会社（会社法（平成17年法律第86号）第２条第３号に規定する子会社をいう。以下同じ。）又は親会社（会社法第２条第４号に規定する親会社をいう。以下同じ。）に当該知的財産権の移転又は専用実施権等の設定等をする場合

ロ　承認ＴＬＯ（大学等における技術に関する研究成果の民間事業者への移転の促進に関する法律（平成10年法律第52号）第４条第１項の承認を受けた者（同法第５条第１項の変更の承認を受けた者を含む。））又は認定ＴＬＯ（同法第11条第１項の認定を受けた者）に当該知的財産権の移転又は専用実施権等の設定等をする場合

ハ　乙が技術研究組合である場合、乙がその組合員に当該知的財産権を移転又は専用実施権等の設定等をする場合

2　乙は、前項に規定する書面を提出しない場合、甲から請求を受けたときは当該知的財産権を甲に譲り渡さなければならない。

3　乙は、第１項に規定する書面を提出したにもかかわらず、同項各号の規定のいずれかを満たしておらず、かつ、満たしていないことについて正当な理由がないと甲が認める場合において、甲から請求を受けたときは当該知的財産権を無償で甲に譲り渡さなければならない。

（知的財産権の報告）

第３条　前条に関して、乙は、本契約に係る産業財産権等の出願又は申請を行うときは、出願又は申請に際して提出すべき書類の写しを添えて、あらかじめ甲にその旨を通知しなければならない。

2　乙は、産業技術力強化法（平成12年法律第44号）第17条第１項に規定する特定研

究開発等成果に該当するもので、かつ、前項に係る国内の特許出願、実用新案登録出願、意匠登録出願を行う場合は、特許法施行規則（昭和35年通商産業省令第10号）、実用新案法施行規則（昭和35年通商産業省令第11号）及び意匠法施行規則（昭和35年通商産業省令第12号）等を参考にし、当該出願書類に国の委託事業に係る研究の成果による出願である旨を表示しなければならない 。

3　乙は、第１項に係る産業財産権等の出願又は申請に関して設定の登録等を受けた場合には、設定の登録等の日から60日以内（ただし、外国にて設定の登録等を受けた場合は90日以内）に、甲にその旨書面により通知しなければならない。

4　乙は、本契約に係る産業財産権等を自ら実施したとき及び第三者にその実施を許諾したとき（ただし、第５条第４項に規定する場合を除く。）は、実施等した日から60日以内（ただし、外国にて実施等をした場合は90日以内）に、甲にその旨書面により通知しなければならない。

5　乙は、本契約に係る産業財産権等以外の知的財産権について、甲の求めに応じて、自己による実施及び第三者への実施許諾の状況を書面により甲に報告しなければならない。

（乙が単独で行った発明等の知的財産権の移転）

第４条　乙は、本契約に関して乙が単独で行った発明等に係る知的財産権を第三者に移転する場合（本契約の成果を刊行物として発表するために、当該刊行物を出版する者に著作権を移転する場合を除く。）には、第２条から第６条まで及び第12条の規定の適用に支障を与えないよう当該第三者に約させなければならない。

2　乙は、前項の移転を行う場合には、当該移転を行う前に、甲にその旨書面により通知し、あらかじめ甲の承認を受けなければならない。ただし、乙の合併又は分割により移転する場合及び第２条第１項第４号イからハまでに定める場合には、この限りでない。

3　乙は、第１項に規定する第三者が乙の子会社又は親会社（これらの会社が日本国外に存する場合に限る。）である場合には、同項の移転を行う前に、甲に事前連絡の上、必要に応じて甲乙間で調整を行うものとする。

4　乙は、第１項の移転を行ったときは、移転を行った日から60日以内（ただし、外国にて移転を行った場合は90日以内）に、甲にその旨書面により通知しなければならない。

5　乙が第１項の移転を行ったときは、当該知的財産権の移転を受けた者は、当該知的財産権について、第２条第１項各号及び第３項並びに第３条から第６条まで及び第12条の規定を遵守するものとする。

（乙が単独で行った発明等の知的財産権の実施許諾）

第５条　乙は、本契約に関して乙が単独で行った発明等に係る知的財産権について第三者に実施を許諾する場合には、第２条、本条及び第12条の規定の適用に支障を与えないよう当該第三者に約させなければならない。

2　乙は、本契約に関して乙が単独で行った発明等に係る知的財産権に関し、第三者に専用実施権等の設定等を行う場合には、当該設定等を行う前に、甲にその旨書面により通知し、あらかじめ甲の書面による承認を受けなければならない。ただし、乙の合併又は分割により移転する場合及び第２条第１項第４号イからハまでに定める場合は、この限りではない。

3　乙は、前項の第三者が乙の子会社又は親会社（これらの会社が日本国外に存する場合に限る。）である場合には、同項の専用実施権等の設定等を行う前に、甲に事前連絡のうえ、必要に応じて甲乙間で調整を行うものとする。

4　乙は、第２項の専用実施権等の設定等を行ったときは、設定等を行った日から60日以内（ただし、外国にて設定等を行った場合は90日以内）に、甲にその旨書面により通知しなければならない。

5　甲は、本契約に関して乙が単独で行った発明等に係る知的財産権を無償で自ら試験又は研究のために実施することができる。甲が　甲のために第三者に製作させ、又は業務を代行する第三者に再実施権を許諾する場合は、乙の承諾を得た上で許諾するものとし、その実施条件等は甲乙協議のうえ決定する。

（乙が単独で行った発明等の知的財産権の放棄）

第６条　乙は、本契約に関して乙が単独で行った発明等に係る知的財産権を放棄する場合は、当該放棄を行う前に、甲にその旨書面により通知しなければならない。

（甲及び乙が共同で行った発明等の知的財産権の帰属）

第７条　甲及び乙は、本契約に関して甲乙共同で発明等を行ったときは、当該発明等に係る知的財産権について共同出願契約を締結し、甲乙共同で出願又は申請するものとし、当該知的財産権は甲及び乙の共有とする。ただし、乙は、次の各号のいずれの規定も遵守することを書面にて甲に届け出なければならない。

一　乙は、甲が国の要請に基づき公共の利益のために特に必要があるとしてその理由を明らかにして求める場合には、無償で当該知的財産権を実施する権利を国に許諾する。

二　乙は、当該知的財産権を相当期間活用していないと認められ、かつ、当該知的財産権を相当期間活用していないことについて正当な理由が認められない場合において、甲が国の要請に基づき当該知的財産権の活用を促進するために特に必要があるとしてその理由を明らかにして求めるときは、当該知的財産権を実施する権利を甲が指定する 第三者に許諾する。

2　前項の場合、出願又は申請のための費用は原則として、甲、乙の持分に比例して負担するものとする。

3　乙は、第１項に規定する書面を提出したにもかかわらず、同項各号の規定のいずれかを満たしておらず、さらに満たしていないことについて正当な理由がないと甲が認める場合において、甲から請求を受けたときは当該知的財産権のうち乙が所有する部分を無償で甲に譲り渡さなければならない。

（甲及び乙が共同で行った発明等の知的財産権の移転）

第８条　甲及び乙は、本契約に関して甲乙共同で行った発明等に係る共有の知的財産権のうち、自らが所有する部分を相手方以外の第三者に移転する場合には、当該移転を行う前に、その旨を相手方に書面により通知し、あらかじめ相手方の書面による同意を得なければならない。

（甲及び乙が共同で行った発明等の知的財産権の実施許諾）

第９条　甲及び乙は、本契約に関して甲乙共同で行った発明等に係る共有の知的財産権について第三者に実施を許諾する場合には、その許諾の前に相手方に書面によりその旨通知し、あらかじめ相手方の書面による同意を得なければならない。

（甲及び乙が共同で行った発明等の知的財産権の実施）

第10条　甲は、本契約に関して乙と共同で行った発明等に係る共有の知的財産権を試験又は研究以外の目的に実施しないものとする。ただし、甲は甲のために第三者に製作させ、又は業務を代行する第三者に実施許諾する場合は、無償にて当該第三者に実施許諾することができるものとする。

２　乙が本契約に関して甲と共同で行った発明等に係る共有の知的財産権について自ら商業的実施をするときは、甲が自ら商業的実施をしないことに鑑み、乙の商業的実施の計画を勘案し、事前に実施料等について甲乙協議の上、別途実施契約を締結するものとする。

（甲及び乙が共同で行った発明等の知的財産権の放棄）

第11条　甲及び乙は、本契約に関して甲乙共同で行った発明等に係る共有の知的財産権を放棄する場合は、当該放棄を行う前に、その旨を相手方に書面により通知し、あらかじめ相手方の書面による同意を得なければならない。

（著作権の帰属）

第12条　第２条第１項及び第７条第１項の規定にかかわらず、本契約の目的として作成され納入される著作物に係る著作権については、全て甲に帰属する。

２　乙は、前項に基づく甲及び甲が指定する 第三者による実施について、著作者人格権を行使しないものとする。また、乙は、当該著作物の著作者が乙以外の者であるときは、当該著作者が著作者人格権を行使しないように必要な措置を執るものとする。

３　乙は、本契約によって生じた著作物及びその二次的著作物の公表に際し、本契約による成果である旨を明示するものとする。

（合併等又は買収の場合の報告等）

第13条　乙は、合併若しくは分割し、又は第三者の子会社となった場合（乙の親会社が変更した場合を含む。第３項第１号において同じ。）は、甲に対しその旨速やかに報告し

なければならない。

2　前項の場合において、国の要請に基づき、国民経済の健全な発展に資する観点に照らし、本契約の成果が事業活動において効率的に活用されないおそれがあると甲が判断したときは、乙は、本契約に係る知的財産権を実施する権利を甲が指定する者に許諾しなければならない。

3　乙は、本契約に係る知的財産権を第三者に移転する場合、次の各号のいずれの規定も遵守することを当該移転先に約させなければならない。

一　合併若しくは分割し、又は第三者の子会社となった場合は、甲に対しその旨速やかに報告する。

二　前号の場合において、国の要請に基づき、国民経済の健全な発展に資する観点に照らし本業務の成果が事業活動において効率的に活用されないおそれがあると甲が判断したときは、本契約に係る知的財産権を実施する権利を甲が指定する者に許諾する。

三　移転を受けた知的財産権をさらに第三者に移転するときは、本項各号のいずれの規定も遵守することを当該移転先に約させる。

（秘密の保持）

第14条　甲及び乙は、第２条及び第７条の発明等の内容を出願公開等により内容が公開される日まで他に漏えいしてはならない。ただし、あらかじめ書面により出願又は申請を行った者の了解を得た場合はこの限りではない。

（委任・下請負）

第15条　乙は、本契約の全部又は一部を第三者に委任し、又は請け負わせた場合においては、当該第三者に対して、本特約条項の各規定を準用するものとし、乙はこのために必要な措置を講じなければならない。

2　乙は、前項の当該第三者が本特約条項に定める事項に違反した場合には、甲に対し全ての責任を負うものとする。

（協議）

第16条　第２条及び第７条の場合において、単独若しくは共同の区別又は共同の範囲等について疑義が生じたときは、甲乙協議して定めるものとする。

（有効期間）

第17条　本特約条項の有効期限は、本契約の締結の日から当該知的財産権の消滅する日までとする。

以上

別添－４

イーター実施協定の調達に係る情報及び知的財産に関する特約条項

本契約については、本契約一般条項によるほか、次の特約条項（以下「本特約条項」という。）による。

（定義）

第１条　本契約において「知的財産権」とは、次の各号に掲げるものをいう。

（１）　特許法（昭和３４年法律第１２１号）に規定する特許権又は特許を受ける権利

（２）　実用新案法（昭和３４年法律第１２３号）に規定する実用新案権又は実用新案登録を受ける権利

（３）　意匠法（昭和３４年法律第１２５号）に規定する意匠権又は意匠登録を受ける権利

（４）　商標法（昭和３４年法律第１２７号）に規定する商標権又は商標登録を受ける権利

（５）　半導体集積回路の回路配置に関する法律（昭和６０年法律第４３号）に規定する回路配置利用権又は回路配置利用権の設定の登録を受ける権利

（６）　種苗法（平成１０年法律第８３号）に規定する育成者権又は品種登録を受ける地位

（７）　著作権法（昭和４５年法律第４８号）に規定するプログラムの著作物及びデータベースの著作物の著作権

（８）　外国における、第１号から第７号に記載の各知的財産権に相当する権利

（９）　不正競争防止法（平成５年法律第４７号）に規定する営業秘密に関して法令により定められた権利又は法律上保護される利益に係る権利（以下「営業秘密」という。）

２　本契約において「情報」とは、法律による保護を受けることができるか否かを問わず、発明や発見の記述のみならず、公表されている資料、図書、意匠、計算書、報告書その他の文書、研究開発に関する記録された資料又は方法並びに発明及び発見に関する説明であって、前項に定義する知的財産権を除いたものをいう。

３　本契約において「発明等」とは、特許権の対象となるものについては発明、実用新案権の対象となるものについては考案、意匠権、商標権、回路配置利用権及びプログラム等の著作権の対象となるものについては創作、育成者権の対象となるものについては育成並びに営業秘密を使用する権利の対象となるものについては案出をいう。

４　本契約において「背景的な知的財産権」とは、本契約の締結前に取得され、開発され、若しくは創出された知的財産権又は本契約の範囲外において取得され、開発され、若しくは創出される知的財産権をいう。

５　本契約において「背景的な営業秘密」とは、背景的な知的財産権のうちの営業秘密をいう。

６　本契約において「生み出された知的財産権」とは、本契約の履行の過程で、乙が単独で又は甲と共同で取得し、開発し、又は創出した知的財産権をいう。

７　本契約において「協定」とは、「イーター事業の共同による実施のためのイーター国際核融合エネルギー機構の設立に関する協定」をいう。

８　本契約において「附属書」とは、協定の「情報及び知的財産に関する附属書」をいう。

９　本契約において「イーター機構」とは、協定により設立された「イーター国際核融合エネルギー機構」をいう。

１０　本契約において「加盟者」とは、協定の締約者をいう。

１１　本契約において「国内機関」とは、各加盟者がイーター機構への貢献を行うに当たって、

その実施機関として指定する法人をいう。

１２　本契約において「団体」とは、国内機関又はイーター機構が協定の目的のために物品又は役務の提供に関する契約を締結する団体をいう。

１３　本契約において「理事会」とは、協定第６条に定める「理事会」をいう。

１４　本契約において「特許等」とは、特許、登録実用新案、登録意匠、登録商標、登録回路配置及び登録品種の総称をいう。

（情報の普及）

第２条　乙は、加盟者又は国内機関が、本契約の実施により直接に生じる情報（著作権の有無を問わない。）を非商業上の利用のため翻訳し、複製し、及び公に頒布する権利を有することに同意する。

２　乙は、前項により作成される著作権のある著作物の写しであって公に頒布されるすべてのものには、著作者が明示的に記名を拒否しない限り、著作者の氏名を明示することに同意する。

（発明等の報告）

第３条　乙は、本契約の履行の過程で発明等を創出した場合には（以下、かかる発明等を「本発明等」という。）、本発明の詳細とともに、速やかに甲に書面により報告するものとする。

２　乙は、甲が前項の本発明の詳細を含む報告をイーター機構及び加盟者に提供すること、並びに、甲が自ら実施する核融合の研究開発に関する活動のため必要とする場合において乙以外の日本の団体に提供することに、あらかじめ同意する。

（生み出された知的財産権の帰属等）

第４条　本発明等に係る知的財産権は、乙に帰属する。ただし、本発明等が甲乙共同で創出したものである場合、当該本発明等に係る知的財産権は甲及び乙の共有となる。

２　前項ただし書きの甲及び乙の共有に係る知的財産権について、甲及び乙は、知的財産権の持分、費用分担、その他必要な事項を協議の上、別途取決めを締結するものとする。

３　乙は、甲及び乙の共有に係る当該知的財産権を自ら又は乙が指定する者が実施する場合、甲及び乙の持分に応じてあらかじめ定める不実施補償料を甲に支払うものとする。

（発明等の取扱い）

第５条　乙は、本発明等に関し、(i)特許等の登録に必要な手続を行うか、(ii)営業秘密として管理するか、又は、(iii)(i)若しくは(ii)のいずれも行わないかという取扱いについて速やかに決定の上、甲に決定内容を書面により報告する。ただし、当該本発明等が甲乙共同で創出したものである場合、甲及び乙は、上記(i)ないし(iii)の取扱いについて別途協議の上決定する。

２　乙は、前項に基づく本発明等の取扱いに関する決定内容について、甲がイーター機構及び加盟者に提供すること、並びに甲が自ら実施する核融合の研究開発に関する活動のため必要とする場合において乙以外の日本の団体に提供することに、あらかじめ同意する。

３　乙は、乙が第１項の(iii)の取扱いをすることを決定した本発明等について、甲又はイーター機構の求めがあった場合は、当該本発明等の知的財産権を甲又はイーター機構に承継させるものとする。

（背景的な知的財産権の認定）

第６条　乙が本契約の履行の過程で利用する背景的な知的財産権は、甲及び乙が別途締結する覚書（以下「覚書」という。）に定める。覚書に定めのない知的財産権であって、本契約の履行の過程で利用されるものは、生み出された知的財産権とみなす。

２　乙は、覚書に掲げる知的財産権の内容に変更が生じたときは、速やかに当該変更内容を甲に書面により報告するものとする。

３　乙は、本契約締結後に本契約の履行の過程で利用すべき背景的な知的財産権の存在が判明したときは、速やかに、当該背景的な知的財産権が、本契約の範囲外において存在することを証明する具体的な証拠とともに、本契約締結前に報告できなかった正当な理由を甲に書面により報告するものとする。

４　甲は、前項の報告を受けた場合は、乙から提出された証拠及び理由の妥当性を検討の上、必要に応じて、甲乙協議の上、覚書の改訂を行うものとする。

５　乙は、本条に基づく報告について、甲がイーター機構及び加盟者に提供すること、並びに甲が自ら実施する核融合の研究開発に関する活動のため必要とする場合において乙以外の日本の団体に提供することに、あらかじめ同意する。

６　乙は、本契約の履行の過程で背景的な知的財産権を利用する場合は、必要な実施権又は利用権を確保し、甲並びに契約物品の提供を受けるイーター機構及び関連する他の加盟者が、支障なく当該物品を使用することができるようにしなければならない。甲並びにイーター機構及び関連する他の加盟者が当該背景的な知的財産権に関し、第三者から知的財産権侵害の苦情を受けた場合には、乙は自己の責任と費用でその苦情を防御又は解決し、当該苦情に起因する損失、損害又は経費のすべてを補償し、甲並びにイーター機構及び関連する他の加盟者に対して何らの損害も与えないものとする。

（背景的な知的財産権の帰属）

第７条　本契約は、背景的な知的財産権の帰属について何ら変更を生じさせるものではない。

（創出者への補償等）

第８条　乙は、乙の従業者又は役員（以下「従業者等」という。）が創出した本発明等に係る知的財産権を、適用法令に従い、乙の費用と責任において従業者等から承継するものとする。

（生み出された知的財産権の実施）

第９条　生み出された知的財産権の実施権の許諾（利用権の付与を含む。以下同じ。）については、次の各号による。

（１）　乙は、甲が自ら実施する研究開発に関する活動のために、平等及び無差別の原則に基づき、当該生み出された知的財産権の取消し不能な、非排他的な、かつ、無償の実施権を甲に許諾する。当該実施権は、甲が第三者に再実施を許諾する権利を伴う。

（２）　乙は、公的な支援を得た核融合の研究開発に関する計画のため、平等及び無差別の原則に基づき、当該生み出された知的財産権の取消し不能な、非排他的な、かつ、無償の実施権を加盟者及びイーター機構に許諾する。当該実施権は、イーター機構及び加盟者が第三

者（加盟者については、それぞれの領域内の第三者に限る。）に再実施を許諾する権利を伴う。

（３）　乙は、核融合の商業上の利用のため、平等及び無差別の原則に基づき、生み出された知的財産権の非排他的な実施権を加盟者に許諾する。当該実施権は、加盟者が第三者（それぞれの領域内の第三者に限る。）に再実施を許諾する権利を伴う。当該実施権の許諾に係る条件は、乙が第三者に対して当該生み出された知的財産権の実施権を許諾するときの条件よりも不利でないものとする。

（４）　乙は、生み出された知的財産権の核融合以外の分野における利用を可能にするため、加盟者、国内機関、団体及び第三者と商業上の取決めを締結することが奨励される。

２　前項の生み出された知的財産権が甲と乙の共有に係るものである場合、甲と乙は、共同して同項に基づく実施権の許諾を行う。

３　乙は、第１項に規定する実施権及び再実施を許諾する権利の許諾の記録を保持し、甲の求めに応じこれを甲に提供する。乙は、上記記録に変更がある場合は、各年の上半期については、７月１５日までに、下半期については翌年の１月１５日までに甲に報告書を提出する。

４　乙は、甲が当該記録をイーター機構及び加盟者に提供すること、並びに甲が自ら実施する核融合の研究開発に関する活動のため必要とする場合において乙以外の日本の団体に提供することに、あらかじめ同意する。

５　乙は、非加盟者の第三者に対し、生み出された知的財産権の実施権を許諾する場合には、理事会が全会一致で決定する規則に従うものとし、甲の事前の同意を得て行うものとする。当該第三者への実施権の許諾は、平和的目的のための使用に限り行うものとする。ただし、当該規則の決定までは、非加盟者の第三者に対する当該実施権の許諾は認めない。

６　乙は、イーター機構又は加盟者に対して直接実施許諾できない理由があるときには、甲が第１項第２号及び第３号に基づきイーター機構又は加盟者に再実施を許諾するための権利を伴う、生み出された知的財産権の取消し不能な、非排他的な、かつ、無償の実施権を甲に許諾するものとする。

（背景的な知的財産権の実施）

第１０条　乙が契約物品その他仕様書に定める納入品に用いる背景的な知的財産権の実施権の許諾については、次の各号による。

（１）　乙は、当該背景的な知的財産権（ただし、背景的な営業秘密を含まない。）が次のいずれかの要件を満たすときは、甲が自ら実施する核融合の研究開発に関する活動のために、平等及び無差別の原則に基づき、当該背景的な知的財産権の取消し不能な、非排他的な、かつ、無償の実施権を甲に許諾する。当該実施権は、甲が研究機関及び高等教育機関に再実施を許諾する権利を伴う。

イ　イーター施設を建設し、運転し、及び利用するために必要とされること又はイーター施設に関連する研究開発のための技術を用いるために必要とされること。

ロ　イーター機構に提供される契約物品を保守し、又は修理するために必要とされること。

ハ　公的な調達に先立ち理事会が必要であると決定する場合において必要とされること。

（２）　乙は、当該背景的な知的財産権（ただし、背景的な営業秘密を含まない。）が次のいず

れかの要件を満たすときは、公的な支援を得た核融合の研究開発に関する計画のため、平等及び無差別の原則に基づき、当該背景的な知的財産権の取消し不能な、非排他的な、かつ、無償の実施権を加盟者及びイーター機構に許諾する。当該実施権は、イーター機構が再実施を許諾する権利並びに加盟者がそれぞれの領域内において研究機関及び高等教育機関に再実施を許諾する権利を伴う。

イ　イーター施設を建設し、運転し、及び利用するために必要とされること又はイーター施設に関連する研究開発のための技術を用いるために必要とされること。

ロ　イーター機構に提供される契約物品を保守し、又は修理するために必要とされること。

ハ　公的な調達に先立ち理事会が必要であると決定する場合において必要とされること。

（３）　乙は、当該背景的な営業秘密が次のいずれかの要件を満たすときは、当該背景的な営業秘密（イーター施設の建設、運転、保守及び修理のための手引書又は訓練用教材を含む。）の取消し不能な、非排他的な、かつ、無償の利用権をイーター機構に付与する。当該利用権は、イーター機構が、協定の情報及び知的財産に関する附属書第４．２．３条（ｂ）に基づき、その下請負人に再利用権を付与する権利及びフランス規制当局に当該背景的な営業秘密を伝達する権利を伴う。

イ　イーター施設を建設し、運転し、及び利用するために必要とされること又はイーター施設に関連する研究開発のための技術を用いるために必要とされること。

ロ　イーター機構に提供される契約物品を保守し、又は修理するために必要とされること。

ハ　公的な調達に先立ち理事会が必要であると決定する場合において必要とされること。

ニ　イーター施設に対して規制当局が要請する安全、品質保証及び品質管理のために必要とされること。

（４）　乙は、当該背景的な営業秘密が次のいずれかの要件を満たすときは、加盟者が公的な支援を得た核融合の研究開発に関する計画のため、金銭上の補償を伴う私的契約によって、当該背景的な営業秘密の商業上の利用権の付与又は当該背景的な営業秘密を用いた契約物品と同一の物品の提供を求めた場合には、当該契約締結のため最善の努力を払うこととする。当該利用権の付与又は物品の提供に係る条件は、乙が第三者に対して当該背景的な営業秘密の利用権を付与し、又は当該背景的な営業秘密を用いた同一の物品を提供するときの条件よりも不利でないものとする。当該利用権が付与される場合には、当該利用権は、利用権者が契約上の義務を履行しない場合にのみ取り消すことができる。

イ　イーター施設を建設し、運転し、及び利用するために必要とされること又はイーター施設に関連する研究開発のための技術を用いるために必要とされること。

ロ　イーター機構に提供される契約物品を保守し、又は修理するために必要とされること。

ハ　公的な調達に先立ち理事会が必要であると決定する場合において必要とされること。

（５）　乙は、当該背景的な知的財産権について、加盟者が核融合の商業上の利用のため、当該背景的な知的財産権の実施権の許諾を受けること又は当該背景的な知的財産権を用いた契約物品と同一の物品の提供を求めた場合には、当該要求の実現のため最善の努力を払うこととする。当該背景的な知的財産権の実施権は、当該加盟者の領域内にある第三者による核融合の商業上の利用のために当該加盟者が再実施を許諾する権利を伴う。当該背景的な知的財産権の実施権の許諾に係る条件は、乙が第三者に対して当該背景的な知的財産権の実施権を

許諾するときの条件よりも不利でないものとする。当該背景的な知的財産権の実施権は、実施権者が契約上の義務を履行しない場合にのみ取り消すことができる。

（６）　乙は、前号に定める目的以外の商業上の目的のため、加盟者から求めがあった場合は、当該背景的な知的財産権が次のいずれかの要件を満たすときは、当該背景的な知的財産権の実施権を許諾することが奨励される。乙が、当該背景的な知的財産権の実施権を当該加盟者に許諾する場合には、当該背景的な知的財産権の実施権は平等及び無差別の原則に基づき許諾されるものとする。

イ　イーター施設を建設し、運転し、及び利用するために必要とされること又はイーター施設に関連する研究開発のための技術を用いるために必要とされること。

ロ　イーター機構の提供される契約物品を保守し、又は修理するために必要とされること。

ハ　公的な調達に先立ち理事会が必要であると決定する場合において必要とされること。

２　前項の背景的な知的財産権が甲と乙の共有に係るものである場合、甲と乙は、共同して当該背景的な知的財産権の実施権の許諾を行う。

３　乙は、第１項に規定する実施権及び再実施を許諾する権利の許諾の記録を保持し、甲の求めに応じこれを甲に提供する。乙は、上記記録に変更がある場合は、各年の上半期については７月１５日までに、下半期については翌年の１月１５日までに甲に報告書を提出する。

４　乙は、甲が当該記録をイーター機構及び加盟者に提供すること、並びに甲が自ら実施する核融合の研究開発に関する活動のため必要とする場合において乙以外の日本の団体に提供することに、あらかじめ同意する。

（知的財産権の帰属の例外）

第１１条　乙は、本契約の目的として作成される提出書類、プログラム及びデータベース等の納入品に係る著作権は、すべて甲に帰属することを認め、乙が著作権を有する場合（第８条に基づき従業者等から承継する場合を含む。）であっても、乙は、かかる著作権（著作権法第 21 条から第 28 条までに定める全ての権利を含み、日本国内における権利に限らない。）を甲に譲渡する。かかる譲渡の対価は、本契約書に定める請負の対価に含まれる。

２　前項の規定により著作権を乙から甲に譲渡する場合において、当該著作物を乙が自ら創作したときは、乙は、著作者人格権を行使しないものとし、当該著作物を乙以外の第三者が創作したときは、乙は、当該第三者に著作者人格権を行使しないように必要な措置を講じるものとする。

（下請負人に対する責任）

第１２条　乙は、本契約一般条項の規定に従い、下請負人に対し本契約の一部を履行させる場合、本特約条項に基づく乙の一切の義務を乙の責任において当該下請負人に遵守させるものとする。

（有効期間）

第１３条　本契約一般条項の定めにかかわらず、本特約条項の定めは協定の終了後又は日本国政府の協定からの脱退後も効力を有する。

（言語）

第１４条　本特約条項に定める乙から甲への書面による報告は、和文だけでなく、英文でも提出することとし、両文書は等しく正文とする。

（疑義）

第１５条　本特約条項の解釈又は適用に関して疑義が生じた場合、協定の規定が本特約条項に優先する。

別添－5

イーター調達に係る貨物の免税輸入について

イーター事業の共同による実施のためのイーター国際核融合エネルギー機構の特権及び免除に関する協定（イーター協定）に基づき、イーターに係る貨物の日本国内機関(JADA)及びメーカー・商社による輸入関税及び引取りに係る内国消費税の免税輸入を可能とする例外的な措置について、以下の要件等を遵守することで免税法令の適用対象となることが出来ます。

1. 免税適用のための要件

(1) 免税適用となる貨物

・イーター活動（R&D 及びクォリフィケーションを含む）のためだけに使用される物品を適用対象とする。

・この内、完成品（本契約における納入品を言う）のみを適用対象とする。

・ただし、8 割方以上完成している物品については、ほぼ完成品の輸入とみなし、適用対象とする。

(2) 免税適用とならない貨物

・原材料及び資機材、並びに製作治具等。

・本契約締結日よりも前に輸入した物品。

・上記(1)に該当する物品と該当しない物品とが混在して輸入され、別個に通関申告が出来ない場合。

疑義が生じる場合には、輸入前にQST担当者と別途協議するものとする。

2. 必要な手続き

(1) 1.(1)に該当する貨物を輸入する際には、輸入手続きを開始する前に必ずQSTの契約担当者に申し出ること。免税適用に疑義がある場合も同様とする。

(2) 受注者は、輸入申告前に原子力機構から発行される「確認書」の正本を受領し、輸入通関書類と併せて申告すること。

3. 契約に係る注意事項

・免税輸入通関のためには、通関申告前に、QSTから通関を予定している税関に連絡する必要がある。(その際、輸入通関書類及び「確認書」(写し）の提出をしている)。

・契約に際しては、免税を加味しない金額で契約を実施するが、免税が適用された場合には、免税相当額を減額して支払うこととし、事前に書面をもって確認する。

・免税適用可否については、通関する担当税関が最終判断を担うが、(1)にて免税適用となりうる貨物に関しては、免税となるよう誠意をもってQST担当者と協力すること。

2.免税適用法令－抜粋（参考）

（1）関税定率法（外交官用貨物等の免税）

第十六条　左の各号に掲げる貨物で輸入されるものについては、政令で定めるところにより、その関税を免除する。

一　本邦にある外国の大使館、公使館その他これらに準ずる機関に属する公用品。但し、外国にある本邦のこれらの機関に属する公用品についての関税の免除に制限を附する国については、相互条件による。

（2）輸入品に対する内国消費税の徴収等に関する法律（免税等）

第十三条　次の各号に掲げる課税物品で当該各号に規定する規定により関税が免除されるもの（関税が無税とされている物品については、当該物品に関税が課されるものとした場合にその関税が免除されるべきものを含む。第三項において同じ。）を保税地域から引き取る場合には、政令で定めるところにより、その引取りに係る消費税を免除する。

三　関税定率法第十六条第一項 各号（外交官用貨物等の免税）に掲げるもの

以上

IDM UID
2MLX45

VERSION CREATED ON / VERSION / STATUS
19 Mar 2010 / 1.1 / APPROVED

EXTERNAL REFERENCE

MQP Quality Plan

QP Template for suppliers and subcontractors

This template is for suppliers and their subcontractors to produce a Quality Plan. This is recommended template for users, not mendatory.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Park S.**	**19-Mar-2010:signed**	**IO/DG/SQS/QA**
CoAuthor			
Reviewers			
Approver	**Sands D.**	**19-Mar-2010:approved**	**IO/DG/SQS/QA**
Document Security: level 1 (IO unclassified) *RO: Sands David*			
Read Access	**AD: ITER, AD: External Collaborators, AD: Division - Quality Assurance, AD: ITER Management Assessor, project administrator, RO**		

Change Log				
Title (Uid)	***Version***	***Latest Status***	***Issue Date***	***Description of Change***
QP Template for suppliers and subcontractors (2MLX45_v1_1)	v1.1	Approved	19 Mar 2010	At the section 7, wordings are changed from (proposed) suppliers or subcontractors to (proposed) suppliers and suncontractors specifying what work they will be performing.
QP Template for suppliers and subcontractors (2MLX45_v1_0)	v1.0	Signed	12 Feb 2010	

Template for Suppliers and subcontractors of a DA

QUALITY PLAN

Document Number:		**Revision Number:**	
ITER PP Number:		**ITER PA Number:**	
Title of Item:			
Name of DA:			
Supplier of the DA:			
Prepared by Supplier	**Approved by Supplier**	**Approved by DA**	**ITER Acceptance**
Position: Name & signature Date:	Position: Name & signature Date:	Position: Name & signature Date:	Position: Name & Signature Date:

<PP: Procurement Package, PA: Procurement Arrangement>

※ This is a recommended template for user's guiding to develop a Quality Plan.

1. Scope

[This section shall describe the scope of work to be covered by this Quality Plan]

2. Quality Management

2.1 Description of Quality Management System of the organization:
[Provide certifications of recognized Quality Standards and valid date of the certifications, if any]

2.2 Detailed the breakdown of responsibilities within the organization:
[Add the organization flow chart]

2.3 Identify the different (external) organizations involved:
[Add the relationship flow chart between different organizations]

2.4 Identify within the different organizations involved the key individuals responsible for:
[Ensuring that the activities performed in connection with the particular contract are planned, implemented and controlled and their progress monitored,
Communicating requirements peculiar to the contract to all affected organizations,
Resolving problems that may arise at interfaces between the organisations involved]

2.5 Identify any access restrictions of IO to the premise of the supplier or its subcontractors that may apply:

3. Contract Review
[Indicate how, when and by whom contract requirements are to be reviewed and the review recorded]
4. Documents
[Show how, when and by whom documents will be controlled, and what kinds of documents will be submitted to IO]
5. Design
[Indicate, if an organization performs design activities for the contract; how, when and by whom design will be controlled, including: - when, how, and by whom the design process is to be carried out, controlled and documented, - the arrangements for the review, verification and validation of design output conformity to design inputs requirements. Where applicable, indicate the extent to which the IO will be involved in design activities, such as participation in design reviews and design verification. Reference applicable codes, standards and regulatory requirements. A list the computer programs to be used and indicate how, when, and by whom they will be controlled. Otherwise "not applicable".]

6. Procurement

[Show how, when and by whom procurements will be controlled.
Any important Items or activities that are to be purchased or subcontracted.
(Proposed) suppliers or subcontractors specifying what work they will be performing.
Relevant Quality Assurance Requirements and the methods to be used to satisfy regulatory requirements, which apply to, purchased or subcontracted products.]

7. Identification and control of items

[Where traceability is a requirement or necessary for the adequate control of the work, define its scope and extent, including;
How affected items are to be identified?
How contractual and regulatory traceability requirements are identified and incorporated into working documents?
What records relating to such traceability are to be generated and how and by whom they are to be controlled?]

8. Manufacture
[Iindicate how processes, manufacture, assembly, inspections and tests will be controlled. Where appropriate, introduce or refer to: Relevant documented procedures and work instructions. The methods to be used to monitor and control processes. Criteria for workmanship. Use of special and qualified processes and associated personnel. Tools, techniques and methods to be used.]
9. Inspection and testing
[Show how, when and by whom inspection and test would be controlled, including;. Any inspection and test plan to be used, and how and by whom they are reviewed and approved. How and by whom inspection and test reports are reviewed and approved? Acceptance criteria to be applied. Acceptance of purchased or subcontracted items. Any specific requirements for the identification of inspections and tests status. The extent to which the IO and (Agreed) Notified Bodies will be involved, such as witnessing inspection and test.]

10. Measuring and Test Equipment

[Indicate the control system to be used for measuring and test equipment specifically used in connection with the contract, including:
- Identification of such equipment,
- Method of calibration,
- Method of indicating and recording calibration status.]

11. Handling, Storage, Packing, Shipping and Delivery

[Show how, when and by whom handling, storage, packing, shipping and delivery will be controlled:
- how contract requirements for handling, storage, packaging and shipping are to be met,
- how the item will be delivered to the specified site in a manner that will ensure that its required characteristics are not degraded.]

12. Records

[This section should indicate:
How records are to be controlled, including how legibility, storage and retrievability will be satisfied
What records are to be kept
What records are to be supplied to the IO, when and by what means
How and by whom the records are reviewed and approved prior to inclusion in the deliverables handed over to the IO
What form the records will take (such as paper, microfilm, tape, disc or other medium) and in what language the records will be provided.]

13. Deviation and Non-Conformities

[Indicate how, when and by whom deviations and non-conformities will be processed including those originating from suppliers and subcontractor.]

14. Training and Qualification
[Address any specific training requirement for personnel and how such training is accomplished and recorded.]

15. Statistical Techniques
[Where statistical techniques are relevant for establishing, controlling and verifying process capability and item characteristics, they should be indicated.]

16. Assessment
[Indicate how, when and by whom the implementation and effectiveness of the Quality Plan will be monitored.]

17. Reference and Others *(If any)*
[A list of documents referenced in this Quality Plan]

- ***Italics* in boxes are provided to give instructions and need to be deleted when completing the form with an actual information.**

[Note] Preparation, implementation and approval of a Quality Plan

1. Much of the generic documentation needed to prepare a Quality Plan will normally already exist as part of the performer's quality management documents and supporting procedures. The Quality Plan need only refer to this documentation and show how it is to be applied to the work contracted.

2. DAs shall prepare a Quality Plan and submit it to the IO for approval.

3. The DA Suppliers/Subcontractors Quality Plans are approved by the DA, and then submitted to the IO for acceptance.

4. Work shall not start until the relevant Quality Plan has been accepted by the IO.

5. Work shall be performed as directed in the Quality Plan. The performers (DAs, and their suppliers and subcontractors) shall monitor the implementation and effectiveness of the Quality Plan.

6. Documents referred to in the Quality Plan should be made available to the IO.

別添－7

IDM UID

22MFG4

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27 Jan 2025 / 6.3 / Approved

EXTERNAL REFERENCE / VERSION

Technical Specifications (In-Cash Procurement)

Quality Requirements for IO Performers

The purpose of this document is to provide IO performers with quality management requirements based on the quality class of structures, systems, and components (SSC).

Table of Contents

1 Purpose

The purpose of this document is to provide IO performers with quality management requirements based on the quality class of structures, systems, and components (SSC).

2 Definitions and acronyms

Term	Acronym	Definition
(Agreed) Notified Body	(A)NB	Notified Body agreed by the French Nuclear Authority (ASN) to perform conformity assessment of Nuclear Pressure Equipment
Acceptance		Acknowledgement that a product or document is in compliance with the Contract requirements
Approval		Formal agreement for the use or application of a product or document. The approver takes responsibility for the use.
Certificate of Conformity	CoC	
Commercial-off-the-shelf (items), Commercial grade item or service	COTS	Item or service commercially available without modification.
Contract		PA, TA or contract
Contractor		An entity that have a contract with IO or DA
Contractor Release Note	CRN	A document to provide a confirmation from a Performer that the products supplied and/or services performed meet the requirements of Contract.
Construction Readiness Review	CRR	
Counterfeit item		Items that are intentionally manufactured, refurbished or altered to imitate original products without authorization in order to pass themselves off as genuine.
Counterfeit / fraudulent / suspect item	CFSI	
Critical quality activity		Any activity or operation that if not performed correctly may affect safety, functionality or reliability.
Domestic Agency	DA	An organization set up under the ITER Framework Agreement to provide goods or services to the IO through Procurement Arrangements (PA) and Task Agreements (TA).
Equipment	PE/NPE	Pressure Equipment or Nuclear Pressure Equipment
Fraudulent items		Items that are intentionally misrepresented with intent to deceive.
ITER Organization	IO	

Inspection Plan	IP	A plan used for the execution and control of Contract activities. It may also be referred to as a Manufacturing and Inspection Plan (MIP), Inspection and Test Plan (ITP), Control Plan (CP), or other similar terms.
Manufacturer		Any natural or legal person who manufactures an equipment or has an equipment designed or manufactured and markets under his name or trademark.
Mechanical Completion Dossier	MCD	
Manufacturing Database	MDB	
Manufacturing Readiness Review	MRR	
Notified Body	NB	Technical organisation approved in an EU state, either for approval and monitoring of the manufacturer's quality assurance system or for direct product inspection for the manufacture of Pressure Equipment.
Performer		An all-inclusive term used to cover DAs, contractors and subcontractors
Procurement Arrangement	PA	
Quality Class	QC	
Quality plan	QP	Document describing the operational quality system to ensure that Contract requirements will be met, and that evidence of such compliance will be maintained. It covers the whole scope of the Contract including work performed by contractors/subcontractors and addresses all activities performed in connection with the Contract.
Protection Important Component	PIC	As per INB Order (French Order of 07/02/2012)
Responsible Officer	RO	IO primary point of contact to manage a Contract.
Structures, systems and components	SSC	
Subcontractor		An entity that performs work for contractors
Suspect items		Items where there is an indication or suspicion that it may not be genuine.
Task Agreement	TA	

3 References

[1]	Quality Classification Determination (24VQES rev. 6.0 or consequent)
[2]	ITER Quality Assurance Program (QAP) (22K4QX)

[3]	Qualification of Protection Important Components (PIC) (XB5ABP)
[4]	Working Instruction for Processing Construction Nonconformities (U8VPSS)
[5]	Procedure for Management of Nonconformities (22F53X)
[6]	Procedure for the management of Deviation Request (2LZJHB)
[7]	Risk and Opportunity Management Procedure (22F4LE)
[8]	Work Instruction for producing an Inspection and Test Plan for construction (UELU9F)
[9]	Working Instruction for Construction Readiness Review (QXW4KQ)
[10]	Working Instruction for Completion Dossier Preparation (UYUSEE)
[11]	Working Instruction for the Delivery Readiness Review (DRR) (X3NEGB)
[12]	Procedure for Transportation of Components to ITER Site (RY5C6Q)
[13]	Procedure for the CAD management plan (2DWU2M)
[14]	Procedure for Analyses and Calculations (22MAL7)
[15]	Design Review Procedure (2832CF)
[16]	Working Instruction for Manufacturing Readiness Review (44SZYP)
[17]	Implementation plan for design & manufacture of PE/NPE (VE2DSP)
[18]	Inspection Plan (IP) Template (QV7GQF)
[19]	Construction Inspection and Test Plan Template (ITP) (TTPQL2)
[20]	Release Note Template (QVEKNQ)

4 Requirement to define quality class (QC)

The quality class of the SSC must be specified in the Contract.

The Performer may grade the SSC quality class specified in the Contract down to the component levels in accordance with reference [1].

The Performer shall inform the IO RO about any downgrade in the quality classification of components.

The Performer may request the IO RO to determine or change the quality class of SSC.

5 Common requirements for QC 1-4

5.1 Quality management system

The Performer shall establish and implement a quality system based on a recognized quality standard and shall meet the requirements outlined in reference [2].

This quality system shall be capable of ensuring that Contract requirements are met, and that evidence of such compliance is maintained.

In case of PA or TA, the Performer shall submit a description of the quality management system for the DA's acceptance. The DA shall forward the accepted description to the IO RO for information.

In the case of a direct contract with IO, the Performer shall submit a description of the quality management system for acceptance by the IO RO.

5.2 Counterfeit, Fraudulent or Suspect Items (CFSI)

The Performer shall prevent CFSI at all levels of operations including

a) selection of subcontractors

b) control of externally provided processes, products and services

d) monitoring and measurement activities

When CFSI are detected, they shall be managed as nonconformities (6.1.3).

5.3 Commercial-off-the-shelf / COTS items

To procure and utilize COTS, controls through dedication method(s) shall be implemented to ensure that the item or service is adequate for its intended function. In particular, for PIC minimum requirements according to reference [3] shall be applied, including requested documentary traceability as applicable.

5.4 Propagation of requirements

The Performer shall ensure that the relevant requirements outlined in this document are communicated throughout their supply chain.

6 Common requirements for QC 1-3

6.1 Contract management (common QC 1-3)

6.1.1 Responsible Officer

The Performer shall appoint a Responsible Officer to:

- communicate with the IO
- coordinate the planning and performance of the work, including work assigned to subcontractors
- maintain time schedules and issue monthly progress reports
- verify that the quality systems are consistently followed during the execution of the Contract
- assess and oversee quality in subcontractor's premises
- monitor the implementation of IO requirements
- provide IO with periodic assessment of quality performance

6.1.2 Quality plan (QP)

The requirements and guidance for the content of QPs are provided in the Annex 1.

The Performer shall prepare a QP for all Contracts when all contractors and subcontractors are identified. Unless specified otherwise, for research and development activities not used for qualification purposes, only the DA (for TA) or the Contractor (for direct contracts) shall prepare a QP.

Subcontractors shall submit QPs to the Contractor for acceptance.

In the case of PA/TA, the Contractor shall submit its own QP and QPs of the subcontractors to the DA for acceptance, and the DA shall then submit all QPs for the IO RO's acceptance.

In the case of direct contract, the Contractor shall submit its own QP and QPs of the subcontractors to the IO RO for acceptance.

The Performer shall revise the QP if changes occur that require it and submit it for acceptance in the same manner as the original plan.

At the IO RO's request, the Performer shall provide the documents referenced in the QP.

The Performer shall carry out the activities in accordance with the QP accepted by IO RO.

6.1.3 Management of nonconformities

For work on the ITER construction site, the Performer shall manage nonconformities in accordance with reference [4].

Otherwise, the Performer shall manage nonconformities in accordance with reference [5].

6.1.4 Management of deviations

To deviate from Contract requirements the Performer shall initiate a deviation request and follow the process in accordance with reference [6].

6.1.5 Risk management

The Performer shall manage risks in accordance with reference [7].

6.1.6 Access to Performer's premises

The Performer shall ensure that the IO/DA representatives and representatives or regulatory bodies have access to the premises when required to oversee or support the work being executed.

6.2 Engineering (common QC 1-3)

The Performer shall have the design approved by design authorities established through controlled procedures.

The Performer shall submit the final design for the IO RO's acceptance.

6.3 Manufacturing, assembly and installation (common QC 1-3)

6.3.1 Inspection and Test Plan (ITP)

For work on the ITER construction site, the Performer shall plan and implement control measures using the Inspection and Test Plan (ITP) in accordance with reference [8].

6.3.2 Readiness Review (CRR)

For work on the ITER construction site, the Performer shall conduct a Construction Readiness Review (CRR) in accordance with reference [9].

6.3.3 Material certificates

The Performer shall submit material certificates to the IO RO for acceptance.

6.3.4 Manufacturing

If the design is included in the Performer's scope of work, the Performer shall not begin manufacturing until the final design has been accepted by the IO RO.

For work on the ITER construction site, the Performer shall treat the mechanical completion dossier (MCD) in accordance with reference [10].

6.4 IO Acceptance (common QC 1-3)

6.4.1 Contractor release note (CRN)

The requirements and guidance for the content of CRNs are provided in the Annex 3.

Prior to factory acceptance, or shipment, if there is no factory acceptance, of products and/or services, the Performer shall certify in the Contractor Release Note (CRN) that all required verifications, inspections, and tests are complete and satisfactory, and that all necessary documentation is available, and shall submit the CRN to the IO RO for acceptance.

6.4.2 Mechanical Completion Dossier (MCD)

For work on the ITER construction site, the Performer shall submit the MCD in accordance with reference [10].

6.5 Storage and shipping (common QC 1-3)

6.5.1 Conditions to ship - CRN and shipping notification

The Performer shall not ship the products prior to the acceptance of the CRN by the IO RO.

The Performer shall submit a shipping notification to the IO RO and shall not ship the products prior to their acceptance by the IO RO.

6.5.2 Conditions to ship - Delivery Readiness Review (DRR)

The Performer shall not ship the products until the Delivery Readiness Review (DRR) is completed in accordance with reference [11].

6.5.3 Shipping

The Performer shall ship the products in accordance with reference [12].

7 Specific requirements for QC 1

7.1 Engineering (extras for QC 1)

The Performer shall submit a request to use software and/or models for design and operations to the IO RO.

The Performer shall manage CAD works and data in accordance with the reference [13].

The Performer shall perform analyses and calculations in accordance with the reference [14].

The Performer shall conduct design reviews in accordance with the reference [15].

7.2 Manufacturing, assembly and installation (extras for QC 1)

7.2.1 Special processes

For special processes, the Performer shall submit qualification documents and records for the IO RO's acceptance.

7.2.2 Preparation and change of inspection plan (IP, MIP/ITP)

For work on the ITER construction site, the Performer plans control measures using the Inspection and Test Plan (ITP) in accordance with chapter 6.3.1 (reference [8]).

Otherwise, the Performer shall plan control measures using generic Inspection Plans (IP) as follows:

The requirements and guidance for the content of IPs are provided in the Annex 2.

When an (Agreed) Notified Body ((A)NB) is involved, the Performer shall submit the IP to the (A)NB before submitting it to DA or IO.

In the case of PA, the Performer shall submit the IP to the DA for marking intervention points. The DA shall then submit the IP to the IO RO for marking interventions and acceptance.

In case of IO direct contracts, the Performer shall directly submit the IP to the IO RO for marking intervention points and acceptance.

At the IO RO's request, the Performer shall provide the documents referenced in the IP.

The Performer may revise the IP if changes are required and shall submit it for acceptance in the same manner as the original plan, unless instructed otherwise in writing by IO RO.

7.2.3 Readiness review (CRR, MRR)

For work on the construction site, the Performer conducts a Construction Readiness Review (CRR) in accordance with chapter 6.3.2 (reference [9]).

Otherwise, the Performer shall conduct manufacturing readiness review (MRR) in accordance with the reference [16].

7.2.4 Execution of IP (MIP/ITP)

For work on the ITER construction site, the Performer implements control measures using the Inspection and Test Plan (ITP) in accordance with chapter 6.3.1 (reference [8]).

Otherwise, the Performer implements control measures using generic Inspection Plans (IP) as follows:

The Performer shall not begin executing activities until the IP is accepted by the IO RO and shall carry out the activities in accordance with the IP once it is accepted.

The Performer shall not begin executing activities until the MRR has been completed.

The Performer shall notify DA and IO of the intervention points before executing the relevant operations as defined in the IP.

The Performer shall ensure that the IP is readily accessible to those performing the work.

The Performer shall ensure that the IP is updated in a timely manner - each operation shall be recorded at least before the next concerned intervention point so that to allow tracking by IO and DAs of IP execution during operation’s progress (e.g. by using MDB or other equivalent digitalized tools).

The Performer shall ensure that each operation is signed off and dated by the person in charge of the operation.

The Performer shall ensure that records associated with operations (inspection reports, test reports, nonconformity reports etc.) are properly referenced in the IP and made available by suitable means to the party responsible for the intervention.

The Performer shall ensure that each intervention point is signed off and dated by the person carrying out the intervention.IO Acceptance (extras for QC 1)

7.2.5 Manufacturing dossier

Prior to factory acceptance or shipment (in the absence of factory acceptance) of products, the Performer shall submit the manufacturing dossier to the IO RO.

7.3 Storage and shipping (extras for QC 1)

7.3.1 Storage

The Performer shall store the products in accordance with IO technical specifications provided by the IO RO.

8 Specific requirements for PE/NPE

8.1 Qualification of personnel (PE/NPE)

If IO is the Manufacturer of Equipment, the qualification of Performer's personnel shall be carried out in accordance with the requirements of the reference [17].

8.2 Engineering (extras for PE/NPE)

The Performer shall submit the final design for the IO RO's approval.

8.3 Manufacturing (extras for PE/NPE)

If the design is included in the Performer's scope of work, the Performer shall not begin manufacturing until the final design has been approved by the IO RO.

8.3.1 Special processes

If IO is the Manufacturer of Equipment, the qualification of special processes shall be carried out in accordance with the requirements of the reference [17].

8.3.2 Inspection plan

When IO acts as the manufacturer of Equipment under the scope of Module H, a specific column in the IP shall be dedicated to defining control points related to the implementation of Module H. The column labelled "Third Party" or "Other" in templates [18] or [19] may be used for this purpose.

8.4 Storage and shipping (extras for PE/NPE)

When IO acts as the Manufacturer of Equipment, the procedures related to handling, storage, or shipping shall be approved by the IO RO.

9 Annex 1. Requirements and guidance for the content and structure of Quality Plans (QP)

9.1 Content

Quality Plans shall be brief and to the point, while giving sufficient visibility on the control of the activities to be carried out.

The Quality Plan shall identify:

- the critical quality activities and associated controls
- the specific allocation of resources, duties, responsibilities and authority
- details of all contractors/subcontractors and how interfaces will be managed
- the specific procedures, methods and work instructions to be applied
- the specific methods of communication, both formal and informal, to be established between working groups

The level of detail in the plan shall be consistent with:

- the technical requirements of the Contract
- the safety and operational importance of the items involved
- the complexity of the organizations, functions and activities involved
- the degree of design innovation
- the involvement of innovative processes
- the involvement of processes which cannot be fully verified by inspection or test
- the degree to which functional compliance can be demonstrated by inspection or test
- design, performance or manufacturing margins

Much of the generic documentation needed to prepare the Quality Plan will normally already exist as part of the performer's quality documents and supporting procedures. The Quality Plan need only refer to this documentation and show how it is to be applied to the particular Contract.

The Quality Plan may be a single document that covers the whole scope of the Contract, including work performed by subcontractors. The plan may also be the compilation of coordinated separate and well-defined documents.

9.2 Structure

It is not essential for the Quality Plan to follow the structure outlined below which is given for guidance.

The elements listed in the following sections are neither prescriptive nor exhaustive and shall be addressed only where relevant:

9.2.1 Quality Management

The plan shall:

- identify all critical quality activities and associated controls
- identify the different organizations involved
- detail the breakdown of responsibilities
- identify within the different organizations involved the key individuals responsible for:

- ensuring that the activities performed in connection with the particular Contract are planned, implemented and controlled and their progress monitored
- communicating requirements peculiar to the specific Contract to all affected organizations
- resolving problems that may arise at interfaces between the organisations involved

An organization flow chart could facilitate the understanding.

9.2.2 Contract Review

The plan shall indicate how, when and by whom Contract requirements are to be reviewed and the review recorded.

9.2.3 Document

The plan shall show how, when and by whom documents will be controlled.

9.2.4 Design

The plan shall show how, when and by whom design will be controlled, including:

- when, how and by whom the design process is to be carried out, controlled and documented
- the arrangements for the review, verification and validation of design output conformity to design inputs requirements

Where applicable, the plan shall indicate the extent to which the IO will be involved in design activities, such as participation in design reviews and design verification.

The plan shall reference applicable codes, standards and regulatory requirements.

The plan shall:

- list the computer programs to be used
- indicate how, when and by whom they will be controlled

9.2.5 Procurement

The plan shall show how, when and by whom procurements will be controlled, including:

- any important items or activities that are to be purchased or subcontracted
- the relevant quality assurance requirements
- the proposed contractors or subcontractors
- the methods to be used to evaluate, select and control contractors and subcontractors
- the methods to be used to satisfy regulatory requirements, which apply to, purchased or subcontracted products

9.2.6 Identification and Control of items

Where traceability is a requirement or necessary for the adequate control of the work, the plan shall define its scope and extent, including:

- how affected items are to be identified
- how Contract and regulatory traceability requirements are identified and incorporated into working documents
- what records relating to such traceability are to be generated and how and by whom they are to be controlled

9.2.7 Manufacture

The plan shall indicate how processes, manufacture, assembly, inspections and tests will be controlled. Where appropriate, the plan shall introduce or refer to:

- relevant documented procedures and work instructions
- the methods to be used to monitor and control processes
- criteria for workmanship
- use of special and qualified processes and associated personnel
- tools, techniques and methods to be used

9.2.8 Inspection and Test

The plan shall show how, when and by whom inspection and test would be controlled, including:

- any inspection and test plan to be used, and how and by whom they are reviewed and approved
- how and by whom inspection and test reports are reviewed and approved
- acceptance criteria to be applied
- acceptance of purchased or subcontracted items
- any specific requirements for the identification of inspections and tests status
- the extent to which the IO and (Agreed) Notified Bodies will be involved, such as witnessing inspection and test

9.2.9 Measuring and Test equipment

The plan shall indicate the control system to be used for measuring and test equipment specifically used in connection with the particular Contract, including:

- identification of such equipment
- method of calibration
- method of indicating and recording calibration status

9.2.10 Handling, Storage, Packing, Shipping and Delivery

The plan shall show how, when and by whom handling, storage, packing, shipping and delivery will be controlled:

- how Contract requirements for handling, storage, packaging and shipping are to be met
- how the item will be delivered to the specified site in a manner that will ensure that its required characteristics are not degraded

9.2.11 Records

The plan shall indicate:

- how records are to be controlled, including how legibility, storage and retrievability will be satisfied
- what records are to be kept
- what records are to be supplied to the IO, when and by what means
- how and by whom the records are reviewed and approved prior to inclusion in the deliverables handed over to the IO
- what form the records will take (such as paper, microfilm, tape, disc or other medium) and in what language the records will be provided

9.2.12 Deviations and Nonconformities

The plan shall indicate how, when and by whom deviations and non-conformances will be processed including those originating from contractors and subcontractors.

9.2.13 Training and Qualification

The plan shall address:

- any specific training requirement for personnel
- how such training is accomplished and recorded

9.2.14 Statistical Techniques

Where statistical techniques are relevant for establishing, controlling and verifying process capability and item characteristics, they shall be indicated in the plan.

9.2.15 Assessment

The plan shall indicate how, when and by whom the implementation and effectiveness of the Quality Plan will be monitored.

10 Annex 2. Requirements and guidance for the content of Inspection Plans (IP)

An IP shall identify:

- Requirements and instructions applicable to those operations
- Operations to be inspected or witnessed by DA, IO and (Agreed) Notified Body ((A)NB).
- Documents providing traceability and recording of the verification and completion of these operations.

The level of detail in the IP shall be such as to prevent the inadvertent bypassing of quality activities and to enable adequate planning, monitoring and verification of operations.

The IP shall be written in English for IO and, if necessary, in Performer's working language to be easily understood by those carrying out the work.

The IP shall identify who is performing each intervention point.

A suggested format for the IP can be found at the IP template [18]. Alternative formats (including in electronic form) may be acceptable at discretion of IO RO in advance of their intended use.

11 Annex 3. Requirements and guidance for the content of Contractor Release Notes (CRN)

The Release Note shall be prepared using the Release Note template [20].

The Release Note shall:

- Certify that the product or service meets the Contract requirements
- List the documents and records constituting the manufacturing dossier and their status
- List any outstanding obligations

The list of documents and records below is non-exhaustive and shall be tailored to meet the Contract requirements.

1. Management Documents:
   - Quality Plan
   - List of contractors/subcontractors
2. Raw Materials - Metals, Ceramics and Other Materials
   - Procurement Specifications
   - Sub-Orders
   - Material Certification traceable to components
3. Manufacturing Documents
   - Fabrication Procedures (machining, forming, soldering, wiring)
   - Welding/Brazing Documents (WPS, PQR, WPQ etc...)
   - Weld Plan
   - Weld Inspection Record
   - Non-Destructive Examination Procedures (VT, PT, MT, RT, UT etc...)
   - Cleaning procedure
   - Surface Treatment Specification
4. Assembly and Test Documents
   - Assembly Sequences, Control Specifications and Procedures
   - Pressure Test Procedure
   - Helium Leak test procedure
   - Function Test Specifications
   - Control Reports (Visual Examination, Non-Destructive Examination, Electrical and
   - Insulation Tests, Leak Tests, Pressure Test, Certification of Cleanliness, etc.).
   - Deviation and Nonconformity Reports
   - Completed Manufacturing & Inspection Plan(s)
   - Drawings marked “As Built”

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2EZ9UM

VERSION CREATED ON / VERSION / STATUS
28 May 2019 / 2.5 / Approved

EXTERNAL REFERENCE / VERSION

Guideline

ITER Vacuum Handbook

ITER Vacuum Handbook.
Updated to include changes reviewed under scope of mPCR 260 Change Notice "PCR-M260 - Application of ITER Vacuum Handbook to standard products, clarification of requirements and minimal update to reflect the phase of the ITER project" for "ITER Vacuum Handbook (2EZ9UM v2.3)": review and approval (SK47R3 v1.0).

v2.5 is v2.3+ changes introduced through mPCR260. there is no change between v2.4 and v2.5.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Worth L.**	**28 May 2019:signed**	**IO/DG/COO/PED/FCED/VS**
Co-Authors			
Reviewers	**Pearce R.**	**28 May 2019:recommended**	**IO/DG/COO/PED/FCED/VS**
Approver	**Lee G.- S.**	**28 May 2019:approved**	**IO/DG/COO**
Document Security: Internal Use *RO: Chiocchio Stefano*			
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Change Log			
ITER Vacuum Handbook (2EZ9UM)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	27 Aug 2008	
v1.1	Signed	28 Aug 2008	
v1.2	Signed	22 Oct 2008	
v1.3	Signed	27 Oct 2008	
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v2.1	In Work	27 May 2009	
v2.2	Signed	28 May 2009	
v2.3	Approved	12 Jun 2009	VH ref. Original sentence V2.2 Modified sentence V2.3 7.1.5 Weld Finish & Repair The size and magnitude of weld leaks found shall be reported to the ITER Vacuum RO and no weld repairs shall be carried out without prior agreement. All weld repairs shall be qualified in accordance with the relevant design and construction codes where applicable, and with Section 7.1.2 above. Where RCCMR or ASME VIII is not applied, if a weld leak is found, the repair procedure shall be subject to specific acceptance by the ITER vacuum RO as well any other relevant approvals. The size and magnitude of all leaks found on welds forming a vacuum boundary shall be reported to the ITER Vacuum RO. All repair welds forming part of a vacuum boundary shall be qualified in accordance with the relevant design and construction codes where applicable, and with Section 7.1.2 above. Where RCCMR or ASME VIII is not applied, if a weld leak is found, the repair procedure shall be subject to specific acceptance by the ITER vacuum RO as well any other relevant approvals. 9 Confinement and Vacuum Containment VQC 2A components that are considered to be vulnerable shall

			normally be doubly vacuum contained with a monitored interspace connected to the Service Vacuum System. VQC 2A components that are considered to be vulnerable are recommended to be doubly vacuum contained with a monitored interspace connected to the Service Vacuum System. 12 Pipework Where practical, for components classified as VQC 2A, water pipes forming part of the cryostat vacuum boundary shall be doubly contained. Where it is not practical to doubly contain the pipework, all welded joints shall be full penetration butt welds subject to 100% Non-Destructive Testing (NDT). It is recommended that pipework classified as VQC 2A, water pipes forming part of the cryostat vacuum boundary, be doubly contained. Where the pipework is not doubly contained, all welded joints shall be full penetration butt welds subject to 100% Non-Destructive Testing (NDT). 17.2 Design of Bellows All vulnerable bellows for use on VQC 1 and 2 systems shall be of double construction (or accepted multilayer design) with a monitored interspace, unless they are accessible for maintenance and fitted behind an approved interlocked isolating valve. Where vulnerable bellows are be used on VQC 2 systems it is recommended that they be of double construction (or accepted multilayer design) with a monitored interspace.
v2.4	Revision Required	10 Dec 2018	Updated to include changes reviewed under scope of mPCR 260 Change Notice "PCR-M260 - Application of ITER Vacuum Handbook to standard products, clarification of requirements and minimal update to reflect the phase of the ITER project" for "ITER Vacuum Handbook (2EZ9UM v2.3)": review and approval (SK47R3 v1.0)
v2.5	Approved	28 May 2019	No change from V 2.4. v2.5 is v2.3 plus changes introduced by mPCR 260. V2.5 is to be applied for future contracts/PAs.

ITER Vacuum Handbook

1 Background

ITER will include one of the largest and the most complex high vacuum systems ever built. Reliable vacuum is key to the success of the ITER project. A characteristic of high vacuum is that the functionally of a whole system can be lost by not appreciating and paying attention to the effect of small details. Due to the pervasive nature of vacuum in the ITER machine, there are very few ITER systems which will not have an important vacuum interface. Orders of magnitude improvements in vacuum reliability are required compared to existing and past fusion devices to achieve the ITER goals because of the scaling in the number of components and the physical size of ITER.

There are two main vacuum systems on ITER, the Torus primary vacuum which requires ultra-high vacuum (UHV) conditions, and the cryostat primary vacuum which requires clean insulation vacuum conditions with permissible operating pressures typically 2 orders of magnitude higher than the torus. In addition, there are secondary vacuums and a cryogenic guard vacuum system. Details are given in Appendix 1.

2 Scope of this Handbook

This Vacuum Handbook outlines the mandatory requirements for the design, manufacturing, testing, assembly and handling of vacuum items to realise and subsequently to maintain the various different ITER vacuum systems. In addition, this Handbook provides significant guides and helpful information which can be used in the production of procurement specifications for ITER components.

The ITER Vacuum Handbook is issued as a high level project requirements document since it is imperative that the requirements contained in this Handbook are followed by the International Organisation, the Domestic Agencies and Industries to ensure that ITER operations are ultimately successful.

This Handbook is supported by a set of Attachments and Appendices. The Attachments are subject to the same approval process as the main handbook and contain detailed mandatory requirements. With the exception of Appendices 3 & 4 the Appendices are for guidance and provide detailed information, guides, specifications, relevant processes and lists of standard and approved components, vacuum materials, etc. Appendices 3 & 4 contain lists of materials (and associated processes) which have been approved for use on, or in, the ITER vacuum systems. Only materials (or associated processes) listed in Appendices 3 & 4 shall be used in, or on ITER vacuum systems. All Appendices are working documents subject to regular update.

The Appendices can be used by *suppliers* to aid the production of vacuum components, specifications and procedures which satisfy the mandatory requirements of the ITER Vacuum Handbook.

2.1 Communications and *Acceptance*

To satisfy the requirements of this handbook *acceptance* or *accepted* is called for in various places, this *acceptance* is to be given by the ITER Vacuum Responsible Officer (RO) or his or her nominated representative. *Acceptance* is to be a positive and recorded action, either by signature or by electronic means. The ITER Vacuum RO will respond in the shortest possible time from receipt of the request, normally within two weeks. An explanation will be provided if the proposal is rejected or if modification is required.

Requests for *Acceptance* shall be sought through the submission of the Request for *Acceptance* (ITER_D_9AY4HD).

Where the Interface compliance check list of an ITER Procurement Arrangement is signed by the ITER Vacuum Responsible officer this shall be taken as *acceptance* of these items which are detailed in the Procurement Arrangement. Where an ITER Procurement Arrangement does not provide adequate details required for *acceptance* of these items, then the PA can define the processes to be followed leading to *acceptance* in which case these processes shall be followed rather than processes of the ITER Vacuum Handbook.

Iterations with both the Domestic Agencies and industry are expected to be necessary to meet the requirements of this Handbook.

Normal communication and approval channels set up in any specific contract for supply should not be bypassed - rather that they should be the normal route by which *acceptance* requests are made and received.

A possible route of communication and acceptance would therefore be:-

Supplier (Contractor) ↔ Domestic Agency Contract Responsible Officer ↔ ITER Technical Responsible Officer ↔ ITER Vacuum Responsible Officer.

A definition of terms can be found in Appendix 21.

3 Vacuum Classification System (VQC)

3.1 Definition

Every vacuum component is given a Vacuum Classification to denote its area of service on ITER. These are defined as:

VQC 1X: Torus primary vacuum components or components which become connected to the torus high vacuum through the opening of a valve during normal operations.

VQC 2X: Cryostat primary vacuum components or components which become connected to the cryostat vacuum through the opening of a valve during normal operations.

VQC 3X: Interspaces and auxiliary vacuum systems connected to the service vacuum system or roughing lines.

VQC 4X: Cryogenic guard vacuum systems or items connected to the cryogenic guard vacuum system.

VQC N/A: Components not exposed to vacuum.

Where:

X = A denotes boundary components.

X = B denotes components within vacuum but which do not form part of the vacuum boundary.

Where a component is part of the boundary between two different vacuum classes, it shall normally meet the more demanding requirements of the higher class unless the division between classes is shown on the drawings. Joints which separate classes shall always be classified according to the requirements of the more demanding class. The surface finish requirements appropriate to each class are to be applied. Surface cleaning of the less highly classified surface may be in accordance with the reduced requirements of that classification provided that the more highly classified surface is not degraded in the process.

Some examples of classification are:

- In vessel divertor cassette water cooling pipe - VQC 1A.
- In-vessel remote handling rail - VQC 1B.
- Cryogenic lines within the cryostat - VQC 2A.
- Support within the cryostat - VQC 2B.
- Cryogenic transfer-line between cryo-plant and tokamak complex - VQC 4A.

Typical base pressures and pumping speeds for the various vacuum systems are given in Appendix 1.

3.2 Notification of the Vacuum Classification

The VQC for a particular component shall be marked on any drawing related to and stated in any specification for that component. If this is not the case, the classification can be provided by the ITER Vacuum Responsible Officer (RO) upon request.

3.3 Components without a Vacuum Classification

3.3.1 Supply

In order ensure vacuum components which are intended for service on ITER and are not classified under section 3 (such as, for e.g., mechanical displacement pumps), meet the requirements for safety and performance the IO shall approve Technical Specifications for the supply of such equipment. Technical Specifications shall be submitted to the ITER Vacuum RO for review and subsequent approval prior to the commencement of the procurement process.

3.3.2 Connections Between Systems

An item of vacuum equipment which is not classified under section 3 may be connected to an item with a VQC, e.g. a leak detector may be connected to a valve on the cryostat or a roughing pump may be connected to the torus vacuum system. In all such cases, the use of such items and the operations for which they are required shall be under administrative control. A written scheme of work shall be submitted on the appropriate form to the ITER Vacuum RO. The main criterion for approval of such a scheme of work (other than the necessity of the work being carried out) shall be an assessment by the ITER Vacuum RO of the possibility of contamination of the system bearing the VQC.

4 Deviations and Non-Conformances

Requests for deviations from, and non-conformance with, the requirements of the ITER Vacuum Handbook shall be made to the ITER IO in writing following the procedures detailed in the ITER Quality Assurance Program (IDM Ref: ITER_D_22K4QX) and ITER Deviations and Non-Conformances (IDM Ref: ITER_D_22F53X) documents. Recommendations on the approval of the non-conformance report will be made by the ITER Vacuum RO.

5 Materials for Use in Vacuum

5.1 Materials Accepted for Use in Vacuum

Only materials *accepted* for the relevant Vacuum Classification shall be used on ITER vacuum systems. All material for use in vacuum shall be clearly specified at the design stage and certified in accordance with EN 10204 3.1 or 3.2 before being used in manufacturing.

Materials which may be used without prior agreement on vacuum systems with the Vacuum Classifications stated in the table are listed in Appendix 3. Materials listed in this Appendix which are shown as being subject to restricted use for a particular Vacuum Classification are subject to either an overall quota or to particular restrictions on their position of use. *Acceptance* for any particular vacuum application of such a material shall be obtained by submitting the Material Acceptance Request Form (ITER_D_2MGWR4) to the ITER Vacuum RO. An example of this completed form is to be found in Appendix 3.

5.2 Adding Materials to the Accepted List for Vacuum

Materials which are not on the accepted list may be proposed for use in vacuum. If the vacuum properties of the material are not sufficiently well documented for an assessment to be carried out, a programme of measurement of the relevant properties shall be agreed between the proposer and the designated ITER Vacuum RO.

Details of materials to be considered for acceptance shall be submitted to the ITER Vacuum RO using the Material Acceptance Request Form (ITER_D_2MGWR4). The proposer shall agree in advance with the ITER Vacuum RO a plan detailing the type and method of testing to be used to qualify the material for use. The Materials Acceptance Request Form along with the test data, report and supporting documentation, including any *supplier's* data (Certificates of Conformity, etc.), shall be submitted for consideration. These shall be assessed by the ITER Vacuum RO who will communicate the acceptance, refusal or restrictions on usage of the material to the originator of the request.

Materials qualified in this way may be added to Appendix 3.

5.3 Metallic Machined Components and Fittings

5.3.1 Final Thickness < 5 mm

All VQC 1A components which are machined from steel, austenitic steel or superalloys and which are of final thickness less than 5 mm and VQC 2A components which are machined from steel, austenitic steel or superalloys and which are of final thickness less than 2 mm and are designed to contain cryogenic helium[1], shall be made from cross-forged material which is Electro-Slag Remelted (ESR) or Vacuum Arc Remelted (VAR).

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.

5.3.2 Final Thickness between 5 mm and 25 mm

VQC 1A components which are machined and are of final thickness between 5 mm and 25 mm shall be manufactured from approved steel (listed in Appendix 3), in the form of stock which has been cross-forged (upset forged).

These requirements are synopsised in Table 5-2.

5.3.3 Manufacture of Vacuum Flanges

Both halves of demountable flanges using metal seals are to be manufactured from cross or upset forged material.

[1] At the time of writing this requirement is under approval and shall be included to the next version of this Handbook.

Stainless steel used for the manufacture of knife-edge sealed flanges of any thickness for all vacuum classifications shall be from cross-forged ESR grade material blanks.

5.4 Outgassing

The outgassing rates of materials used on ITER vacuum systems shall be consistent with the values in Table 5-1. Appendix 17 gives details on how outgassing requirements are derived, how they can be achieved and how they may be measured.

		Maximum Steady State Outgassing rate Pa.m^3.s^{-1}.m^{-2}		
VQC+	**Outgas temperature °C**	**Hydrogen isotopes**	**Impurities**	**Testing Guidelines**
1	100‡	1 x 10^{-7}	1 x 10^{-9}	Appendix 17
2	20	1 x 10^{-7*}		Appendix 17
3	20	1 x 10^{-8}		Appendix 17
4	20	1 x 10^{-7}		Published data and conformity to clean work plan.

For VQC 2, 3 and 4, the outgassing rate excludes the partial outgassing rates for water and hydrogen.

‡ The outgas test temperature can be reduced to 20 °C for components which normally operate at cryogenic temperatures.

+ For CFC refer to section 26.7

* In the case of resins for magnets it is considered that this target outgassing rate will be achievable. However, a factor of 10 increase will be permitted as an acceptance criterion.

Table 5-1 - Outgassing rates pertaining to VQC

These limits have been produced by taking into account the total surface area expected, the available pumping speed, the desired pressure and post assembly conditioning time, with due consideration of what is reasonably achievable. The addition of novel high surface area components to the design requires specific *acceptance* and appropriate limits to be assessed.

Published data and/or experimental trials shall be used to show design and process consistency with the limits.

An outgassing rate acceptance test shall be performed for all VQC 1 components to an *accepted* procedure such as those described in Appendix 17. Exceptions will be *accepted* for components which normally operate at a pressure above 1 Pa. Outgassing acceptance tests may, with prior *acceptance*, be performed using representative samples which follow, and are subjected to, the complete manufacturing process.

Where it is agreed that a specific vacuum component should not be subjected to a specific outgassing rate acceptance test, compliance shall be demonstrated by conformity to a clean work and quality plan.

5.5 Hot Isostatic Pressing

Hot Isostatic Pressing (HIP) of sintered material is allowable for use on all VQC components, provided that it is demonstrated that the components meet the mechanical and leak rate requirements for the proposed application and the vacuum boundary thickness is greater than 5mm. It must be demonstrated that HIP formed components comply with the outgassing rates in Table 5-1. Proposals for the use of HIP formed components, and the procedure for qualification of the components for use as vacuum containment, shall be subject to prior *acceptance* at the design stage.

These requirements are synopsised in Table 5-2.

5.6 Castings

For VQC 1, 2A & 3, metallic castings shall not normally be used. Where it is considered that a casting technology could provide acceptable porosity and meet the outgassing and leak rate requirements in the final application, then a vacuum properties validation program shall be proposed for *acceptance*.

These requirements are synopsised in Table 5-2.

5.7 Plate Material

Where hot or cold rolled plate material is used, it is recommended for all vacuum classes, that a surface parallel to the direction of rolling forms the vacuum boundary. This is due to the possibility of long leak paths caused by the stratification of inclusions.

For VQC1A applications which have been assigned Remote Handling Class 3 or are Non-RH classified (ITER_D_2FMAJY) where the component becomes embedded in ITER and could not in future be changed, hot or cold rolled plate material (approved steels from Appendix 3) produced with conventional smelting and refining processes such as Argon-Oxygen Decarburization (AOD), Vacuum Arc decarburization (VOD)) shall not be used where the transverse cross section across the vacuum boundary (wall thickness) is less than 25mm.

Where for VQC1A hot or cold rolled plate material (approved Steel – Appendix 3) is used with the transverse cross section crossing the vacuum boundary (wall thickness less than 25 mm), ESR or VAR low inclusion rate material shall be used which meets the inclusion limits as specified in Section 5.3.1 The component shall also be proven by leak testing in an environment which conforms as closely as possible to the operating conditions (See Section 25) with due consideration taken of the effects of possible leaks along laminations on the response time for the test method.

These requirements are synopsised in Table 5-2.

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 5-2 Synopsised requirements pertaining to metallic components

6 Cutting and Machining

6.1 Use of Cutting Fluids

6.1.1 General

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

6.1.2 VQC 1 and 3 Cutting Fluids

Cutting fluids for use on VQC 1 and 3 systems shall be water soluble, non-halogenated and phosphorus and sulphur Free. The maximum allowable content of halogens, phosphorus, and sulphur is 200 ppm (each)

Accepted cutting fluids for use in VQC 1 and 3 vacuum applications are listed in Appendix 4. The use of other cutting fluids requires prior *acceptance*.

Acceptance for the use of any particular non-approved cutting fluid shall be obtained by submitting the Fluid Acceptance Request Form (ITER_D_48XLVJ) to the ITER Vacuum RO. An example of this form is to be found in Appendix 4.

6.1.3 VQC 2 and 4 Cutting Fluids

For VQC 2 & 4 vacuum applications it is recommended that cutting fluids be water soluble, non-halogenated and phosphorus and sulphur free (< 200 ppm for each). They should be chosen from those listed in Appendix 4. Where this recommendation is not followed particular care shall be taken to ensure the appropriateness of the cleaning procedures (See section 24).

6.2 Cleaning Prior to Joining

To minimise the risk of trapped contamination which can subsequently cause leaks or enhanced outgassing, parts and sub-components shall be degreased using solvents or alkaline detergents, rinsed with demineralised water, and dried prior to joining in accordance with Section 24 below. The use of halogenated solvents is forbidden at any stage for systems of class VQC 1 and 3. Accepted fluids are listed in Appendix 4.

7 Permanent Joining Processes

Permitted joining techniques for vacuum applications and their applicability to each VQC are shown in Table 7-1. Proposals for joining techniques not listed here shall be submitted for prior *acceptance*.

7.1 Welded Joints

Lack of attention to the details of vacuum sealing weld design, qualification and testing has proved to be a significant cause of vacuum leaks on vacuum systems.

All vacuum welds, except those excluded below, shall be qualified, produced and inspected in accordance with Attachment 1. The requirements of Attachment 1 are mandatory until superseded by the ITER baseline Welding Handbook.

Where there is regulatory requirement to design and subsequently build a vacuum system to RCC-MR or ASME VIII, the requirements of these codes shall take precedence over the requirements of Attachment 1, while remaining in compliance with Section 7.1.6. In other cases where vacuum sealing welds are to be qualified, produced and inspected to meet a code, and there is variation between the requirements of the code and Attachment 1, the more extensive or stringent requirements shall be applied.

	VQC 1		VQC 2		VQC 3		VQC 4	
	A	B	A	B	A	B	A	B
Welded joints	✓	✓	✓	✓	✓	✓	✓	✓
Brazed/soldered joints	✝	✝	✝	✝‡	✓	✓	×	✓
Diffusion bonding	✓	✓	✓	✓	✓	✓	✓	✓
HIP	✓	✓	✓	✓	✓	✓	✓	✓
Compression joints	×	×	✝	✝	✓	✓	✓	✓
Adhesive bonding	×	✝	✝	✝	✝	✝	✝	✝
Explosion bonding	✓	✓	✓	✓	✓	✓	✓	✓

✓ - indicates an acceptable technique × - indicates an unacceptable technique

✝ - application specific *acceptance* required

‡- For soldering of super conducting joints see Section 7.2

Table 7-1 Joining methods applicable to VQC

7.1.1 Joint Configuration

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, for all vacuum classes, vacuum sealing welds shall be either internal (i.e. facing the vacuum) or external. In VQC 2, double sided welding may be used where unavoidable, but an NDT inspection schedule giving 100% volumetric examination must be used to ensure that a full-thickness melt zone has been achieved.

The use of stitch welds on the vacuum facing side is prohibited.

For VQC 1A, VQC 2A and VQC 3A on the boundary to air or water, full penetration welds are required.

For VQC 4A (process to insulation vacuum) welds full penetration welds are required.

It is good engineering practice to design joints to be accessible for repair if necessary.

Butt welded joints are preferred to fillet or lap joints, since testability is improved. Fillet, corner, lap and cross joints should be avoided wherever possible on VQC 1 systems.

Welds shall normally be made in such a way that they can be leak tested at the time of completion. Welds that cannot be inspected (see Sections 7.1.4 & 7.1.6) are not permitted for use on VQC 1 and VQC 3 and should be minimised for use on VQC 2 and VQC 4. Where leak detection is not practical at the time of completion, a test plan including provision for repair of the weld must be *accepted* at the design stage.

7.1.2 Qualification of Welding Processes

Qualification of welding processes for use on vacuum sealing welds shall follow the requirements of Attachment 1 and section 7.1.

A welding and inspection plan shall always be submitted to the ITER IO.

7.1.3 Selection of the Welding Process

The selected welding technique for vacuum applications (e.g. electron beam, laser or TIG welding) should produce a clean, pore free weld with minimal oxidation. Autogenous welding shall be used where practical.

7.1.4 Inspection and Testing of Production Welded Joints

All such inspection and testing shall be carried out using approved procedures in accordance with Attachment 1.

For all VQC 1A, VQC 2A water boundaries, vacuum boundary welds which become inaccessible and VQC2A cryogenic pipework connections, 100% volumetric examination of production welds shall be performed, unless a method of pre-production proof sampling is approved.

For VQC 4A (process to insulation vacuum) 100% volumetric examination of production welds shall be performed, unless a method of pre-production proof sampling is approved.

The range of thickness and preferred volumetric examination method to be applied is given in Table 7-2.

Wall Thickness (wt) (mm)	**Preferred Volumetric Examination Method**
wt < 8	Radiography
8 < wt < 19	Radiography & Ultrasonic
wt > 19	Ultrasonic or radiography
Note: For wt > 19 mm ultrasonic examination of welds is preferred only in cases where radiographic examination would require excessive exposure times.	

Table 7-2 Range of wall thickness and preferred volumetric examination method to be applied

For all other vacuum boundaries, volumetric examination of 10% of production welds shall be performed with the wall thickness limits specified in Table 7-2, unless a method of pre-production proof sampling is agreed by the ITER IO.

On welds forming the vacuum boundary the use of liquid penetrant testing (LPT) or magnetic particle techniques shall not in general be permitted for the inspection of welds or in the inspection of weld preparations. This is because such substances may block leaks temporarily and can be difficult to remove satisfactorily.

Where there is a mandatory requirement to build a component to a code then the flexibility of the code to avoid the use of LPT on welds forming the vacuum boundary shall be a key factor in the assessment of that code for selection. The selection process shall be recorded and *accepted*.

Where a code selected for building a component requires the use of a qualified surface examination method, and LPT cannot be avoided, only the ITER vacuum qualified liquid dye penetrant (see Appendix 4) may be used. If the use of LDP is permitted, then cleaning must be performed to procedures qualified and subsequently *accepted* by the ITER Vacuum RO.

For VQC 1B welds which are subject to high cyclic stresses, the use of ITER qualified LDP for detection of surface defects is permitted subject to notification of this application to the ITER Vacuum RO.

For VQC 2B and 4B the use of ITER qualified LDP is permitted. The method of application and subsequent removal of LDP shall be performed to procedures qualified and *accepted* by the ITER Vacuum RO.

7.1.5 Weld Finish & Repair

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.

All weld regions shall be free from scale, voids, blowholes, etc., and there shall be no visible evidence of inclusions.

The size and magnitude of weld leaks found shall be reported to the ITER Vacuum RO and no weld repairs shall be carried out without prior agreement.

All weld repairs shall be qualified in accordance with the relevant design and construction codes where applicable, and with Section 7.1.2 above. Where RCCMR or ASME VIII is not applied, if a weld leak is found, the repair procedure shall be subject to specific *acceptance* by the ITER vacuum RO as well any other relevant approvals.

7.1.6 Helium Leak Testing of Production Welds

All vacuum sealing welds in each VQC shall be subject to helium leak testing in accordance with the procedures of Section 25.

Where multi-pass welding is required in the production of components of VQC 1A and VQC 2A, it is recommended that leak testing of the root weld pass shall be performed with only this pass completed. However, for multi-pass welding that takes place on the ITER site, this requirement is mandatory.

If it has been agreed that liquid dye penetrant may be used for testing such a weld (see Section 7.1.4), the root weld leak test shall be performed before the application of this liquid.

Any leak which is found in the root weld to be above the minimum detectable leak rate of the equipment which has been *accepted* for use in the *accepted* procedures for such tests, must be repaired and re-tested before proceeding with further weld passes.

In all cases, a further leak test shall be carried out (see Section 25).

7.1.7 Helium Leak Testing after Repair of Welds

All repaired vacuum boundary welds shall be subject to full vacuum leak testing in accordance with the procedures of Section 25.

7.2 Brazed and Soldered Joints

Brazing shall be carried out in a vacuum, hydrogen or inert gas atmosphere. Torch brazing is not permitted except where unavoidable for VQC 2B. Where the use of brazing flux is unavoidable a cleaning procedure shall be qualified and submitted for *acceptance* to the ITER vacuum RO.

Brazing materials which contain silver are subject to specific quotas for components for VQC 1, 2 or 3 in systems where the irradiation environment may lead to significant silver transmutation to cadmium. The use of such materials is subject to prior *acceptance*.

Brazing is not permitted for any water to vacuum joint in VQC 1, 2 or 3.

Brazing is not permitted for VQC 4A where there is contact with cryogenic fluid.

All brazing techniques shall be to an *accepted* standard or to a procedure *accepted* prior to manufacture.

On account of the relatively high vapour pressure of the solder, soft soldering (< 400°C with Sn, Zn, alloys of Pb, Cd, etc) shall not be permitted for VQC 1 or VQC 2A, or VQC 3A and is only allowable on VQC 2B for applications which operate at a temperature < 60 K.

7.2.1 Design of Brazed Joints

The design of brazed joints shall be such as to minimise the risk of trapped volumes.

7.2.2 Qualification of Brazed joints

All brazing techniques shall be qualified to an *accepted* standard or to an *accepted* qualification programme. Tests on pre-production samples of brazed joints shall be performed to *accepted* procedures or to an *accepted* standard. Brazing procedure qualification shall be compliant with EN 13134:2000 (or equivalent).

7.2.3 Inspection and Testing of Brazed Joints

Brazed joints shall be subject to qualification to ensure the vacuum integrity of the joint.

All brazed joints shall be inspected visually to ensure that the vacuum exposed braze regions are clean, flush and free from voids, blowholes, etc., that there is no visible evidence of inclusions and that the braze material has filled the joint without excessive over-run.

Where practicable, radiography of an agreed percentage sample of brazed joints shall be carried out. Where this is not practicable, then samples shall be produced for sectioning and microscopic examination.

The use of liquid dye penetrant or magnetic particle techniques shall not be permitted for the inspection of brazed joints or in the inspection of joint preparations.

All brazed joints which form part of a vacuum boundary shall be subject to 100% helium leak testing.

No braze shall be re-run for rectification of any sort without prior agreement.

7.3 Diffusion Bonding

Diffusion bonding of joints is acceptable for all VQC. If it is used, diffusion bonded inter-layers shall comprise materials listed in Appendix 3. Diffusion bonded joints shall be subject to the same vacuum qualification procedures as brazed joints to ensure the integrity of the joint and compliance with the requirements of this Handbook.

7.4 Explosion Bonding

Explosion bonding of metals is acceptable for all VQC. Explosion bonded joints shall be subject to the same vacuum qualification process as brazed joints to ensure the integrity of the joint and compliance with the requirements of this Handbook. Existing qualifications of the process may be used for VQC2 applications if compliant with the requirements of this Handbook.

7.5 Adhesive Bonding

Adhesive bonding may only be used in limited circumstances (see Table 7-1) and using materials listed in Appendix 3.

8 Surface Finish

8.1 Surface Roughness

Metallic components for different VQC shall be supplied with the maximum average surface roughness listed in Table 8-1. Surface roughness is defined in accordance with ISO 4287: 2000.

Classification	Maximum average Surface Roughness Ra (μm)	Measurement Technique
VQC 1	6.3	Electric stylus
VQC 2	12.5†	Electric stylus
VQC 3	12.5	Electric stylus
VQC 4	12.5	Electric stylus
† Where to satisfy this surface roughness requirement additional machining would be required a rougher surface is accepted provided the surface is easily cleanable and can be shown not to catch fibres when wiped with a lint free cloth.		

Table 8-1 - Maximum permissible average surface roughness for metals

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

- Machining.
- Electropolishing.
- Bead Blasting in a slurry in a water jet with alumina or glass beads.
- Surface Passivation / Pickling (see Section 24.4).

All processes on vacuum surfaces shall be followed by appropriate cleaning of the surface (see Section 24 below).

8.2 Coatings

Only materials accepted by ITER for the relevant Vacuum Classification shall be used for coatings on ITER vacuum systems (see Section 5).

Surface coatings for VQC1 shall be subject to qualification and *acceptance* at the design stage. The assessment of the coating shall include consideration of :-

- The risk of the coating producing trapped volumes and temporary leak blocking.
- The method of applying the surface coating (e.g. painting, chemical, plasma spray, etc.).
- The chemical composition, morphology, cleaning and outgassing of the surface coating.
- Conformance of the coating with the ITER outgassing requirements as detailed in Section 5.4.
- The method for testing the adhesion of the surface coating to the substrate.

9 Confinement and Vacuum Containment

Confinement is the term used for the physical enclosure of hazardous substances (e.g. tritium).

“Vacuum containment” is a term used for vacuum tight boundaries which cope with differential pressure in either direction. Vacuum containment may also provide a confinement function.

Vulnerable components are generally considered to be those components which have been shown to exhibit a failure rate higher than 10^{-5} per year in an experimental environment and typically include windows, bellows, lip seals, flexible hoses, metallic to non-metallic joints, feedthroughs, electrical breaks, thin walled material (<1.5 mm), and demountable seals. Reliability data and references can be found in Appendix 18.

VQC 2 high voltage electrical breaks and high voltage feedthroughs are considered vulnerable only if they have a specified failure rate greater than 10^{-5} per year or have been shown, in the specific design proposed, to exhibit a failure rate greater than 10^{-5} per year.

VQC 1A components that are considered to be vulnerable shall be doubly vacuum contained with a monitored interspace connected to the Service Vacuum System (see Section 11). This requirement is necessary to achieve overall machine reliability. Lip seals which are accessible for repair in port cells are excluded from this requirement but shall have provision for remote leak identification. If a vulnerable component is accessible for maintenance and fitted behind an approved, interlocked, isolating valve then *acceptance* may be sought for single vacuum containment.

Demountable joints on VQC 1A shall use double seals with the interspace monitored and connected to the Service Vacuum System.

Demountable joints shall not be used for water to vacuum boundaries for any vacuum class.

Boundaries between VQC 1A and VQC 2A components that are considered to be vulnerable shall be doubly vacuum contained with a monitored interspace connected to the Service Vacuum System. This is a requirement to avoid an undetected leak of tritium into the cryostat vacuum.

VQC 2A components that are considered to be vulnerable are recommended to be doubly vacuum contained with a monitored interspace connected to the Service Vacuum System. Where it is considered that double vacuum containment increases the failure risk or failure consequences, then an alternative method to provide leak localisation and mitigation shall be proposed for *acceptance*.

An analysis of the probability of air ingress is required for safety and investment protection for any vacuum system which contains hydrogen and can reach a deflagration pressure above the design pressure. (For a 200 KPa design pressure the hydrogen isotope concentration limit is 1.5 mole/m^3 for volumes or 0.8 mole/m^3 for pipes). If the probability of air ingress is greater than 10^{-6} per year, then the probability shall be reduced by design. For example, measures such as double vacuum containment with a monitored interspace may be applied.

The requirements of this Handbook for VQC 1A will generally satisfy the requirements for primary tritium confinement (also see ITER Tritium Handbook ITER_D_2LAJTW))5

The requirements of this Handbook for VQC 3A will generally satisfy the requirements for the temporary confinement of tritium in off-normal events and of levels expected to be permeated (also see ITER Tritium Handbook ITER_D_2LAJTW).

On ITER, the secondary tritium confinement function is generally performed by buildings, ventilation and detritation systems, and hence is not part of this Handbook.

Further information on requirements for the confinement of tritium can be found in the ITER Tritium Handbook (ITER_D_2LAJTW).

10 Trapped Volumes

For VQC 1 and VQC 2A, 3A and 4A, the design of any vacuum component shall avoid trapped volumes in vacuum spaces which could result in virtual leaks.

For VQC 2B, 3B and 4B, care in the design of any vacuum component shall minimise trapped volumes in vacuum spaces which could result in virtual leaks.

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

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

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

11 Connections to the Service Vacuum System

Interspaces, e.g. between double windows, double bellows, double-sealed valves, etc., should be designed to be connected to the Service Vacuum System (SVS) with a minimum of two independent connections in every case meeting the following requirements:

- Interspaces which have a total volume less than 50 L shall utilise 6 mm tube welded to 6 mm (1/4 inch) VCR male fittings.
- Where the interspace volume is between 50 L and 500 L, the connections to the SVS shall utilise 12 mm tube welded to 12 mm (1/2 inch) VCR male fittings.
- Interspaces with volume greater than 500 L shall be fitted with 40 mm tubes with flanges selected from those listed in Appendix 8 welded to the tubes.

This requirement is valid for all interspaces except where the interspace is to be pumped to less than $5x10^{-1}$ Pa, in which case connections to the SVS shall be *accepted* by the ITER Vacuum RO.

12 Pipework (Pipe & Fittings)

12.1 General

In all applications in VQC 1A and VQC 2A and VQC 4A (process to insulation vacuum), pipe and fittings shall be seamless. Where this is not possible, specific *acceptance* is required to use seamed components which shall conform to the testing requirements of Section 7.1.4.

To mitigate risk of the loss of availability associated with water leaks in the cryostat, it is recommended that single contained water pipes do not pass through the cryostat.

Where practical, for components classified as VQC 2A, water pipework forming part of the cryostat vacuum boundary shall be doubly contained. Where it is not practical to doubly contain the pipework, all welded joints shall be full penetration butt welds subject to 100% Non-Destructive Testing (NDT).

Interspaces on VQC 2A water pipework shall be brought out to the port cells or pipe chase area and provision made for water detection, draining and temporary vacuum connection for vacuum leak testing the interspaces.

Where interspaces are not used as a method of water leak localization for water pipes passing through the cryostat, an alternative *accepted* method shall be integrated with the water pipe design.

For VQC 1A and VQC 2A, & VQC 4A (process to insulation vacuum) pipework of wall thickness less than 2.0 mm designed to contain helium, Electro-Slag Remelted (ESR) or Vacuum Arc Remelted (VAR) material shall be used for the pre-extruded material and the inclusion limits of Section 5.3 adhered to.

In the case of VQC 4 (atmosphere to insulation vacuum), there is no restriction on the use of seamed pipe provided that it conforms to the testing requirements of Section 7.1.4.

12.2 Pipework Sizes

To comply with the ITER standard vacuum flange dimensions as specified in Appendix 8, standard pipework sizes shall be used where practical. Standard pipe sizes are listed in Appendix 11.

13 Demountable Joints

Demountable vacuum joints i.e. quick release couplings, compression joints, transition couplings, flange pairs, etc. for use on ITER vacuum systems shall be *accepted* prior to use. Lists of standard joints are given in Appendix 8.

For VQC 1 and 2 there shall be no demountable vacuum joints within the vacuum.

Vacuum joints for use on VQC 1, 2 and 3 systems shall use all-metal seals. In addition, vacuum joints for use on VQC 1A shall utilise a double seal arrangement, with the interspace connected to the Service Vacuum System consistent with Section 9 (Confinement and Vacuum Containment).

All demountable joints must be accessible for maintenance/testing.

In all cases the fixed sealing face of the vacuum joint shall be accessible for manned inspection and repair during periods of ITER maintenance.

Seal faces must have the requisite surface finish and cutting lay or lap direction for the seal design. Seal faces shall not be electropolished.

For VQC 4, demountable vacuum joints shall normally use all-metal seals, although the use of other types of seals is permitted subject to prior *acceptance*.

For all VQC, the reuse of metal seals is permitted for system testing only. However, the final mating of demountable vacuum joints shall be made using previously unused metal seals.

Where demountable vacuum joints are mated for testing purposes, the applied sealing bolt loading on the test flanges shall be consistent with the final sealing option utilised. Once the sealing flange is proven, temporary use of other sealing options can be permitted. When the item is in its operational position and a temporary seal is used this must be recorded using a non-conformance.

All demountable vacuum joints shall be subject to 100% helium leak testing to installation procedures following the guidelines specified in Appendix 12. Installation procedures shall be approved by the ITER Vacuum RO. A design guide for the manufacture of demountable joints and sealing options for use on ITER vacuum systems is given in Appendix 8.

14 Fasteners and Fixings

14.1 Tapped Holes

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

Tapped holes shall be cut using only the approved cutting fluids listed in Appendix 4. Cutting fluids not listed in Appendix 4 may be *accepted* in advance by the ITER Vacuum RO and submitted for inclusion in Appendix 4 using the procedure in Section 5.2. Where an insertion is used to provide a screw thread in a plain hole (e.g. Helicoil™ inserts), the material used shall be consistent with those listed in Appendix 3.

14.2 Bolts

14.2.1 Bolts for use on the Vacuum Boundary (P < 0.15 MPa)

It shall be demonstrable that bolts for use in the formation of a vacuum boundary are of satisfactory mechanical properties to provide the relevant seal force requirements of Appendix 8. Bolts should be of rolled thread and supplied with certification in accordance with EN 1024, 3.1.

14.2.2 Prevention of Bolt Seizing

For all VQC, threaded fixings (e.g. bolts), shall be treated to prevent seizing. Approved solid (dry) lubricants, aluminium bronze inserts or coatings are preferred. Lubricants for each class are listed in Appendix 3. The use of any other lubricant is subject to prior *acceptance*. Bolts for use on ITER vacuum systems but not exposed to vacuum (i.e. VQC N/A), shall be lubricated to prevent seizing with a hard coating or, where appropriate, Molykote®.

14.2.3 Bolt Locking

It is recommended that bolts in vacuum for use on VQC 1 and VQC 2 systems shall be locked after loading to prevent them becoming free and causing damage to other parts of the vacuum system. Bolts may, for example, be locked using resistance spot welded stainless steel tangs. Other suitable materials may be selected from those listed in Appendix 3.

14.3 Riveting

Riveting is an approved technique for the joining of components in VQC 2B and 3B. Rivets shall only be formed from the materials listed in Appendix 3.

Trapped volumes formed by riveting shall be eliminated at the design stage in accordance with Section 10 above.

14.4 Bearings and Sliding Joints

Designs for in-vacuum bearings and sliding joints for VQC 1 to 3 shall be subject to prior *acceptance* at the design stage. These should be eliminated by design wherever practical, for example by the use of flexure pivots. Solid (dry) lubricants or coatings are preferred, but other permitted lubricating materials are listed in Appendix 3.

In VQC 2 and 4 applications, polytetrafluoroethylene (PTFE) bearings are approved for positions where the predicted radiation fluence over the full operational life of ITER is less than 10^3 Gray (up to 10^6 Gray for *accepted* cross-linked PTFE) (Gamma or Neutron dose equivalents).

15 Windows and Window Assemblies

15.1 General

Window assemblies for VQC 1 and VQC 2 shall be double, with no 'design basis' common mode failure between the two windows, or shall be fitted behind a UHV isolation valve and have direct connection through the window to a VQC 3 vacuum system.

For windows transmitting high power (e.g. RF heating systems) the interspace pressure shall be continuously monitored and suitably interlocked with the power system.

Window assemblies accessible from outside the vacuum systems should incorporate mechanical protection against accidental impact.

For VQC 1A double window assemblies to air, the maximum diameter permitted is 160 mm.

An example of a specification for the design, qualification, manufacture and acceptance testing of window assemblies for use on ITER vacuum systems can be found in Appendix 6.

15.2 Qualification of Window Assemblies

Prior to manufacture, the design of window assemblies shall be qualified by performing type tests on pre-manufacture window assemblies. The *supplier* shall submit for *acceptance* a qualification test plan detailing the qualification tests to be performed in order to qualify the window for a particular application.

The qualification of the window assemblies for use on a vacuum boundary shall include the following tests:

- Pressure testing of window assemblies.
- Mechanical shock testing.
- Thermal shock testing.
- Helium leak testing.

15.3 Testing of Window Assemblies

Prior to the manufacture of window assemblies the *supplier* shall supply for *acceptance* a test plan and test procedures detailing the tests to be performed on window assemblies before delivery to the ITER site. After the completion of all manufacturing processes the window assemblies shall be subject to a thermal cycle test, pressure test, and helium leak test.

Acceptance testing of window assemblies which operate at elevated temperatures requires a minimum of three thermal cycles to be performed to their maximum operating temperature consistent with Section 25.5.

16 Vacuum Valves and Valve Assemblies

For VQC 1, 2 & 3, valves shall be of all-metal construction with the exception of the valve closure seal, for which polyimide is also permitted.

For VQC 2 valves, elastomers may be used on the valve closure seal only with the prior *acceptance* of the ITER Vacuum RO.

For VQC 4, valves need not be all-metal except where they may be in contact with cryogenic fluids.

For VQC 1A all actuating and actuator bellows and seals shall be of double construction with the interspaces connected to the Service Vacuum System (see Section 11). Valves requiring compressed gas to maintain a seal shall be avoided where practical and any use requires prior *acceptance.*

Valve assemblies shall normally be installed such that the internal actuating system for the valve is on the side exposed to lower vacuum quality or to atmosphere and the seal face to the higher vacuum quality side. To facilitate this, all valve assemblies shall be permanently marked on the outside with an arrow pointing towards the seal face end of the assembly.

The valve position shall be positively identified by means of “open” and “closed” limit switches and a visual position indicator shall be provided on the valve or actuator body.

16.1 Acceptance Testing of Vacuum Valves and Valve Assemblies

Prior to shipping, valves shall be subject to an acceptance vacuum leak test. Detailed leak testing procedures shall be submitted for prior *acceptance*. Guidance can be found in Appendix 12.

Valve testing shall include the following helium leak tests:

- Valve body (global).
- Across the valve seat.
- Valve actuator bellows.
- Internal pressure element.
- Valve double bellows interspace.

Valves for use on VQC1 systems at elevated temperature shall be baked and hot leak tested at 200 °C.

An example specification for the design, manufacture and testing of valves for use on ITER vacuum systems is given in Appendix 7.

17 Bellows and Flexibles

17.1 General

In general, bellows and flexibles are considered to be inherently vulnerable components (see section 9) due to their method of construction and because their application is typically to facilitate movement.

The use of bellows or flexibles in water circuits inside vacuum systems with any VQC shall be avoided by design wherever possible, and shall only be only permitted with prior *acceptance* for VQC 1A and VQC 2A when the surrounding vacuum is behind an isolation valve. For such usage, consideration must be made at the design stage to proven reliable performance in similar applications. Double bellows are not recommended for use in water circuits in vacuum.

In all test situations and after installation, the bellows shall be protected against all abnormal load conditions. This may include the design of physical constraints.

An example of a specification for the design, qualification, manufacture and acceptance testing of bellows assemblies for use on ITER vacuum systems can be found in Appendix 9.

17.2 Bellows Protection

Bellows shall be protected against damage from falling objects. The bellows protection shall be equivalent too, or better than, that provided by a cover of schedule 20 pipe.

17.3 Design of Bellows

Circular bellows are to be designed to the EJMA or EN14917 or equivalent. The use of other design codes is subject to *acceptance*. Where design codes are not applicable, design shall be by analysis and shall be proven by qualification.

Care shall be taken to ensure that the operational loading parameters are fully considered. Precautions need to be taken against rupture and other failure modes where there is a pressure difference in either direction between the inner and outer surfaces of the unit.

Bellows for use on VQC 1 systems shall be of double construction (or *accepted* multilayer design) with a monitored interspace, unless they are accessible for maintenance and fitted behind an approved interlocked isolating valve.

Where bellows are be used on VQC 2 systems it is recommended that they be of double construction (or *accepted* multilayer design) with a monitored interspace.

Multiple ply bellows are not permitted for VQC 1A components unless they are accessible for maintenance and fitted behind an approved isolating valve.

For VQC 1A and VQC 2A, where regular and significant movement is to be taken up by a double bellows, the norm shall be to design the double arrangement such that one bellows is in compression whilst the other is in expansion so as to reduce the chances of a common mode failure.

The interspace between the two bellows of an assembly shall normally be filled with a suitable tracer gas and the pressure in the interspace shall be continuously monitored. The interspace shall be connected to the Service Vacuum System (see Section 11).

Normally accessible bellows assemblies and bellows assemblies which become accessible during machine maintenance shall be supplied with mechanical protection (such as the use of metal braiding or removable cover plates) to prevent accidental damage and ingress of matter to the bellows edge-welds or convolutions.

Non-circular bellows of non edge-welded construction are to be welded and then formed, rather than formed in parts then joined. This does not apply to the post-forming welding of bellows sections to collars. Cross welds are to be avoided where possible.

Hydrostatic, rolling or elastomeric formation is approved for all vacuum classes.

Bellows which are of edge-welded construction shall be acceptable provided that they comply with Section 7.1.

Cleaning of bellows shall be in accordance with the requirements of Section 24.

17.4 Qualification of Bellows

Bellows designed by analysis shall be subject to a qualification procedure prior to manufacture. The design of bellows shall be qualified by performing type tests on pre-manufacture bellows assemblies. The *supplier* shall submit for *acceptance* a qualification test plan detailing the qualification tests to be performed.

The qualification of the bellows assemblies shall include the following:

- Pressure test.
- Fatigue life test.
- Mechanical shock testing.
- Helium leak test.

17.5 Testing & Inspection of Bellows

Prior to the manufacture of bellows assemblies the *supplier* shall supply for *acceptance* a test plan and test procedure detailing the tests to be performed on bellows assemblies before delivery to the ITER site. After the completion of all manufacturing processes the bellows assemblies shall undergo a vacuum baking cycle to the operating temperature and a helium leak test. The *supplier* shall perform a survey of the bellows convolutions to confirm compliance with the bellows technical specification. The survey results shall be supplied to ITER and any non-conformance may lead to rejection of the bellows.

17.6 Bellows Protection

Bellows shall be protected against damage from falling objects. The bellows protection shall be equivalent too, or better than, that provided by a cover of schedule 20 pipe.

18 Feedthroughs

18.1 General

Where for VQC 1A and 2A a feedthrough penetrating the air boundary is considered vulnerable (see Section 9) a doubly vacuum contained electrical feedthrough with interspace connected to the Service Vacuum System shall be used. Where necessary, alternative arrangements shown to ensure sufficient integrity of the feedthrough may be *accepted*.

The sheaths of mineral insulated cable shall not pass directly through a VQC 1A and 2A feedthrough, but shall be discontinuous and sealed within feedthrough interspaces.

Where applied or induced voltages may be present on such feedthroughs, then protection against arcing or Paschen breakdown shall be provided.

18.2 Paschen Breakdown

Where there is a risk that Paschen breakdown may occur in an interspace of a feedthrough, it must either be continually pumped or be backfilled with a gas of *accepted* composition to a pressure appropriate to mitigate the risk of Paschen breakdown.

In both cases, the interspace pressure must be continuously monitored and interlocked with the system controls to prevent power being applied in the event of single barrier failure.

19 Electrical Breaks

Where for VQC 1A and 2A, an electrical break (i.e. providing electrical isolation between systems) is considered vulnerable (see Section 9), a doubly vacuum contained electrical break with interspace connected to the Service Vacuum System shall be used, unless it is accessible for maintenance and fitted behind an approved interlocked isolating valve.

If an electrical break is at risk of Paschen breakdown in an external or internal rough vacuum, suitable precautions shall be taken to ensure that the risk of breakdown is eliminated.

20 Cables for use in Vacuum

20.1 General

Up to 80 km of cables are anticipated in the ITER vacuum vessel. Many kilometres are also required in the cryostat. Special care shall be taken in the choice and quality control of such cables. In-vacuum cabling shall comply with all the general vacuum requirements for its VQC.

In particular:

- Materials shall be selected to be in accordance with Appendix 3.
- Outgassing shall be consistent with Table 20-1.

VQC	Outgassing temperature (°C)	Maximum steady state outgassing rate per unit length+ [$Pa.m^3.s^{-1}.m^{-1}$]		Testing guidelines
		Hydrogen Isotopes	Impurities	
1	100	1×10^{-9}	1×10^{-11}	Appendix 17
2‡	20	1×10^{-9}		Appendix 17
3	20	1×10^{-10}		Appendix 17
4	20	1×10^{-9}		Published data and conformity to clean work plan.

For VQC 2, 3 & 4 the total outgassing rate excludes water and hydrogen.

+Valid for cables up to Ø 5mm outer sleeve. Pro-rata values can be applied for larger cables.

‡ The requirements for high voltage cables in the cryostat are still being studied and hence requirements will be specified in future.

Table 20-1 – In vacuum cabling outgassing rates

Approved cable types pertaining to each VQC are listed in Appendix 10. The use of other cables is subject to prior *acceptance*.

All mineral insulated cables shall be sealed at both ends, and the void volume shall be less than 5%. The cable shall be proven to be leak tight, consistent with the levels for VQC 1 and VQC 2 given in Table 25-1, by helium bombing (see Appendix 12).

Specification for the manufacture and qualification of in-vacuum cables shall be *accepted* by the ITER Vacuum RO prior to production. A guide for the supply of in-vacuum cables can be found in Appendix 10.

20.2 Connectors and Terminations

In-vacuum connectors shall comply with the general vacuum requirements for the relevant VQC.

21 Interconnection between VQC 1 systems

Any system which can be directly connected to the main ITER tokamak vacuum by opening a valve shall have, as a minimum, full range pressure monitoring. Residual gas analysis capability is also required for systems with volume > 1 m^3.

The control of the isolating valve shall be via the ITER vacuum control system. Signals for all vacuum monitoring shall be made available to the ITER vacuum control system.

Any necessary inhibits on valve movements required to protect the sub-system, shall be made available to the ITER vacuum control system.

22 Proprietary Components

In the context of this Handbook, proprietary components are standard products which are listed in *supplier's* catalogues and are sufficiently well documented for their specification to be checked for fitness for purpose.

Proprietary components fully meeting the ITER specification of the item and the requirements of each VQC are permissible for use.

For VQC 1, 2 and 3, proprietary components meeting the requirements of this Handbook shall be supplied with an individual certificate of conformity, stating that the item conforms to the specification provided by the *supplier*.

For VQC 4, proprietary components shall be supplied with a certificate of conformity as above, but this may be in the form of generic or type conformance certificates to the catalogue specification.

A list of standard proprietary components which are known to conform to the requirements of this Handbook and so can be recommended for use on ITER vacuum systems is to be found in the Appendix 20.

Other proprietary components will be added to Appendix 20 when they are shown to meet the requirements of this Vacuum Handbook. Proposed additions should be submitted to the ITER Vacuum RO for consideration using the form in Appendix 20.

23 Vacuum Instrumentation

The requirements stated below shall be applicable to any instrumentation that directly interfaces with ITER vacuum spaces, and is applicable to all Vacuum Classifications.

In all cases instrumentation shall be compatible with ITER operational requirements and the ITER physical environment. This shall include among other matters:

- Being compatible with the relevant VQC.
- Being compatible with operation in a hydrogen environment.
- Exhibiting an outgassing rate consistent with those given in Section 5.4.
- Being leak tight consistent with Table 25-1.

- Being resistant to neutron and gamma radiation at the instrument location. The radiation map to define these levels is defined in the ITER Room Book. See also Appendix 3.
- Being able to survive any pressure within the full operational and off-normal range (from 10^{-9} Pa to 0.15 MPa for VQC 1 and 2).

Instrumentation shall be servicing free to the maximum extent.

Generally on VQC 4, wherever the operational environment permits, active sensors may be used.

VQC 1 and 2 Instrumentation for use in the control of vacuum shall be fitted behind a UHV isolation valve or have agreed redundancy, and shall be accessible for maintenance.

24 Cleaning and Handling

24.1 Cleaning

Cleanliness is required during the whole manufacturing process and the preservation of cleanliness is good practice for any component to achieve the necessary vacuum standards and to minimise the time required to recover from any contamination incident. All components shall be subjected to a rigorous cleaning procedure, consistent with the Vacuum Classification of that particular component. A guide to cleaning and handling of components for use on ITER vacuum systems can be found in Appendix 13.

A detailed Clean Work Plan shall be submitted for prior *acceptance* to the ITER Vacuum RO before any cleaning operations are undertaken at the *supplier's* site. The plan shall specify how cleanliness will be maintained throughout the manufacturing process. It shall state when specific cleaning procedures will be applied and all of the controls which will be in place to maintain cleanliness, including handling.

Parts and sub-components shall be degreased using solvents or alkaline detergents, rinsed with demineralised water, and dried in hot gas or an oven to *accepted* procedures. The use of halogenated solvents is forbidden at any stage.

Lists of accepted cleaning fluids can be found in Appendix 4.

VQC 2 components incorporating cryostat vacuum-facing resins give a risk from volatile surface compounds which, if sticking to the reflective coatings of the tokamak thermal shields, could degrade the emissivity of the shields. As no acceptable procedure is foreseen for cleaning volatiles from a resin surface, care shall be taken not to introduce them to the surface.

24.2 Design Rules for Cleanability

At the design stage for a vacuum component, careful consideration shall be given to how the item is to be cleaned. In particular, crevices, blind holes, cracks, trapped volumes, etc., shall be avoided as these will act as dirt and solvent traps and it can be very difficult to remove contaminants from such areas. Fortunately, good vacuum practice regarding trapped volumes will also usually result in a component which is cleanable.

24.3 Mechanical Processes on Vacuum Surfaces

Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components must be kept to an absolute minimum and are preferably avoided. For all VQC the use of files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and may not be used without prior agreement. However, for VQC 2, shot or dry bead blasting is permitted. Stainless steel wire brushes, cleaned to the standards of this handbook, may be used only when it is considered essential to do so.

If grinding is essential on VQC 1 systems, the grinding wheel shall be free of organic components and shall have been manufactured in an oil-free, clean environment. The material and manufacturing process of the grinding wheel shall be *accepted* by the ITER Vacuum RO before use.

24.4 Pickling/passivation of Steels and Copper

If an assembly is pickled, then final machining of vacuum sealing surfaces must be left until after the pickling/passivation process.

Pickling should always be followed by passivation. This is best carried out chemically, although native oxide layers can reform on exposure to atmosphere. Pickling and passivation must always be followed immediately by an appropriate cleaning process relevant to the VQC of the component.

It should be noted that thermal outgassing from surfaces which have been pickled/passivated may well be greater than that from a native metal surface and baking may be required to reduce outgassing rates to acceptable levels prior to installation.

A guide to the pickling/passivation of steels and copper can be found in Appendix 14.

24.5 Post-Cleaning Handling of Vacuum Equipment

After final cleaning, the handling of vacuum equipment shall be strictly controlled to preserve cleanliness. General area cleanliness requirements pertaining to Vacuum Classifications are summarised in Table 24-1. The continuing suitability of any given area used for handling vacuum equipment should 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 per m^3 for VQC 1.

VQC	Cleanliness requirements	Personnel	Area Cleanliness	Monitoring
1	Segregated clean area. Limited Access to authorised personnel.	Trained personnel. Protective hair nets. Clean powder free	Daily Cleaning of area including floors	Daily air quality checks. Results stored

	Authorised equipment operated to approved procedures. Management of equipment (e.g. no vacuum pumps or other machinery exhausting into clean area).	latex or nitrile outer gloves. Clean white overalls. Overshoes. Clean job specific footwear.	and surfaces. Sticky mats at area entry.	in component document package. Weekly cleanliness test of area with results stored in component document package.
2	Authorised equipment operated to approved procedures. Management of equipment (e.g. no vacuum pumps or other machinery exhausting into clean area).	Trained personnel. Clean outer protective gloves for the handling of clean equipment.	Daily Cleaning of work area including floors and surfaces.	
3&4	House Keeping.	Trained personnel. Clean powder free latex or nitrile outer gloves for the handling of clean equipment.	Daily cleaning of area.	

Table 24-1 – Environmental cleanliness pertaining to VQC

Additional cleanliness requirements shall be defined in the component installation procedures.

Handling cleanliness guidelines for each VQC are detailed in Appendix 2.

24.6 Cleanliness during the Assembly of Vacuum Equipment

The mandatory requirements relating to cleanliness during assembly of vacuum equipment are detailed in Attachment 2 (ITER_D_MBXPP3).

25 Leak Testing

25.1 General

Generally, leak tests shall be performed:-

- During manufacturing to confirm the soundness of joining processes and sub-components and to reduce the risk of Incorporating leaks in a system that are subsequently difficult to locate or to repair.
- As an acceptance test at the *supplier's* site to show that completed assemblies meet the acceptance leak criteria.
- When a component arrives at the ITER site, to confirm that there has been no damage during packaging and transport. This test, which is under the

control and at the discretion of ITER, will be designed to be as simple and fast as possible.

- During installation, under the control of ITER, when testing is implemented to reduce the risk of newly made joint leaks only being detected at the completion of the total installation.
- On pumping down of the completed installation as part of the final commissioning.

Leak testing shall be carried out by suitably trained and experienced personnel. Acceptance test methods require prior *acceptance*. Guidance can be found in Appendix 12.

Leak testing shall be performed after pressure testing (if applicable). Before leak testing, components shall be cleaned, dried or baked in accordance with Section 27 of this Handbook.

Unless otherwise specified in the relevant contract or Procurement Arrangement the supply of any vacuum component shall include all testing jigs, flange closure plates (welded or otherwise) and fittings to allow helium leak testing at the ITER site. These may be the same items that were used for tests prior to delivery. Methodologies for the subsequent removal of such features shall also be supplied.

The requirement to leak test proprietary components delivered to the ITER site with a *supplier's* Certificate of Compliance may be waived by ITER at the discretion of the ITER Vacuum RO.

25.2 Maximum Acceptance Leak Rates

Maximum acceptance leak rates for several of the ITER vacuum systems are given in Table 25-1.

Any concession to permit leak rates greater than those specified in Table 25-1 can only be by prior *acceptance*.

25.3 Design Considerations for Leak Testing

All components and systems forming a vacuum boundary shall be designed so as to facilitate leak testing using tracer gas leak detection methods during the building of ITER.

Components shall also be designed to facilitate the timely localization of leaks occurring during ITER operations. Different techniques can be considered which may include the provision of small-bore tubing to allow the introduction of helium to the vicinity of potential leaks.

The design of vacuum systems shall be such that leak tightness can to be proven across all vacuum boundaries.

25.4 Scheduling of Leak Tests

Prior to manufacture the *supplier* shall have an *accepted* leak test plan detailing the timing and type of tests to be performed during manufacture. The plan shall include which tests are to be witnessed by the ITER or Domestic Agency Vacuum Specialist.

The ITER Vacuum RO shall be informed a minimum of two weeks in advance of a test requiring witnessing by ITER.

Scheduling of leak testing shall be in compliance with the ITER Leak Testing Policy (ITER_D_L5P5P2).

System/ Component	Maximum Leak Rate ($Pa.m^3/s$ air equivalent†)
VQC 1 *	1×10^{-10}
VQC 2*	1×10^{-9}
VQC 3*	1×10^{-9}
VQC 4* (Atmosphere to insulation Vacuum)	1×10^{-7}
VQC 4* (Process line to insulation Vacuum)	1×10^{-10}
Tokamak primary vacuum (including all in-vessel components and attachments)	$2x10^{-7}$
Vacuum vessel (Including ports but excluding attachments) (Total allocation of leakage into main chamber vacuum)	$1x10^{-7}$
Individual vessel sector (Total allocation to a sector main chamber vacuum assuming enclosed)	$1x10^{-8}$
Individual field joints (covers port and sector field joints)	1×10^{-8}
Individual port plugs (complete)	5×10^{-10}
Each NB/DNB injector enclosure	$1x10^{-8}$
Cryostat vessel (excluding contents)	$5 x10^{-5}$
Completed Cryostat (including all in-cryostat components and attachments) ‡	$1x10^{-4}$
Central solenoid assembly‡	$1x10^{-7}$
Individual PF-coil assembly‡	$1x10^{-7}$
Individual TF-coil assembly‡	$1x10^{-7}$
Complete thermal shield assembly‡	$1x10^{-5}$

*Individual system or component not otherwise mentioned.

† Helium equivalent Leak Rate (LR) = Air equivalent x 2.69 at the same temperature.

$$\frac{LR_{Helium}}{LR_{Air}} = \frac{\sqrt{M_{Air}}}{\sqrt{M_{Helium}}} = 2.69\,(\mathrm{M} = \text{atomic mass})$$

‡ Values quoted refer to systems under normal operational pressures and temperatures. Conversion to room temperature and atmospheric pressure tests can be supplied on request.

Table 25-1 Maximum acceptance leak rates for various vacuum systems

Generally it is advised that component parts should be tested before assembly, but final assemblies must be tested before shipping to ITER. For VQC2A in the case of a construction with many joints which become embedded and inaccessible in an assembly, then individual leak tests may be *accepted* as an acceptance test to replace final assembly acceptance leak testing prior to shipping.

Leak testing may be performed at the ITER site following transportation of vacuum components prior to it being accepted by ITER for installation.

Installation leak testing will be carried out to *accepted* procedures as part of the ITER assembly. All ITER vacuum systems will undergo final leak testing as part of the integrated commissioning of the ITER machine.

25.5 Methods and Procedures

The leak test procedure for acceptance tests shall be *accepted* in advance by the ITER vacuum RO. The procedure shall describe how the leak test will be performed, and include configuration diagrams and full details of the equipment to be used. Guidance on acceptable methods of carrying out leak testing is given in Appendix 12.

The acceptance leak test method shall ensure leak tightness is proven across all vacuum boundaries.

Test conditions (pressure, temperature) for the acceptance leak test shall be as close as practical to the design conditions. Testing shall be carried out with the component at ambient temperature and as close as practical to both its maximum and minimum design temperatures. The direction of the pressure differential shall normally be in the same direction as during operation exhibited by the components. Exceptions will be considered for the larger ITER components for tests prior to the final commissioning tests.

Where acceptance leak tests are not to be performed on cryogenic systems at cryogenic temperatures, a method of cold leak testing any welded connections shall be *accepted* in advance.

For an acceptance helium leak test, the helium concentration around the test piece shall be at a minimum of 50% for the duration of the test. The helium concentration shall be measured and recorded. The helium shall be maintained for a period calculated to be sufficient to identify leaks at the acceptance level.

Acceptance leak tests on VQC 1A or VQC 3A components which include joints of dissimilar materials[2] shall be subject to a minimum of three thermal cycles from ambient to the maximum possible operating temperature prior to leak testing. The time taken for any component to reach the specified bake temperature from ambient shall be less than 100 hours.

A representative of the ITER Organisation may inspect the *supplier's* leak testing equipment and witness a proof of procedure prior to the acceptance leak test.

Acceptance leak tests shall be witnessed or, where there are many tests agreed to form the acceptance leak testing, a representative sample of the test shall be witnessed. The ITER Vacuum RO shall nominate or approve the Vacuum Specialist to witness the acceptance leak tests. ITER may require that other key (ITER_D_L5P5P2) leak tests to be implemented as part of a manufacturing process be witnessed. Those tests to be witnessed by ITER, including the acceptance tests, shall be defined in the Manufacturing Inspection Plan (MIP).

25.6 Acceptance Leak Testing at the *Supplier's* Premises

The *supplier* is responsible for the supply of all testing equipment, vacuum components, all testing jigs, flange closure plates (welded or otherwise) and fittings to allow an acceptance helium leak test to be carried out.

No repair or re-work of the components (with the exception of simple tightening of flange joints or replacement of gaskets) shall be undertaken without prior agreement. Any repair or rework will require the leak test procedure to be repeated and may include a repeat leak test at the operating temperature.

No vacuum component which fails to meet the specified acceptance leak rate at the *supplier's* site shall be accepted for delivery to the ITER site without prior *acceptance*.

25.7 Acceptance Criteria for Leak Testing

On successful completion of the specified leak tests, the item under test may be accepted provided the following conditions have been met:

- The leak detector in the test configuration has been calibrated and its calibration value is 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.
- The background level of the leak test was below the acceptance leak rate without electronic correction prior to the test.
- The reading from the leak detector has not increased in value above the measured background by more than the specified leak rate as defined for

[2] Metallic joints shall be considered to be of dissimilar materials if the difference in linear thermal expansion coefficients over the operating temperature range of the materials comprising the joint is greater than or equal to 20%. Joints between non-metallic materials shall be considered as dissimilar.

the item under test throughout the entire duration of the leak test procedure.

- The test has been performed to the agreed procedure and, where specified in the Quality Plan, has been witnessed by the ITER Vacuum Specialist.

25.8 Acceptance Leak Testing at the ITER site

Normally, vacuum components shall be subject to a leak test at the ITER site following transportation. The purpose of such a test is to reduce the risk of installing a leaking component and is of particular importance for components which would have a high impact to replace or repair. This test will normally be performed by ITER but a *supplier* may witness this test. This test may be a more limited test than that performed at the *supplier's* site and may be performed at ambient temperature at the discretion of the ITER Vacuum RO.

25.9 Reporting of Leak Tests

Full records of the tests carried out shall be compiled in order to maintain traceability of the leak test history of a particular item. The records shall become part of the final document package for the component concerned. Records shall include the following:

- Data records of the output of the leak detector for all the global tests specified including the standard leak calibration and response time determination. These data records shall include the date and time of all the tests as well as any other data necessary to allow a full analysis of the results, such as the start and finish of helium gas application to the item under test.
- A record of the helium concentration during the leak test.
- A record of the system total pressure and temperature during a temperature cycle as it may pinpoint the time when a leak opened up and be instrumental in the subsequent diagnosis of the leak.
- The make and model of the helium mass spectrometer leak detector used in the test.
- The nominal value of all standard leaks used, their date of calibration, ageing and temperature characteristics, and the ambient temperature(s) experienced during the tests.
- Results of all tests showing whether it was a pass or fail and if a failure, the measured leak rate and the location of the leak plus the steps taken for repair or elimination.
- The magnitude and location (if applicable) of all leaks identified during testing. This includes leaks of size lower than the acceptance criteria for which no remedial action may have been taken.

- A full record of any residual gas scans taken with appropriate time markers to identify the scans to the position in the component leak test cycle.

An example template for the reporting of leak tests is provided as part of Appendix 12

26 Baking

26.1 General

Vacuum components for the various classifications may require to be baked to ensure satisfactory vacuum performance. Raw materials may also require baking before being used in manufacture if a higher temperature is required to achieve satisfactory vacuum properties than will be possible later.

Baking can be included in the component leak testing procedure (see Section 25) and/or the component cleaning procedure (see Section 24). A bake temperature and duration will normally be specified in the specification documents and/or drawings for individual components or assemblies. If this is not the case, then the standard temperatures listed in Table 26-1 shall be used. Normally, the time taken for any component to reach the specified bake temperature from ambient shall be less than 100 hours and the component shall normally be held at the baking temperature for a minimum of 24 hours.

Where the *supplier* is unable to carry out a bake procedure, either to the standard conditions in Table 26-1 or as otherwise specified, then any variation shall be agreed with ITER before proceeding.

For all vacuum components that require baking, a detailed procedure describing the baking process shall be submitted for *acceptance* before any baking is started. The acceptable leak rate and vacuum conditions of any baking chamber shall be agreed as part of this procedure.

Vacuum ovens containing heating filaments within the vacuum are not permitted for VQC 1 baking operations without full qualification of the baking process.

Post bake handling of vacuum components shall be in accordance with Section 24.5.

A guide to the vacuum baking of components, including baking temperatures, is to be found in Appendix 15.

26.2 VQC 1 Components (non plasma-facing)

After manufacture, VQC 1 non plasma-facing components which operate at elevated temperature shall be baked using the guidance of Appendix 15. Baking shall be for a minimum of 24 hours at the maximum operating temperature. The bake cycle may be performed as part of the cleaning process or, if applicable, the hot leak test. There is no vacuum requirement to bake at temperatures in excess of the design temperature.

26.3 VQC 1 Components (plasma-facing)

To ensure vacuum cleanliness and to reduce impurity outgassing, components which are plasma facing or operate within 0.25 m of plasma shall be conditioned after manufacture by vacuum baking following the guidance of the ITER Vacuum Handbook Appendix 15. For VQC 1 component materials in proximity to the plasma, the normal vacuum baking temperature is given in Table 26-1. Where the temperature is too high for a composite assembly, the component part requiring higher temperature baking shall be baked at that temperature prior to assembly and then the complete assembly baked at the lowest listed temperature of the component parts. Temperature requirements for baking materials not listed shall be agreed in advance of baking operations.

For any individual component, the point in the manufacturing schedule or testing procedure at which such bake or bakes is carried out and the maximum temperature used shall be agreed with the ITER Vacuum RO. Post baking handling shall be minimised to preserve cleanliness and shall be in accordance with Section 24.

Component Material	Baking temperature (°C)[1]
Beryllium	350[2]
Stainless Steel (all grades)	250
Carbon Composites	450 or 2000[3]
Precipitation-hardened copper alloys	250
Tungsten	350

[1] Maximum temperature for baking complete systems may be limited by the system components

[2] A 250 °C baking cycle for a substantially increased duration at may be permitted on approval.

[3] Section 26.7 and Appendix 16

Table 26-1 Baking temperature VQC 1 materials in proximity to the plasma

26.4 VQC 2 Components

There is normally no vacuum requirement to bake VQC 2 components, but baking may be used as part of the cleaning and surface conditioning process to achieve the outgassing requirements of Table 5-1.

26.5 VQC 3 Components

There is normally no vacuum requirement to bake VQC 3 components, but baking may be used as part of the cleaning and surface conditioning process to achieve the outgassing requirements of Table 5-1.

26.6 VQC 4 Components

There is no vacuum requirement to bake VQC 4 components.

26.7 Vacuum Conditioning of Carbon Composites

In order to remove impurities from graphite or carbon fibre composite components (CFC), it is necessary to bake components in a suitable furnace. Due to the high temperature requirements of CFC, subcomponents shall be baked prior to system assembly.

Conditioning of CFC is dependent on the manufacturing processes involved; hence baking procedures must be qualified and *accepted* prior to manufacture.

After baking the total outgassing rate for Carbon Fibre Composites shall be < 1 x 10^{-6} $Pa.m^3.s^{-1}.m^{-3}$ at 200 °C (excluding the partial outgassing rates for H_2, CO and CO_2)

The *supplier* shall perform a degassing cycle of components after machining to a procedure approved by the ITER Vacuum RO in accordance with Section 26.

Guidance for the conditioning of CFC can be found in Appendix 16.

26.8 Documentation to be Supplied for Vacuum Baking

For each vacuum item, the following records shall be supplied:

- Record of the pre-baking conditioning cycle for the vacuum baking chamber.
- The initial leak rate of the vacuum baking chamber.
- The final leak rate of the vacuum baking chamber.
- A record of the temperature distribution for the item and the pressure within the vacuum item against time for the full duration of the bakeout process.
- A full record of any residual gas scans taken with appropriate time markers to identify the scans to the position in the component bakeout cycle.
- Full documentation regarding any leaks or any other problems which occurred during the baking and any remedial action taken.

27 Draining and Drying

27.1 Design Considerations for Draining and Drying

In order to perform effective vacuum leak testing systems under test must be dry.

VQC 1 in-vessel systems which contain water shall be designed in such away as to facilitate draining and drying. Systems shall be designed to be drained and dried so that after drying for <100 hours purge gas passing through the component has a water content <4000 ppm at ambient temperature and pressure.

Consideration shall be given to the position of inlet and outlet water feeds to minimise the volume of trapped water which cannot be removed without drying.

27.2 Components Delivered to ITER

Vacuum components delivered to the ITER site shall be dry internally and externally. Any internal volumes wetted during acceptance testing shall be drained completely and dried by purging with dry air until the purge gas has a water content of <4000 ppm (alternatively the system may be dried by baking using the guidance of Appendix 15 and backfilled with dry air). The volumes will then be left at atmospheric pressure of dry air for a minimum period of 24 hours at ambient temperature. If after that time, the water content of the enclosed gas has risen to >4000 ppm, the drying process shall be repeated until this condition is met.

28 Marking of Vacuum Equipment

Surfaces which are to be exposed to vacuum shall only be marked or identified if necessary and shall be marked by scribing with a clean sharp point, laser scribing or electromagnetic dot peen method. Seal faces shall not be marked in any way. For VQC1, chemical etching shall not be used unless *accepted* by the ITER Vacuum RO.

Only approved (appendix 4) dyes, marker pens, paints, etc. shall be used on surfaces which will be exposed to vacuum.

29 Packaging and Handling of Vacuum Equipment

Components shall be packed with adequate protection from thermal or mechanical stresses which may adversely affect the operation of the component. All packing shall be sealed and marked externally with the component VQC. Handling instructions shall also be clearly marked on the outside of the packaging. Chemical or radiological hazards, etc., shall be identified on the packaging. All such marking shall be in English and French.

All vacuum components shall be shipped dry internally and externally, irrespective of final acceptance testing at the *supplier's* site.

Aluminium foil is recommended for sealing pipe openings, and protective caps shall be fitted to flanges before packaging and sealing. Where it is not practical to enclose the components, e.g. due to size, all apertures must be sealed to prevent the ingress of contaminants during transit. Sealing surfaces shall be protected to prevent damage by scratching, impact, etc.

The use of adhesive tape for the protection and packaging of vacuum components shall be restricted to prevent the risk of contamination from the tape. In particular, tape used on austenitic stainless steel shall meet leachable chloride and fluoride limits of 15 ppm and 10 ppm, respectively. Where used, tape shall be fully removable leaving no residue, using isopropyl alcohol or acetone as the solvent to remove all traces of the adhesive.

To prevent damage and possible contamination during transit, the packaging of components shall be done as soon as possible after acceptance testing and final cleaning at the *supplier's* premises. Cleaning and packaging operations may be witnessed by ITER.

Vacuum components shall be handled as little as possible after final cleaning. All subsequent operations shall be carried out in clean conditions consistent with Section 24.5.

In particular persons handling VQC 1 components shall wear clean powder-free latex or nitrile gloves (over cotton or linen gloves if desired) and, as a minimum, be dressed in clean white overalls. In the cases where the component is large (e.g. a vessel sector) and internal access is required, hair nets and clean overshoes over footwear specifically provided for use in the vacuum component shall be worn.

Volumes which have been pumped for leak testing shall be backfilled with dry nitrogen or air (<4000 ppm H_2O) at a positive pressure of 0.12 MPa and valved off. Where the equipment allows manned access, air shall always be used. Where this is not practical, alternative conditions shall be *accepted* by the vacuum RO.

Cryogenic volumes which have been previously filled with helium for testing shall also follow the above or may be backfilled with dry helium (<4000 ppm H_2O) at a positive pressure of 0.12 MPa and valved off.

Where practical, vacuum components shall be entirely enclosed in heat sealed polyethylene for shipping. The polyethylene enclosure shall be purged and backfilled with dry air (<4000 ppm H_2O). Where this is not practical, alternative conditions shall be *accepted* by the vacuum RO.

30 Incoming Inspection at ITER of Vacuum Equipment

Before acceptance by ITER all components delivered to the ITER site will be subject to incoming inspection.

The following inspections will normally be carried out on vacuum equipment delivered to ITER:

- Checking of backfilled volumes (see Section 29).
- Seal face inspection.
- Checking the integrity of packing and status of accelerometers (if fitted).
- Cleanliness check.
- Leak test.

On completion of the incoming inspection any non-conformance with, or deviation from, the vacuum specification or this Handbook shall be raised in accordance with Section 4.

31 Long Term Storage of Vacuum Equipment

In many cases vacuum components will be delivered to the ITER site in advance of installation to the ITER vacuum system. Vacuum components shall be stored in such a state as not to degrade the vacuum performance.

In the case of VQC 1 components, after incoming inspection and acceptance, the components, where practical, shall be entirely enclosed in heat sealed polyethylene. The polyethylene enclosure shall be purged and backfilled with dry air (<4000 ppm water). Volumes which have been pumped for leak testing shall be backfilled with dry nitrogen (<4000 ppm water) at a positive pressure of 0.12 MPa and valved off. The component shall then be re-packed into its transportation case and stored at a suitable location.

After incoming inspection and acceptance VQC 2, 3 and 4 components shall be stored in clean, dry packing cases in a suitable location.

32 QA and Documentation

All vacuum components supplied to ITER shall be subject to the ITER Quality Assurance System detailed in the ITER Procurement Quality documentation (IDM Ref; ITER_D_22MFG4).

Specific guidance on satisfying the vacuum requirement of such a system is outlined in Appendix 19.

33 Acknowledgements

The ITER Vacuum Group acknowledges the following in the preparation of the ITER Vacuum Handbook:

UKAEA and JET, Culham Science Centre, Oxfordshire, UK

Accelerator Science and Technology Centre (ASTeC), Daresbury, UK

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In addition the efforts of many in extensively reviewing the Handbook are acknowledged.

34 List of Attachments

1. Inspection and Qualification of Welded Vacuum Joints
2. Cleanliness Requirements Relating to the Assembly of Vacuum Equipment (ITER_D_MBXPP3)

35 List of Appendices

1. Base Pressures and Expected Pumping Speeds (ITER_D_2ELEJT).
2. Environmental Cleanliness Requirements pertaining to Vacuum Classification (ITER_D_2EL9Y6)
3. Accepted Materials (ITER_D_27Y4QC)
4. Accepted Fluids (ITER_D_2ELN8N)
5. *Acceptance* Checklist (ITER_D_2N4NDK)
6. Guide to the Supply of Windows (ITER_D_2DXZZ3)
7. Guide to the Supply of Valves (ITER_D_2EPFG4)
8. Supply and Manufacture of Vacuum Flanges (ITER_D_2DJYQA)
9. Guide to the Supply of Bellows (ITER_D_2E5LJA)
10. Supply and Manufacture of Cables for use in Vacuum (ITER_D_2ETNLM)
11. Standard Pipe Sizes (ITER_D_2E5PJK)
12. Guide to Leak Testing (ITER_D_2EYZ5F)
13. Guide to Cleaning and Cleanliness (ITER_D_2ELUQH)
14. Guide to Passivation and Pickling (ITER_D_2F547S)
15. Guide for Vacuum Baking (ITER_D_2DU65F)
16. Guide for the Conditioning of Graphite and Carbon Composites (ITER_D_27YH3U)
17. Guide to Outgassing Rates and their Measurement (ITER_D_2EXDST)
18. Vacuum Component Reliability Data (ITER_D_2F2PYS)
19. Guide Documentation and QA (ITER_D_2DMNNR)
20. Standard Components (ITER_D_2F9QWX)
21. Glossary of Vacuum Terms Relevant to ITER (ITER_D_2F94QX)

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Baseline Report (not under Configuration Control)

Appendix 2 Environmental Cleanliness

This Appendix provides guidelines relating to the cleanliness requirements for the post cleaning handling of vacuum components for installation in the various ITER Vacuum systems. It only refers to the post final cleaning cleanliness requirements to maintain the achieved cleanliness.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Worth L.**	**02 Sep 2009:signed**	**IO/DG/COO/PED/FCED/VS**
Co-Authors			
Reviewers			
Approver	**Pearce R.**	**14 Sep 2009:approved**	**IO/DG/COO/PED/FCED/VS**
Document Security: Internal Use *RO: Chiocchio Stefano*			
Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: [CCS] CCS-All for Ext AM, LG: [CCS] CCS-Section Leaders, LG: [CCS] JACOBS, LG: [CCS] CCS-Doc Co...**		

Change Log			
Appendix 2 Environmental Cleanliness (2EL9Y6)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	27 Aug 2008	
v1.1	In Work	12 Jan 2009	
v1.2	In Work	13 Jan 2009	
v1.3	Signed	18 Jun 2009	Updated to include new figures for airbourne contamination and minor textual changes
v1.4	Approved	02 Sep 2009	Minor changes to text for consistency with Vacuum Handbook

ITER Vacuum Handbook
Appendix 2

Environmental Cleanliness

	Name	Affiliation
Author/Editor	Liam Worth	Vacuum Group - CEP
Vacuum Responsible Officer	Robert Pearce	Vacuum Group - CEP

2 Environmental Cleanliness requirements pertaining to Vacuum Quality Classification

2.1 Scope

This Appendix provides guidelines relating to the cleanliness requirements for the post cleaning handling of vacuum components for installation in the various ITER Vacuum systems. It only refers to the post final cleaning cleanliness requirements to maintain the achieved cleanliness.

It is anticipated that further guidance which will not be mandatory may be provided in the future.

2.2 Post Cleaning Handling of Vacuum Components

The following details are reproduced from the ITER Vacuum Handbook (Issue 2.3), Section 24.5 and Table 24.1and are therefore mandatory.

"After final cleaning, the handling of vacuum equipment shall be controlled to preserve cleanliness. General area cleanliness requirements pertaining to Vacuum Classification are summarised in Table 2-1. The suitability of any given area used for handling vacuum equipment should be assessed on a regular basis by monitoring the airborne particulate count and should not exceed 5.0 x 10^6 particles of size > 0.5 µm per m^3 for VQC 1.

VQC	Cleanliness requirements	Personnel	Area Cleanliness	Monitoring
1	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
2	Authorised equipment operated to approved procedures. Management of equipment (e.g. no vacuum pumps	Trained personnel Powder free latex or nitrile outer gloves for the handling of clean equipment	Daily Cleaning of work area including floors and surfaces.	

	exhausting into clean area)			
3&4	House Keeping	Trained personnel. Powder free latex or nitrile outer gloves for the handling of clean equipment	Daily cleaning of area.	

Table 2-1 Environmental cleanliness pertaining to VQC

Additional cleanliness requirements shall be defined in the component installation procedures.”

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Guideline (not under Configuration Control)

Appendix 3 Materials

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Vine G.**	**17 Jul 2017:signed**	**IO/DG/COO/PED/FCED/VS**
Co-Authors			
Reviewers	**Pearce R.** **Worth L.**	**31 Aug 2017:recommended** **17 Jul 2017:recommended**	**IO/DG/COO/PED/FCED/VS** **IO/DG/COO/PED/FCED/VS**
Approver	**Lee G.- S.**	**08 Sep 2017:approved**	**IO/DG/COO**
#SecureIDM# *RO: Chiocchio Stefano*			
Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: EUROfusion-DEMO, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: [CCS] CCS-All for Ext AM, LG: [CCS] CCS-Section Leaders, LG: [CCS] JACOBS,...**		

Change Log			
Appendix 3 Materials (27Y4QC)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	27 Aug 2008	
v1.1	In Work	29 Aug 2008	
v1.2	In Work	12 Jan 2009	
v1.3	In Work	14 Jan 2009	
v1.4	Signed	26 Jan 2009	
v1.5	Signed	13 May 2009	
v1.6	Signed	18 Jun 2009	Changed approved to accepted throughout document
v1.7	Approved	02 Sep 2009	Minor textual changes for consistency with Vacuum Handbook
v1.8	Approved	26 Sep 2011	Reference to Material Approval Request form added. New materials added. References to requested materials added. Simplification to material groups. Changes agreed with ITER Vacuum RO prior to Up-load.
v1.9	Approved	11 Feb 2014	Added grade and standard for Alumina
v1.10	Approved	11 Feb 2014	Date correction. Affiliation modification.
v1.11	Signed	23 Jan 2015	Changes between v1.10 and v1.11 of 27Y4QC. Links added for, 304 B7 Outgassing data YDH 50 MAR XM-19 MAR Oxygen Free (OF) UNS C10200 Al-15 (Mirrors for EC Equatorial launcher) Tantalum sheet TiN Materials added:- Nitronic-60 (UNS S21800) 431 (UNS S43100) (1.4057) 431 (UNS S43100) (1.4059) Inconel 708 N-type thermocouple STEMET 1301 amorphous brazing alloy Nicuman 23 brazing alloy Nicuman 37 brazing alloy STEMET 1101 microcrystalline brazing alloy STEMET 1108 microcrystalline brazing alloy Aluminium Grade 6061 Tungsten Carbide Mechanical pump (sliding seal) Gold Thin leaf 100 micron (bonding agent) Silver-based braze BAg-8 Titanium ASTM Grade2 T2 & 5 T5 Silicon Mono-crystalline Silicon Poly –crystalline Diamond composite Sckeleton-1 Glass Ceramic MACOR (MGC) Aluminum Oxide (TS-03312) Alumina Filled Cyanate Ester (MC7885-UF) Aluminium Nitride Shapal SH-15) Aluminium Nitride Shapal M-soft Aluminium Nitride (Circuit Board Substrate)

			Quartz Filled Cyanate Ester (MC7883-UF or MC9883-LPM) Kalrez Non-vacuum application (3rd party pump) Barium Fluoride vacuum windows Molybdenum (Tracks on surface of silicon wafer sensor) ZrO2 with TiN coating Non-vacuum application (3rd party pump) ZrO2 Non-vacuum application (3rd party pump)
v1.12	Approved	23 Jan 2015	Approval corrected to restricted for:- Aluminium Nitride (Shapal SH-15, Shapal M-soft, Circuit Board Substrate) Plus previous:- Links added for, 304 B7 Outgassing data YDH 50 MAR XM-19 MAR Oxygen Free (OF) UNS C10200 Al-15 (Mirrors for EC Equatorial launcher) Tantalum sheet TiN Materials added:- Nitronic-60 (UNS S21800) 431 (UNS S43100) (1.4057) 431 (UNS S43100) (1.4059) Inconel 708 N-type thermocouple STEMET 1301 amorphous brazing alloy Nicuman 23 brazing alloy Nicuman 37 brazing alloy STEMET 1101 microcrystalline brazing alloy STEMET 1108 microcrystalline brazing alloy Aluminium Grade 6061 Tungsten Carbide Mechanical pump (sliding seal) Gold Thin leaf 100 micron (bonding agent) Silver-based braze BAg-8 Titanium ASTM Grade2 T2 & 5 T5 Silicon Mono-crystalline Silicon Poly –crystalline Diamond composite Sckeleton-1 Glass Ceramic MACOR (MGC) Aluminum Oxide (TS-03312) Alumina Filled Cyanate Ester (MC7885-UF) Aluminium Nitride Shapal SH-15) Aluminium Nitride Shapal M-soft Aluminium Nitride (Circuit Board Substrate) Quartz Filled Cyanate Ester (MC7883-UF or MC9883-LPM) Kalrez Non-vacuum application (3rd party pump) Barium Fluoride vacuum windows Molybdenum (Tracks on surface of silicon wafer sensor) ZrO2 with TiN coating Non-vacuum application (3rd party pump) ZrO2 Non-vacuum application (3rd party pump)
v1.13	Signed	23 Feb 2015	MAR ITER_D_9K3J5P for Alumimium 6061 use in VQC 2B and 4B now deleted as request is unnecessary. Use of Aluminium use in all VQC (except VQC 1A-restricted) is already indicated in Appendix 3 Table.
v1.14	Approved	25 Feb 2015	Materials:- -EPDM (Ethylene-propylene), & -Nitrile rubber (Buna – N) Added with use restricted to 2nd, outer, seal gasket only (i.e. between SVS pumped volume/Air) in VQC 2A double sealed flanges (1st, inner seal,

			being metallic) for consistency with materials noted in VH App 8, Flanges, Table 6. Aluminium "and alloys" noted in grades for clarity
v1.15	Approved	20 Aug 2015	Materials added Cu and Cu based alloys:- CuBe1.7 CuBe2 SeCu Ni and Ni based alloys:- Nilo 42 (Nickel Iron Alloy 42 material) Mineral cement:- Thermoguss 2000 Glass / Ceramic:- Zirconia ZrO2
v1.16	Approved	03 Nov 2015	Materials added:- Nicrobraz 10 Alloy BNi6 (Ni / P 11%) Molybdenum solid, pure (not powdered or compound)
v1.17	Approved	06 Jun 2016	Materials added;- PEEK shrink tubing, Brazing Filler Material (Ni 102 / BNi2 / L-Ni2 / B-Ni82CrSiBFE DuPont 951 Green Tape Shapal M-Soft NiP-11% electroless nickel braze Aluminium Nitride (W Coated) G11 / EPGC203 epoxy glass composite Magnesium Oxide, MgO, sintered
v1.18	Approved	12 Dec 2016	Materials added:- Polyimide-cable insulant Zirconia based ceramic paste (Resbond 940) Papyex: N 998 Flexible Graphite Inconel X-750 Aluminium alloy EN AW-6082-T6 Boron Carbide F4C Molybdenum alloy APT-3 TZM SA-240 316Ti Stainless steel Steel 316Ti (1.4571 according to VDEh)
v1.19	Signed	17 Jul 2017	Materials added:- Molybdenum Molykote D-321 R Anti-Friction Coating Sputtered MoS2 Brazing matrial NIORO AuNi 82/18% Araldite Rapid Ticuni Braze BrazeTec_CB10 Copper Alloy (Cu-Sn-Pb) Ertalon 66 SKTN-MED optical glue BPd-2 Braze
v1.20	Approved	17 Jul 2017	Materials added as previous version:-

			Molybdenum Molykote D-321 R Anti-Friction Coating Sputtered MoS2 Brazing matrial NIORO AuNi 82/18% Araldite Rapid Ticuni Braze BrazeTec_CB10 Copper Alloy (Cu-Sn-Pb) Ertalon 66 SKTN-MED optical glue BPd-2 Braze (& 1 correction-Nicrobraz 10 restored)

ITER Vacuum Handbook
Appendix 3

Accepted Materials

	Name	Affiliation
Author/Editor	Liam Worth	IO Vacuum Section
Vacuum Responsible Officer	Robert Pearce	IO Vacuum Section

3 ITER Approved Materials

3.1 Scope

This appendix relates to the materials *accepted* for use in ITER vacuum exposed to the ITER vacuum environments.

The ITER Vacuum Handbook (section 5.1) states that

"Only materials *accepted* by ITER for the relevant Vacuum Classification shall be used on ITER vacuum systems. All material for use in vacuum shall be clearly specified at the design stage and certified in accordance with EN 10204 2.2, 3.1 or 3.2, or equivalent, before being used in manufacturing."

Pursuant to this, materials which may be used freely on vacuum systems with the Vacuum Classifications stated are listed in the tables below.

Materials listed in this Appendix and shown as being subject to restricted use for a particular Vacuum Classification are subject to either an overall quota or to particular restrictions on their position of use. *Acceptance* for any particular vacuum application of such a material shall be obtained by submitting the Material Approval Request Form, stored on IDM (ITER_D_2MGWR4), to the ITER Vacuum RO. An example of this form completed is to be found at the end of this Appendix.

3.2 Materials Not on the Approved List

Materials which are not on the *accepted* list may be proposed for use in vacuum. If the vacuum properties of the material are not sufficiently well documented for an assessment to be carried out, a programme of measurement of the relevant properties shall be agreed between the proposer and the designated ITER Vacuum RO.

Details of materials to be considered for *acceptance* shall be submitted to the ITER Vacuum RO using the Material Approval Request Form. The proposer shall agree in advance with the ITER Vacuum RO a plan detailing the type and method of testing to qualify the material for use. The Materials Approval Request Form along with the test data, report and supporting documentation, including any *supplier's* data (Certificates of Conformity, etc.), shall be submitted for consideration.

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

3.3 Material Selection / Qualification

The materials listed in the following tables have been considered in terms of usage (vapour pressure, outgassing etc) and in terms of the environment of intended use.

The properties of materials may change either permanently or temporarily when irradiated. Such changes which can affect their suitability for use in vacuum may include -

- Induced radioactivity – which might necessitate the use of remote handling techniques to disassemble or remove a component (e.g. steels may become active). Induced activity may be long-lived or short-lived.
- Mechanical degradation – which might affect the physical integrity of a component or a bond between components or which may generate particulates which could spread through a vacuum system (e.g. PTFE degenerates to a powder). Such changes are permanent.
- Transmutation – where a particular atomic species with good vacuum properties is transformed into one with poor vacuum properties (e.g. silver transmutes to cadmium). The products formed by transmutation can themselves transmute hence such changes can not be considered permanent.
- Chemical change – where the material decomposes under the influence of radiation (e.g. Viton releases hydrochloric acid, and PTFE releases fluorine, both of which are undesirable). Such changes are permanent.
- Desorption – under the influence of radiation, many materials exhibit enhanced outgassing due to induced desorption (e.g. hydrogen from steel when irradiated with X-rays). This stops when the source of radiation is switched off.

The effect of irradiation has been considered for *accepted* materials, and shall be considered in the qualification when materials not on the list are assessed for inclusion on the list.

Table 3-1 *Accepted* Materials

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Austenitic stainless steels	316L, 316LN 316L(N)-IG + Corresponding EN grades	✓	✓	✓	✓	✓	✓	✓	✓
	316 + Corrsponding EN grades	✗	✓	✝	✓	✝	✓	✝	✓
	316Ti SA-240 (NB Bellows Convolutions) MAR: ITER_D_TT37NF			✓					

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	316Ti (Elektical and optical patch boxes) MAR: ITER_D_TLM3YP				✓				
	304L 304LN 304B4 + Corresponding EN grades	✓	✓	✓	✓	✓	✓	✓	✓
	304 304 B7 Outgassing data:- ITER_D_EMZ98G + Corresponding EN grades	×	✓	✝	✓	✝	✓	✝	✓
Austenitic stainless steels	YDH 50 MAR:- ITER_D_4CRYM8	✓	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Austenitic Chromium-Manganese-Nickel stainless steels	XM-19 (UNS S20910), MAR:- ITER_D_DG7SKX JJ1	✓	✓	✓	✓	✓	✓	✓	✓
Austenitic Chromium-Manganese-Nickel stainless steels	Nitronic-60 (UNS S21800) MAR:- ITER_D_CA3TB6 Material data sheet ITER_D_CX9QCX Material information ITER_D_DCEREP	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation Hardening Iron Base Super-alloy	Grade 660 (UNS S66286), another name A286 + Corresponding EN grades	✓	✓	✓	✓	✓	✓	✓	✓
Ferritic (martensitic) stainless steel	430 (UNS S43000) Eurofer, F82H, Rusfer,	✓	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Ferritic (martensitic) stainless steel	431 (UNS S43100) (1.4057) ITER roughing pump shaft MAR:- ITER_D_DCCQYE Materials cert ITER_D_DBY4WW	✗	✗	✗	✗	✝	✝	✗	✗
Ferritic (martensitic) stainless steel	431 (UNS S43100) (1.4059) ITER roughing pump rotor and case MAR:- ITER_D_DCHJDM Materials cert ITER_D_DCEQ7B	✗	✗	✗	✗	✝	✝	✗	✗
Kovar	ASTM F15 KV-1~9	✓	✓	✓	✓	✓	✓	✓	✓
Nickel		✓	✓	✓	✓	✓	✓	✓	✓
Nickel based Alloys	Nimonic 80A(UNS N070080)	✓	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Monel 400	✓	✓	✓	✓	✓	✓	✓	✓
	Alumel (95% Ni, 2% Mn, 2%Al, 1%Si)	×	✝	×	✓	×	✓	×	✓
	Chromel (90%-10% Ni – Cr)	✓	✓	✓	✓	✓	✓	✓	✓
	Alloy 718 (UNS N07718) Alloy 625 (UNS N06625)	✓	✓	✓	✓	✓	✓	✓	✓
	Inconel 708 Bellows seal MAR:- ITER_D_KTP2JW	✓	✓	✓	✓	✓	✓	✓	✓
	N-type thermocouple MAR :- ITER_D_64J7S9	×	×	×	✓	×	×	×	×
	Nilo 42 (Nickel Iron Alloy 42 material) MAR:- ITER_D_QTVQ7F	×	✓	×	✓	×	✓	×	×

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Material / Material Class	**Grades, (or composition applicable to ITER)**	**Vacuum Quality Classification**							
		1A	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**
	Inconel X-750 (UNS N07750, DIN W.-Nr. 2.4669) MAR: ITER_D_S98EXM Material datasheet ITER_D_SM54DQ	✓	✓	✓	✓	✓	✓	✓	✓
Nickel based Braze	STEMET 1301 amorphous brazing alloy Vacuum brazing of W-Cu joint in the Divertor Dome PFUs armour (only PRPs) MAR:- ITER_D_7NTH2J Outgassing data:- ITER_D_7NSWW8 Mat Cert ITER_D_7NTH2J	×	✓	×	✓	×	✓	×	✓
	Nicrobraz 10 Alloy BNi6 (Ni / P 11%) Brazing of stainless steel cable sheaths into stainless steel bulkheads. MAR:- ITER_D_QZW8DY	✓	✓	✓	✓	✓	×	×	×

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Ni 102 Nickel-based high temp brazing paste For Brazing of non-vacuum boundary components DNB Beam (AKA:-Ni 102, BNi2 , L-Ni2, B-Ni82CrSiBFE-970/1000, 4777F, 9500/97) MAR ITER_D_S43LCB	✗	✓	✗	✓	✗	✓	✗	✓
Nickel based Braze	Nickel - Phosphorus 11% vacuum braze for the 6x diamagnetic coils (55.AG) under Triangular Support MAR ITER_D_S5EHB2	✗	✓	✗	✓	✗	✓	✗	✓

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Material / Material Class	**Grades, (or composition applicable to ITER)**	**Vacuum Quality Classification**							
		1A	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**
Pure Copper	Oxygen Free (OF) UNS C10200 Oxygen Free electronic (OFE) UNS C10100 EU grades: Cu-ETP (CW004A), Cu-FRTP, (CW006A), Cu-OF (CW008A), Cu-OFE (CW009A), Cu-PHCE (CW022A)	✝	✓	✓	✓	✓	✓	✓	✓
Pure Copper	Oxygen Free (OF) UNS C10200 OF (CW008A) MAR:- ITER_D_NT9JT5	✝	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Copper alloys	CuCrZr-IG: Cr (0.6 – 0.9 %), Zr (0.07 – 0.15 %) CuCr1Zr (CW 106C) CuCrZr (UNS C18150) БрХЦр (RF grade) YZC (JA grade)	✓	✓	✓	✓	✓	✓	✓	✓
	CuBe1.7 MAR:- ITER_D_RBENAP	×	✓	×	×	×	×	×	×
	CuBe2 MAR:- ITER_D_RB34RC	×	✓	×	×	×	×	×	×
	SeCu MAR:- ITER_D_R7NEZM	×	✓	×	×	×	×	×	×

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Copper alloys-Bronze	Aluminum bronze: UNS C63200,(82Cu-9Al-5Ni4Fe), CuAl10Ni5Fe4 (CW307G) CW301G (CuAl6Si2Fe)	✝	✓	✓	✓	✓	✓	✓	✓
Copper alloys-Bronze	Aluminium Bronze Casting (SO-5) (oilless bearing for in -vessel mirror motors. MAR:- ITER_D_4CT93S	×	✓	×	✝	×	✝	×	✝
Copper alloys-Bronze	Bronze (Cu-Sn-Pb) Application is VQC N/A (approved for installation use only) MAR: ITER_D_UG2K5V								
Copper alloys-Alumina Dispersion Strengthened	Glidcop Al60 Glidcop Al25-IG Al-15	✓	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Copper alloys- Alumina Dispersion Strengthened	Al-15 (Mirrors for EC Equatorial launcher) MAR:-ITER_D_4CQPLA	×	✓	×	✓	×	✓	×	✓
Copper-based braze	Nicuman 23 brazing alloy as a brazing alloy for use in the divertor MAR:- ITER_D_9K83MF Outgassing data:- ITER_D_6XLFJQ	×	✓	×	×	×	×	×	×
Copper-based braze	Nicuman 37 brazing alloy for use in VQC 1B as a brazing alloy for use in the divertor. MAR :- ITER_D_9K6V2C Outgassing data:- ITER_D_6XLFJQ Materials cert ITER_D_9K6V2C	×	✓	×	×	×	×	×	×

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Copper-based braze	STEMET 1101 microcrystalline brazing alloy Vacuum brazing of Cu-CuCrZr joint in the Dome PFUs armour MAR:- ITER_D_7NXAUN Outgassing data:- ITER_D_7NSWW8 Materials certificate ITER_D_7NSWW8	✗	✓	✗	✓	✗	✓	✗	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Copper-based braze	STEMET 1108 microcrystalline brazing alloy Vacuum brazing of Cu-CuCrZr joint in the Dome PFUs armour MAR:- ITER_D_7NSWW8 Outgassing data:- ITER_D_7NSWW8 Materials certificate ITER_D_7NSWW8	×	✓	×	✓	×	✓	×	✓
Beryllium	S – 65C VHP, DShG-200, TGP-56FW, CN-G01	✓	✓	✓	✓	✓	✓	×	×
Aluminium	Pure or alloys	✝	✓	✓	✓	✓	✓	✓	✓
	Aluminium alloy EN AW-6082-T6 MAR : ITER_D_S97FXR Deviation request also required for this VQC 1A application	✝							

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Tungsten	Pure sintered W and rolled, cast W alloy, W-1%La_2O_3 CVD	✗	✓	✗	✓	✗	✓	✗	✓
Tungsten Carbide	WC Cemented Carbide (Bearing Ring). MAR:-ITER_D_4CSC86 Mechanical pump (sliding seal) MAR :- ITER_D_L25NLL	✗	✓	✗	✓	✗	✓	✗	✓
Caesium		✗	✓	✗	✓	✗	✓	✗	✓
Gold		✝	✝	✝	✓	✓	✓	✓	✓
Gold	Thin leaf 100 micron (bonding agent) MAR:- ITER_D_QDASPX	✗	✝	✗	✗	✗	✗	✗	✗

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Gold based braze	Nioro brazing materials (AuNi 82/18%) MAR: ITER_D_TVU72E	✓	✓	✓	✓	✓	✓	✓	✓
Silver		✝	✝	✝	✓	✓	✓	✓	✓
Silver-based braze	BAg-8 (Japanese Industrial Standard; JIS Z3261) Ag as filler material for brazing on the DNB bushing MAR :- ITER_D_AJL8YX Deviation request ITER_D_4AHGK6 Transmutation data ITER_D_4FJRHJ, ITER_D_7PGX7C	×	✝	×	×	×	×	×	×
Silver-based braze	BrazeTec_CB10 MAR: ITER_D_UMF87D		✝						

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Silver-based braze	BPd-2 MAR: ITER_D_UXN7AY				✝				
Tantalum	Sheet MAR:-ITER_D_2LN64R	✓	✓	✓	✓	✓	✓	✓	✓
Germanium		✝	✓	✝	✓	✝	✓	✝	✓
Samarium Cobalt ($Sm_2Co^{17)}$	R26HS	×	✓	×	✓	×	✓	×	✓
Zinc		×	×	×	×	×	×	×	×
Cadmium		×	×	×	×	×	×	×	×
Titanium	Pure or alloys	✝	✝	✝	✓	✝	✓	✝	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Titanium	Titanium ASTM Grade2 T2 & 5 T5 ICH & CD antenna: Removable vacuum transmission lines MAR:- ITER_D_6R2ZJW Related attachments ITER_D_6R2ZJW, ITER_D_6R2ZJW, ITER_D_6R2ZJW	✝	✗	✗	✗	✝	✗	✗	✗
Titanium based braze	Ticuni Braze MAR: ITER_D_UMFFFP		✝						
Quartz		✓	✓	✓	✓	✓	✓	✓	✓
Silicon	Mono-crystalline, 380 µm thick board Ex-vessel magnetic sensor (55.A5/A6 MEMS) Total mass ~2.5g for all sensors MAR:- ITER_D_DFVQ4C	✗	✗	✗	✝	✗	✗	✗	✗

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Silicon	Poly-crystalline 40 µm diameter plugs through 380 µm thick mono-Si circuit board Ex-vessel magnetic sensor (55.A5/A6 MEMS) Total mass ~0.001g (1mg) for all sensors MAR ITER_D_DG5JJR	✗	✗	✗	✝	✗	✗	✗	✗
Silica,	Fused SiO2	✓	✓	✓	✓	✓	✓	✓	✓
Composite (diamond, silicon carbine, silicon)	Sckeleton-1 MAR:- ITER_D_64NG84	✗	✓	✗	✗	✗	✗	✗	✗
Diamond	Pure and DLC, CVD	✓	✓	✓	✓	✓	✓	✓	✓
Graphite	Pyrolytic (Langmuir Probe) MAR:- ITER_D_2LUWMJ	✗	✝	✗	✝	✗	✗	✗	✗

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
(see note 1)	GR-1 (restricted to allow tracking). MAR:- ITER_D_4CRPVS	×	✝	×	✝	×	×	×	×
	Papyex: N 998 Flexible Graphite MAR: ITER_D_KZWER7 Technical guide ITER_D_RZM4SU	×	✝	×	×	×	×	×	×
Composite (Carbon Fibre Composite CFC, see note 1)	SNECMA and Dunlop: various grades Supercarb NB 31 (3D), NIC-01 Toyo Tanso:CX2002U (2D)	×	✓	×	✓	×	✓	×	✓
Porcelain	C221	✓	✓	✓	✓	✓	✓	✓	✓
Ceramic	Kyocera A479	✓	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Glass Ceramic	DuPont 951 Green Tape For Low-Temperature Co-fired Ceramics sensor applied to PBS 55.AA/AB/AC MAR ITER_D_S22ME4 Outgassing test reports ITER_D_QYRA8N ITER_D_QYM8ZD	×	✓	×	✓	×	✓	×	✓
	MACOR (MGC) Small machined parts MAR:-ITER_D_LF5RDE Vac data:- ITER_D_LEYH7S	×	✓	×	✓	×	✓	×	✓
	Shapal Hi-M SOFT (machinable AlN) In-vessel Magnetic Sensors (55.AA/AB/AC/AJ) applications Outgassing data ITER_D_C9TP4H Material datasheet ITER_D_C9XYVT	×	✓	×	✓	×	✓	×	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
$MgAl_2O_4$		✓	✓	✓	✓	✓	✓	✓	✓
MgO	Magnesium oxide as base insulation material for the In-Vessel Coils conductor. Powder glued and sintered in blocks, confined in the conductor jacket MAR ITER_D_STESWL	×	✓	×	✓	×	✓	×	✓
Titanium dioxide TiO_2		×	✓	×	✓	×	✓	×	✓
Alumina Al_2O_3	Grade IV to ASTM D2442	✓	✓	✓	✓	✓	✓	✓	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Alumina (Al_2O_3)	Aluminum Oxide (TS-03312) Surface coating for slid pin, internal shield etc MAR:- ITER_D_4CQG7F	×	✓	×	×	×	×	×	×
Alumina cyanate ester	Alumina Filled Cyanate Ester (MC7885-UF) Ex-vessel Magnetic Sensors (55.A5/A6 MEMS), Qty ~30g for all sensors MAR:- ITER_D_DFZ4YK	×	×	×	✓	×	×	×	×
Aluminium Nitride	Shapal SH-15 (Small moulded/machined parts) MAR:- ITER_D_EH72BL	×	✝	×	✝	×	×	×	×

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Aluminium Nitride	Shapal M-soft (sintered composite of Al nitrate and B nitrate) MAR:- ITER_D_C9TCXH Outgassing data:- ITER_D_C9TP4H	×	✝	×	✝	×	×	×	×
Aluminium Nitride	Aluminium Nitride (Circuit Board Substrate) Ex-vessel sensor, total quantity 1.3kg maximum MAR:- ITER_D_DG7QJY Outgassing Data :- ITER_D_DG46FA	×	×	×	✝	×	×	×	×
Aluminium Nitride	AlN (high purity sintered for IVS RF shield) MAR ITER_D_SMX5GR Outgassing data ITER_D_DG46FA Chemical analysis ITER_D_SLZRLQ	×	✓	×	✓	×	✓	×	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Silicon Nitride (SiN_4)	TSN-03 (in vacuum ball brearing) MAR:- ITER_D_4C5QZJ	×	✓	×	×	×	×	×	×
Caesium Iodide CsI	Ti activated	×	✓	×	✓	×	✓	×	✓
Resin -Epoxy	TGDDM	×	×	✝	✓	✝	✓	×	✓
Resin -Epoxy	Araldite rapid MAR: ITER_D_UELUT4								✓
Resin -Cyanate Ester	Quartz Filled Cyanate Ester (MC7883-UF or MC9883-LPM) Bonding agent in sensor silicon wafer Ex-vessel Magnetic Sensors (55.A5/A6 MEMS), Qty ~30g for all sensors MAR:- ITER_D_DG4HDK	×	×	×	✝	×	×	×	×

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Optical glue	SKTN-MED optical glue MAR: ITER_D_76JZCP		✝						
Composite (Epoxy / (glass fibre)	G10. Electrical insulator MAR:- ITER_D_4E9Q2M	×	×	×	✓	×	×	×	✓
	G11 / EPGC203. Electrical insulator MAR ITER_D_SRSGTV	×	×	×	×	×	×	×	✓
Inorganic adhesive	Thermoguss 2000	×	✓	✝	✓	✝	✓	×	✓
	Thermoguss 2000 MAR:- ITER_D_R69NWA Performance as a seal on MI cable must be demonstrated by qualification tests on actual cables	×	×	×	×	✓	×	×	×
Glass	S 2, R- and T	×	✝	×	✓	×	✓	×	✓

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Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Polyimide	Vespel	×	✓	×	✓	×	✓	×	✓
Polyimide	ERTALON 66 Application is VQC N/A (approved for installation use only) MAR: ITER_D_UG2BMP								
Polyimide	Thermopastic Polyimide (TPI), Axon Cable MAR: ITER_D_RTNM3U This sample accepted by outgassing test in MAR				✝				
PEEK (Polyether ether ketone)	As shrink tubing for steady-state sensors 55.A5/A6 MAR ITER_D_RT2T5V Product datasheet ITER_D_RMLNSM	×	×	×	✓	×	✓	×	✓

KEY: ✓ = approved for use. × = not approved for use. ✝ = restricted use

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
EPDM (Ethylene-propylene)	Use restricted to 2nd , outer, seal gasket only (i.e. between SVS pumped volume/Air) in VQC 2A double sealed flanges (1st, inner seal, being metallic)	×	×	✝	×	×	×	×	×
Nitrile rubber (Buna – N)	Use restricted to 2nd , outer, seal gasket only (i.e. between SVS pumped volume/Air) in VQC 2A double sealed flanges (1st, inner seal, being metallic)	×	×	✝	×	×	×	×	×
Superinsulation	Aluminium deposited Kapton, Mylar. Aluminium foil	×	×	×	✝	×	×	×	✓
	Aluminium deposited Polyester	×	×	×	×	×	×	×	✝
Halogenated materials	PTFE, Fibreslip (Teflon fibre-glass weave)‡ ‡ PTFE bearings are approved for positions where the predicted radiation fluence over the full operational life of ITER is less than 103 Gray (Gamma or Neutron dose equivalents)	×	×	×	✓	×	×	✓	✓

KEY: ✓ = approved for use. × = not approved for use. ✝ = restricted use

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Viton	✗	✗	✝	✝	✝	✓	✓	✓
	Kalrez Non-vacuum application (3rd party pump) VQC=N/A MAR:- ITER_D_L5MK2Q								
	Bromine (In Halogen lamp for CXRS Diagnostic in-situ calibration. MAR:- ITER_D_48D5EX	✗	✝	✗	✗	✗	✗	✗	✗
Barium Fluoride	Barium Fluoride vacuum windows MAR:- ITER_D_P8Q4NT ITER_D_32KTBX	✓	✗	✗	✗	✓	✗	✗	✗
Molybdenum	Molybdenum as solid pure form (i.e. not powdered or compound form)	✓	✓	✓	✓	✓	✓	✓	✓

KEY: ✓ = approved for use. ✗ = not approved for use. ✝ = restricted use

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Molybdenum	Tracks on surface of silicon wafer sensor Ex-vessel Magnetic Sensors Qty ~0.001g (1mg) total for all sensors MAR:- ITER_D_DG5ZG5	×	×	×	✝	×	×	×	×
Molybdenum alloy	Mo alloy (Titanium(0.5)-Zirconium(0.08)-Molybdenum, TZM) MAR: ITER_D_TRZ5LS Outgassing data ITER_D_TR7YZC	✓	✓	✓	✓	✓	✓	✓	✓
MoS_2	Molykote D-321 R Anti-Friction Coating MAR: ITER_D_U3HP3S								✝
MoS_2	Molykote D-321 R Anti-Friction Coating MAR: ITER_D_UAT6CB				✝				

KEY: ✓ = approved for use. × = not approved for use. ✝ = restricted use

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
MoS_2	Sputtered MoS_2 MAR: ITER_D_TL5DS8		✝						
MoS_2		×	✝	×		×	✝	×	✝
$MoSe_2$		×	✝	×	✝	×	✝	×	✝
WS_2		×	✝	×	✝	×	✝	×	✝
WSe_2		×	✝	×	✝	×	✝	×	✝
Boron Nitride		×	✓	×	✓	×	✓	×	✓
Titanium Nitride (TiN)	PVD hard coating (anti-seizing of bolt threads, used generally) MAR:- ITER_D_2LPCE9	×	✓	×	✓	×	✓	×	✓

KEY: ✓ = approved for use. × = not approved for use. ✝ = restricted use

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Boron Carbide		×	✝	×	✝	×	✝	×	✝
	Boron Carbide, Hot pressed sintered MAR: ITER_D_T7DB99		✝						
Zirconium Nitride	Chemical Vapour Deposition Coating	×	✝	×	✝	×	✝	×	✝
Zirconia	ZrO_2 with TiN coating Non-vacuum application (3rd party pump) VQC=N/A MAR:- ITER_D_L239S5								

KEY: ✓ = approved for use. × = not approved for use. ✝ = restricted use

Material / Material Class	Grades, (or composition applicable to ITER)	Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Zirconia	ZrO_2 ceramic can in a mechanical vacuum pump Non-vacuum application (3rd party pump) VQC=N/A MAR :- ITER_D_KZAGJN								
	ZrO_2 sintered or plasma sprayed MAR:- ITER_D_R64Q62	×	✓	×	×	×	×	×	×
	Zirconia based adhesive RESBOND 940. MAR & Outgassing data ITER_D_RUDVER:				✝				

KEY: ✓ = approved for use. × = not approved for use. ✝ = restricted use

3.4 Example Material Request Form

Material Approval Request *(v1.0)*										Ref No: Mat-Cha-1 *(Assigned by Vacuum RO)*
Material submitted for approval:	Ceramic TRADE Name xxx									
Proposed form:	Solid									
Proposed Use:	HV Bushing									
VQC of proposed use:	1A	1B	2A	2B	3A	3B	4A	4B	N/A	
	☒	☒	☒	☒	☒	☒	☒	☒	☐	
If restricted give details of coverage (e.g. amount, surface area etc)										
Chemical Analysis / Material Safety Data Sheet available:	YES	*Attached Copy document ref. (electronic if available)*								
Agreed test plan:	NO	*Attached Copy document ref. (electronic if available)*								
Vacuum Test data Available:	YES	*Attached Copy document ref. (electronic if available)*								
Outgassing rate (at 100 °C)	N/A									
Vapour pressure (at 100 °C)	N/A									
Max temperature:	1000		Operating temperature:	240						
Pre installation treatment *(baking, electropolishing etc)*			Baked clean							
Requested by:	A.N.Other		Date Submitted:	25/03/09						
Affiliation :	USA		E-Mail	A.Other@USA.org						
Vacuum Material Approval Status: (*To be completed by ITER Vacuum Group RO)*										
Approved for VQC:	1A	1B	2A	2B	3A	3B	4A	4B	N/A	
	☒	☒	☒	☒	☒	☒	☒	☒	☐	
Limits / Restrictions (Attached Doc.)†										
ITER Vacuum RO	Approver:	L.Pressure								
	Date:30/03/09									

Grey boxes to be completed by requesting officer. Boxes in Red to be completed by ITER Vacuum RO.

† Reasons for material rejections shall be supplied with the notification of material refusal.

3.5 Notes:-

1. Carbon and carbon composites shall be conditioned for (vacuum) use in accordance with the ITER Vacuum Handbook. ITER vacuum handbook ITER_D_29DFGH

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IDM UID
2ELN8N
VERSION CREATED ON / VERSION / STATUS
17 Jul 2017 / 1.14 / Approved
EXTERNAL REFERENCE / VERSION

Guideline (not under Configuration Control)

Appendix 4 Accepted Fluids

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Vine G.**	**17 Jul 2017:signed**	**IO/DG/COO/PED/FCED/VS**
Co-Authors			
Reviewers	**Pearce R.** **Worth L.**	**31 Aug 2017:recommended** **17 Jul 2017:recommended**	**IO/DG/COO/PED/FCED/VS** **IO/DG/COO/PED/FCED/VS**
Approver	**Lee G.- S.**	**08 Sep 2017:approved**	**IO/DG/COO**
#SecureIDM# *RO: Chiocchio Stefano*			
Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: EUROfusion-DEMO, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: [CCS] CCS-All for Ext AM, LG: [CCS] CCS-Section Leaders, LG: [CCS] JACOBS,...**		

Change Log			
Appendix 4 Accepted Fluids (2ELN8N)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	27 Aug 2008	
v1.1	In Work	12 Jan 2009	
v1.2	In Work	18 Jun 2009	Name change from approved to accepted. Cutting fluid removed.
v1.3	Approved	02 Sep 2009	Minor textual changes for consistency with Vacuum Handbook
v1.4	Approved	29 Feb 2012	New fluids added
v1.5	Approved	05 Oct 2012	Included new cutting fluid and approved liquid dye penetrant product families (with restrictions)
v1.6	Signed	26 Jan 2015	Fluids added:- Cutting fluids Blasocut Castrol SYNTILO 75 EF Cut1 - Carecut S cuting fluid Garia 2608 S-12 Green Star SINTOL Micro Jokisch Foam Cut Magicutsynth-g-60 QUAKER 3755 BIO Hocut 2000 SWISSCOOL 7722 Vasco 1045 Acids 20% Sulphuric Acid solution Concentrated Nitric Acid Hydroflouric Acid LDP FluidLDP W divertor Couplants Babb Co matrix UT coupling agent CGM US Paste U49 Other Demin Water Elektrolyt EH01 Neutralix NG01
v1.7	Signed	10 Feb 2015	Fluids added:- Cutting fluids Blasocut Castrol SYNTILO 75 EF Cut1 - Carecut S cuting fluid Garia 2608 S-12 Green Star SINTOL Micro Jokisch Foam Cut Magicutsynth-g-60 QUAKER 3755 BIO

			Hocut 2000 SWISSCOOL 7722 Vasco 1045 Acids 20% Sulphuric Acid solution Concentrated Nitric Acid Hydroflouric Acid LDP FluidLDP W divertor Couplants Babb Co matrix UT coupling agent CGM US Paste U49 Other Demin Water Elektrolyt EH01 Neutralix NG01
v1.8	Approved	11 Feb 2015	Document version in header matched to IDM version Fluids added:- Cutting fluids Blasocut Castrol SYNTILO 75 EF Cut1 - Carecut S cuting fluid Garia 2608 S-12 Green Star SINTOL Micro Jokisch Foam Cut Magicutsynth-g-60 QUAKER 3755 BIO Hocut 2000 SWISSCOOL 7722 Vasco 1045 Acids 20% Sulphuric Acid solution Concentrated Nitric Acid Hydroflouric Acid LDP FluidLDP W divertor Couplants Babb Co matrix UT coupling agent CGM US Paste U49 Other Demin Water Elektrolyt EH01 Neutralix NG01
v1.9	Approved	19 May 2015	Fliuds and other processing media added:- Cutting fluids:- Xtreme Cut 250

			Pickling and passivation:- Avesta Passivator 601 Avesta Cleaner 401 Avesta picking paste BlueOne TM 130 Markers:- Intrama SL.250 SL2100 Abrasive media:- Cutting wheel: Abratec TIPO 42 Cutting wheel: Sait “A30S” [Thk. 2 mm] Cutting wheel: Sait “XA24Q” [Thk. 3,2 mm] Cutting wheel: Sait “XA24Q” [Thk. 7 mm] Cutting wheel: Sait “XA46R” [Thk. 1,6 mm] Flapper wheel: Abratec LAMELLARE Flapper wheel: Abratec LAMELLARE Flapper wheel: Sait "SAITLAM UK 3A" Flapper wheel: S.L.F. Abrasivi LASER DISC Rough Wheel: Abratec TIPO 27 Rough Wheel: 3M “987C CUBITRON 2”
v1.10	Approved	19 Aug 2015	Temporary fixings incorporating adhesive tape added, all VQC N/A. 3M™ Aluminum Foil Tape 431 3M™ Preservation sealing Tape 481 Delvigo DVC 48040/7 A5 weld backing strip Delvigo DVC 44040/6 A5 weld backing strip Scapa 336 Aluminium adhesive tape For any use on higher VQC categories, verification of full cleaning process required on sample coupons
v1.11	Approved	05 Nov 2015	Fluids added to previous version:- Metalsierra DF Cutting fluid Stratomet Protective paint (for processing equipment-not vacuum components) HC 1100-Passivator. Cleansafe 787-Cleaning agent VK Jelly / VK Jelly – Power / VK Spray / VK Spray - 1000 -Pickling and passivation K-2 Jelly / K-2 Jelly – Power / K-2 Spray / K-2 Paste -Pickling and passivation Ultrasonic couplant, Rock Oil 09060 -Ultra Sonic Testing (UT) coupling fluid Dodecane, 297879, Sigma-Aldrich -Ultra Sonic Testing (UT) coupling fluid
v1.12	Approved	07 Jun 2016	Fluids added:- Blasocut BC 935 Kombi, cutting fluid Vasco 7000, cutting fluid HE 111 Electrolytic polisher, HC 1100-K3W1, passivator HC 500, cleaning agent HE 310 Electrolytic Polisher, DR60, as LDP remover, NGL 17.40 P, ultrasonic cleaning PROSOLV HP, solvent ALCATUM / ALCATUM HO, cleaning agent

			DOWCLENE 1601, cleaning agent Kool Mist Formula 78, machining coolant Oil Eater, degreaser Rebound 7, degreaser Trim E206, machining coolant Trim Tap Heavy, cutting fluid Trim Tap Light, cutting fluid Blasocut 4000, cutting fluid
v1.13	Approved	06 Dec 2016	Abrasive media added:- Klingspor KL 315 abrasive paper PMUC 10067 3M Roloc Disc 984F Abrasive disk 3M Cloth Belts 984F. Abrasive Belt for belt grinder 3M Cubitron™ II: Cut off Wheels 3M Flap Disc 967A. Lukas Tungsten carbide burrs. Stainless steel brush 3M XT-RD-Cleaning Disc Cleaning agent -Surtec®089 with Surtec®132 Cleaning agent -PROCIV CUP Cutting Fluid -Hocut 795 HX Cutting Fluid -SWISSCOOL 7722 Markers-Edding 750 white, Silver and Blue Pickling and passivation-PROCAP 137 Tape-3M 425 & 431 Aluminium Foil Tape Handling material-Kraitec Elastomer pad UT coupling fluids-MR 750 Ultrasonic Coupling Agent
v1.14	Approved	17 Jul 2017	Fluids / other process media added:- Paper KL361 grain 240, grain 120 and grain 80 ; Grinding tool RB Adhesive Technologies Glue Stick, Part #229 Tacky tape SM 5142 Cleaning fluid RBS826 CitriSurf 2310 Oemeta Novamet 100 Coolant SemiSyn-200 Blue Coolant S-787_Request__Fluid_Acceptance Castrol CareCut S 600 HOCUT 795 MP Hocut 795 H Blasocut BC 25 MD Pentagon Coolcut S Blasocut BC 35 Kombi MK-SOL Soluble metal working oil Synergy 915 APIEZON T Markal paint marker Edelstahlbeize Typ 14 AveryDennison HP MPI 2121 Tesa 4613 – Utility grade Duct Tape Soundclear 60 Soundclear 40 UT Couplant for ITER Cryostat

ITER Vacuum Handbook
Appendix 4

Accepted Fluids

	Name	Affiliation
Author/Editor	Liam Worth	Vacuum Group - CEP
Vacuum Responsible Officer	Robert Pearce	Vacuum Group - CEP

4 ITER *Accepted* Fluids

4.1 Scope

This Appendix relates to fluids *accepted* to be used in the preparation and processing of materials and components which are exposed to the ITER vacuum environments, e.g. cutting fluids and cleaning solvents.

The ITER Vacuum Handbook (Section 6.1) states that

> "Cutting fluids for use on VQC 1 and 3 systems shall be water soluble, non-halogenated and phosphorus and sulphur free"[1].
>
> "*Accepted* cutting fluids for use in VQC 1 and 3 vacuum applications are listed in Appendix 4. The use of other cutting fluids requires prior *acceptance*.
>
> *"Acceptance* for the use of any particular non-approved cutting fluid shall be obtained by submitting the Fluid *Acceptance* Request Form, stored on IDM, to the ITER Vacuum Responsible Officer (RO).
>
> "For VQC 2 & 4 vacuum applications it is recommended that cutting fluids be water soluble, non-halogenated and phosphorus and sulphur free[1]. They should be chosen from those listed in Appendix 4. Where this recommendation is not followed particular care shall be taken to ensure the appropriateness of the cleaning procedures"

The ITER Vacuum Handbook Section 24 states that

> "Lists of *accepted* cleaning fluids can be found in Appendix 4"

Pursuant to this, materials which may be used freely for use on vacuum system items with the Vacuum Classifications stated are listed in the tables below.

4.2 Fluids not on the Accepted List

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

Details of fluids to be considered for *acceptance* should be submitted to the ITER Vacuum RO using the Fluid *Acceptance* Request Form. The proposer shall agree in advance with the ITER Vacuum RO a plan detailing the type and method of testing to qualify the material for use. The Fluid *Acceptance* Request Form along with the test data, report and supporting documentation, including any *supplier's* data (Certificates of Conformity, etc.), is to be submitted for consideration.

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

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

A completed sample of the Fluid *Acceptance* Form is to be found at the end of this Appendix.

4.3 Fluid Selection / Qualification

The fluids listed in the following tables have been considered in terms of usage for vacuum purposes.

The properties of interest for this purpose include, *inter alia*,

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

Fluids

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Cleaning fluids	Isopropyl Alcohol	✓	✓	✓	✓	✓	✓	✓	✓
	Ethyl Alcohol	✓	✓	✓	✓	✓	✓	✓	✓
	Acetone	✓	✓	✓	✓	✓	✓	✓	✓
	Axarel 9100™,	✓	✓	✓	✓	✓	✓	✓	✓
	Citrinox™	✓	✓	✓	✓	✓	✓	✓	✓
	P3 Almeco™, P36 or T5161	✓	✓	✓	✓	✓	✓	✓	✓
	RBS 25	✓	✓	✓	✓	✓	✓	✓	✓
	RBS 35								

KEY: ✓ = *accepted* for use. × = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	RBS A350	✓	✓	✓	✓	✓	✓	✓	✓
	Cleansafe 787 MAR: ITER_D_RWAQR3 Datasheet:- ITER_D_RWH2NT	✓	✓	✓	✓	✓	✓	✓	✓
	HC 500 Liquid cleaning agent (Used in electropolishing process for cryogenic piping for the pre-production cryopump) FAR ITER_D_RZ3F5Q SDS ITER_D_RZ7ZFP MDS ITER_D_RZJVUT Approved cleaning procedure ITER_D_S2FG8X	✓	✓	✓	✓	✓	✓	✓	✓
	NGL 17.40 P Precision Cleaning for Ultrasonic processes FAR ITER_D_SEW4QA	✓	✓	✓	✓	✓	✓	✓	✓

KEY: ✓ = *accepted* for use. ✗ = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	DOWCLENE* 1601 Cleaning Fluid FAR ITER_D_STQSEK	✓	✓	✓	✓	✓	✓	✓	✓
	Oil Eater Manufacture of ITER-style vacuum flanges. FAR ITER_D_Q8DUKT SDS ITER_D_SRFUYV Cleaning Aqueous wash with Rebound 7 followed by DI water rinse	✓	✓	✓	✓	✓	✓	✓	✓
	CitriSurf 2310 MAR : ITER_D_UHXTT3	✓	✓	✓	✓	✓	✓	✓	✓
	RBS826 Cleaning fluid MAR : ITER_D_TF3G4P							✓	✓

KEY: ✓ = *accepted* for use. × = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Rebound 7 Manufacture of ITER-style vacuum flanges. Aqueous wash followed by DI water rinse FAR ITER_D_QCK53E SDS ITER_D_SRF2G7	✓	✓	✓	✓	✓	✓	✓	✓
	Surtec®089 with Surtec®132 FAR:- ITER_D_TTWQVK	✓	✓	✓	✓	✓	✓	✓	✓
	PROCIV CUP FAR ITER_D_STHJGP	✓	✓	✓	✓	✓	✓	✓	✓
Cutting fluids	Castrol CareCut S 125	✓	✓	✓	✓	✓	✓	✓	✓
	Vasco 1045	✓	✓	✓	✓	✓	✓	✓	✓

KEY: ✓ = *accepted* for use. × = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Vasco 7000 MAR ITER_D_RFQND9 MDS ITER_D_RAW9TK Chemical Analysis ITER_D_RZBSEF SDS ITER_D_RF4MWR	✓	✓	✓	✓	✓	✓	✓	✓
	Alusol M-FX Only approved for use for the processing of base material which is subject to subsequent machining / cleaning operations utilising accepted water miscible fluids.	✝	✝	✝	✝	✝	✝	✝	✝
	Hocut 2000	✓	✓	✓	✓	✓	✓	✓	✓
	Hocut 795 HX Soluble Metalworking Oil FAR:- ITER_D_4H3QL6 Use accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

KEY: ✓ = *accepted* for use. ✗ = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Fluid Blasocut BC 35 Kombi SW ITER_D_HY3BCT	✓	✓	✓	✓	×	×	×	×
	Blasocut Kombi 935 MAR: ITER_D_RGD6JH Chemical analysis ITER_D_RZKU4T Safety datasheet ITER_D_=RGCLWS	✓	✓	✓	✓	✓	✓	✓	✓
	Blasocut 4000 Cleaning: Remove with water or solvent wipes FAR ITER_D_N54G6D	×	×	✓	✓	✓	✓	✓	✓
	CASTROL SYNTILO 75 EF ITER_D_PVM8M6	✓	×	×	×	×	×	×	×
	Garia 2608 S-12 https://user.iter.org/?uid=LXQXBA Only for use on non-vacuum facing surfaces (which must be protected) and all surfaces cleaned post machining.	✝	×	✝	×	×	×	×	×

KEY: ✓ = *accepted* for use. × = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Green Star SINTOL MICRO ITER_D_Q3N7N7	✝	×	×	×	×	×	×	×
	Thread Cutting Oil Jokisch Foam Cut ITER_D_PNPSKN	✝	✝	✝	✝	✝	✝	✝	✝
	Magicutsynth-g-50 ITER_D_N3Q69Y	×	×	✝	✝	✝	✝	✝	✝
	QUAKER 3755 BIO ITER_D_NR4E2J	×	×	✝	✝	✝	✝	✝	✝
	Metalsierra DF Metalworking fluid FAR:- ITER_D_RMNBXQ Chemical analysis ITER_D_RMLNX3 Product data sheet ITER_D_RKLNT9 Safety data sheet ITER_D_RKLNX7	✓	✓	✓	✓	✓	✓	✓	✓

KEY: ✓ = *accepted* for use. × = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Cutting fluids	SWISSCOOL 7722 FAR: ITER_D_NFJ2N8 Approved for the spider application only	✝	✝	✝	✝	✝	✝	✝	✝
	SWISSCOOL 7722 FAR:- ITER_D_TTWU7X Use accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Xtreme Cut 250 MAR:- https://user.iter.org/?uid=QT8QGH Chemical analysis:- https://user.iter.org/?uid=QQ6LSM Subject to accepted cleaning procedure	×	×	✓	✓	✓	✓	✓	✓
	Hangsterfer's S787 Cutting Fluid MAR: ITER_D_SGMMPE				✓	✓	✓	✓	✓
	Castrol CareCut S 600 MAR: ITER_D_UCWFVD	✓	✓	✓	✓	✓	✓	✓	✓

KEY: ✓ = *accepted* for use. × = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	HOCUT 795 MP MAR : ITER_D_TR7XRQ			✓	✓	✓	✓	✓	✓
	Hocut 795-H MAR : ITER_D_UDSBHL			✓	✓	✓	✓	✓	✓
	Blasocut BC 25 MD MAR : ITER_D_UFCFJC				✓	✓	✓	✓	✓
	Pentagon Coolcut S MAR : ITER_D_UJ8YF4			✓	✓	✓	✓	✓	✓
	Blasocut BC 35 Kombi MAR : ITER_D_U4EZRD	✓	✓	✓	✓	✓	✓	✓	✓
	MK_SOL_LUBE MAR : ITER_D_U4F3YE	✓	✓	✓	✓	✓	✓	✓	✓
	Hocut 795MP MAR : ITER_D_UVF5MT								

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Synergy 915 MAR : ITER_D_UXSKL9			✓	✓	✓	✓	✓	✓
	Trim Tap Heavy FAR ITER_D_N9XD58 SDS ITER_D_T3BGTK (manufacture of ITER-style vacuum flanges) Cleaning: Aqueous wash with Rebound 7 followed by DI water rinse	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Trim Tap Light FAR ITER_D_Q5UH9M SDS ITER_D_T3C35D (manufacture of ITER-style vacuum flanges) Cleaning: Aqueous wash with Rebound 7 followed by DI water rinse	✓	✓	✓	✓	✓	✓	✓	✓
Machining Coolant	Kool Mist Formula 78 (manufacture of ITER-style vacuum flanges) FAR ITER_D_RCAFRL SDS ITER_D_SYC4EU Cleaning: Aqueous wash with Rebound 7 followed by DI water rinse	✓	✓	✓	✓	✓	✓	✓	✓
	Oemeta Novamet 100 Coolant MAR : ITER_D_U8W2E5			✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	SemiSyn-200 Blue MAR : ITER_D_UVF66V			✓	✓	✓	✓	✓	✓
	Trim E206 (manufacture of ITER-style vacuum flanges) Cleaning: Aqueous wash with Rebound 7 followed by DI water rinse FAR ITER_D_RZEV86 SDS ITER_D_SZWMS6	✓	✓	✓	✓	✓	✓	✓	✓
Solvents	Nefras S2-80/120 Wiping of Dome divertor parts for degreasing after machining FAR ITER_D_JREV32	✓	✓	✓	✓	✓	✓	✓	✓
	PROSOLV HP Degreasing of Copper & Tungsten for IVT Phase I FAR ITER_D_ST35B5	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Acids	Nitric acid (65%) FAR https://user.iter.org/?uid=PNAPTE https://user.iter.org/?uid=PNHPFU https://user.iter.org/?uid=PQA6AW	✓	✓	✓	✓	✓	✓	✓	✓
	Sulphuric Acid (20% solution) FAR https://user.iter.org/?uid=PJRKC5 https://user.iter.org/?uid=PK32SY https://user.iter.org/?uid=PKZE6A	✓	✓	✓	✓	✓	✓	✓	✓
	Nitric Acid Concentrated FAR https://user.iter.org/?uid=D29SZG https://user.iter.org/?uid=CZMVE5 https://user.iter.org/?uid=DBQPL9 https://user.iter.org/?uid=DBQPL9	✝	✝	✝	✝	✝	✝	✝	✝

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Acids	Hydrofluoric acid (in the manufacture of Divertor components prior to HIP) FAR https://user.iter.org/?uid=JQH3BW https://user.iter.org/?uid=JQH73T https://user.iter.org/?uid=JQHPHU	✝	✝	✝	✝	✝	✝	✝	✝
Alkaline solution	ALCATUM / ALCATUM HO Degreasing of Copper & Tungsten for IVT Phase I FAR ITER_D_STLR2W	✓	✓	✓	✓	✓	✓	✓	✓
Demin Water	Demin Water https://user.iter.org/?uid=N3PDHF	✓	✓	✓	✓	✓	✓	✓	✓
Etch and neutralise	Elektrolyt EH01 FAR https://user.iter.org/?uid=JEZ7DD	✓	✓	✓	✓	✗	✗	✗	✗
	Neutralix NG01 FAR https://user.iter.org/?uid=JF7ME6	✝	✝	✝	✝	✝	✝	✝	✝

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Lubricant	APIEZON Medium Temperature Approved for VQC N/A only MAR : ITER_D_TF84U8								
Pickling and passivation	Avesta Passivator 601 FAR:- https://user.iter.org/?uid=NVPBLQ Datasheets:- https://user.iter.org/?uid=NW5VLQ https://user.iter.org/?uid=P3WC76 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Avesta Cleaner 401 FAR:- https://user.iter.org/?uid=NSE9MN Datasheets:- https://user.iter.org/?uid=NSEMN4 https://user.iter.org/?uid=NSH4DX Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Pickling and passivation	Avesta picking paste BlueOne TM 130 FAR:- https://user.iter.org/?uid=NQ4Y7N Datasheets:- https://user.iter.org/?uid=NQTMJC https://user.iter.org/?uid=NS77X8 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	HC 1100 Passivation solution for Stainless Steel (cryogenic piping for the pre-production cryopump) FAR:- ITER_D_RXJZB7 Datasheet :- ITER_D_RYMSKU	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	HC 1100-K3W1 Stainless steel passivator (cryogenic piping for the pre-production cryopump) FAR ITER_D_RZ5MBE MDS ITER_D_RZ7JP4 SDS ITER_D_RZK5GK Cleaning procedures ITER_D_S2FG8X to be used	✓	✓	✓	✓	✓	✓	✓	✓
	VK Jelly / VK Jelly – Power / VK Spray / VK Spray – 1000 FAR:- https://user.iter.org/?uid=RUGXSS			✓	✓	✓	✓	✓	✓
	Edelshahlbeize Typ 14 MAR : ITER_D_U7VKQS	✓	✓	✓	✓	✓	✓	✓	✓
	K-2 Jelly / K-2 Jelly – Power / K-2 Spray / K-2 Paste FAR:- ITER_D_RVVJ9S			✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	PROCAP 137 FAR:- ITER_D_STGBAW Use with approved cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
Liquid Dye Penetrant product families	**Sherwin Inc. USA: NDT Europa BV:** Developer: D100 Cleaner: DR62 Penetrant: DP51 ***For VQC 1A/B This product is restricted and may only be used if component / system under test is subsequently baked at T ≥ 200 °C for a minimum of 24 hours prior to vacuum leak testing.*** ***For VCQ2A, 3A& 4A this product may only be used to accepted procedures on the prior acceptance of a deviation request from the ITER Vacuum Handbook to cover the proposed area of use.***	✝	✝	✝	✓	✝	✓	✝	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	DR60 as remover of dye penetrant FAR ITER_D_S7UXTC Accepted for this application on basis of post-use impregnation processes. Other uses will require approved cleaning process	✗	✗	✓	✓	✗	✗	✗	✗

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	CGM CIGIEMME Developer : Rotrivel U (R2.82) 02011200 Cleaner: Velnet / Solnet (R2.60) 02011000 Penetrant: Rotvel Avio B (R2.72) 02021800 ***For VQC 1A/B This product is restricted and may only be used if component / system under test is subsequently baked at T ≥ 200 °C for a minimum of 24 hours prior to vacuum leak testing.*** ***For VCQ2A, 3A& 4A this product may only be used to accepted procedures on the prior acceptance of a deviation request from the ITER Vacuum Handbook to cover the proposed area of use.***	✝	✝	✝	✓	✝	✓	✝	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	GS CHEM Co LTD Developer: DA (P101017D) Cleaner: RA (P101015C) Penetrant: PA (P101016P) ***For VQC 1A/B This product is restricted and may only be used if component / system under test is subsequently baked at T ≥ 200 °C for a minimum of 24 hours prior to vacuum leak testing.*** ***For VCQ2A, 3A& 4A this product may only be used to accepted procedures on the prior acceptance of a deviation request from the ITER Vacuum Handbook to cover the proposed area of use.***	✝	✝	✝	✓	✝	✓	✝	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	EISHINKAGAKU corp. Japan Developer: R-1S (NT) Special Cleaner: R-1M (NT) Special Penetrant: R-1A (NT) Special ***For VQC 1A/B This product is restricted and may only be used if component / system under test is subsequently baked at T ≥ 200 °C for a minimum of 24 hours prior to vacuum leak testing.*** ***For VCQ2A, 3A& 4A this product may only be used to accepted procedures on the prior acceptance of a deviation request from the ITER Vacuum Handbook to cover the proposed area of use.***	✝	✝	✝	✓	✝	✓	✝	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	MAGNAFLUX Dye penetrant testing of Tungsten monoblocks for ITER IVT https://user.iter.org/?uid=JP6EW8 Penetrant: Zyglo ZL-27A, fluorescent post emulsifiable penetrant Cleaner: Zyglo ZR-10C, hydrophilic remover Developer: Zyglo ZP-4B, dry powder developer Fluid to be removed by hot demineralised water rinse followed by baking.	✝	✝	✝	✝	✝	✝	✝	✝
Ultra Sonic Testing (UT) coupling fluids	Babb Co matrix UT coupling agent FAR https://user.iter.org/?uid=PTZ2WR https://user.iter.org/?uid=PUW2LU Part to be cleaned to an accepted procedure after UT	✝	✝	✝	✝	✝	✝	✝	✝
	CGM US Paste U49 FAR https://user.iter.org/?uid=PUXQHP https://user.iter.org/?uid=PVAE22 Remove residues with clean cloth and acetone.	✝	✝	✝	✝	✝	✝	✝	✝

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Ultra-Sonic Testing (UT) coupling fluids	09060, Rock Oil, Vacuum test data https://user.iter.org/?uid=RRAZ87 ITER_D_RMSL86	✓	✓	✓	✓	✓	✓	✓	✓
	Dodecane, 297879, Sigma-Aldrich Vacuum test data ITER_D_RRAZ87 ITER_D_RMSL86	✓	✓	✓	✓	✓	✓	✓	✓
	Soundclear Grade 60 MAR : ITER_D_U2WF3L (can be recommended for use as component is baked)	✓	✓	✓	✓	✓	✓	✓	✓
	Soundclear Grade 40 MAR : ITER_D_U348TX (can be recommended for use as component is baked)	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Pentagon Ultra 30 for use as UT couplant (approved for this application only, on basis of post –use surface removal by machining) MAR : ITER_D_UVC2BJ			✓					
	MR 750 Ultrasonic Coupling Agent FAR:- ITER_D_TX5XPV Cleaning as per ITER approved procedure document no. ITER CR- LTTS-602.	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Markers	Intrama SL.250 SL2100 MAR https://user.iter.org/?uid=QZSP86 Outgassing test report_MarkerPen_Intrama.SL.250 https://user.iter.org/?uid=QXVLSU Outgassing test report_MarkerPen_Intrama.SL.2100 https://user.iter.org/?uid=QXM5QJ Material acceptance report https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓					
	Markal Certified Valve Action Paint Marker MAR : ITER_D_UBF44E (Certified for <200ppm halogen - agreed but should not be used on thin wall boundaries with material < 1.5mm.)			✓	✓				

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Edding 750 White, Silver & Blue FAR:- ITER_D_AFEQ97 Cleaning as per approved procedure ; ITER-CR-LTTS-602			✓	✓	✓	✓	✓	✓
Protective paint (on material processing equipment)	Stratomet Protective paint FAR:- ITER_D_R7TFB7 Chemical analysis:- ITER_D_R6CD9Z Safety data sheet:- ITER_D_R6CCRZ	✓	✓	✓	✓	✓	✓	✓	✓
Abrasive media	Cutting wheel Abratec TIPO 42 MAR:- https://user.iter.org/?uid=QZRF3E Outgassing report :- https://user.iter.org/?uid=GGREMQ Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Cutting wheel: Sait “A30S” [Thk. 2 mm] MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Cutting wheel: Sait “XA24Q” [Thk. 3,2 mm] MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Cutting wheel: Sait “XA24Q” [Thk. 7 mm] MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Cutting wheel: Sait “XA46R” [Thk. 1,6 mm] MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Flapper wheel: Abratec LAMELLARE MAR:- https://user.iter.org/?uid=QZRF3E Outgassing report:- https://user.iter.org/?uid=GJ584M Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Flapper wheel: Sait "SAITLAM UK 3A" MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Flapper wheel; S.L.F. Abrasivi LASER DISC – "SERIE 10-ALU DISC" MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Rough Wheel: Abratec TIPO 27 MAR:- https://user.iter.org/?uid=QZRF3E Outgassing report ;- https://user.iter.org/?uid=HD5Z3U Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Rough Wheel: 3M "987C CUBITRON 2" MAR:- https://user.iter.org/?uid=QURJQL Outgassing report:- https://user.iter.org/?uid=HK7F54 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	Klingspor KL 361 Abrasive paper. PMUC 10067 FAR:- ITER_D_TXD2ZJ Cleaning with alcohol after usage	✓	✓	✓	✓	✓	✓	✓	✓
	3M Roloc Disc 984F Abrasive Disc FAR:- ITER_D_4H8PDW Area to be cleaned with solvent after processing	✓	✓	✓	✓	✓	✓	✓	✓
	3M Cloth Belts 984F Abrasive Belt for belt grinder FAR:- ITER_D_4HBVE3 Must be followed by cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	3M™ Abrasive Products, High Performance Cut off Wheels, Depressed Center Grinding Wheels, Grind Wheels Type 27, Cubitron™ II FAR:- ITER_D_4HD79D Must be followed by cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓
	3M Flap Disc 967A Flap disc FAR:- ITER_D_T79GNQ Area to be cleaned with solvent after operations with flapper	✓	✓	✓	✓	✓	✓	✓	✓
	3M XT-RD-Cleaning Disc FAR:- ITER_D_4H3ZHJ Must be followed by cleaning with solvent	✓	✓	✓	✓	✓	✓	✓	✓
	Tungsten carbide burrs Lukas Abrasive Pencil FAR:- ITER_D_T8FBAG	✓	✓	✓	✓	✓	✓	✓	✓
	Stainless steel brush FAR:- ITER_D_T8FUKG	✓	✓	✓	✓	✓	✓	✓	✓
	Paper KL361 grain 240, grain 120 and grain 80 ; Grinding tool RB 317 LX-R grain 80 FAR : ITER_D_UAMCD5	✓							

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Tetrabor lapping paste (water/polyalcohol based) FAR:- https://user.iter.org/?uid=QF6X54 Datasheets:- Safety https://user.iter.org/?uid=QED2DQ https://user.iter.org/?uid=QEJ42W https://user.iter.org/?uid=QERFGW https://user.iter.org/?uid=QF2HJZ https://user.iter.org/?uid=QEH9AG https://user.iter.org/?uid=QF7K99 Subject to accepted cleaning procedure	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	HE 111 Electrolytic polisher (cryogenic piping for the pre-production cryopump) FAR ITER_D_RN4QKV Cleaning procedures ITER_D_S2FG8X to be used SDS ITER_D_RN6FUA	✓	✓	✓	✓	✓	✓	✓	✓
	HE 310 Electrolytic Polisher (cryogenic piping for the pre-production cryopump) FAR ITER_D_RYS3HQ SDS ITER_D_RYTRXG Cleaning procedures ITER_D_S2FG8X to be used	✓	✓	✓	✓	✓	✓	✓	✓

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Adhesive tapes	3M™ Aluminum Foil Tape 431 FAR:- ITER_D_R23U88 For use on VQC N/A surfaces only with solvent clean. Before use on higher VQC categories, verification of full cleaning process cleaning required on sample coupons								
	3M™ Preservation sealing Tape 481 FAR:- ITER_D_R24JEX For use on VQC N/A surfaces only with solvent clean. Before use on higher VQC categories, verification of full cleaning process cleaning required on sample coupons								

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
Adhesive tapes	Delvigo DVC 48040/7 A5 weld backing strip FAR:- ITER_D_R477ZK For use on VQC N/A surfaces only with solvent clean. Before use on higher VQC categories, verification of full cleaning process cleaning required on sample coupons								
	Delvigo DVC 44040/6 A5 weld backing strip FAR:- ITER_D_R25TST For use on VQC N/A surfaces only with solvent clean. Before use on higher VQC categories, verification of full cleaning process cleaning required on sample coupons								

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Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	Scapa 336 Aluminium adhesive tape FAR:- ITER_D_R4AZFV For use on VQC N/A surfaces only with solvent clean. Before use on higher VQC categories, verification of full cleaning process cleaning required on sample coupons								
	AveryDennison HP MPI 2121 MAR : ITER_D_UDWANR (Recommended as component is cleaned and baked after use)	✓							
	Tesa 4613 – Utility grade Duct Tape (use of cryostat) MAR : ITER_D_UPXQCQ (Ok for VQC 2 but avoid to use on thin walled bellows or lips <1.5 mm thick)			✓					

KEY: ✓ = *accepted* for use. ✗ = not *accepted* for use. ✝ =*accepted* for restricted use only

Type	Name / type	Applicable to Vacuum Quality Classification							
		1A	1B	2A	2B	3A	3B	4A	4B
	3M 425 & 431 Aluminium Foil Tape FAR: ITER_D_U33P6M			✓	✓	✓	✓	✓	✓
Handling / transport materials	Kraitec anti-slip elastomer pads FAR:- ITER_D_4GRXXK	✓	✓	✓	✓	✓	✓	✓	✓
Adhesives	Adhesive Technologies Glue Stick, Part 229 MAR : ITER_D_UHDX7N (glue pucks for laser tracking to tie plate)			✓	✓				
	TACKY TAPE SM5142 (vacuum bag tape sealant) MAR : ITER_D_TX66XF			✓					

KEY: ✓ = *accepted* for use. ✗ = not *accepted* for use. ✝ =*accepted* for restricted use only

Request for Acceptance of Fluid					Ref No: fluid-01 ***(Assigned by Vacuum RO)***			
Fluid submitted for *acceptance*:	Cut ace 123							
Proposed Use:	Metal Cutting fluid							
VQC of proposed use:	1A	1B	2A	2B	3A	3B	4A	4B
	✓							
Chemical Composition / suppliers data sheet	Yes	*Attached Copy (electronic if available)*						
Agreed test plan:	No	*Attached Copy (electronic if available)*						
Vacuum Test data Available:	Yes	*Attached Copy (electronic if available)*						
Solubility in water (at ambient temperature)								
Cleaning method (if applicable)	Rinse in de mineralised water							
Vapour pressure (at 100 °C)	No	Pa						
Supporting information	Evaporates in air leaving oily residue							
Requested by	L.Pressure		Date Submitted		29/07/08			
Affiliation:	US DA		E-Mail		L.Pressure@iter.org			
Fluid *Acceptance* Status: ***(To be completes by ITER Vacuum Group RO)***								
Acceptance for VQC:	1A	1B	2A	2B	3A	3B	4A	4B
	✓	✓	✓	✓	✓	✓	✓	✓
Limits / Restrictions (Attached Doc.)	Fluid to be removed by hot demineralised water rinse (Cut ace 123 .doc IDM Ref 15R8UI)							
ITER Vacuum RO	*Acceptor*:	H.M. Self						
	Date: 09/08/08							

Grey boxes to be completed by requesting officer. Boxes in Red to be completed by ITER Vacuum RO.

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IDM UID

2EYZ5F

VERSION CREATED ON / VERSION / STATUS

16 Sep 2009 / 1.4 / Approved

EXTERNAL REFERENCE / VERSION

Guideline (not under Configuration Control)

Appendix 12 Leak Testing

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Worth L.**	**16 Sep 2009:signed**	**IO/DG/COO/PED/FCED/VS**
Co-Authors			
Reviewers			
Approver	**Pearce R.**	**16 Sep 2009:approved**	**IO/DG/COO/PED/FCED/VS**
Document Security: Internal Use *RO: Chiocchio Stefano*			
Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: [CCS] CCS-All for Ext AM, LG: [CCS] CCS-Section Leaders, LG: [CCS] JACOBS, LG: [CCS] CCS-Doc Co...**		

Change Log			
Appendix 12 Leak Testing (2EYZ5F)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	27 Aug 2008	
v1.1	In Work	22 Sep 2008	
v1.2	In Work	12 Jan 2009	
v1.3	Approved	18 Jun 2009	Changed approved to accepted
v1.4	Approved	16 Sep 2009	Maximum detectable leak rate changed from 0.1Mpa.m3.s-1 to 100Pa.m3.s-1

ITER Vacuum Handbook
Appendix 12

Guide to Leak Testing of Components for the ITER Project

	Name	Affiliation
Author/Editor	Liam Worth	Vacuum Group - CEP
Vacuum Responsible Officer	Robert Pearce	Vacuum Group - CEP

12 Vacuum Leak Tightness and Testing

12.1 Scope and Status

As an Appendix to the ITER Vacuum Handbook, the status of this document is advisory and not mandatory on the supplier of any component. Nevertheless, it is strongly advised that the requirements of this document are adhered to for the supply of vacuum components to ITER.

The purpose of this Appendix is to define the criteria for the leak tightness of vacuum related components supplied to ITER. It is applicable to equipment destined for use on the ITER facility and any other area on site, which utilises items and assemblies with a vacuum boundary. It defines the test criteria and gives general instruction and guidelines to those persons, be they on site at the supplier, on site at ITER, or as part of an off site organisation which is called upon to perform vacuum helium leak detection.

12.2 General

Tests shall be performed both at ambient temperature and at the maximum and minimum working temperatures of the component, with the pressure differential in the same direction as for operation of the component. Where possible, component parts shall be tested before assembly. However, final assemblies must also be tested.

Where it is not envisaged that leak tests will be performed at cryogenic temperatures on vacuum components which are for use on cryogenic systems, a method of “thermal shocking” of welded connections shall be agreed in advance.

The supplier is responsible for all jigs, seals and equipment to allow the leak tightness to be proven across all vacuum boundaries, unless otherwise stated in the contract. Where pressure testing is required, this must always be performed prior to final vacuum leak testing. Acceptance tests shall wherever possible use the same type of seal which shall be used after installation of the component.

The supplier is responsible for the supply of tooling and methodologies for the subsequent removal of jigs, seals, temporary closure plates, etc., which have been fitted to components to facilitate the leak testing of such components.

The leak test method shall be agreed in advance with ITER. This will involve the submission for approval of a procedure as part of an external supply contract. The procedure should describe how the leak test will be performed, and include configuration diagrams and full details of the equipment to be used etc.

The ITER Vacuum Responsible Officer (RO) will nominate a Vacuum Specialist to witness the acceptance leak tests and any other leak test deemed necessary as part of a manufacturing process.

In no circumstance shall ***any*** vacuum equipment be installed without an *accepted* pre-installation leak check being performed at the ITER site, without the express permission of the ITER Vacuum Responsible Officer. This applies to ***all*** Vacuum Quality Classifications.

12.3 Leak testing Methodologies

This Appendix describes recommended procedures for carrying out the most widely used methods of helium leak testing; it does not consider all available methods. Other methods may be used, but only with the prior approval of the ITER Vacuum RO

12.3.1 Over Pressure Methods

Over-pressure methods enable thin-walled vacuum chambers to be leak tested which might otherwise collapse under vacuum. This method is also useful when the equipment to be tested is already filled with a gas which can be used as the test gas. However the test gas which flows out through any leaks always mixes with contaminants present in the air, and this might reduce sensitivity.

12.3.1.1 Mass Spectrometer Sniffing Probe

Helium, or some other suitable gas, is used to slightly pressurise the component to be tested and a sampling probe “sniffs” for leaks. Helium passing through the leak is sampled from the surrounding atmosphere through a long narrow flexible tube which is connected to a mechanical pump to give a drop in pressure from atmosphere to about 10^{-2} Pa at the ion source of a mass spectrometer detector. Traces of helium or halogen in the environment can also be detected, which may lead to errors in the measured leak rate.

The helium content of atmospheric air limits the sensitivity of the sampling probe, and the detection limit is typically ~1 x 10^{-7} Pam^3s^{-1} if the volume is filled with pure helium (or the tracer gas appropriate for the detector used such as argon).

The sampling tube should be as short as possible to reduce the response time of the gas flow of the air-helium mixture from the entrance of the tube to the detector. The flow rate may also be limited by the available pumping throughput.

12.3.1.2 Probe Leak Testing (vacuum box or suction cup method)

Open objects can be tested using the vacuum box or suction cup method. A partial enclosure which can be evacuated by a leak detector is tightly pressed against the wall of the component being tested. The enclosure is evacuated and helium tracer gas applied to the opposite surface of the wall by a spray gun or other means. Helium leaking through the wall can pass to the detector via the vacuum box. This method of leak detection is widely used for the testing of welds on incomplete enclosures. The sensitivity is usually limited by diffusion of helium through the seal between the evacuated enclosure and the component wall.

12.3.1.3 Pressurisation – Evacuation (“bombing”) Test

Hermetically sealed objects which cannot be pumped out can be leak tested using the so-called “bombing” method. The component to be tested is subjected to a high pressure of tracer gas, usually helium, to force gas into the component through any leaks present. After flushing to remove adsorbed tracer gas from the surface of the component, it is placed in a vacuum chamber which is connected to a leak detector. This can then detect any tracer gas passing out of the sealed volume through the leaks. This method is usually employed as a “go/no go” test since it is very difficult to locate the position of any leaks on such components.

12.3.2 Vacuum Leak Detection Methods

12.3.2.1 Pressure Rise Test

A pressure rise test is a useful way of determining the overall magnitude of any leaks present in a component.

A vessel to be tested of volume V is evacuated and sealed off. The pressure rise ΔP is measured over a time interval Δt and the leak rate q_L (at constant temperature) is evaluated from:

$$q_L = V \cdot \frac{\Delta P}{\Delta t}$$

This calculated leak rate also includes contributions from any other gas sources such as virtual leak and outgassing.

Real leaks may be distinguished from other sources of pressure rise since a real leak gives a pressure rise which is strictly proportional to time, while virtual leaks and outgassing result in an initially rapid pressure rise which tends to level off after some time

12.3.2.2 Helium Leak Detectors

These are based on a mass spectrometer, usually a small magnetic sector device. Leak detection can begin only when high vacuum conditions are obtained in the mass spectrometer. Due to its high sensitivity this method is the most frequently used method of leak detection for vacuum applications. The inlet pressure at the entrance to the leak detector depends on the design of the unit, but can range from atmosphere down to about 10^{-4} Pa.

Helium is usually used as the tracer gas, but other gases such as argon, neon, krypton, hydrogen and mixed gases may be used with the mass analyser suitably tuned. Modern helium leak detectors are usually supplied with the capability of detecting H_2, He^3, and He^4.

To increase the helium detection sensitivity and improve detector stability, the mass analyser in helium leak detection systems is often de-tuned to give lower mass resolution. This can lead to a contribution to the measured mass 4 intensity from mass 2 and mass 3, thus giving a higher leak detector background signal at mass 4. For large component leak testing at high sensitivity, it may be necessary to reduce the partial pressure of hydrogen at the analyser by selectively pumping it with a getter in series with the leak detector input. It may also be necessary to selectively pump condensable gasses at the leak detector inlet. This can be achieved by the addition of a cold (e.g. liquid nitrogen) trap in series with the inlet.

12.4 Procedure for Helium Leak Tightness and Testing

12.4.1 Equipment

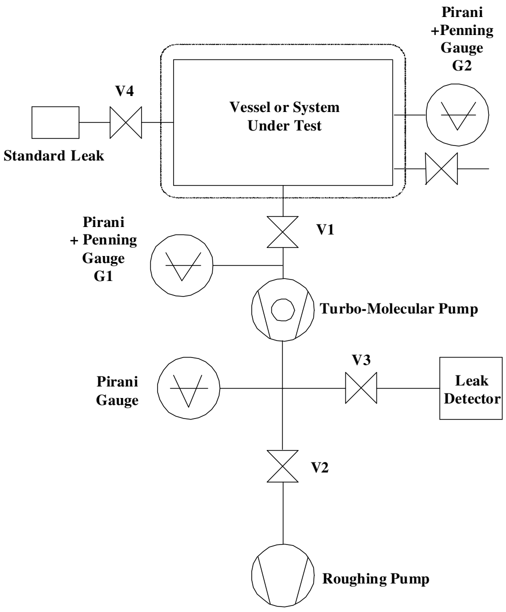

Figure 12-1 Typical Leak Detection Equipment

12.4.2 Pumping System

An indication of the basic elements of a pumping system, which could be used for leak detection, is illustrated in Figure 12-1. In this form it consists of the following items: -

1. A turbo-molecular pump isolated by a valve V1 and backed by a roughing pump via a valve V2, of enough pumping capacity to pump the system under test down to a suitable pressure at the inlet of the leak detector. Ideally all fittings and seals (at least those on the high vacuum side) should be all-metal to alleviate the problem of helium permeation.

2. A Pirani gauge to measure the pressure in the backing line of the turbo-molecular pump and a pressure gauge system (G1) on the high vacuum side of the turbo-molecular pump (but below valve V1) capable of measuring in the range 0.1 MPa to 10^{-7} Pa.

Possible additional options to this pumping system could include a quadrupole or other type of mass spectrometer to measure the residual gas spectrum. This is essential if system cleanliness is to be assessed. A hydrogen getter and liquid nitrogen trap may be used to lower the detector background signal.

A vent valve on the vessel side of V1 is also advisable for venting the item under test to a clean dry gas such as nitrogen to retain cleanliness.

12.4.2.1 Detection System

This is the system used to detect any vacuum leaks which may be present, thus it is the central part of the system and normally consists of the following items:

1. A helium mass spectrometer leak detector installed such that it can be connected into the backing line of the turbo-molecular pump through valve V3. For maximum leak detection sensitivity, it should provide the necessary backing pressure for the turbo-molecular pump. It therefore should have its own pumping system comprising a turbo-molecular and backing pump combination. It must be able to detect leaks at least one order of magnitude smaller than that required by the specification of the item under test, and up to at least 100 Pam^3s^{-1}.

   It should be noted that with modern leak detectors, it is possible to suppress the background and gain up to 2 orders of magnitude in sensitivity. Although this mode is useful in localising leaks, it shall not be used for the purpose of acceptance testing without prior approval by the ITER Vacuum RO.

   An alternative when the item under test is of relatively small volume of less than 1 m^3, and when only a simple cold leak test is required, is to use the mass spectrometer leak detector on its own. In this case the leak detector is connected directly to the item under test. The separate turbo-molecular and roughing pump system is not required.

   If there is a large leak on the item to be tested or where the pumping system is incapable of pumping the item under test to a sufficiently low pressure for the leak detector to be connected directly to the backing line of the turbo molecular pump, valve V2 may be left open and valve V3 partially opened so that the leak detector samples part of the gas stream to the backing pump. This configuration may be used to locate, but not size, any leaks.

2. A pressure gauge system (G2) on the vessel under test, capable of measuring in the range 0.1 MPa to 10^{-7} Pa.

3. A calibrated helium standard leak of value commensurate with the magnitude of leak rate required by the specification of the item under test, mounted on the system under test, and isolated by valve V4. Traceable calibration certificates shall be kept for this item and these should be readily available.

4. A helium bag or other enclosure fashioned in such a way that the test gas can surround all parts of the item under test with a concentration preferably exceeding 50% in air.

5. A system for continuous recording of the leak test process. This can be achieved by using an analogue recording device such as a paper strip chart recorder connected to the output of the helium mass spectrometer leak detector or by continuous logging (and display) of data on a computer or dedicated data logger.

12.4.2.2 Miscellaneous

The following equipment is optional but experience has shown the items to be of use in helium leak tests.

1. A standard vacuum cleaner to pump the helium enclosure out if it is a sealed collapsible type such as a plastic bag before inflating it with helium, to ensure maximum concentration of the helium in the enclosure.
2. A helium-in-air concentration monitor to ascertain the percentage of helium in the bag or other enclosure during the test.
3. A triggered helium spray gun for subsequent probe testing of the item to localise any leaks found during the global leak test.

12.4.3 Preliminaries

12.4.3.1 Initial Checks on the Leak Detection System

1. With valve V2 open and valves V1 and V3 closed, the roughing pump is started. When the pressure falls to a suitable level, the turbomolecular pump is started and left until the pressure on gauge G1 stabilises.
2. The leak detector is switched on and when it is ready, an internal calibration is carried out as per the manufacturer's instructions.
3. The backing line Pirani gauge pressure reading is noted and valve V3 is carefully opened so that the leak detector does not trip out. (Most modern leak detectors can cope with this.)
4. The roughing pump valve V2 is closed.
5. When a relatively stable reading has been obtained on the leak detector, a leak check is carried out, by using a helium gun to probe with helium gas all joints and welds up to and including the pumped sides of V1 and V3.
6. If any leaks are found of magnitude greater than one decade smaller than the maximum leak rate called for in the specification of the item under test, then these shall be rectified and this sequence repeated until no such leaks are found.

12.4.3.2 Pump-down

Before the leak test can be undertaken, the item under test must be pumped down to the requisite pressure. In the case of the system shown in Figure 12-1 which uses a turbo-molecular and roughing pump set, the following actions shall be performed.

1. The roughing pump is started and valves V1 and V2 are opened.

2. When the system Pirani pressure reaches the level given in the manufacturers instructions the turbo-molecular pump is started.
3. The system is ready for initial tests when the pressure reaches 10^{-3} Pa or lower on G1, or such other pressure specified as suitable by the manufacturer of the leak detector. If it does not reach this pressure then there may be a large leak present which must be located and rectified. It should be located using either an overpressure technique as described in Section 12.3.1.1 or the procedures of Section 12.4.5.2 but with valve V3 only partially opened so that the pressure at the inlet of the leak detector remains below the upper pressure limit specified by the manufacturer with the gas flowing to the roughing pump being sampled into the leak detector.

12.4.3.3 Background Determination

After a stable pressure reading has been obtained on gauge G2 with valves V1 and V2 open and the turbomolecular pump set running normally, with the leak detector fully functioning and the data logging device connected and operating, then the roughing valve V2 is closed and the leak detector valve V3 opened.

The leak detector reading is monitored until it has stabilised, without any electronic correction. This should take around 10 minutes, but the time can be longer depending on the size of the system under test.

This reading is recorded as the background level. Any reading above this value during the overall test constitutes a positive indication of a leak.

12.4.4 Leak Detector Calibration

With the system in the state as above for background determination, leak detector calibration shall be performed.

Valve V4 is carefully opened and the reading on the leak detector monitored until it is stable. This should correspond to the value of the standard leak to within ±5% after suitable corrections for the age of the standard leak and its temperature have been applied.

If a response time measurement is not required, then V4 is closed and the reading should then return to the background level.

12.4.4.1 Response and Cleanup Time Measurement

This should be done for a large system or where there is a long path length involving small bore tubes. This ensures that the duration of the overall test will be valid.

1. With the standard leak open to the system and the leak indication stable at the value of the standard leak, suitably corrected for age and temperature, valve V4 is closed.

2. The time taken for the reading on the leak detector to return to the background level is recorded. This is the cleanup time for the system and will depend on the applied pumping speed for helium and the configuration of the system under test.
3. When the background level has been attained, valve V4 is opened and the time taken to return to the level of the standard leak indication, suitably corrected, is recorded. This is the response time for the system.
4. Valve V4 is closed and the system is allowed to return to the background level.
5. This concludes the initial set-up tests and the overall leak test may then be undertaken.

12.4.5 Cold Leak Tests

12.4.5.1 Global Leak Check

If all the preceding conditions have been met with all equipment functioning and ready for use, a global cold leak test may be carried out according to the following procedure.

1. The data recording system is connected to the output of the leak detector and started and the date and time are recorded.
2. Valves V1 and V3 are opened and valves V2 and V4 are closed.
3. When the background reading is stable and is at a level consistent with the leak specification of the item under test, which will be for most purposes at least an order of magnitude lower than the specified maximum leak rate of the component under test and without electronic correction, the global leak check may be started.
4. The component under test is surrounded by a suitable helium enclosure. If the helium enclosure is a flexible type, it should have as small a volume as possible. The enclosure is filled with helium to a concentration of at least 50% in air and the time is recorded in the data log
5. Helium should remain in contact with the item under test for at least 10 minutes or longer, depending on the size of the object and the response time previously measured, or for the time specified in the test specification for the component under test, whichever is longer.

   In the case of components where there might be possible low conductance leak paths, for example porosity, the time required for a sensible test may be significantly longer than the response time measured for the system using the techniques of Section 12.4.4.1. Details of the method and time of duration of helium application shall be included in the leak testing procedure to be *accepted* by the ITER Vacuum Responsible Officer.
6. Where the helium enclosure is not completely sealed, then suitable precautions shall be taken to ensure that helium cannot back-diffuse through the roughing pumps and/or the leak detector pumps into the mass spectrometer detector. In the

case of long-duration global tests, it may be advisable to house these items in a separate enclosure held at a small positive pressure above atmosphere.

7. After the appropriate time interval, the helium supply is closed off (where appropriate), and the enclosure vented to atmospheric air and removed. The time is recorded in the data log.
8. If the leak rate indication on the leak detector has not risen by more than the specified maximum leak rate at any time during this test procedure, the item under test shall be deemed to have passed, subject to the requirements of Section 12.4.5.3.
9. It may be advisable to recheck the background reading and leak detector calibration if the global test has been of significant duration. When that has been done according to the procedures of 12.4.3.3 and 12.4.4, then the global leak test is complete.
10. Valves V1 and V3 are closed and valve V2 opened.
11. The item is vented, or left under vacuum for further work as required.
12. If the leak rate reading during the test has at any time exceeded the specification value, then the item has failed the test, and the leaks shall be located using the procedures of Section 12.4.5.2.

12.4.5.2 Probe Tests

These are necessary to locate any leaks greater than the value in the specification of the component being tested which may have been indicated during the global test. They may be required not only at this stage, but may be needed also after the hot global test and the final cold global test, if those two tests are required as part of the contract or other instruction.

The following procedure shall be used, although others are possible and may be used after prior agreement.

1. Any helium enclosure or other covering or obstruction is removed from the item under test wherever possible.
2. If the component under test is at cryogenic temperatures, it may have to be warmed to ambient temperature before probe tests can be carried out.
3. Valves V1 and V3 should be open and valves V2 and V4 should be closed.
4. In the case of a large item, the data logging system shall continuously record the leak detector signal so that any longer term variations in leak rate may be observed.
5. Using a helium gun, helium gas is sprayed over or into all suspect locations and under any non-removable coverings, starting at the top of the item under test and working down as required. The helium spray should be introduced to the area under test for a time period consistent with the response time of the system measured in accordance with Section 12.4.4.1

6. If a leak indication is found, then the point of maximum reading shall be localised. For subsequent testing to localise any other leaks, it is advisable to blanket that point with a physical barrier such as a polythene bag or sheet or with a stream of another gas whilst checking the remainder of the system.
7. When all detectable leaks have been located, then the leak detector is isolated by closing valve V3. Valve V1 is closed and the item under test shall be vented to dry nitrogen or clean dry air admitted through the vent valve. The ITER Vacuum Responsible Officer shall be contacted to agree a procedure to rectify the leak or leaks.
8. When any agreed repair has been successfully accomplished, the process starting from stage 12.4.3.2 and to point 10 at the end of stage 12.4.5.1 is repeated until the item is proved to meet the relevant specification.

12.4.5.3 Acceptance Criteria

If all the stages above have been successfully completed then the item under test may be accepted by the ITER Vacuum Specialist as having met the relevant specification provided that the following conditions have been met.

1. The leak detector has been correctly calibrated and its calibration value is within ±5% of the standard leak rate value as corrected for the ambient temperature and the age of that item and that standard leak rate value is commensurate with the value of the maximum leak rate specified for the item under test.
2. The leak test has been performed by suitably qualified and experienced personnel to the *accepted* procedure, with no significant deviation from that procedure and has been witnessed by the ITER Vacuum Specialist.
3. The leak rate value as measured by the leak detector has not increased in value above the measured background to a value greater than the specified leak rate during the entire duration of the global leak test.

The location and magnitude of <u>all</u> identified leaks shall be recorded. Normally, all practicable efforts shall be made by means agreed with the ITER Vacuum Responsible Officer to reduce any leak discovered during the manufacturing phase to a level lower than the limit of detection of the leak detection method used for the tests.

12.4.6 Hot Leak Check

12.4.6.1 Test Conditions

If it is required as part of the contract or other instruction to perform a hot leak test on an item which during its life may be subject to increased temperature usage, then the following procedure shall be carried out.

1. Before commencing any part of this leak test procedure, the item under test must have completed one or more temperature cycles as specified and be at that point on the cycle where it is specified that the hot leak test shall take place.

2. The leak detector shall be set up using the procedures of Sections 12.4.3.3 and 12.4.4. If the response time of the system has already been determined, or is not required, it need not be re-measured.
3. If the background is elevated when the item under test is at temperature (as may often be found), then the conditions stipulated in 12.4.5.1 Point 3 may not be met. However with judicious choice of scale it may be possible to do a perfectly valid leak check at a raised background level. It may also be necessary to selectively pump hydrogenic species from the leak detector input gas stream. This can be done by the correct choice of getter installed in series with the leak detector inlet. The applicable conditions for this test must be agreed with the ITER Vacuum Responsible Officer.
4. The helium enclosure used for these tests must be capable of tolerating temperatures above ambient since the increased thermal conductivity of helium will raise the temperature of this item above the level it would reach with only atmospheric air in the enclosure.

12.4.6.2 Global Leak Check with the Component under test Hot

Essentially, this is a repeat of the cold global leak test described in Section 12.4.5.1 except that, if a leak indication is observed, the item may need to be cooled down before probe tests can be performed. The temperature at which the hot leak test is performed shall be recorded and shall be within the limits as specified in the leak testing procedure.

If, with the component at the specified hot temperature, no leak rate of size greater than that specified for the component has been observed, then provided that the conditions of Section 12.4.5.3 have been met, the component will be deemed to have satisfied the hot leak test requirement.

If, however, with the component at the specified hot temperature, a leak rate of size greater than that specified for the component has been observed, then a probe test to localise any leaks present must be undertaken.

The supplier should be aware that under some conditions, a leak may be observed at temperature but may disappear when the component is cooled to ambient temperature. If this is the case, then it may be necessary to implement an agreed procedure for leak location at elevated temperature.

12.4.6.3 Probe Test

1. This method of probe leak testing baked components is the essentially the same procedure as detailed in 12.4.5.2., but with additional steps as noted below:
2. If the probe test cannot be carried out at the hot temperature, the component shall be cooled to ambient temperature
3. Steps 1 – 7 of section 12.4.5.2 shall be carried out.

4. If, after probe testing at ambient temperature, no leak has been identified, then, as agreed with the ITER Vacuum Responsible Officer, a further temperature cycle shall be completed as specified up to the point on the cycle where it is specified that the hot leak test shall take place.
5. Then either

   a. an agreed procedure for leak location at this elevated temperature shall be carried out

   or

   b. the component shall be cooled and step 2 of this Section shall be carried out in the hope that the hot leak may have opened up further and now may be detectable at or close to ambient temperature.
6. Step 5 shall be repeated until no leaks which have not been localised are evident at the hot temperature.
7. When all detectable leaks have been located and the component is close to ambient temperature, then the leak detector is isolated by closing valve V3. Valve V1 is closed and the item under test shall be vented to dry nitrogen or clean dry air admitted through the vent valve. The ITER Vacuum Responsible Officer shall be contacted to agree a procedure to rectify the leak or leaks.
8. When any agreed repair has been successfully accomplished, the global hot leak test procedure of this Section is repeated.

12.4.6.4 Final Cold Acceptance Check

This test shall be carried out following a satisfactory global hot leak test procedure when the item under test has cooled down to a temperature in the range 60°C to 80°C, since experience has shown that small leaks can be blocked by water vapour below this temperature.

It shall follow the procedures of Section 12.4.5.1.

12.4.6.5 Acceptance Criteria

These shall be the same as those specified in Section 12.4.5.3

12.5 Responsibilities

It shall be the responsibility of the supplier to ensure that all vacuum leak tests carried out off-site and of the ITER Vacuum Responsible Officer when such tests are carried out on-site that they be performed in accordance with the contract or other specification. All deviations from such specification or agreed variation thereof shall require a non-conformance to be raised covering each specific case. In the case of any particular component, a nominated ITER Vacuum Specialist may witness the tests.

All records as detailed in the following section shall be completed and shall become part of the final document package for the component concerned.

12.6 Reporting

Full records of the tests carried out on any component shall be completed in order to maintain traceability of the leak test history of a particular item. The records shall consist of the following.

1. Data records of the output of the leak detector for all the global tests specified including the standard leak calibration and response time determination. These data records shall include the date and time of all tests as well as anything else of relevance, such as the start and finish time of helium gas application to the item under test.
2. A record of the helium concentration during the leak test where that is required. In the case of a simple cold leak test this will be on request of the ITER Vacuum Responsible Officer, but in the case of a full cycle of leak testing involving temperature variation it will be required.
3. A record of the system total pressure throughout a temperature cycle since it may pinpoint the time when a leak opened up and be instrumental in the subsequent diagnosis of the leak.
4. The make, model and date of manufacture of the helium mass spectrometer leak detector used in the tests.
5. The nominal value of all standard leaks used, their date of calibration, ageing and temperature characteristics, and the ambient temperature(s) experienced during the tests.
6. The results of all tests showing whether it was 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.

   The magnitude and location (if applicable) of ***all*** leaks identified during testing shall be recorded. This includes leaks of magnitude lower than the acceptance criteria for which no remedial action may have been taken.

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Appendix 13 Cleaning and Cleanliness

This Appendix specifies typical processes which conform to the requirements of the ITER Vacuum Handbook for the cleaning of vacuum vessels, components and assemblies which are required for the ITER Project. This covers vacuum vessels and any item which will be in a vacuum environment, whether individually or made up into assemblies containing a number of such items.

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ITER Vacuum Handbook
Appendix 13

Guide to Cleaning and Cleanliness for the ITER Project

	Name	Affiliation
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13 Guide for Cleaning and the Cleanliness of ITER Vacuum Components

13.1 Scope

As specified in the ITER Vacuum Handbook all vacuum components to be supplied to ITER are subject to the provision of a “clean work plan” and cleaning procedures. This requirement is waived for proprietary components which are compliant with the mandatory requirements of the ITER Vacuum Handbook and are supplied to ITER with Certification of Conformity.

This Appendix specifies typical processes which conform to the requirements of the ITER Vacuum Handbook for the cleaning of vacuum vessels, components and assemblies which are required for the ITER Project. This covers vacuum vessels and any item which will be in a vacuum environment, whether individually or made up into assemblies containing a number of such items.

This guide is intended to assist the *supplier* of vacuum components to ITER in the preparation of a clean work plan and cleaning procedures for submission to ITER for *acceptance.* Following the guidance in this Appendix should help *suppliers* to achieve the requirements of the ITER Vacuum Handbook.

The *supplier* is at liberty to utilise other techniques not described in this Appendix provided that the components manufactured comply with the requirements of the ITER Vacuum Handbook.

13.2 General Cleaning Requirements

In general, all components classified as VQC1 will need cleaning to Ultra High Vacuum standards. Those components classified as VQC2, VCQ3 and VCQ4 will generally be operated in less stringent vacuum environments and will therefore not require cleaning to such rigorous standards.

However, it is the responsibility of the *supplier* to satisfy themselves that they understand fully the implications of cleaning to the requisite standard.

Any proposed deviation from the procedures and processes described in this Appendix need to be *accepted* in writing by ITER. This is particularly important where the use of any chemical product (solvent, etchant, detergent, etc.) other than those specified is proposed.

13.3 Health and Safety

Some of the chemicals or equipment used in cleaning processes may be classified as hazardous.

It is the responsibility of the *supplier* to satisfy themselves that any cleaning procedure complies fully with local legislative and regulatory standards regarding health and safety of any or all processes used and that all operatives have received the necessary training.

The *supplier* shall have the responsibility of ensuring that all staff fully understand all health and safety information issued by the manufacturer or *supplier* of any chemical or equipment to be used. Neither ITER nor any of its agents shall be held responsible for any consequences arising from the application of any cleaning process described in this handbook unless it is under their direct control.

13.4 Proprietary Items and Trademarks

Where propriety items from particular manufacturers or *supplier*s are mentioned in this specification any or all trademarks are duly acknowledged. Manufacturers or contractors are free to suggest alternative items from other manufacturers or *supplier*s provided that they are chemically identical. Any such substitutions need to be *accepted* in writing by ITER.

13.5 Design Rules for Cleanability

At the design stage for a vacuum item, careful consideration should be given as to how the item is to be cleaned. In particular, crevices, blind holes, cracks, trapped volumes, etc., should be avoided as these will act as dirt and liquid traps and it can be very difficult to remove both dirt and cleaning materials such as solvents from such areas. Fortunately, good vacuum practice regarding trapped volumes will also result in a component which is cleanable.

13.6 Initial Inspection and Preparation

Prior to cleaning any item, the following inspection should take place:

1. All vacuum flanges or covers should be removed and the item stripped down as much as is permissible, ideally to single components.
2. All items should be clearly identified by scribing a suitable identification mark on an external surface (never a vacuum surface). This identifier will often be a drawing number with component identifier or some such which is carefully recorded. Alternatively, for items which are either small and are to be exposed to a vacuum, a suitable metal label, preferably of the same material as the component and bearing a scribed identifier may be tied with clean bare wire to the component. If none of this is possible, the items should be stored in a suitable container which is marked with an identifier before and after the cleaning process. After cleaning, these items should be packed in such a way that they will not be re-contaminated by the container.
3. The item should be inspected visually to identify any possible traps, etc. (see 13.5 above) which could affect the vacuum performance of the item, taking into account the specified cleaning process and vacuum regime in which the item is to be used.
4. All vacuum sealing faces should be inspected to ensure that there is no damage to the seal area such as scratches, pitting or other defects. If the seal is of the knife edge type, the knife edge should be carefully examined for damage which could affect the sealing properties.

5. Any adhesive tape attached to surfaces of the item whether or not they are to be exposed to vacuum must be removed and any adhesive residue carefully removed with the solvent isopropyl alcohol or ethanol.
6. Any marker pen or paint or similar on any surfaces of the item whether or not they are to be exposed to vacuum should be carefully removed by scraping if necessary followed by washing with the solvent isopropyl alcohol or ethanol and rinsing in demineralised water.
7. Any threaded holes, etc., whether or not they are to be exposed to vacuum, should be examined to see if there are traces of lubricants, cutting fluids or swarf left inside. Any such should be removed carefully using brushing or blowing out with clean compressed air or nitrogen and/or washing with a suitable solvent followed by rinsing with demineralised water, taking care that no residue is transferred to a vacuum surface.

13.7 Mechanical Processes on Vacuum Surfaces

Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components should be kept to an absolute minimum and are preferably avoided. The use of grinding wheels, wire brushes, files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and certainly without prior *acceptance* by ITER.

Accepted techniques are 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 using fine mesh alumina in an isopropyl alcohol or ethanol carrier on a lint free cloth; hand polishing with ScotchBrite™ (Alumina loaded, Grade A).

If any such surface finish technique is employed, care must be taken that any powder or other residues are removed by copious washing in hot water.

Any other such operations may be carried out only with prior *acceptance*.

13.8 Use of acids

Acid treatment of any sort is to be avoided wherever possible and may only be carried out with specific prior *acceptance* by the ITER Vacuum RO. Most acid treatments are for cosmetic purposes only and may result in degradation of vacuum performance.

Where the use of acids is *accepted*, then exposure of the component must be kept to a minimum and must be followed by copious washing in hot demineralised water.

13.9 Treatment of Weld Burn

One particular use of acid pastes is in the removal of weld burn. In general such burns do not affect vacuum performance and are best left alone. Any scaling (i.e. loose oxides) should be removed using the techniques of Section 13.7.

If it is desired to remove burns, then slurry blasting with alumina in water or hand burnishing with alumina powder is a satisfactory alternative. Heavy abrading, grinding or wire brushing is prohibited. Hand finishing with ScotchBrite™ or a dry stone is also *acceptable*.

13.10 Electropolishing for VQC1 Applications

Electropolishing should only be carried out where it is necessary to produce a smooth surface for reasons of electrical discharge or field emission minimisation, emissivity or similar purposes. It is usually unnecessary from a pure vacuum point of view and indeed can be detrimental to vacuum performance.

Electropolishing should be carried out in clean polishing tanks, using fresh electrolyte.

Local electropolishing can be carried out with tampons. Fresh clean pads dipped in clean electrolyte should be used and excessive pressure should be avoided.

After electropolishing, the item should be washed with copious quantities of hot demineralised water.

If required, vacuum Items for use in Class VQC 1 may be baked to 450 ^{o}C for at least 24 hours to remove the residual hydrogen and other contaminants introduced into the surface layers by the electropolishing process.

13.11 Handling and Packing

Handling and packaging of components should be in accordance with the requirements specified in the ITER Vacuum Handbook .

Specifically:

1. Once components have completed initial rough cleaning care should be taken that vacuum surfaces are never touched by bare skin. Powder free latex or nitrile gloves (over cotton or linen if desirable) should always be used when handling components. Coloured gloves are not *acceptable*.
2. Once components have started the cleaning process they should complete the cycle without a break. If it is unavoidable that a delay occurs between stages, then care must be exercised that the component is thoroughly dry before storage, and all seal faces and ports must be protected as below. There must never be a break between any chemical cleaning stage and a subsequent water washing stage.
3. After the component has been cleaned and is completely dry, it should be packed carefully to ensure that it remains clean and free from damage. All vacuum sealing faces should be protected with a clean metal plate or a hardboard or similar fibre free board covered with clean aluminium foil held in place by a number of bolts through the fastener holes. Knife edges should be protected with clean metal gaskets (which may have been used previously, but they should be completely free from loose oxide scale). All ports should be covered with strong clean new aluminium foil and plastic covers. Small items should be wrapped in clean aluminium foil and sealed in a polyethylene bag, under dry nitrogen if possible.

Clean conditions for the handling of vacuum components are also defined in the ITER Vacuum Handbook.

13.12 Spray washing

Where an item is cleaned by spray washing, it should be ensured that all hoses, lances, spray heads, etc are thoroughly cleaned out with clean hot water before the cleaning process starts.

Washing should start at the top of the item and the spray should be worked down to the bottom, ensuring good run-off.

13.13 Standard Cleaning Procedure for Stainless Steel Components

13.13.1 Preclean

All debris, such as swarf, should be removed by physical means such as blowing out with a high pressure air line, observing normal safety precautions. Gross contamination, e.g. greases or cutting oils, etc., should be removed by washing, swabbing and rinsing with any non halogenated general purpose solvent. Scrubbing, wire brushing, grinding, filing or other mechanically abrasive methods may not be used (see 13.7 above).

13.13.2 Wash

1. The item should be washed down using a high pressure jet of hot town water (at approx. 80°C), using a simple mild alkaline detergent. The detergent should then be switched off and the item rinsed thoroughly with hot water until all visible traces of detergent have been eliminated.
2. If necessary, any scaling or deposited surface films should be removed by stripping with alumina or glass beads in a water jet in a slurry blaster.
3. The item should be washed down with a high pressure hot demineralised water jet (at approx. 80°C), with no detergent, ensuring that any residual beads are washed away. Particular attention should be paid to any trapped areas or crevices.
4. The item should be dried using an air blower with clean dry air, hot if possible.

13.14 Chemical Clean for Stainless Steel, or similar Items, for VQC 1 application.

With the addition of the relevant safety precautions, the cleaning process below can also be applied to beryllium,

1. Where possible, the item should be immersed completely in an ultrasonically agitated bath of hot clean liquid solvent for at least 15 minutes, or until the item has reached the temperature of the bath, whichever is longer. The temperature should be the maximum specified by the *supplier* of the solvent.
2. Halogenated solvents are not permitted.

3. Suitable solvents need to be *accepted* by ITER before use. Isopropyl Alcohol, Ethyl Alcohol, Acetone, Axarel 9100™, Citrinox™, P3 Almeco™ P36 or T5161 are *accepted* for this purpose.
4. Where technically feasible, after the liquid immersion stage, the item should be immersed in the vapour of the solvent used for at least 15 minutes, or until the item has reached the temperature of the hot vapour, whichever is longer.
5. It must be ensured that all liquid residues have been drained off, paying particular attention to any trapped areas, blind holes etc.
6. The item is then be washed down with a high pressure hot (approx. 80°C) water jet, using clean demineralised water. Detergent must not be used at this stage.
7. The item is dried in an air oven at approx 100°C or with an air blower using clean, dry, hot air.
8. If the item is too large to be cleaned by immersion the item may be cleaned by washing it down with a high pressure jet of P3 Almeco™ P36 or T5161.
9. The item is cooled to room temperature in a dry, dust free area conforming clean conditions as defined in ITER Vacuum Handbook .
10. The item is inspected for signs of contamination, faulty cleaning or damage.
11. The item is baked to a temperature of 300°C or whatever other temperature has been specified for a minimum period of 24 hours at temperature in accordance with the ITER Vacuum Handbook Appendix 15
12. The item is packed and protected as in 13.11 above.

13.15 Chemical Clean for Stainless Steel or similar Items for use on VQC 2, 3 & 4 components

All items may be cleaned to the specification for items in Class VQC 1

It is also be permissible to use halogenated hydrocarbon solvents for cleaning items in these classes by analogy with 13.13 and 13.14.

For items for Class VQC 2, 3 and 4, baking will not normally be necessary with the exception of items specifically listed in the Vacuum Handbook.

13.16 Chemical Clean for Copper and Copper Alloys

Items manufactured from copper or copper alloys may be cleaned using the procedures for stainless steel, except that in this case Almeco P3-36™ is not acceptable.

Copper surfaces may alternatively be cleaned using a light chromic acid or citric acid etch, followed by thorough washing in hot, clean demineralised water.

13.17 Cleaning Ceramics

Ceramics such as alumina and beryllium oxide may be cleaned using the process described here. Other ceramics may not be able to withstand the high temperature air bake, so manufacturers specifications' must be checked.

Beryllium oxide must in no circumstances be ground or scraped except in specialist facilities.

1. Any surface contamination is removed by wet slurry blasting with alumina powder, or by hand polishing with fine-mesh alumina or diamond powder in an acetone, ethanol or isopropyl alcohol carrier.
2. Components are baked at 1000°C in atmosphere for 24 hours in accordance with Appendix 15. The maximum baking temperature may be limited by the system component materials.
3. Items are wrapped in clean aluminium foil and sealed under dry nitrogen in a sealed polyethylene bag

13.18 Cleaning of Aluminium

1. Components are sprayed with high pressure jets at 60 °C with a 2% solution of Almeco 29™ (an alkaline detergent).
2. This is be repeated with a 2 % solution of Amklene D Forte™.
3. Components are rinsed thoroughly with a jet of hot demineralised water.
4. Components are dried with hot air at 80 °C.

Alternatively,

5. Components are immersed in Sodium Hydroxide (45 g l^{-1} of solution) at 45 °C for 1 - 2 minutes.
6. Components are rinsed thoroughly in hot demineralised water.
7. Components are immersed in an acid bath containing Nitric acid (50% v/v) and Hydrofluoric acid (3% v/v).
8. Components are rinsed thoroughly in hot demineralised water.
9. Components are dried in warm air.

13.19 Air Baking

Items manufactured from stainless steel and the like may be air baked to provide a low hydrogen outgassing surface.

Note that this procedure is not suitable for materials that form a loose oxide, e.g. copper.

Items should be chemically cleaned using the procedures of 13.13 above

Items should then be heated in air at a temperature of 450 °C for a period of 24 hours in accordance with Appendix 15.

13.20 "Snow" Cleaning

A final clean after assembly of components into a large vacuum system may be achieved by the use of "snow" cleaning.

Snow cleaning uses a high velocity stream of soft microscopic particles of solid CO_2 to wash the surface and is effective for removing particulates and some organic contamination from surfaces.

Operatives undertaking this procedure must wear suitable protective clothing and personal safety equipment

The procedures used will be as specified by the *supplier*s of the equipment.

Snow cleaning will normally only be used for items to Class VQC 1, but may be used on all vacuum components.

13.21 Cleaning Procedures for Vacuum Bellows

13.21.1 General

Great care has to be exercised when cleaning thin walled metal bellows, particularly those of edge-welded, nested construction. If any cleaning residues are trapped between the convolutions, either inside or outside, these can result in corrosion which can rapidly cause leaks to develop. Similarly, if any particulates are deposited in the convolutions, mechanical puncturing can take place. Alkaline degreasing solutions such as Almeco are prone to particulate precipitation and therefore must not be used for bellows assemblies.

13.21.2 Procedure for Bellows for Class VQC 1 use

The bellows must be fixed in an extended position if possible.

1. Any traces of visible, loose contamination are removed with a gentle jet of clean, dry air or nitrogen.
2. The bellows are immersed in an ultrasonically agitated bath of isopropyl alcohol (IPA) or ethyl alcohol (ethanol).
3. The bellows should be vapour washed immediately in isopropyl alcohol or ethanol vapour.
4. The bellows, including the interspace where appropriate, must be thoroughly dried inside and out using a gentle jet of clean, dry, particulate free air or nitrogen.
5. The bellows should be placed in a dry air oven at 100 °C for at least 1 hour.
6. The bellows should be baked in a vacuum oven, for 24 hours at 250 °C with the bellows interspace pumped.
7. The bellows should be sealed under dry nitrogen in a polyethylene bag.

This procedure can be used for bellows used on VQC 2, 3 & 4 systems with the vacuum bake requirement waived.

13.22 Cleanliness

13.22.1 Wipe Test for Cleanliness

Gross contamination of a vacuum component may be assessed by means of a wipe test. This may be carried out "dry" or "wet".

Gross contamination may also manifest itself as an "oily" or "solvent-like" smell.

Note that these tests are of a somewhat subjective nature 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 failure of cleanliness.

13.22.1.1 Dry test

The surface of the component is wiped gently with a clean lint free cloth.

If there is any evidence of a deposit on the cloth (i.e. a stain or a change in colour) then the item should be regarded as unclean.

Similarly if the surface of the component which has been wiped shows any evidence of a change in colour or reflectivity of light, then the item should be regarded as unclean.

13.22.1.2 "Wet" test

This uses a clean lint free cloth dipped in a solvent which evaporates at room temperature, such as isopropanol, ethanol or acetone.

Appropriate safety precautions against fire hazard, breathing in of solvent fumes, eye and skin protection must be taken.

1. The cloth is dipped in the solvent which is then be allowed to evaporate in a safe manner. There should be no change in the appearance of the surface of the dry cloth.
2. The cloth is dipped in the solvent and the surface of the component is wiped gently while the cloth is still wet.
3. The solvent is allowed to evaporate from the cloth and the surface of the component until they are dry.
4. If there is any evidence of a deposit on the cloth (i.e. a stain or a change in colour) then the item should be regarded as unclean.
5. Similarly if the surface of the component which has been wiped shows any evidence of a change in colour or reflectivity of light, then the item should be regarded as unclean.

If required, the deposit on the cloth may be analysed by a suitable means to determine the chemical nature of the contamination.

13.22.2 General Test for Cleanliness

An item shall be deemed to be clean for the purposes of this Appendix provided that it meets the following criteria.

Cleanliness is defined to mean that the concentrations of “contaminants” (i.e. unwanted gas species) in the residual gas spectrum of the item are less than the specified values.

The concentration of a species is defined as the fractional intensity of its measured partial pressure components related to that species defined in a particular way to the total pressure in the system expressed as a percentage.

The partial pressures of species in the vacuum system or related to the component being measured should be obtained using the equipment and procedures defined in Appendix 17 of the Vacuum Handbook.

The residual gas spectrum will have been recorded over 1 –200 amu

The spectrum will have been corrected for sampling error, mass discrimination and species relative sensitivities.

The definition of “general contaminants” is the sum of the partial pressures of all peaks present in the residual gas spectrum of mass to charge ratio (amu) equal to 39, 41-43 and 45 and above (*excluding* any above 45 specifically listed in the table below). Also to be excluded from this summation are any peaks related to the rare gases xenon (i.e. 132, 129, 131) and krypton (i.e. 84, 86, 83)

Table 13-1 Allowed concentrations of contaminants pertaining to VQC

Vacuum Class	General Contaminants	Perfluoropolyphenylethers Sum of (peak at 69 and 77 amu)	Chorinated species (Sum of peaks at 35 and 37 amu)	Comment
VQC 4	5	1	1	Excluding water (sum of 17 and 18 amu) from the total pressure
VQC 3	2	0.5	0.5	
VQC 2	1	0.1	0.1	If unbaked, excluding water as above
VQC 1	0.1	0.01	0.01	After bake

This general test for cleanliness can be carried out as part of the verification of component outgassing in accordance with Appendix 17

13.23 Definition of Terms

For the purposes of this specification, the words or terms listed in Table 13-2 below are taken to have the stated meanings.

Table 13-2 Definitions of terms used

Term	Definition
Contaminant	Any unwanted substance present on a surface
Brushing	Using a fibre glass or wire brush to gently remove loosely adhered matter (e.g. dust) from a surface
Swabbing	Vigorous rubbing with a lint free cloth or rag
Wiping	Gentle rubbing with a lint free cloth or rag, either dry or soaked in a liquid
Washing	Cleaning an item by total immersion in a liquid or by pouring or spraying a liquid over it
Dipping	Immersing an item in a liquid and removing it relatively quickly
Rinsing	Using copious quantities of a liquid to remove traces of a contaminant or other material from an item, usually by repeated dipping or pouring the liquid over the item
Scraping	Using a hand tool of a material harder that the item being scraped to gently remove a thin layer from a surface
Grinding	Using a wheel or stone to remove a substantial amount of material from a surface
Scribing	Marking a surface with a clean metal point, vibrating engraver or laser engraving device, usually for identification or marking out purposes
Sand or shot blasting	Using a stream of abrasive particles e.g. silica or alumina to remove a surface layer. The medium may be a gas or a liquid.
Polishing or burnishing	Using a paste of fine particles, e.g. diamond or alumina, or a dry tool to produce a smooth surface
Solvent	A material which removes a contaminant from an item by dissolving it to form a solution
Detergent	A material which removes a contaminant from an item by acting as a surfactant i.e. by hydrophobic or hydrophilic action. Often used interchangeably (but incorrectly) with the term soap.
Etching	Removing a surface layer by chemical action
Pickling	Stripping of the oxide layer from a surface by use of acids
Passivation	Modifying a surface so that it is left in an inactive state, usually by leaving a uniform oxide film on the surface
Electropolishing	Removal of the surface layers of a metal by immersing the surface in a buffered acid solution and applying an electrical potential.
Ultrasonic cleaning	Immersion of a component in a bath of liquid with ultrasonic agitation

Vapour washing	Immersion of a component in a hot vapour such that the vapour condenses on the item and runs off by gravitation, carrying any contaminant in solution or suspension
Glow discharge	An electrical discharge set up in a low pressure gas. Discharges may use dc or radio frequency potential (voltage) sources
Clean surface	A surface with the desired properties e.g. outgassing.

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Appendix 15 Vacuum Baking

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ITER Vacuum Handbook
Appendix 15

Guide to the Vacuum Baking of Components for the ITER Project

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15 Guide for Vacuum Baking

15.1 Scope

This Appendix specifies typical procedures and processes which may be used when vacuum components and materials used for vacuum components for the ITER project are required to be baked.

It is intended that the *suppliers* using such processes should follow the guidance in this Appendix to achieve the requirements of the ITER Vacuum Handbook.

The *supplier* is at liberty to utilise other techniques not described in this Appendix provided that the components supplied comply with the requirements of the ITER Vacuum Handbook.

15.2 General Comments

Vacuum components for the various classifications may require to be baked to ensure satisfactory vacuum performance. Baking can be included as in the component leak testing procedure (Appendix 12) and/or the component cleaning procedure (Appendix 13). A bake temperature and duration will normally be specified in the specification documents and/or drawings for individual components or assemblies. If this is not the case, then the standard temperatures and durations listed in Table 15-1 should be used.

Vacuum baking has three functions, *viz*., (a) the removal of contaminants which can break down to volatile components under the application of temperature (b) reducing the outgassing rate of the surface by accelerating the thermal desorption of molecular species (most often water) and (c) opening up incipient leaks, particularly porosity, where the leak path has been blocked by, for example, a carbon inclusion.

In order that the objectives of this Appendix are achieved, the times and temperatures specified for vacuum bakes have been based on considerable experience of using the processes.

In the following sections, the term “vacuum item” shall be taken to refer to an individual vacuum component, a sub-assembly or complete assembly as appropriate. It may also refer to material, e.g. steel sheet, being processed prior to manufacture.

Where the temperature is too high for a composite assembly the component part requiring higher temperature baking should be baked at that temperature prior to assembly and then the complete assembly baked at the lowest listed temperature of the component parts. Temperature requirements for baking materials not listed should be *accepted* in advance of baking operations.

Where the manufacturer is unable to carry out a bake procedure, either to the standard conditions in Table 15-1 or as otherwise specified, then any variation shall be *accepted* by ITER before proceeding.

Table 15-1Standard Temperatures and Durations for Vacuum Baking

Vacuum Classification	Temperature (^oC)	Time (hr)	Comment
VQC 1	240	24	
VQC 1*	350	24	Stainless steel and beryllium
	450 - 2000	24	Carbon composites (see Appendix 16)
	250	24	Precipitation-hardened copper alloys
	350	24	Tungsten

* For vacuum items in line vicinity of plasma

15.3 General Procedures for Baking of Vacuum Items

15.3.1 Preliminary

Prior to baking, the vacuum item will have been thoroughly cleaned in accordance with the procedure of Appendix 13 of the ITER Vacuum Handbook.

If the vacuum item is not capable of being vacuum sealed and pumped down (e.g. it may be a batch of material or a part-finished vessel), then the vacuum item should be subjected to a total immersion bake (see 15.5.1 below)

All vacuum flanges should be sealed with a blank flange of material and thickness similar to that on the main vacuum item, using gaskets of the type to be used when the vacuum item is in service and fasteners of the appropriate strength.

Where a copper gasket is to be used and the bake temperature is greater than 100^oC, then the gasket should be silver plated to avoid the formation of a loose oxide on the atmospheric side of the joint.

The vacuum item should be placed in or on a suitable bakeout stand which can safely support the vacuum item at the maximum temperature of the bake procedure. Any fixings should take into account the thermal expansion of the vacuum item and stand.

The vacuum item should be pumped down to an appropriate vacuum level and thoroughly leak tested to the appropriate specification in accordance with Appendix 12 of the ITER Vacuum Handbook prior to starting any baking process.

15.3.2 Vacuum Pumps and Gauges

Vacuum Pumps of the appropriate pumping speed and base pressure specification should be used in these processes.

Vacuum pumps used for these processes should be inherently clean (e.g. turbomolecular pumps with magnetic or greased bearings, dry backing/roughing pumps, cryosorption pumps or sputter ion pumps). Otherwise, the supplier needs to satisfy ITER that a suitable failsafe trapping system has been implemented to protect against back-streaming and/or pump failure.

Vacuum gauges (total and partial) with suitable measurement ranges and with appropriate calibration certificates should be fitted as required to monitor satisfactorily the progress of the bakeout process.

The manufacturer should provide ITER with complete details of all such equipment (including manufacturer, age, calibration certificates and history).

No bake procedure should be started before ITER has *accepted* the use of this equipment.

ITER will have the right to request documentary proof of the performance of the pumping equipment in the form of blank pump down characteristics and/or residual gas scans of the pumping equipment.

15.3.3 Temperature Monitoring and Control

The manufacturer should implement a suitable system to monitor, control and record the temperature of the baked vacuum item throughout the procedure.

It is important that the rate of rise and fall of temperature is controlled to within the *accepted* specification as detailed in the *accepted* baking procedure.

Full details of this system should be supplied to ITER.

No bake procedure may be started before ITER has *accepted* the use of this equipment.

15.3.4 Completing the Bake Process

When the temperature of the vacuum item has fallen to room temperature, the vacuum item should be leak tested thoroughly to the appropriate specification in accordance with Appendix 12 of the ITER Vacuum Handbook.

The vacuum item should be vented to dry nitrogen (dew point –50 °C), removed from the bakeout stand and suitably packed and protected for transport or storage.

15.4 Control of the Bake Process

To avoid undue stress on the vacuum item being baked, the temperature should be controlled such that it is uniform to within ±20 °C at all points on the surface of the vacuum item, unless otherwise *accepted* by ITER.

The temperature differential across a metal sealed vacuum flange pair of greater that 200 mm diameter should be less than 10 °C at all times.

The rate of rise and fall of the temperature of the vacuum item should be held within specified limits and, unless otherwise *accepted* by ITER, should be no greater than 10 °C per hour.

When the temperature is falling, it is normally permissible to switch off the temperature control when the temperature falls below 50 °C and let the vacuum item cool naturally to room temperature.

Thus for a 200 °C bake, the rise time will normally be 18 hours, the dwell time 24 hours and the fall time 15 hours plus the natural final cooling time.

At no time during the bake process should the pressure within the vacuum item being baked exceed 10^{-3} Pa. If it should approach this level, the temperature must be held until the pressure falls again as the outgassing rate decreases.

The use of a residual gas analyser to monitor the bake process is strongly advised. This can indicate possible leaks opening up during the process. It can also be used for “end point” detection – e.g. when the water peak falls to below a specified partial pressure.

15.5 Types of Bake Procedure

15.5.1 Total Immersion Bake

In this procedure, the vacuum item is totally immersed in the vacuum environment of a vacuum furnace which is capable of reaching the required temperature and maintaining a pressure less than 10^{-3} Pa at the maximum temperature used.

The manufacturer should, before the start of any baking process, demonstrate to ITER, by the provision of residual gas analysis spectra of the furnace during a blank run at the temperature to be used for the bake procedure, that the vacuum level and the cleanliness of the furnace at the temperature at which the bake is to be performed is satisfactory for the purpose . This requirement may be waived by agreement with ITER where the furnace has not been used for any other purpose between two successive bake processes for the ITER organisation.

Any vacuum joints on the vacuum item to be baked shall be left open.

The vacuum item is placed in the furnace, which is sealed and pumped down to the starting pressure with equipment conforming to the requirements of Section 15.3.2 above.

The furnace is checked for leaks.

The appropriate time/temperature bake cycle is carried out.

15.5.2 Oven Bake

The vacuum item, which will be a sealed vacuum vessel or assembly, is placed inside a suitable insulated enclosure and connected by a suitable pumping manifold to a vacuum pumping system conforming to the requirements of Section 15.3.2 above.

The arrangement shall be *accepted* by ITER before use.

Wherever possible, a suitable vacuum gauge or gauges capable of being operated at the maximum temperature of the bake cycle should be attached directly to the vessel or assembly being baked. Pressure readings on these gauges should be scaled to room temperature values by the appropriate temperature correction factor.

The insulated enclosure may be heated by convection heaters, radiant heaters or hot gas. It is recommended that some form of circulation of the air inside the enclosure be used to assist temperature uniformity.

A suitable number of temperature monitors should be fixed to the vacuum item so that the temperature distribution may be adequately monitored to ensure that the appropriate limits are not exceeded (15.4 above).

If any glass or similar viewports or accessories are fitted, they should be covered in triple thickness aluminium foil for thermal protection and fitted with suitable mechanical protection against impact or implosion.

The assembly should be leak tested to the appropriate specification.

The appropriate time/temperature bake cycle is carried out

15.5.3 "Tape" Bake

In this procedure, the sealed vacuum item is wrapped with heater tapes. Rod heaters, heater plates or flange band heaters may also be used.

A suitable number of temperature monitors is fixed to the vacuum item so that the temperature distribution may be adequately monitored to ensure that the appropriate limits are not exceeded (15.4 above). In this case, it is very important to monitor the temperature on each side of every large (i.e. greater than 200mm diameter) flange pair. Temperature measurement sensors will normally be located close to the heating device (i.e. in the location of highest expected temperature)

Wherever possible a suitable vacuum gauge or gauges capable of being operated at the maximum temperature of the bake cycle are attached directly to the vessel or assembly being baked. Pressure readings on these gauges should be scaled to room temperature values by the appropriate temperature correction factor.

The vacuum item is connected by a suitable pumping manifold to a vacuum pumping system conforming to the requirements of Section 15.3.2 above.

The assembly shall be leak tested to the appropriate specification in accordance with Appendix 12 of the ITER Vacuum Handbook.

The vacuum item may then be wrapped in aluminium foil to assist in uniformity of the temperature distribution, taking care around electrical connections.

If there are glass or similar viewports or accessories fitted, they must be covered in triple thickness aluminium foil for thermal protection and fitted with suitable mechanical protection against impact or implosion.

The vacuum item is then covered with suitable thermal insulation, preferably a ceramic fibre filled flexible jacket or blanket.

The appropriate time/temperature bake cycle is carried out.

15.5.4 Air Bake

Where an air bake is specified for any item, the general procedures are as specified in this Appendix for the particular type of bake (Immersion, Oven or Tape) except that in this case all sections referring to pumping are ignored and all surfaces (interior and exterior) of the item shall be exposed to normal atmospheric air during the bake process.

Vacuum equipment conforming to the above requirements may still be required where a leak test and/or outgassing test has been specified as part of the bake process either before or after such a process.

15.6 Documentation to be Supplied

For each vacuum item, the following certificates and records will normally be supplied:

- If requested by ITER a record of the performance of the pumping equipment
- A certificate of the initial leak rate
- A certificate of the final leak rate
- A record of the temperature distribution for the item and pressure within the vacuum item against time for the full duration of the bakeout process
- If agreed between the manufacturer and ITER, a full record of any residual gas scans taken with appropriate time markers which identify the scans to the position on the component bakeout cycle
- Full documentation regarding any leaks or other problems which occurred during the tests and any remedial action taken

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Appendix 17 Guide to Outgassing Rates and their Measurment

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ITER Vacuum Handbook

Appendix 17

Guide to Outgassing Rates and their Measurement

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17.1 Scope

This Appendix is intended as a guide to the measurement of the total and partial thermal outgassing rates of materials, vacuum vessels, components and assemblies for the requirements of the ITER Project. It is intended that the guide be used to assist *suppliers* in producing outgassing test procedures to comply with the mandatory requirements of the ITER Vacuum Handbook. It also gives details on how the outgassing requirements for ITER systems have been derived.

It is envisaged that outgassing tests will normally be performed on components, parts of the component or “coupons” which have been subjected to the complete manufacturing process. Manufacturing operations which have been applied, including baking and cleaning operations, should be recorded and traceable to the coupon (where used) or to the manufactured component.

17.2 Limitations

This Appendix describes a set of procedures for the measurement of thermal outgassing from a vacuum item when used as part of the vacuum quality assurance procedures for the ITER Project. This Appendix describes the recommended procedures of the most widely used methods of measuring the outgassing rates; it does not consider all available methods. Despite this limitation, the techniques are more widely applicable and form a basis for more general good practice.

The supplier is at liberty to propose other methods of thermal outgassing measurement not described in this Appendix.

When this set of procedures is used to measure the outgassing from a component or coupon placed within a vacuum chamber, the outgassing of the chamber walls cannot usually be neglected and must be subtracted from the measured value to obtain that from the coupon. For this, an independent measurement of the wall outgassing from the empty chamber will be required – often referred to as a *blank run*.

Unless otherwise specifically indicated, outgassing measurements using these procedures will be carried out with the component under test at 100 °C

In these procedures the term *outgassing* shall be taken to mean *thermal outgassing* unless otherwise indicated.

The methods of measuring outgassing rates described in these procedures yield an average value of the outgassing rate for each surface exposed to the vacuum measurement system.

17.3 Specific Outgassing Rate

Outgassing is described in terms of the rate of desorption of gas from a vacuum surface.

The measured (or net) outgassing rate is the difference between the intrinsic outgassing rate (of the component) and the rate of re-adsorption on the surfaces of the test chamber.

The specific outgassing rate defined as the total gas load generated per unit time due to gas desorbing from a vacuum surface due to the temperature of the surface per unit area of desorbing surface. It is represented here by q_{th}. Units are $Pam^3s^{-1}m^{-2}$

Clearly,

$$Q_{th} = q_{th} \cdot A$$

Where:

Q_{th} is the total outgassing rate ($Pa.m^3.s^{-1}$)

A is the area of the desorbing surface (m^2)

17.4 Generic Methods of Measuring Outgassing Rates

17.4.1 Rate of Rise of Pressure Method

This method of measuring outgassing rates is in principle very simple, but there are a number of considerations that need to be taken into account if the measurements are to be meaningful.

The principle of the method is that if one has a volume evacuated to a given pressure p_0 and then isolated from the vacuum pump, the specific thermal outgassing rate q_{th} is given by

$$q_{th} = \frac{V}{A} \cdot \frac{(p_t - p_0)}{t}$$

where V is the containing vessel volume

A is the total internal surface area of the desorbing surface

p_t is the pressure after a time interval t

provided that the outgassing rate is reasonably constant with both pressure (over the range $p_t \rightarrow p_0$) and the time interval t and that the temperature of the outgassing surfaces is constant.

Partial (i.e. species dependent) outgassing rates may be determined by using a calibrated gas analyser to measure the rate of rise of the partial pressure of a particular species.

What is actually measured using the rate of rise technique when the pressure remains in the high vacuum region or below, is the increase in number density of gas molecules entering the measurement volume of the “pressure” sensor. This increase can be affected by various processes, which can be classified as being either gas sources or gas sinks. A gas source is something which releases gas molecules into the interior of the vessel, and hence eventually into the measurement volume. A gas sink is something which adsorbs or absorbs a gas molecule which strikes it, i.e. it acts as a pump. This is further discussed later.

This method is quite simple to implement and requires the minimum of equipment. Since, during the measurement time the vacuum pump is valved off, there is no need to know the pumping speed (especially where the speed may be species dependent). Only one vacuum gauge is required. For absolute measurements, the gauge needs to be calibrated for the outgassing species. Where only *relative* measurements of outgassing are required (e.g. before and after a process such as baking), provided the gauge is known to be reasonably stable in sensitivity, calibration may not be required.

No vacuum parameters of the system need to be calculated or measured, apart from the pressure.

This method works best for relatively low outgassing rates, where measurements can be take over a long time period. For high outgassing rates, the rise in pressure can be quite rapid, making time and/or pressure dependent measurements difficult.

The volume of the vessel (and all appendages) needs to be measured or calculated to a reasonable degree of accuracy.

This method is more suitable for the measurement of outgassing from vessels or assemblies rather than coupon samples, unless either the intrinsic outgassing rate of the coupon is very much higher than that of the containing vessel or the surface area of the sample is much higher than that of the vessel or both.

17.4.2 Dynamic Flow (Conductance) Method

In this method, the item being measured is pumped through a known conductance and the pressure difference across this conductance is measured. The specific thermal outgassing rate q_{th} is then given by

$$q_{th} = C \cdot \frac{\Delta p}{A}$$

where:

C is the conductance

Δp is the pressure difference across the conductance

A is the area of the desorbing surface

Partial (i.e. species dependent) outgassing rates may be determined by using calibrated gas analysers to measure the differences in partial pressure of the particular species.

The method is suitable for all but the lowest values of outgassing, since the value of the conductance can be chosen to give a sensible pressure difference. Variation in outgassing rate with time can readily be measured even when the outgassing rate is quite high or is varying relatively rapidly and the volume of the vessel is not required.

The method requires two vacuum gauges which must both be calibrated for the desorbing species for the most accurate results. Both must remain stable across the full range of measurement for the duration of the test. If partial outgassing rates are required, then two calibrated residual gas analysers (RGAs) should be fitted.

It requires the use of a pump whose speed is much larger than the conductance for all gas species.

The conductance, which is gas species dependent, must be measured or calculated to a reasonable degree of accuracy.

When measuring outgassing from coupon samples, the outgassing rate of the containment vessel must remain sufficiently stable for a blank run to yield a meaningful correction.

17.4.3 Variant Dynamic Flow Methods

One variant of this method assumes that the pressure on the pump side of the conductance is very much less than that on the sample side and so can be ignored. In this case only one calibrated gauge and one RGA is required, both situated upstream of the conductance. Good practice would require a total pressure gauge also to be fitted downstream of the conductance to ensure that the pressure conditions were being met, but this gauge need not be calibrated.

A second variant uses an arrangement of valves so that a single calibrated gauge can alternatively be exposed to either side of the conductance. This requires good linearity in the gauge and an outgassing rate which is stable over the time of measurement.

17.4.4 Weight Loss Method

The method of weight loss measurement can be used to measure outgassing rates from materials with high outgassing rates, for example organic materials.

The test consists of measuring the weight loss of a sample which has been subject to a defined thermal cycle under vacuum. The sample is placed in an effusion cell and heated. The outgassing flux is condensed on temperature controlled collectors which are placed in front of the sample. From the mass deposit on the collector the total mass loss (TML) and hence outgassing rate are derived, as function of time, and is usually expressed as %TML

The setup and procedure are described in the ASTM E595-93 standard and are widely used in characterisation of materials for use in space applications.

17.5 Sources of Errors in Measuring Outgassing

All methods of measuring outgassing are susceptible to errors which may yield misleading results. Detailed consideration should always be given to this.

17.5.1 System Effects

17.5.1.1 Vacuum Vessels and Conductance’s

Either the internal volume of the outgassing measurement chamber, or the conductance between this and the pump, must be known to a reasonable degree of accuracy, dependent on the technique employed. Volumes are notoriously difficult to measure or calculate to high accuracies and are temperature dependent. In some cases (e.g. where bellows are present) they may also be dependent on the atmospheric pressure in the laboratory. Volumes will change if there are movable items present, e.g. vacuum valves.

The value of a conductance element is also temperature dependent and, more importantly, dependent on the mass of the gas species traversing the conductance. To some extent the transmission probability of gas molecules through a conductance is dependent on the size and shape of the vacuum chamber at each end.

It is usually assumed that in measuring outgassing, free molecular flow conditions prevail. This may or may not be the case and needs to be checked.

In the dynamic flow method, it is assumed that outgassing of the vacuum system downstream of the conductance does not influence what is happening in the measurement chamber upstream of the conductance.

17.5.1.2 Vacuum Gauges

The calibration of both total pressure and partial pressure gauges is non trivial and the stability of many gauges is not good. Clearly this may introduce significant measurement errors, especially in the two-gauge dynamic flow method.

17.5.1.3 Vacuum Pumps

Pumping speeds of vacuum pumps vary with the species being pumped, so for the dynamic flow method it is important to ensure that a sufficiently high pumping speed (i.e. compared to the conductance for the particular gas species) is maintained at all times.

17.5.1.4 Temperature

Some of the effects of temperature have been discussed above. However, outgassing is itself strongly dependent on temperature, so it is important that for the most accurate measurements, the entire apparatus is maintained at a constant temperature during the period in which measurements are being taken.

17.5.2 Gas Sources and Sinks

Errors in measured outgassing rates may be affected by sources of gas other than true outgassing entering the measuring volume of the gauge or gauges used. In this case an enhanced value will be measured. Likewise any pumping in the vessel for which outgassing is being measured will lead to an apparent value being measured which is lower than the true value. In extreme cases, negative values of apparent outgassing may be measured.

17.5.2.1 General Types of Gas Source or Sink

Possible sources of gas include:

- any surfaces exposed to the vacuum which release molecules by desorption other than thermal desorption or by permeation
- all joints, which tend to be areas of increased permeation
- leaks, real or virtual
- any gauge
- gas bursts from items moving in the vacuum system

Possible sinks for gas include:

- any surfaces exposed to the vacuum which can exhibit wall pumping, particularly "active" surfaces found in capture pumps even when switched off
- any gauge which can act as a pump

17.5.2.2 Surfaces as Sources

The point of the measurement is to measure thermal desorption from the surface of interest, i.e. gas molecules released by the absorption of phonons, so it is important that extraneous forms of desorption are minimised. Details are not discussed here, but it should be noted that the surfaces under investigation should not be exposed to significant fluxes of photons of wavelengths shorter than the short-wavelength end of visible or to electrons of energy greater than a few eV. It is also important that the temperature of the surfaces under test is kept constant as thermal desorption is an exponential function of temperature.

For metals at room temperature, permeation is only significant for hydrogen and even that would normally be very low unless very thin walls are present or when measuring very low outgassing rates. However it should be remembered that hydrogen is by far the dominant species in such cases and there is some debate as to whether hydrogen permeation is in fact the rate limiting step in outgassing from metals. The source of the hydrogen may be either dissolution from the bulk metal or passing from atmosphere on one side of the wall to the other. In practice, both will happen.

Glasses, plastics and elastomers may have quite large permeabilities for hydrogen, helium or water. Care must therefore be exercised when these are exposed to both atmosphere and vacuum.

A special case of thermal outgassing is evaporation or sublimation of the wall material (vapour pressure). For most normal vacuum materials, this is only a problem when measuring extremely low outgassing rates.

17.5.2.3 Surfaces as Sinks

When gas molecules strike a surface, in general they stick. They may stick for a short time before being re-emitted or they may stick for a long time. Here, the former process is ignored although it is important for the thermodynamics of the system. However, the latter process gives rise to the phenomenon known as wall pumping. In some cases this process can be enhanced by preparing a surface which is chemically active and deliberately used as a pump in, for example, a Titanium Sublimation Pump (TSP) or a Non-Evaporable Getter (NEG). A similar effect is seen when a surface is cooled to cryogenic temperatures. In normal circumstances the walls of a vacuum system are sufficiently inert that wall pumping is insignificant. However there are circumstances where this may not be the case. A surface which has been glow discharged will have had its chemistry altered somewhat and until a passivation film, usually an oxide, is formed may exhibit wall pumping. Similarly a surface where the gas concentration has been reduced by photon desorption, electron or ion desorption or high temperature thermal desorption may be sufficiently far from equilibrium to exhibit wall pumping.

It is very difficult to estimate what wall pumping speeds might be in such circumstances.

17.5.2.4 Joints

Vacuum joints can be regions of enhanced permeability, especially demountable joints using elastomer gaskets. However, welds and brazes may also be suspect. If components have been hydrogen brazed, then enhanced hydrogen outgassing may be experienced from all surfaces. Joints which have been welded using the Tungsten Inert Gas (TIG) process may exhibit enhanced outgassing of (usually) argon.

17.5.2.5 Leaks

Naturally, the presence of leaks can vitiate any sensible measurement of outgassing and so thorough leak checking of the test system is a necessity.

17.5.2.6 Moving items

When items move in a vacuum, gas molecules can be desorbed. The most common moving item in an outgassing measurement system will be a vacuum valve. These can generate significant gas bursts when moving. This can be minimised by operating them slowly and by thorough outgassing.

In practice, this is not usually very important in measuring outgassing rates. In the case of rate-of-rise measurements, the system is sealed and static. Any gas generated when the valve is closed at the start of measurement forms part of the base pressure. In the two gauge dynamic flow technique, valve states do not change during the measurement. In the variant of this technique where a single gauge is exposed successively to either side of the conductance to eliminate gauge errors, some care has to be exercised to minimise any such effects.

17.5.2.7 Gauges as Sources

Hot filament gauges are clearly potentially major sources of error in measurements of this type, since they not only run at high temperatures but will also cause local heating of the vacuum system. Enhanced outgassing will be experienced from the gauge and walls.

Cold cathode gauges are better than hot filament gauges in this respect since they operate at room temperature.

Ionisation gauges, hot or cold cathode, are also sources of x-rays, ions and electrons of sufficient energy to cause desorption when they strike surfaces. Cold cathode gauges may also generate energetic neutrals which may themselves cause desorption.

17.5.2.8 Gauges as Pumps

All ionisation gauges will act as pumps. Hot filament Bayard-Alpert Gauges typically exhibit pumping speeds of around 0.1 $l.sec^{-1}$ but this will normally be swamped by the outgassing.

Cold cathode gauges of the Penning or magnetron (whether inverted or not) type may well exhibit (net) pumping speeds of up to 1 $l.sec^{-1}$.

17.5.3 Some Practical Considerations

17.5.3.1 Minimising Errors

Clearly if one wishes to measure an outgassing rate, all of the above effects may play a part in introducing errors. Good vacuum practice will help in many cases to vitiate the worst of these. Leak testing should be carried out with a sensitivity of at least an order of magnitude better than the measured total outgassing rate. Permeation (but not of course bulk dissolution) can be reduced by surrounding the measurement chamber with a guard vacuum. Wall pumping may be reduced by waiting or by saturating the surface with an inert gas. This may of course make nonsense of what one is trying to do!

In practice, the bulk of the errors will come from the gauge. A hot cathode gauge should be mounted on a water-cooled side arm, preferably with a cooled baffle in the gauge throat. It should be well-degassed, and any pressure difference between the gauge and the measurement chamber carefully evaluated. If possible a cold cathode gauge should be used or a gauge specially designed to minimise outgassing.

The gauge head must be mounted out of line of sight of the surfaces being tested and tubulation to the gauge head should have as large a conductance as possible. As is so often the case, such requirements are to some extent contradictory so some compromise is necessary. There is not a lot one can do to eliminate the effects of gauge pumping. Recent developments using stable field ion emitters as the electron source for a Bayard-Alpert gauge may offer a good compromise for measuring low outgassing rates. The temperature effect is eliminated and gauge pumping is relatively low. Energetic electrons and X-rays are still produced however.

The most troublesome effect is gauge pumping. In many cases it is relatively easy to guess what the minimum outgassing rate to be expected from a sample might be. The surface area of the sample should then be such that the expected gas load generated is significantly greater than the gas load pumped by the measuring gauge. If this is not the case, then the measurement is not meaningful.

In some cases, where the measured pressures are within it's operating range, a suitable gauge is the spinning rotor gauge. Outgassing form this type of gauge is simply that of its rather small internal surface area and there is no pumping effect. It is best suited to rate of rise measurements.

Because not all sources of error can be eliminated, rate-of-rise measurements, for example, can only set a lower bound for the outgassing rate. It may be possible to estimate an upper bound by guessing the gauge pumping speed. If these two values are reasonably close, then the result may be meaningful. This assessment cannot be done unless a real effect, i.e. a measurable pressure rise, is obtained.

It will be apparent that in the rate of rise method, sufficient time must be allowed for the pressure to rise significantly. Initially after isolating the main pump, there will be a period when the system is not in a steady state as the various gas sources and sinks settle down, but in a well-behaved and well designed experiment, this should be relatively short and for a constant outgassing rate a log-log plot of pressure against time should yield a straight line of positive slope. For outgassing rates close to the pumping speed of the system sensible measurement times may well be of the order of hours, not minutes.

17.5.3.2 Time Zero for outgassing

As noted earlier, the outgassing rate measured is a function of the time that a surface has been exposed to vacuum (i.e. has been pumped), and an idealised characteristic is shown in Figure 17.5.3-1 (Note that no great significance should be attached to the actual values of outgassing rate shown in the figure.) It is clear that the measured value of outgassing will depend on when the measurement is made.

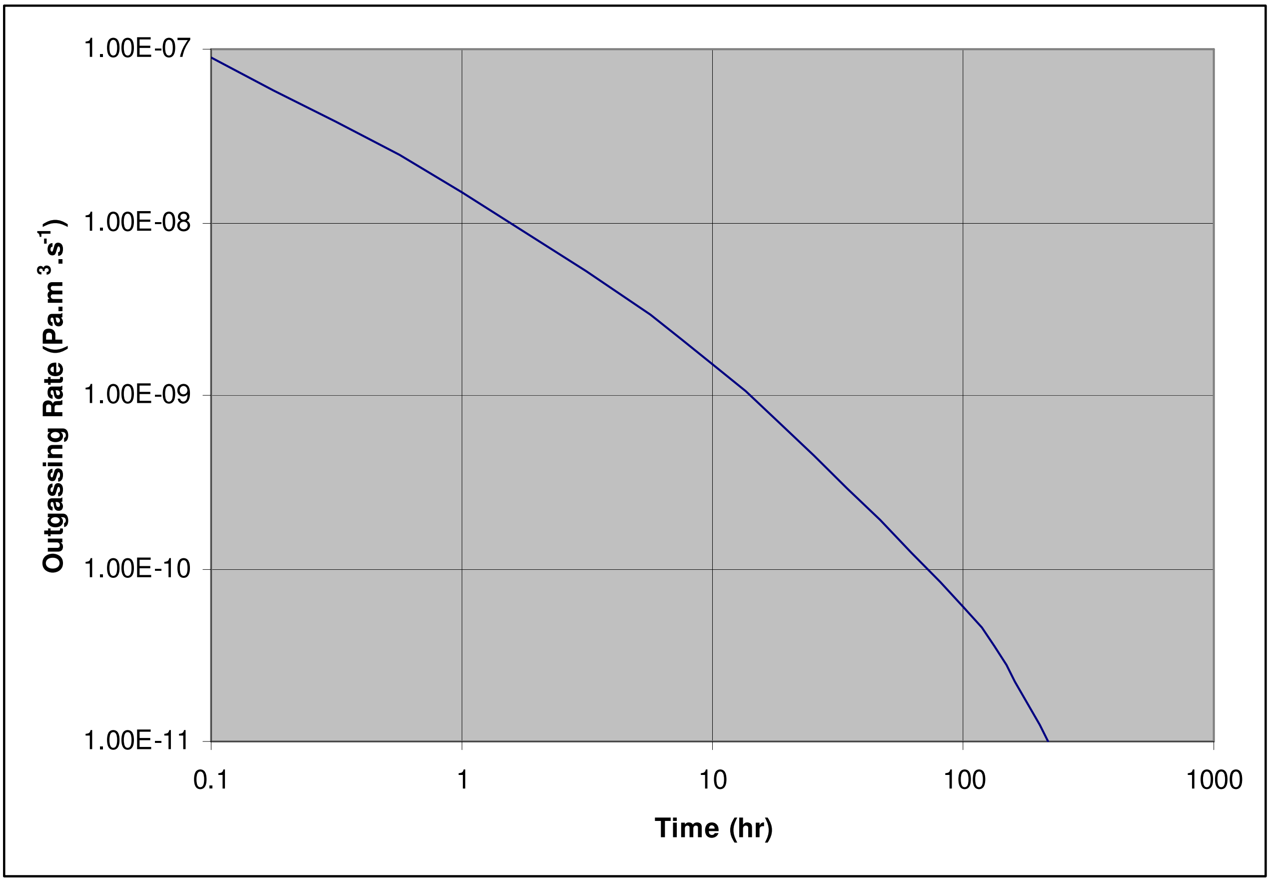

Figure 17.5.3-1 Idealised outgassing rate of a surface as a function of exposure time to vacuum

Because of the above, in order to achieve some sort of comparability, outgassing rates are often quoted as either 1 hour, 10 hour, 100 hour or “long term” rates. These are rates measured at these time intervals after time = 0. One matter of particular difficulty is determining just when time = 0 actually is. In a pump down, for example, when is the pressure determined by outgassing rather than removal of gas from the volume?

Since this set of procedures is intended for use in a quality assurance environment, this difficulty can be circumvented by careful specification of what should be done in individual cases.

17.5.4 Stating Outgassing Requirements

17.5.4.1 Vessel or Component Acceptance Tests as normally used in a Vacuum Quality Assurance Series of Procedures

In the specification for the vacuum item, if an outgassing test is required, then the specification should state the requirement in one of three alternative forms. These are as follows:

"*x* hours after the end of the procedure *y*, the specific outgassing rate shall be less than a value of *z* $Pa.m^3.sec^{-1}.m^{-2}$ using the measurement techniques described in the ITER Vacuum Handbook Appendix 17."

or

"m hours after the end of the procedure *n*, the total outgassing rate shall be less than a value of *r* $Pa.m^3.sec^{-1}$ using the measurement techniques described in the ITER Vacuum Handbook Appendix 17."

or

"k hours after the end of procedure g, the steady state specific outgassing rate shall be less than a value of *s* $Pa.m^3.sec^{-1}.m^{-2}$ using the measurement techniques described in the ITER Vacuum Handbook Appendix 17".

The steady state outgassing rate is defined at as the outgassing rate at the time when the rate of change of measured outgassing rate is less that 5 % over an elapsed time of 120 minutes.

That is to say:

$$\frac{q_t - q_{(t+120)}}{q_{(t+120)}} \leq 0.05$$

Where $q_{(t)}$ = specific outgassing rate at time *t* (minutes).

Procedures y, n and g will have been defined earlier in the specification and, unless there are good reasons otherwise, x and m will normally be 10 hours.

17.5.4.2 Testing items, materials or procedures for acceptability for more general use

Such tests are of a more generic nature and so some standardisation of results is necessary. There are two particular cases to be considered (a) where there is no form of processing and (b) where there is a processing stage included e.g. a bake.

Where no processing is involved outgassing measurements should be taken at intervals of 1 hour, 10 hours and (optionally) 100 hours after the start of pump down of the vacuum item. It should be noted that such results may be influenced by the pumping speed applied, so this should always be quoted.

Following a process stage, outgassing measurements should be taken at intervals of 1 hour, 10 hours and (optionally) 100 hours after the end of the process. In the case of a bakeout, the end of the process may be defined as when the system returns to room temperature, unless a particular specification states otherwise. It should be noted that results may be influenced by the pumping speed applied, so this should always be quoted.

17.6 Procedures

17.6.1 General

17.6.1.1 Start Time

In the following procedures, it is assumed that the appropriate starting time for measurements has been set according to the considerations discussed earlier. This is referred to below simply as the start time.

17.6.1.2 Pump Set Conditioning

Before the start time, all pump sets will have been conditioned and proved to be leak tight and clean.

17.6.1.3 Vacuum Vessel Outgassing Measurements

The vessel should be assembled into the appropriate apparatus using flanges and gaskets appropriate to the vacuum regime for which the vessel is designed.

In the case of the measurement of outgassing of a vacuum chamber whilst being pumped from atmospheric pressure, a preliminary pump down should be made and the vessel and its appendages proved leak tight. Following this leak test, the vessel should be vented to either clean dry nitrogen (dew point $< -50^oC$) or normal atmosphere as specified in the test documentation. If nothing is so specified, then clean dry nitrogen is recommended.

In the (usually rare) circumstances of an outgassing measurement being required for a vessel in “as received” condition, then leak tests should be carried prior to the completion of the outgassing measurements to ensure that the results are not dominated by any leak being present. Clearly, great care must be taken during assembly to minimise the possibility of such leaks. If such a leak is detected, the originator of the request for test must be consulted before any further work is carried out.

17.6.1.4 Vacuum Component or Sample Outgassing Measurements

The component or sample should be inserted into a vacuum chamber for which the outgassing characteristics have been established in a blank run immediately prior to the tests.

For a meaningful measurement of outgassing, the expected outgassing load of the component or sample must be at least 10 times greater than that of the empty chamber.

The procedure to be followed will be the same as that for a vessel as specified in the request for test.

17.6.2 Rate of Pressure Rise Method

17.6.2.1 Equipment

The equipment used will typically take the form shown in Figure 17.6.2-1.

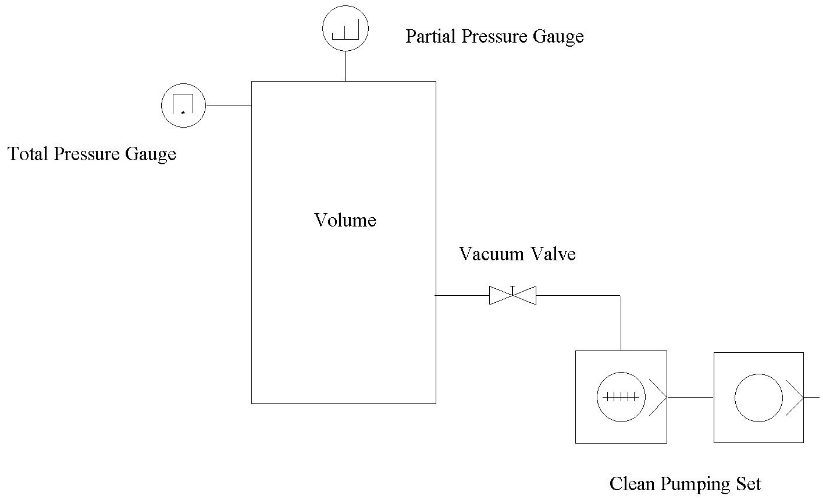

Figure 17.6.2-1 of outgassing - pressure rise technique.

The choice of pumping set and the type of total pressure gauge to be used will depend on the maximum total pressure expected during the measurements. The gauge is shown as a cold cathode device, but need not be. There are distinct advantages to using a Spinning Rotor Gauge if the pressures measured lie within its range of operation.

The use of a partial pressure gauge will normally mean that the total pressure should not normally rise above about 10^{-3} Pa during measurements unless some sort of sampling stage is used. The pump set should be chosen so that the volume may be evacuated through the valve to a reasonable pressure in a reasonable time. What “reasonable” means must be assessed on a case-by-case basis, but must be short compared to the time at which the first outgassing result is required.

17.6.2.2 Procedure

With the pump set under vacuum at or close to its ultimate, the vacuum valve is opened carefully and the volume evacuated to its base pressure or for the time at which an outgassing measurement is required, whichever is less.

Any processes specified (e.g. a bake cycle) are completed.

If the pressure achieved is below about 10^{-6} Pa, then any hot filament measuring devices should be thoroughly outgassed and the outgassing products pumped away.

The vacuum valve is closed and the pressure or partial pressure of the species of interest recorded at frequent intervals until a pressure rise of at least one decade is obtained. The times of recording each pressure should be noted. The use of a continuous record as on a chart recorder or a data logger is to be preferred.

If outgassing measurements are required at a number of values of pumping time, then the valve should be opened and the process repeated at the appropriate time.

The outgassing rate(s) are then calculated using the above formula.

17.6.3 Dynamic Flow Method

Note that only the two-gauge method is described here.

17.6.3.1 Equipment

The equipment used will typically take either of the forms shown in Figure 17.6.3-1. That on the left is more suited to measurements on vessels or assemblies, that on the right to coupon samples.

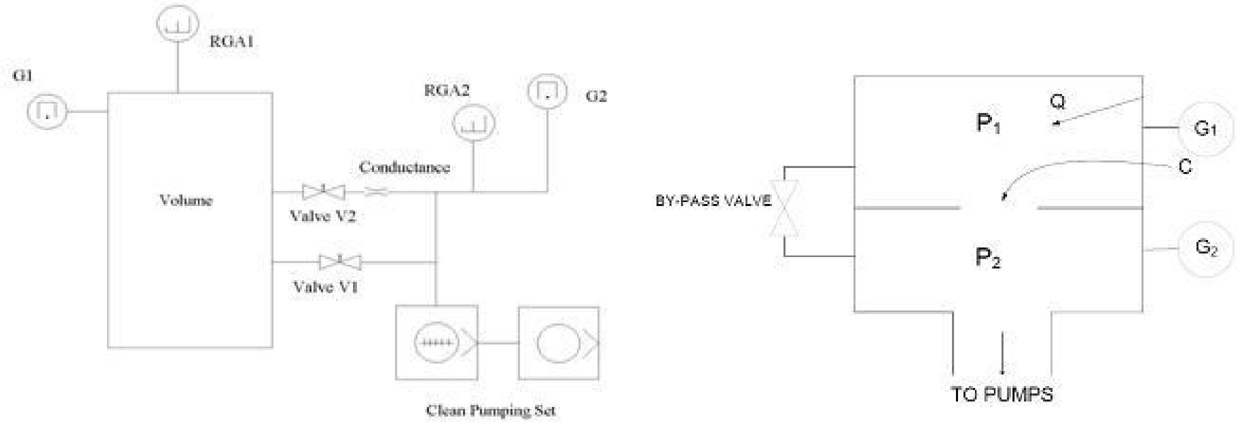

Figure 17.6.3-1 Equipment for the measurement of outgassing - dynamic flow technique.

The choice of pumping set and the types of total pressure gauges to be used will depend on the maximum total pressure expected during the measurements. The gauges shown are cold cathode devices, but need not be. The use of partial pressure gauges will normally mean that the total pressure should not normally rise above about 10^{-3} Pa at the gauge during measurements, unless some sort of sampling stage is used. The pump set should be chosen so that the volume may be evacuated to a reasonable pressure in a reasonable time. What “reasonable” means must be assessed on a case-by-case basis, but must be short compared to the time at which the first outgassing result is required.

The value of the conductance should be chosen so that a reasonable pressure differential is obtained.

17.6.3.2 Procedures

17.6.3.2.1 Outgassing measurements on a vessel

Here, the equipment shown on the left of Figure 17.6.3-1is the more suitable.

With the pump set under vacuum at or near its ultimate, vacuum valves V1 and V2 are opened carefully and the volume evacuated to its base pressure or for the time at which an outgassing measurement is required, whichever is less.

Any processes specified (e.g. a bake cycle) are completed.

If the pressure achieved is below about 10^{-6} Pa, then any hot filament measuring devices should be thoroughly outgassed and the outgassing products pumped away.

The vacuum valve V1 is closed and the pressures on either side of the conductance monitored until the values have stabilised over a period of about 15 minutes.

If quasi-continuous measurements of outgassing as a function of time are required, then sets of readings shall be taken at appropriate time intervals.

If outgassing measurements are required at a number of discrete values of pumping time, then the valve V1 is opened after a set of readings is complete and closed shortly before the next set is due, allowing sufficient time for the system to stabilise before each set of readings.

The outgassing rate(s) are then be calculated using the formula above.

17.6.3.2.2 Outgassing measurements on coupon samples

In this case, the equipment shown on the right of Figure 17.6.3-1 is the more suitable.

To be meaningful, the following procedure should be carried out first with the upper (test) chamber empty, then vented to clean, dry (dew point <-50°C) nitrogen and the sample inserted. The sequence is then repeated, the sample removed and, ideally, a final sequence carried out on the empty system. The two blank (i.e. empty chamber) runs should give consistent results. The measured pressure in the upper chamber with the sample inserted must be significantly higher than the blank runs if a meaningful value of outgassing is to be calculated.

With the pump set under vacuum at or near its ultimate, the valve to the pumping set (not shown) and the by-pass valve are opened and the volume evacuated to its base pressure or for the time at which an outgassing measurement is required, whichever is less. The by-pass valve should be of sufficient size that adequate pumping speed is achieved above the conductance.

Any processes specified (e.g. a bake cycle) are completed.

If the pressure achieved is below about 10^{-6} Pa, then any hot filament measuring devices should be thoroughly outgassed and the outgassing products pumped away.

The by-pass valve should be closed and the pressures on either side of the conductance monitored until the values have stabilised over a period of about 15 minutes.

If quasi-continuous measurements of outgassing as a function of time are required, then sets of readings should be taken at appropriate time intervals.

If outgassing measurements are required at a number of discrete values of pumping time, then the by-pass valve should be opened after a set of readings is complete and closed shortly before the next set is due, allowing sufficient time for the system to stabilise before each set of readings.

The outgassing rate(s) are then calculated using the formula above.

17.7 Presentation of Results

On completion of outgassing tests a report should be issued recording:

- full details of the apparatus used (including volumes where appropriate)
- copies of calibration certificates for all gauges used
- details of the calculation of the value of the conductance (where appropriate)
- results of system leak tests
- proof of cleanliness of the pump set
- tabulated measurements of pressure with times at which readings were taken or copies of recorder traces as appropriate
- tabulated values of calculated total and partial outgassing rates as appropriate

17.8 Derivation of the ITER Outgassing Rate Requirements

The limits of outgassing rates for materials for use in ITER vacuum systems are given Table 17.8-1, which is Table 5-1 of the ITER Vacuum Handbook and the values are therefore mandatory.

These limits have been produced by taking into account the total surface area expected, available pumping speed, the desired pressure, and post assembly conditioning time, with due consideration of what is reasonably achievable.

		Maximum steady state Outgassing rate $Pa.m^3.s^{-1}.m^{-2}$		
VQC+	**Outgas temperature °C**	**Hydrogen isotopes**	**Impurities**	**Testing Guidelines**
1	100‡	1×10^{-7}	1×10^{-9}	Appendix 17
2	20	$1 \times 10^{-7*}$		Appendix 17
3	20	1×10^{-8}		Appendix 17
4	20	1×10^{-7}		Published data and conformity to clean work plan.

For VQC 2, 3 and 4, the outgassing rate excludes the partial outgassing rate for water and hydrogen.

‡ The outgassing test temperature can be reduced to 20 °C for components which normally operate at cryogenic temperatures.

+ For CFC, refer to the ITER Vacuum Handbook Section 26.7

* In the case of resins for magnets, it is considered that this target outgassing rate will be achievable. However a factor 10 increase will be permitted as an acceptance criterion.

Table 17.8-1 – Outgassing rates pertaining to VQC

17.8.1 Vacuum Vessel

In calculating the maximum outgassing rates specified for the Vacuum Vessel (VQC 1) the following assumptions and calculations have been used.

The approximate total surface area of vacuum vessel is 20000 m^2 and is calculated as the sum of the following:

- vacuum vessel+ports ≈ 3000 m^2
- port plugs ≈ 4000 m^2
- blankets ≈ 5000 m^2
- divertor ≈ 2000 m^2
- piping ≈ 1000 m^2
- in-vessel cabling ≈ 2500 m^2
- fixtures and fittings ≈ 2500 m^2

The ITER Project Integration Document (PID) specifies the vacuum vessel base pressure to be < 10^{-5} Pa for hydrogen and <10^{-7} Pa for impurities prior to ITER operations at the operating temperature of 100 °C.

Using a conservative estimate of the vacuum vessel pumping speed of 20 $m^3.s^{-1}$ yields a derived maximum hydrogen throughput of 2 x 10^{-4} $Pa.m^3.s^{-1}$

Thus, the maximum allowable outgassing rate of hydrogen prior to pulsing is calculated as,

$$q = \frac{Q}{A} = \frac{2.0x10^{-4}}{20000} = 1x10^{-8}\,\mathrm{Pa.m^3.s^{-1}.m^{-2}}$$

It is expected that a factor 10 decrease in the outgassing rate for hydrogen can be achieved by baking the vessel to 200 °C and hence the maximum outgassing rates for VQC 1 components has been defined in Table 17.8-1 as:

- 1x10^{-7} $Pa.m^3.s^{-1}.m^{-2}$ for hydrogen at 100 °C
- 1x10^{-9} $Pa.m^3.s^{-1}.m^{-2}$ for impurities at 100 °C

17.8.2 Cryostat

The outgassing requirement for VQC2 is derived from the need to manage three areas:-

1) To be able to pump down the cryostat initially in a reasonable time with limited pumping and conditioning capacity and to achieve a level of vacuum suitable for an insulation vacuum.
2) To avoid poisoning of the activated charcoal in the reference cryostat cryo-pumps with heavy hydrocarbons.
3) To ensure that over time, the build up impurities on the cold thermal shields does not adversely affect their emissivity and hence the heat load on the superconducting coils and the cryo-plant.

The specified outgasing limit for VQC 2 excludes water because it is considered that it will not be possible during the cryostat construction to avoid surfaces becoming water contaminated.

It is the case that for item 3 above water ice is likely to be the dominant issue. However other gasses which are condensable at 80K can also present a similar problem and these can be more difficult to condition once the cryostat is complete. To quantify an acceptable outgassing rate, water is used below, as there is a better database available for the relevant emissivity change.

In calculating the maximum outgassing rates specified for the ITER cryostat (VQC 2) the following assumptions and calculations have been used.

Source[27]	A (m^2)[27]	qH_2O($Pa.m^3.s^{-1}.m^{-2}$)+	QH_2O_{tot} ($Pa.m^3.s^{-1}$)	Pressure in cryostat (H_20,Pa)‡
Metallic surface	2.5×10^4	1×10^{-7}	2.5×10^{-3}	5.0×10^{-5}
Vacuum facing epoxy	1.3×10^3	1×10^{-5}	1.3×10^{-2}	2.6×10^{-4}
‡Assumes 50 m^3s^{-1} H_2O cryostat pumping speed.[27] +Values from Table 17.8-1 & equation Section 17.8.1 after 100 hours.				

Table 17.8-2- Assumed cryostat areas and calculated H_2O outgassing rates

Using the figures from Table 17.8-1 the calculated partial pressure of water vapour in the cryostat prior to the cool down of the magnets is approximately 2.6×10^{-4} Pa.

The 2007 ITER PID value for partial pressure of H_2O before cool-down is quoted as ≤ 2×10^{-7} Pa. This figure is considered to be unachievable and the basis can not be found.

Assuming the cryostat thermal shield does not cool uniformly, residual water will initially condense on cold spots covering an estimated 10% of the thermal shield surface area with an equivalent thickness of 0.02 monolayers.

After baking the vacuum vessel and cooling the magnet structures and thermal shields, the remaining source of condensable water will be from the cryostat walls and internal components which are at ambient (or elevated) temperature, having an estimated total surface area of 3000 m^2.

Assuming a steady state outgassing rate of 1×10^{-7} (H_2O) $Pa.m^3.s^{-1}.m^{-2}$, the load to the thermal shield remains unchanged for 3 years. Over approximately 8 years a coverage of H_2O of 2000 monolayers (1μ thickness) will form on the cryostat-facing thermal shield. The change in emissivity of the thermal shield due to formation of this water layer results in a calculated increase in heat load to the cryo-plant of approximately 50% [28].

The ice crystal size significantly affects the infra-red absorption and consequently the emissivity of a panel: the larger the crystals, the higher is the emissivity; therefore the morphology of the ice formation significantly effects the change in emissivity.

In this estimation, it is assumed that the water forms a uniform layer of ice over the thermal shield with the coverage rate constant over the time period considered. If the coverage rate is not constant, and it is assumed water condenses on the thermal shield in batches as "snow", the time taken for a similar change in emissivity decreases to approximately 3 years.

The effect on emissivity due to the build up of ice can be seen in Figure 17.8.2-1[28] and the effect on the additional load to the cryo-plant due to water condensing on the cryostat-facing thermal shield is shown in Figure 17.8.2-2[28].

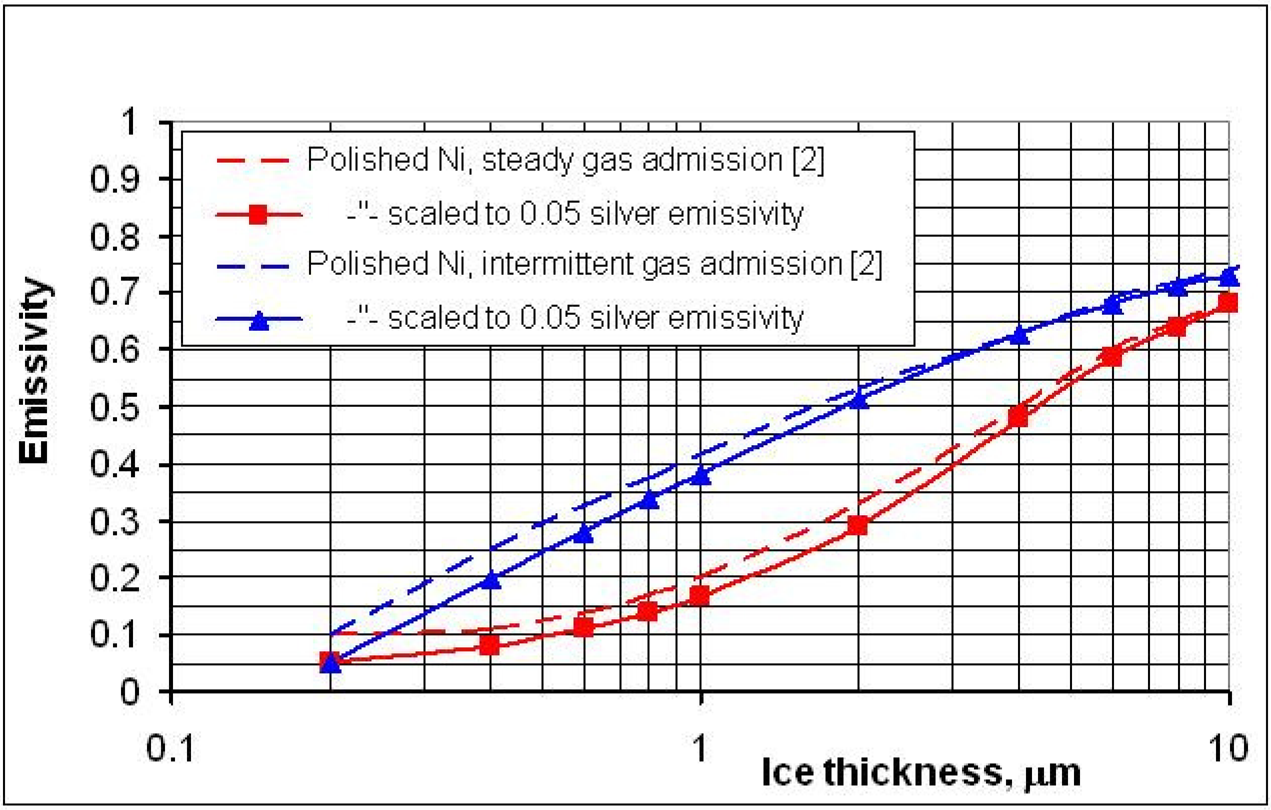

Figure 17.8.2-1 Effect on emissivity due to ice layer formation

It is considered that the effect on the emissivity of the cryostat thermal shields will be greater due the condensation of hydrocarbons outgassing from the cryostat internal components. Hence the maximum outgassing rate from cryostat vacuum-facing surfaces is defined in Table 17.8-1 to be1 x 10^{-7} Pa.m^3.s^{-1}.m^{-2} (excluding water and hydrogen) at ambient temperature

In order to reduce the steady state outgassing rate of water from the cryostat internal surfaces, a method of purging the cryostat with dry nitrogen prior to cool down of the magnet structures and thermal shields is being studied. The order in which the cryostat cryogenic surfaces are cooled, and the resulting effect on the emissivity of the cryostat cold surfaces due to condensed gas, is also to be studied. (See [28] for further recommendations)

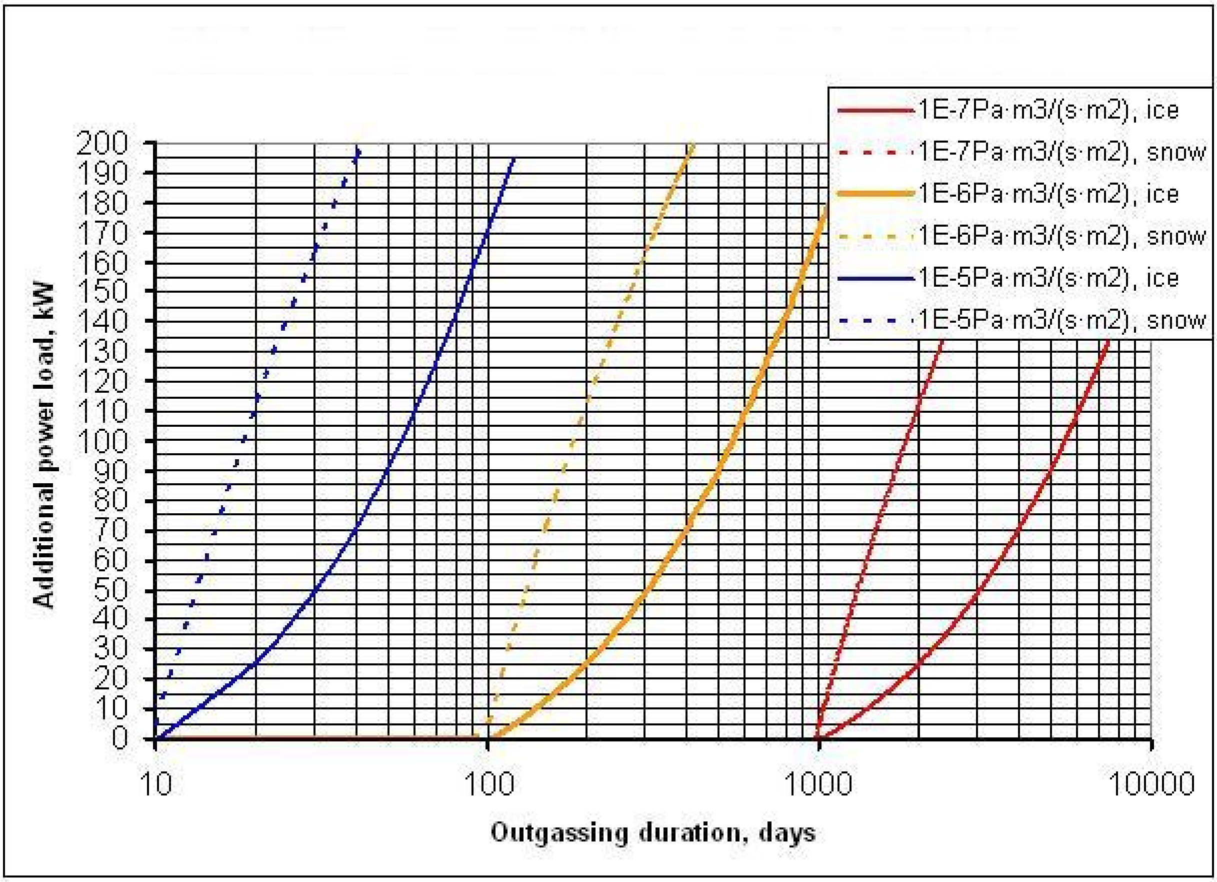

Figure 17.8.2-2 Additional power load on thermal shield coolant due to H_2O Outgassing

17.9 Outgassing Rates Review

The purpose of this section of the Appendix is to outline the methodology used in the assessment of outgassing rates from published data and to establish the relationship between common parameters which influence material outgassing rates

17.9.1 Material thermal outgassing

Thermal outgassing from material surfaces is time and temperature dependant and it can be shown that the measured outgassing rate from a metallic surface will increase by factor of about 10 by increasing the sample temperature from ambient to 100 ºC, and increases by a further decade by raising the sample temperature from100 to 250 ºC.[5]

The medium term (1 to 100h) outgassing from a surface can be described by a power law of the form:

$$Q = Q_0 . t^{-\alpha}$$

Where, α (the outgassing decay index) is typically near unity for metallic surfaces and 0.5 for epoxies and *t* is the time in hours [21].

The outgassing rate of a surface is also dependant on the surface condition. Factors affecting the outgassing rate include:

- chemical composition
- the presence of oxide layer's
- surface finishing
- cleaning and other processes

References to published data, listing outgassing rates for materials after varying surface treatments, are to be found in Section 17.10.

While a large record of outgassing rates can be found in literature for vacuum compatible materials comparisons of the reported data are difficult as, in many cases, for the same material differing surface treatments and measurement techniques are reported, some important factors may not be reported at all.

17.9.2 Unbaked Stainless Steel

The rate of outgassing from unbaked stainless steel is dependant of the process to which the stainless steel surface has been subjected. Outgassing rates gathered from literature (see Section 17.10) for Stainless steel after surface treatments are summarised in Table 17.9-1.

SST treatment	q_{tot} (Pa.m^3.s^{-1}.m^{-2}) at 1h, 20ºC
As received/fresh	$1x10^{-4}$
Degreased	$2x10^{-6}$
Surface finished (machined)	$2x10^{-7}$

Table 17.9-1 Outgassing rates of stainless steel after surface processing

Generally water is the dominant species outgassed from unbaked stainless steel and will evolve at a rate dependant on the elapsed pumping time of the surface. Generally, for unbaked stainless steel surfaces, water will remain the dominant outgassing species at pumping times in excess of 100 h.

17.9.3 Baked Stainless Steel

Baking at 150 ºC for a minimum of 24 h can reduce the total outgassing rate by a factor of 100 as water is desorbed from the metal surface. After this time the predominant outgassing species from clean stainless steel is hydrogen [5]. A reduction in the hydrogen outgassing rate can be achieved by vacuum firing or air baking the material.

After baking, stainless steel will generally exhibit outgassing rates between 10^{-9} and 10^{-10} Pa.m^3.s^{-1}.m^{-2} (see Section 17.10.1)

17.9.4 Organic Material

For organic materials (epoxies etc), the method of weight loss measurement is usually used for the determination of outgassing rates with the outgassing rate quoted as a percentage of total weight loss, or gram/s.

Using the formula below the outgassing rate can be calculated from the total mass loss measurement

$$q = \frac{dM}{dt} \cdot \frac{RT}{M} \cdot 10^3$$

where:

q is the outgassing rate in $Pa.m^3.s^{-1}.m^{-2}$

R is the universal gas constant ($83.14\ mbar.l.mol^{-1}.K^{-1}$)

dM/dt is the mass loss per unit time ($g.s^{-1}$)

T is the sample temperature (K)

M is the molecular mass of the outgassing species

Using the above formula it can be shown that for water outgassing from a surface at a rate of $1 \mu g.s^{-1}$ the specific outgassing rate near room temperature will be approximately 1 $Pa.m^3.s^{-1}.m^{-2}$.

The outgassing rate of organic materials is also dependent on the fabrication process (curing temperature, chemical hardener, vacuum, inert gas process, etc.). There is a lack of published data on outgassing rates for material of the same composition which has undergone different fabrication processes, making comparisons difficult. Hence qualification of new organic materials for use on ITER will have to be performed using experimental data.

An analysis of weight loss measurements on epoxies shows that the ratio of water outgassing to impurity outgassing is approximately 100 to 1, so, assuming a well controlled fabrication process, a low outgassing epoxy should outgas at a rate in the range of 10^{-7} $Pa.m^3.s^{-1}.m^{-2}$ (excluding water) after 100 h baking (see Section 17.10.2).

17.10 Outgassing Rates - Published Data

Outgassing rates quoted in referenced publications are summarized in the tables below.

17.10.1 Stainless Steel

Published data on the outgassing rates of stainless steel following various surface treatments is given in Table 17.10-1.

Treatment	Total outgassing rate ($Pa.m^3.s^{-1}.m^{-2}$)	Time meas. (hours)	Reference
None	$2x10^{-4}$	1h	2
None	$2x10^{-5}$	10h	2
Polished & vapor degreased	$1.4x10^{-6}$	10h	2
None	$1.1x10^{-7}$	100h	2
Degrease + water rinse	$4.0x10^{-8}$	40h	2
Degrease + water rinse, baked in vacuum 150ºC for 12h	$4.0x10^{-9}$	5h after bakeout	2
Baked 24h @ 200°C	$9.3x10^{-10}$	100h	2
Unbaked	$2x10^{-7}$	10h	1
Baked (150º C,24h)	$2x10^{-9}$		1
Std cleaning	10^{-6}	1h	3
Baked	10^{-8}	1h	3
Untreated	$7x10^{-5}$		4
Degreased	$1x10^{-6}$		4
Baked	$3x10^{-10}$		4
unbaked	$9x10^{-7}$	20h	5
Electrochemical buffing	$5x10^{-8}$	50h	8
Electrochemical buffing followed by baking(215 °C,23h) and air (10days)	$1x10^{-8}$	50h	8
Electropolished, baked, air oxidation	$1x10^{-11}$		9
Air exposure/baking cycles	$1x10^{-10}$		10
UT cleaning + bake 250C,24h	$3x10^{-10}$		12
Various treatments	$2x10^{-6}$	100h	13
Annealing+bake	$2x10^{-11}$		14
Air firing	$3x10^{-11}$		15
Pre-baking+baking	$4x10^{-10}$		16
Chemical cleaning	$4x10^{-9}$		17
	$1x10^{-6}$	1h	18
Cleaned With bakeout	$8x10^{-7}$ $2x10^{-9}$		19
	$2x10^{-6}$	4h	20

Table 17.10-1 Outgassing rates for stainless steel – published data

17.10.2 Epoxies

Published data on the outgassing rates of various epoxies and resins is given in Table 17.10-2

Material	Outgassing rate (Pa.m3.s-1.m-2)	Outgassing rate % Total Mass Loss (TML)	Reference

Material	Outgassing rate (Pa.m3.s-1.m-2)	Outgassing rate % Total Mass Loss (TML)	Reference
RF4000 EV Roberts (baked)	$5x10^{-6}$ (10h)		22
ERL4221 union carbide (baked)	$1x10^{-5}$(10h)		
CY179 Ciba Geigy (baked)	$3x10^{-6}$(10h)		
1138 Ciba-Geigy (baked)	$2x10^{-6}$(10h)		
828 Shell chemical (baked)	$1x10^{-5}$(10h)		
DGEBA, + ≠ materials	10^{-3} -10^{-4}(10h)		23
Stycast	$4x10^{-5}$ (72h)	0.87	24
Redux 312UL	$7x10^{-6}$(72h)	0.40	25
Ablebond Ablestik		0.2	ESA database
Araldite resin	10^{-3}-10^{-4}(10h)		1
Polymers	10^{-5}(10h)		26

Table 17.10-2 Outgassing rates for epoxies and resins – published data

17.11 References

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2FMM4B

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Baseline Report

ITER Vacuum Handbook Attachment 1 - Welding

This Attachment 1, to the ITER Vacuum Handbook, relates to welding of vacuum boundaries and outlines the procedures for documentation, qualification, approval and testing.
This Attachment is based on the international standards ISO 9606, ISO 15614 and ISO 15609, additional requirements are specified to achieve the high integrity and reliability of the vacuum systems to ensure the required ITER machine reliability – Additional requirements are identified in this document.
The requirements are designed to complement codes which may be used. Where requirements differ in general the more stringent standard should be applied or advice sort from ITER.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Bansal G.**	**05 Jun 2020:signed**	**IO/DG/CNST/MCD/TCD/VDI**
Co-Authors	**Worth L.**	**05 Jun 2020:signed**	**IO/DG/CNST/MCD/TCD/VDI**
Reviewers	**Pearce R.** **Yu X.**	**09 Jun 2020:recommended** **11 Jun 2020:recommended**	**IO/DG/CNST/MCD/TCD/VDI** **IO/DG/SQD/QMD**
Approver	**Becoulet A.**	**11 Jun 2020:approved**	**IO/DG/ENGN**
Document Security: Internal Use *RO: Chiocchio Stefano*			
Read Access	**GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: External Management Advisory Board, AD: EUROfusion-DEMO, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: VDI team member temp, LG: Section Scheduling...**		

Change Log			
ITER Vacuum Handbook Attachment 1 - Welding (2FMM4B)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	17 Dec 2008	
v1.1	Signed	26 Jan 2009	
v1.2	Approved	10 Apr 2009	
v1.3	Signed	19 May 2020	Updated list of codes and standards with current applicable versions and removal of obsolete ones. Welding clarifications (MUXMPR, MUZQFU and MUX8HR) and reflected in the new version. Document update required as a result of PCR-1141.
v1.4	In Work	05 Jun 2020	Minor formatting issues corrected
v1.5	Approved	05 Jun 2020	Formatting errors corrected

ITER Vacuum Handbook

Attachment 1
Inspection and Qualification of Welded Joints

Table of Contents

1 Scope

This Attachment relates to welding of vacuum boundaries and outlines the procedures for documentation, qualification, approval and testing.

Whilst this Attachment is based on the international standards ISO 9606, ISO 15614 and ISO 15609, additional requirements are specified to achieve the high integrity and reliability of the vacuum systems to ensure the required ITER machine reliability. Specifically this Attachment is more stringent in places than the standards in the range of approval for joint types, mechanical testing and acceptance criteria.

The requirements are designed to complement codes which may be used. Where requirements differ in general the more stringent standard should be applied or advice sort from ITER.

2 The Welding and Inspection Plan

Before fabrication can commence the *supplier* shall prepare for approval a weld plan. The weld plan is a drawing which cross references each welded joint to a supporting Welding Procedure Specification (WPS).

3 Welder and operator Qualification

The welder qualification is intended to show the competence of the welder/operator for implementing the specified WPS.
Welder qualification shall be in accordance with ISO 9606 or equivalent standards agreed in advance. For welding operators ISO 14732 shall be used.
Other standards may be approved by ITER on submission of documentation detailing the equivalence between the proposed standards and the standards quoted herein. All standards and documentation pertaining to equivalence shall be submitted in English and must be agreed in advance of welding operations.

The *supplier* shall establish and maintain a list of qualified welders and operators. This list shall include their individual identification and range of welds for which they are qualified.

4 Applicable Standards

The latest revisions of the standards listed in Table 4-1 shall be applied in the procedure, qualification, and acceptance testing etc. of any welding process and form, where applicable, part of this attachment. Alternative national standards may be submitted for approval but they must meet the minimum technical requirements of this Attachment. Alternatives must be formally accepted through written communication before welding can commence.
Where this attachment is more stringent than the standards, this document takes precedence. Where specified in this document, additional requirements to or requirements differing from the quoted international standards have been highlighted ***in bold italics.***

ISO 15607	Specification for the qualification of welding procedures for metallic materials – general rules
ISO 15614	Specification and qualification of welding procedures for metallic materials-welding procedure test
ISO 15609	Specification and qualification of welding procedures for metallic materials – Welding procedure specification
ISO 17637	Non-destructive examination of fusion welds. Visual examination.
ISO 4063	Welding and allied processes – Nomenclature of processes and reference numbers.
ISO 3452	Non-destructive testing. Penetrant testing.
ISO 17638, ISO 9934	Non-destructive examination of welds. Magnetic particle examination of welds
ISO 17636	Non-destructive examination of welds. Radiographic examination of welds.
ISO 17640	Non-destructive examination of welds. Ultrasonic Examination.
ISO 9606-1	Qualification test of welders – Fusion welding – Part 1: steels.
ISO 9606	Qualification test of welders – Fusion welding – Part 2: aluminium and aluminium alloys.
ISO 14344	Welding and allied processes – Flux and gas shielded electrical welding processes – Procurement guidelines for consumables.
ISO 5817	Fusion welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections.
ISO 14732	Welding personnel. Approval testing of welding operators
ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
ISO 22825	Non-destructive testing of welds - Ultrasonic testing - Testing of welds in austenitic steels and nickel-based alloys
ISO 10380	Corrugated metal hoses and hose assemblies

Table 4-1 Standards relating to welding

5 Welding Procedure Specification

The Welding Procedure Specification (WPS) is a document which details all the variables which must be defined to produce a weld of acceptable quality. The qualification of the WPS shall be performed in accordance with this Attachment.

Each WPS shall detail each type of weld and shall include, but not be limited to, the following in accordance with ISO 15609:

- Identification of equipment manufacturer
- Equipment calibration records
- Examiner or test body
- WPS number
- Parent material(s), defining which joint element is comprised of a given material
- Filler material(s): classification, type, trade name, flux, diameter of electrode, rod, or wire

- Joint sketch and weld run sequence
- Range of qualified thicknesses and/or diameters
- Welding position
- Welding process (in accordance with ISO 4063)
- Welding technique (single, multipass etc)
- Groove or edge preparations (cleaning, degreasing, jigging etc)
- Shielding and backing gas (composition and flow rates)
- Welding equipment parameters which may include:-
    - AC or DC
    - Polarity
    - Current range
    - Voltage range
    - Pulsed welding parameters
    - Tungsten electrode diameter and type
    - Nozzle diameter
- Backing: method and type, materials and dimensions
- Back gouging: method
- Heating: pre-heat temperature, interpass temperature, post weld temperature
- Drying and preservation temperatures for covered electrodes (if applicable)

Additional Parameters for automatic welding may include:

- Welding equipment specification
- Tool and programme numbers (where applicable)
- Travel speed range
- Wire feed speed range
- Arc Voltage Control parameters

For special processes (remote welding etc) additional information may be required.

6 Welding Procedure Qualification Record

The Welding Procedure Qualification Record (WPQR) is used to record all the relevant data from the welding of test pieces in the qualification of the WPS.

- The qualification of the WPS provides proof that the defined welding process, will achieve a weld of acceptable quality. The welding and testing of this must be witnessed by an ITER recognised Independent Inspection Authority.

All welding data and results from the required non-destructive and destructive testing shall be documented using a Welding Procedure Qualification Record (WPQR). It can also be called Welding Procedure Approval Record (WPAR).

6.1 Qualification of the Welding Procedure Specification.

An existing Welding Procedure Qualification Record (WPQR or WPAR) is acceptable if the following conditions are met:

- The test must have been performed in the same environment as proposed for production, using the same welding technique, process, joint configuration and welding equipment (for mechanised welds)
- The allowable ranges are the same with regard to essential variables.
- The related Preliminary Welding Procedure Specification (pWPS) has been qualified in accordance with ISO 15614
- The test must have been witnessed by an ITER recognised Independent Inspection Authority

Weld produced for qualification must be performed by suitably qualified welders.

The *supplier* must also demonstrate that the welding equipment and plant use for qualification is properly maintained and calibrated in accordance with the relevant operation and maintenance schedules.

6.2 Extent of Approval

6.2.1 Material Groups

For differing grades of stainless steel (304, 304L, 316, 316L and 316LN-IG), cross qualification can be accepted for manual welds when 316L filler is used. Cross qualification is not acceptable for automatic welds. Transition welds joining dissimilar materials other than those listed above must have specific qualification tests performed.

6.2.2 Base Materials

Qualification on production metal type and grade is mandatory. There is no requirement for the use of material from the production heat number for qualification of the WPS.

ISO9001:2000 (clause 7.5.2) states that welding is always a special process. Welding processes commonly used in the manufacture of ITER components with a vacuum classification (according to ITER Vacuum Handbook) and their classification in the context of ITER are listed in Table 1. For special welding processes (Table 6-2) Production Proof Samples shall be manufactured from the production heat number.

Name	N†	AWSᶲ	Special (Yes/No)
Gas metal arc welding	131 135	GMAW	No
Manual Gas Tungsten Arc Welding	141	GTAW	No
Automatic, or mechanized Gas Tungsten Arc Welding			Yes
Electron Beam Welding	51 511	EBW	Yes
Laser Beam Welding	521 522	LBW	Yes
† N reference numbers as specified in ISO 4063 (in the European Union published as EN ISO 4063 ϕ AWS reference codes of the American Welding Society are commonly used in North America			

Table 6-1 Welding Processes

6.2.3 Thickness Range

6.2.3.1 Thickness Range for Welds Excluding Fillet and Branch

The qualification of a welding procedure test on thickness t shall include qualification for thickness in the ranges given in Table 6-2 in accordance with ISO 15614.

Thickness of test piece 't' (mm) (where 't' is the thickness of the thinner material)	Range of Approval[1,2] (Dimensions in mm)		
	Parent material thickness		Deposited weld metal thickness for each process 's'
	For single run or single run from both sides	Multi-run	
t ≤ 3	0.5 t to 2 t		Max. 2 s
3 < t ≤ 12	0.5 t (3 min) to 1.3 t	3 to 2 t	Max. 2 s
12 < t ≤ 20	0.5 t to 1.1 t	0.5 t to 2 t	Max. 2 s
20 < t ≤ 40	0.5 t to 1.1 t	0.5 t to 2 t	Max. 2 s when s < 20 Max. 2 t when s ≥ 20
40 < t ≤ 100		0.5 t to 2 t	Max. 2 s when s < 20 Max. 200 when s ≥ 20
100 < t ≤ 150		50 to 2 t	Max. 2 s when s < 20 Max. 300 when s ≥ 20
t > 150		50 to 2 t	Max. 2 s when s < 20 Max. 1.33 t when s ≥ 20
1 - When impact requirements are specified but impact tests have not been performed, the maximum thickness of qualification is limited to 12 mm. 2 – The range of approval may have to be reduced in order to avoid hydrogen cracking.			

Table 6-2 Range of Approval for material thickness and weld deposit thickness– all welds

6.2.3.2 Thickness Range for Fillet Welds

The qualification of a welding procedure test on thickness t shall include qualification for thickness in the ranges given in Table 6-3 in accordance with ISO 15614.

Thickness of test piece 't' (mm)	Range of approval (Dimensions in mm)		
	Material thickness	Throat thickness	
		Single run	Multi-run
$t \leq 3$	0.7t to 2 t	0.75 a to 1.5 a	No restriction
$3 < t < 30$	3 to 2 t	0.75 a to 1.5 a	No restriction
$t \geq 30$	≥ 5	†	No restriction
Note 1: a is the throat thickness of the test piece ***Note 2: Fillet welds cannot be qualified by Butt welds*** † For special applications only. Each throat thickness has to be proofed separately by a welding procedure test			

Table 6-3 Range of qualification for material thickness and throat thickness of fillet welds

6.2.3.3 Thickness Range for Branch Pipes (Diameter Range)

The qualification of a welding procedure test on diameter D shall include qualification for diameters in the following ranges give in Table 6-4 in accordance with ISO 15614.

Diameter of test piece D[1,2] (in mm)	Range of approval
$D \leq 25$	0.5 D to 2 D
$D > 25$	$\geq$ 0.5 D up to plates (25 mm min)
1) D is the outside diameter of the pipe or the outside diameter of the set-on branch pipe 2) Approval given for plates also covers pipes when outside diameter is > 500 mm	

Table 6-4 Range of approval for pipe and branch connections

6.2.4 Range of Approval of Welded Joints

Lip weld and Automatic socket welds shall be qualified on actual size within nominal material specification tolerances. Pre-weld /socket/spigot gap shall be adequate to preclude post-weld abutment contact and minimise weld stress. The range of approval for other types of joint is given in Table 6-5.

6.2.5 Range of Approval Welding Consumables

All consumables shall be certified to a standard acceptable to the ITER IO (e.g. ISO 14344). In the case of manual welding processes the approval range of filler materials covers other filler metals as long as they are in the same range and chemical composition.

In the case of automatic and semi automatic welding processes the welding consumables used for qualification shall be the same batch as those used for production welds. Following any change during production, weld samples shall be welded and examined prior to the continuation of production with the new batch of consumables. Qualification using filler does not qualify autogenous (fusion welding with out filler material) welds or vice versa.

6.2.6 Welding Processes

In all cases, any change in the welding process will require a requalification of the process. In addition, in the case of automatic welding any change to the welding equipment will require requalification.

6.2.7 Welding Position

Welds for qualification shall be done in local conditions similar to the local conditions where the production weld will be made. Local access to the test piece (in terms of welder access) and the orientation of the test piece (relative to the welder) shall be similar to those for the production weld for which they qualify.

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 both sides*		*Welded from one side*	*Welded from both sides*		*Welded from one side*			*Set on*	*Set through*
			With backing	*No backing*	*With gouging*	*No gouging*				*With backing*	*No backing*			
Butt weld on plate	*Welded from one side*	*With Backing*	✓	×	Δ	Δ	×	×	×	×	×	×	×	×
		No Backing	Δ	✓	Δ	Δ	×	×	×	×	×	×	×	×
	Welded from both sides	*With gouging*	×	×	✓	Δ	×	×	×	×	×	×	×	×
		No gouging	×	×	×	✓	×	×	×	×	×	×	×	×
Butt weld on pipe	*Welded from one side*	*With backing*	Δ	×	Δ	Δ	×	Δ	×	✓	×	×	×	×
		No backing	Δ	Δ	Δ	Δ	Δ	Δ	×	Δ	✓	×	×	×
T Butt weld on plate	*Welded from one side*		×	×	×	×	Δ	Δ	×	×	×	×	×	×
	Welded from both sides		×	×	×	×	×	✓	×	×	×	×	×	×
Fillet weld	*Plate*		×	×	×	×	×	×	✓	×	×	×	×	×
	Pipe		×	×	×	×	×	×	Δ	×	×	✓	×	×
Branch weld in pipe	*Set on*		×	×	×	×	×	×	×	×	×	×	✓	×
	Set through		×	×	×	×	×	×	×	×	×	×		✓

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
× Indicates those welds for which the WPS in not approved

Table 6-5 Range of approval for type of joint

6.3 Non –Destructive Examination

Supplier's inspectors shall be competent in accordance with ISO 9712.

6.3.1 Examination

After post weld heat treatment and prior to destructive testing, test pieces shall be examined by the following:

- Visual examination (in accordance with ISO 17637)
- Dye Penetrant testing (in accordance with ISO 3452) or Magnetic particle testing (in accordance with ISO 9934)

  Inspection using Photothermal camera is permitted in the case where the manufacturer has qualified the method/acceptance criteria prior to the weld qualification
- Radiographic examination (in accordance with ISO 17636)

and/or

- Ultrasonic examination (in accordance with ISO 17640 and ISO 22825 for austenitic steels and nickel alloys)

For a pipe or plate of 2 mm (or less) wall thickness, the method of examination shall be agreed prior to examination.

6.3.2 Acceptance Criteria

Defects which are detected by the relevant non-destructive examination method shall be assessed in accordance with ISO 5817 level B. In particular acceptance criteria are detailed in Table 6-6. Table 6-6 is in accordance with ISO 5817 however contains additional requirements for production vacuum boundary welds.

Defect Type		Permitted maximum
Planar Defects	Cracks or lamellar tears Lack of root fusion Lack of side fusion Lack of inter-run fusion Lack of root penetration	Not permitted
Solid inclusions	Slag inclusions - individual	20% of t or 2 mm, which ever is smaller
	Slag inclusions - Group	Aggregate length not to exceed t in a length of 12 t, except when the distance between successive indications exceeds 6L where L is the longest indication in the group
	Inclusions – ***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	***Under cut***	***Some intermittent undercut permitted. Depth not to exceed 0.5 mm for t > 3 mm or 10% for t < 3 mm. Under cut to blend smoothly with the parent material.***
	Incompletely filled groove, sagging. Root concavity, shrinkage groove	0.05 t or 0.5 mm, which ever is smaller. Weld thickness shall not be less than the parent plate thickness
	Excess penetration - pipe	Not greater than 5% of the pipe 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 backside of 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 purge gas is specified in the WPS

Table 6-6 Acceptance levels

6.4 Destructive Tests

6.4.1 Test Specimens

The number of test specimens that shall be subjected to destructive testing is given in Table 6-7 in accordance with ISO 15614.

TEST SPECIMEN	No of Tests
BUTT WELD	
Transverse Tensile (room temp.)	2
Root Bend (for t <12mm)	2
Face Bend (for t <12mm)	2
Side Bend (for t >12mm)	4
Transverse Tensile (design temp. if required by tech. spec.)	1
Impact test (for t ≥12 mm one set from weld metal and one set from HAZ if required by tech. spec).	2
Macro-examination (with photo)	1
Micro-examination x 200 (if required by tech spec.)	1
Hardness test survey	1
Burst test†	1
FILLET WELD	
Fracture Test	1
Macro-examination (with photos)	***4***
Micro-examination x 200 (if required by tech. spec.)	2
Hardness Survey	2
T-BUTT/BRANCH CONNECTION	
Macro-examination (with photos)	***4***
Micro-examination x 200 (if required by tech. spec.)	2
Hardness Survey	2
SOCKET/LIP WELD+	
Macro-examination (with photos)	4
Micro examination x 200 (if required by tech. spec.)	2
Hardness Survey	2
† Longitudinal butt weld on bellows (or flexible) tube to ISO 10380	

Table 6-7 Number of destructive test specimens

6.4.2 Test Results

Unless specified differently in Table 6-8 destructive testing and test results shall comply with ISO 15614.

Bend test (stainless steel and nickel alloy only)	***The bend angle shall be 180° round a former of diameter 2t, where t is the thickness of the specimen. The bend test specimen shall have no open defects exceeding 2 mm measured in any direction on the convex surface after bending.***
Micro - Examination	***In general micro-examination shall only be required for welds which form part of the vacuum boundary or are in contact with cryogenic liquids. If required micro-examination tests shall be specified in the technical specification.***
Macro Examination	***For lip welds, penetration shall be 0.7t where t is the thickness of the thinner material.***

Table 6-8 Acceptable test results

6.4.3 Qualification for Welds Under Stressed Applications.

Additional destructive tests to those listed in Table 6-7 to qualify welds under stressed applications may be required as defined in the technical specification.

7 Production Welds

Production welds shall be performed to qualified procedures by qualified welders.

The WPS shall be available for reference by welders or welding operators, by the responsible welding engineer and by the authorised inspector.

The contractor must also demonstrate that the welding equipment and plant is properly maintained and calibrated in accordance with the relevant operation and maintenance schedules.

7.1 Inspection of Fusion Welded Joints

After post weld heat treatment welds shall be subject to the following tests:

- Visual examination (in accordance with ISO 17637)
- Dye Penetrant testing (in accordance with ISO 3452) if permitted†. (Inspection using Photothermal camera is permitted in the case where the manufacturer has qualified the method/acceptance criteria prior to the weld)
- Radiographic examination (in accordance with ISO 17636)

  and / or
- Ultrasonic examination (in accordance with ISO 17640 and ISO 22825 for austenitic steels and nickel alloys)

† See ITER Vacuum Handbook Section 7.1.4.

The range of wall thickness and preferred volumetric examination method is given in Table 7-1 .

Defects which are detected by the relevant non-destructive examination method shall be assessed in accordance with Table 6-6.

For all VQC 1A, VQC 2A water boundaries and vacuum boundary welds which become inaccessible, 100% volumetric examination of production welds shall be performed, unless a method of pre-production proof sampling is approved.

For all other vacuum boundaries, volumetric examination of 10% of production welds shall be performed unless a method of pre-production proof sampling is approved. In the event of failures, this shall be increased to 100% examination of the batch, defined as same welder/same WPS/ same weld. ……. Acceptance criteria are specified in Table 6-6

On welds where it is specified that volumetric examination be performed and radiography or ultrasonic inspection is not possible, Production Proof Sampling is required.

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

Table 7-1 Range of wall thickness and preferred volumetric examination method

7.2 Production proof samples

Welds where radiography or Ultrasonic testing is impractical (e.g. welds that are not full penetration butt welds) must be covered by Production Proof Sampling (PPS). Each PPS will only represent a specific type of weld and must use the same materials, thickness and set-up as the production weld.

For VQC 1 and 2 vacuum boundary welds a PPS must be welded during the same shift as the production welds and by the same welder using the same equipment to be representative of the production welding.
If more than one welder welds the production welds, each must perform a PPS.
PPS's are required each shift production welding is being performed to represent the welds performed on that shift.

For VQC 3 and 4 vacuum boundary welds a PPS shall be welded for each welder performing the production welds.

PPS's should be sectioned and macro examined in four places (including one stop/start area). Photographs of the macros giving the date the PPS was welded, the welder's identity and identifying the production welds it is covering must be included in the final documentation package.

An ITER representative will normally witness PPS welding and all PPS macros shall be reviewed. Operations with witness and hold points to facilitate this must be incorporated in the Work Schedule.

As the PPS is a representative sample, rejection of the macro will result in rejection of all welds covered by this PPS.

7.3 Helium Leak Testing of Production Welds

100% of vacuum sealing welds (VQC 1A, 2A, 3A, 4A) shall be subject to helium leak testing in accordance with the requirements and procedures of the ITER Vacuum Handbook.

7.4 Repair by welding of production welds

No weld repair shall be performed with out qualification of the welding procedure. Welding procedures used for welding repair shall be qualified in accordance with this document.

8 Documentation

All quality assurance documentation required by this procedure shall form part of the delivery to ITER, and shall include:

- Weld plans
- WPS's
- WPQR's and test reports
- Welder qualification's and test reports
- PPS test reports
- Production weld test reports
- Reports on weld repairs
- Non-Conformance Reports

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Guideline (not under Configuration Control)

CAD Manual 12-2 Piping Design

This document describes the DO Piping design rules and methodologies.

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	Name	*Action*	*Affiliation*
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CAD Manual

Section 12-2 Piping Design Guidelines

Abstract

This document describes the DO Piping design rules and methodologies.

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1.2	4-02-2010	All	Figures reformatted to correct errors First Approved Version

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12.2 Piping Design Guidelines

12.2.1 Routing Basic Guidelines

1. The high energy lines need to be arranged in the High Energy Line Break (HELB) area where civil structure has been designed with the function of pressure retention and leak tightness in case of line break and other top priority class lines have to be laid out first such as safety related systems.

2. Large diameter pipes should be arranged at the back and small pipes at the front of supports. Pipes that require regular inspection or traced pipes should be positioned to enable access.

3. Non-seismically classified pipes need to be arranged as far as possible from the seismic pipes so as not to affect the seismic pipes in case of break.

4. The safety related components have to be protected from the potential risks of internal or/and external hazards such as impact, earthquake, missiles and high energy line break.

5. Pipes should not be routed above cable trays whenever possible.

6. Routing of pipes containing inflammable gases or fluids should be avoided in areas with potential risk of fire.

7. Pipes with temperatures above 100C should not be routed near a tank with inflammable material.

8. Insulation of pipes is required for heat retention or/and protection against touching if surface temperature >60C.

9. The slope should be followed for gravity pipes and instrumentation according to the requirement shown on the P&ID.

Drain – vent

10. The drain tap need to be designed in order to drain all liquid before inspection/ maintenance.

11. The vent tap need to be designed in order to fill the pipe with liquid without air pocketing after inspection/maintenance.

12. The vent and drain need to be designed as least as possible on which stress is focused, and so the piping dead zone is minimized.

13. The vent and drain valves should be designed for easy access and maintenance by providing platform or ladder, if necessary.

14. Double drain valves can be applied depending on the pressure rating shown on the P&ID. The support should be installed in case of double valves, and support for the double valves needs to be installed from the header line (Tie Back Support) so as to be less-affected from thermal movement and vibration of the header line.

Pump

15. (Pump suction side) 3 to 5 diameter straight pipe length is required at suction side of centrifugal pumps. For the other type of pumps the required straight pipe length is depending on vendor requirements.

16. High points in pump suction lines should be avoided.

17. Do not route piping over the pump, as this interferes with maintenance

18. Locate the pump as closely as practicable to the source of liquid to be pumped from storage tank with consideration of piping flexibility

Welding

19. Weld connections between special parts (e.g.: valve on elbow, T-Piece on elbow etc…) should be avoided where feasible. A distance of a least 1 DN should be considered between two special parts. The pressure drop should be limited.

20. Minimum distance between adjacent welds is 50 mm

12.2.2 Preferred pipe sizes

Preferred pipe sizes according to ASME B36.19 M

DN	NPS	OD (mm)	Schedule	Wall* (mm)	Weight* (kg/m)	Water* (kg/m)
6	1/8	10.3	10 S	1.24	0.28	0.05
			40 S	1.73	0.37	0.04
			80 S	2.41	0.47	0.02
8	1/4	13.7	10 S	1.65	0.49	0.08
			40 S	2.24	0.64	0.07
			80 S	3.02	0.80	0.05
10	3/8	17.1	10 S	1.65	0.64	0.15
			40 S	2.31	0.85	0.12
			80 S	3.20	1.10	0.09
15	1/2	21.3	5 S	1.65	0.80	0.25
			10 S	2.11	1.00	0.23
			40 S	2.77	1.27	0.20
			80 S	3.73	1.63	0.15
20	3/4	26.7	5 S	1.65	1.03	0.43
			10 S	2.11	1.29	0.40
			40 S	2.87	1.70	0.35
			80 S	3.91	2.21	0.28
25	1	33.4	5 S	1.65	1.30	0.71
			10 S	2.77	2.11	0.61
			40 S	3.38	2.52	0.56
			80 S	4.55	3.26	0.46
32	1 ¼	42.2	5 S	1.65	1.66	1.19
			10 S	2.77	2.71	1.06
			40 S	3.56	3.41	0.97
			80 S	4.85	4.50	0.83
40	1 ½	48.3	5 S	1.65	1.91	1.59
			10 S	2.77	3.13	1.44
			40 S	3.68	4.08	1.32
			80 S	5.08	5.45	1.14
50	2	60.3	5 S	1.65	2.40	2.55
			10 S	2.77	3.96	2.36
			40 S	3.91	5.47	2.16
			80 S	5.54	7.53	1.90

(*) Thickness and weight for information only to be validated by calculation (based on schedule)

Table 12.2-1 Preferred ASME pipe sizes (DN6 – DN50)

Non-preferred DN - to be avoided if possible

DN	NPS	OD (mm)	Schedule	Wall* (mm)	Weight* (kg/m)	Water* (kg/m)
65	2 ½	73.0	5 S	2.11	3.71	3.72
			10 S	3.05	5.29	3.52
			40 S	5.16	8.69	3.09
			80 S	7.01	11.48	2.73
80	3	88.9	5 S	2.11	4.54	5.63
			10 S	3.05	6.50	5.38
			40 S	5.49	11.36	4.77
			80 S	7.62	15.37	4.26
100	4	114.3	5 S	2.11	5.88	9.52
			10 S	3.05	7.42	9.19
			40 S	6.02	16.18	8.21
			80 S	8.56	22.46	7.42
125	5	141.3	5 S	2.77	9.52	14.48
			10 S	3.40	11.64	14.21
			40 S	6.55	21.91	12.91
			80 S	9.53	31.14	11.74
150	6	168.3	5 S	2.77	11.38	20.81
			10 S	3.40	13.91	20.48
			40 S	7.11	28.44	18.65
			80 S	10.97	42.83	16.82
200	8	219.1	5 S	2.77	14.87	35.82
			10 S	3.76	20.10	35.16
			40 S	8.18	42.82	32.28
			80 S	12.70	65.06	29.47
250	10	273.1	5 S	3.40	22.76	55.70
			10 S	4.19	27.96	55.04
			40 S	9.27	60.70	50.89
			80 S	12.70	82.08	48.19
300	12	323.9	5 S	3.96	31.44	78.42
			10 S	4.57	36.22	77.81
			40 S	9.53	74.28	72.99
			80 S	12.70	98.09	69.98
350	14	355.6	5 S	3.96	34.56	94.94
			10 S	4.78	41.62	94.05
400	16	406.4	5 S	4.19	41.83	124.42
			10 S	4.78	47.65	123.69

(*) Thickness and weight for information only to be validated by calculation (based on schedule)

Table 12.2-2 Preferred ASME pipe sizes (DN65 – DN400)

[grey box] Non-preferred DN - to be avoided if possible

DN	NPS	OD (mm)	Schedule	Wall* (mm)	Weight* (kg/m)	Water* (kg/m)
450	18	457	5 S	4.19	47.09	158.07
			10 S	4.78	53.65	157.24
500	20	508	5 S	4.78	59.70	195.13
			10 S	5.54	69.09	193.94
600	24	610	5 S	5.54	83.11	281.73
			10 S	6.35	95.13	280.20
700	28	711	-	7.92	138.20	379.54
			-	9.53	165.91	376.03
800	32	813	-	7.92	158.25	499.09
			-	9.53	190.04	495.07
900	36	914	-	7.92	178.10	633.57
			-	9.53	213.93	629.04
1000	40	1016	-	7.92	198.15	785.65
			-	9.53	238.05	780.60
1100	44	1118	-	7.92	218.20	954.07
			-	9.53	262.18	948.50
1200	48	1220	-	7.92	238.25	1138.83
			-	9.53	286.30	1132.75

(*) Thickness and weight for information only to be validated by calculation (based on schedule)
For DN greater than 600, ASME B36.10 M does not define schedule.

Table 12.2-3 Preferred ASME pipe sizes (DN450 - DN1200)

12.2.3 Preferred tube sizes

Preferred tube sizes				
OD (mm)	OD (inch)	WT (mm)*	Weight (kg/m)*	Water (kg/m)*
6.35	1/4	0.89	0.1	0.1
9.57	3/8	0.89	0.2	0.1
12.7	1/2	0.89	0.3	0.1
19.1	3/4	1.24	0.6	0.2
25.4	1	2.1	1.2	0.4

(*) Thickness and weight for information only and shall be validated by calculation

Table 12.2-4 Preferred tube sizes

12.2.4 Lateral distance between pipes

12.2.4.1 Lateral Distance L between Pipes

The distance between pipes shall be respected as indicated in **Figure 12.2-1** and **Table 12.2-5**

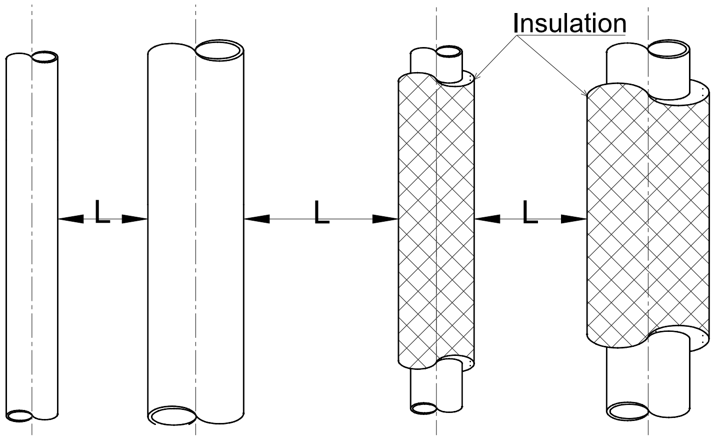


Figure 12.2-1 Distance L between pipes

Lateral distance L between pipes (mm)											
DN	**6 to 10**	**15 to 20**	**25 to 32**	**40 to 50**	**65**	**80**	**100 to 150**	**200**	**250 to 400**	**450 to 700**	**800 to 1200**
6 to 10	10										
15 to 20	20	20									
25 to 32	30	30	30								
40 to 50	50	50	50	50							
65	60	60	60	60	60						
80	80	80	80	80	80	80					
100 to 150	100	100	100	100	100	100	100				
200	150	150	150	150	150	150	150	150			
250 to 400	200	200	200	200	200	200	200	200	200		
450 to 700	250	250	250	250	250	250	250	250	250	250	
800 to 1200	300	300	300	300	300	300	300	300	300	300	300

Table 12.2-5 Lateral distance L between pipes

12.2.4.2 Lateral distance L between clamps

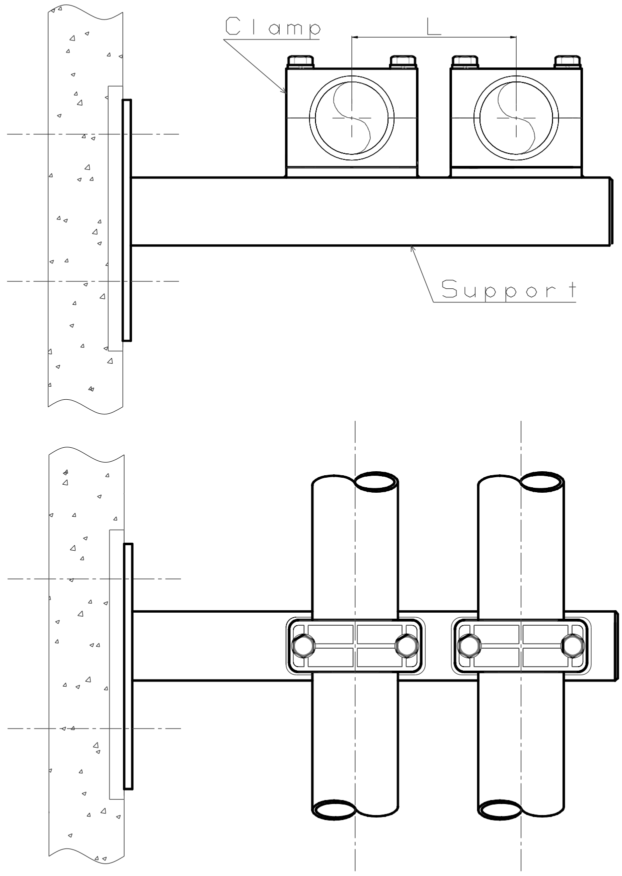


Figure 12.2-2 Distance L between clamps

Lateral distance between Clamps L (mm)										
DN	**NPS**	**6**	**8**	**10**	**15**	**20**	**25**	**32**	**40**	**50**
6	**1/8**	85	85	85	85	90	90	100	120	120
8	**1/4**	85	85	85	85	90	90	100	120	120
10	**3/8**	85	85	85	85	90	90	100	120	120
15	**1/2**	85	85	85	85	90	90	100	120	120
20	**3/4**	90	90	90	90	95	95	105	125	125
25	**1**	90	90	90	90	95	95	105	125	125
32	**1 ¼**	100	100	100	100	105	105	110	130	130
40	**1 ½**	120	120	120	120	125	125	130	150	150
50	**2**	120	120	120	120	125	125	130	150	150

Table 12.2-6 Lateral distance L between clamps

12.2.4.3 Lateral distance L between pipe and wall

The distance between pipe and wall shall be respected as indicated in the **Figure 12.2-3.**

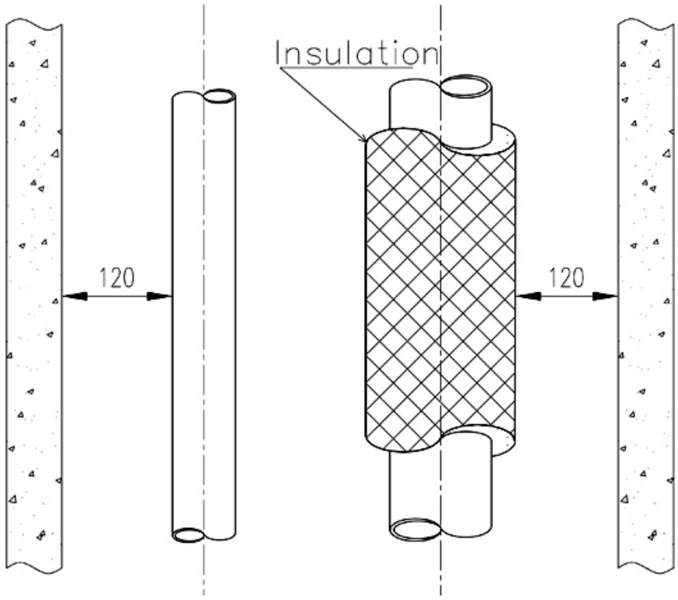


Figure 12.2-3 Lateral distance L between pipe and wall

12.2.5 Thermal Insulation

One of the main goals of the thermal insulation is to increase the efficiency of the facility. The insulation will reduce heat loss by conduction and/or by convection during the process. Personnel will be protected from injury by being prevented from coming into contact with the pipe surface. That is the reason why we have defined the following six functions:

i. HC: Heat Conservation
ii. CC: Cold Conservation
iii. FP: Freezing Protection
iv. CP: Anti-condensation
v. PP: Physical Protection
vi. DC: Double Containment

The material used to perform the insulation is given in the list below:

- Mineral fibre
- Glass-wool

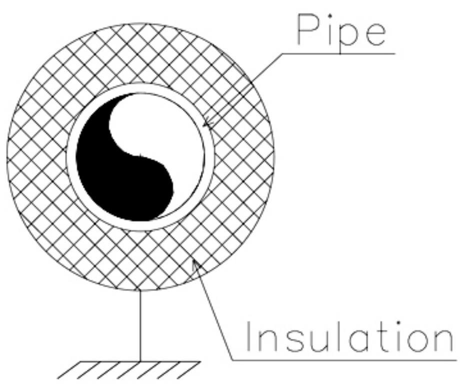


Figure 12.2-4 Insulated pipe

Types of insulation			
Spec	**From (°C)**	**To (°C)**	**Function**
HC	60	Above	Heat conservation
PP	60	Above	Physical protection
X	20	60	None required
FP	Under	0	Freezing protection
CP	-80	20	Anti-condensation
CC	-80	20	Cold conservation
DC	-269	-80	Double containment

Table 12.2-7 Type of insulation

12.2.5.1 HC: Heat Conservation

The minimum insulation thickness in case of heat conservation given in **Table 12.2-1** shall be respected for a preliminary design.

Material calculation data: $\lambda = 0.042 + 0.00014\ T$ (λ in W/m.K and T in K)

Insulation thickness (mm)								
DN	**NPS**	**OD (mm)**	**60 to 100°C**	**101 to 200°C**	**201 to 300°C**	**301 to 400°C**	**401 to 500°C**
6	1/8	10.3	30	40	50	60	70
8	1/4	13.7	30	40	50	60	70
10	3/8	17.1	30	40	50	60	70
15	1/2	21.3	30	40	50	60	70
20	3/4	26.9	30	40	50	70	100
25	1	33.7	30	40	50	70	100
32	1 ¼	42.4	30	40	50	70	100
40	1 ½	48.3	30	50	60	80	100
50	2	60.3	40	50	60	80	100
65	2 ½	73.0	40	50	60	80	100
80	3	88.9	40	50	60	100	100
100	4	114.3	40	50	60	100	120
125	5	139.7	40	50	60	100	120
150	6	168.3	40	50	70	100	120
200	8	219.1	50	60	70	100	120
250	10	273.0	50	60	70	100	150
300	12	323.9	50	60	70	120	150
350	14	355.6	50	60	70	120	150
400	16	406.4	50	60	70	120	150
450	18	457	50	60	70	120	150
500	20	508	50	60	70	120	150
600	24	610	50	70	100	120	150
700	28	711	50	70	100	120	150
800	32	813	50	70	100	120	150
900	36	914	50	70	100	120	150
1000	40	1016	50	70	100	120	150
1100	44	1118	50	70	100	120	150
1200	48	1220	50	70	100	120	150

Table 12.2-8 Insulation thickness for heat conservation

12.2.5.2 CC: Cold Conservation

The minimum insulation thickness in case of cold conservation given in **Table 12.2-9** shall be respected for a preliminary design.

Material calculation data: $\lambda = 0.051 + 0.00015\,T$ (λ in W/m.K and T in K)

Insulation thickness (mm)							
DN	**NPS**	**OD (mm)**	**+1 to +20°C**	**0 to -20°C**	**-21 to -40°C**	**-41 to -60°C**	**-61 to -80°C**
6	1/8	17.2	30	40	50	50	60
8	1/4	21.3	30	40	50	60	70
10	3/8	17.2	30	40	50	50	60
15	1/2	21.3	30	40	50	60	70
20	3/4	26.9	30	40	50	60	70
25	1	33.7	30	40	50	60	70
32	1 ¼	42.4	30	40	60	70	80
40	1 ½	48.3	30	50	60	70	80
50	2	60.3	30	50	60	70	80
65	2 ½	73.0	30	50	60	80	90
80	3	88.9	40	50	70	80	90
100	4	114.3	40	50	70	80	90
125	5	139.7	40	60	70	90	100
150	6	168.3	40	60	80	90	100
200	8	219.1	40	60	80	90	100
250	10	273.0	40	60	80	90	110
300	12	323.9	40	60	80	90	110
350	14	355.6	40	60	80	100	110

Table 12.2-9 Insulation thickness for cold conservation

12.2.5.3 FP: Freezing Protection

The minimum insulation thickness for freezing protection given in **Table 12.2-10** shall be respected for a preliminary design.

Material calculation data: $\lambda = 0.051 + 0.00015\ T$ (λ in W/m.K and T in K)

			Thickness of insulation depending on the time without fluid flowing inside the pipe				Time possible to stop with 30mm thickness of insulation
DN	Inch	OD	72 h	48 h	24 h	12 h	Time (h)
6	1/8	10.3					
8	1/4	13.7					
10	3/8	17.1					1
15	1/2	21.3					1
20	3/4	26.9					2
25	1	33.7					3
32	1 ¼	42.4					4
40	1 ½	48.3				90	6
50	2	60.3			200	60	8
65	2 ½	73.0			135	45	9
80	3	88.9		220	70	25	13
100	4	114.3	250	120	50	20	18
125	5	139.7	170	90	40	0	22
150	6	168.3	100	60	25	0	28
200	8	219.1	65	40	20	0	38
250	10	273	50	30	0	0	49
300	12	323.9	40	25	0	0	59
350	14	355.6	35	20	0	0	66

Table 12.2-10 Insulation thickness for freezing protection

(grey box) Electrical heat tracing to be provided

12.2.5.4 CP: Condensation Protection

The minimum insulation thickness for condensation protection given in **Table 12.2-11** shall be respected for a preliminary design.

Ambient temperature	Relative humidity			
	70 %	80 %	90 %	95 %
20°C (293 K)	14.2 °C	16.3 °C	18.2 °C	19.2 °C
30°C (303 K)	24.0 °C	26.2 °C	28.1 °C	29.1 °C
40°C (313 K)	33.5 °C	35.9 °C	38.0 °C	39.0 °C

Table 12.2-11 Dew point temperature

Material calculation data: $\lambda = 0.051 + 0.00015\ T$ (λ in W/m.K and T in K)

Insulation thickness (mm)							
DN	Inch	OD (mm)	+1 to +20°C	0 to -20°C	-21 to -40°C	-41 to -60°C	-61 to -80°C
6	1/8	10.3	30	40	60	70	80
8	1/4	13.7	30	40	60	70	80
10	3/8	17.1	30	40	60	70	80
15	1/2	21.3	30	40	60	70	80
20	3/4	26.9	30	50	60	80	90
25	1	33.7	30	50	60	80	90
32	1 ¼	42.4	30	50	70	90	100
40	1 ½	48.3	30	50	70	90	100
50	2	60.3	30	50	70	90	100
65	2 ½	73.0	30	60	70	100	110
80	3	88.9	30	60	80	100	110
100	4	114.3	30	60	80	100	120
125	5	139.7	40	60	90	110	30
150	6	168.3	40	60	90	110	130
200	8	219.1	40	70	100	120	140
250	10	273	40	70	100	120	140
300	12	323.9	40	70	100	120	140
350	14	355.6	40	70	100	130	150

Table 12.2-12 Insulation thickness for condensation protection

12.2.5.5 PP: Physical Protection

1. The minimum insulation thickness for physical protection given in **Table 12.2-13** shall be respected for a preliminary design.

Material calculation data: $\lambda = 0.042 + 0.00014\ T$ (λ in W/m.K and T in K)

Insulation thickness (mm)							
DN	Inch	OD (mm)	60 to 100°C	101 to 200°C	201 to 300°C	301 to 400°C	401 to 500°C
6	1/8	10.3	30	40	50	60	80
8	1/4	13.7	30	40	50	60	80
10	3/8	17.1	30	40	50	60	80
15	1/2	21.3	30	40	50	60	80
20	3/4	26.9	30	40	50	60	80
25	1	33.7	30	40	50	60	80
32	1 ¼	42.4	30	40	50	60	80
40	1 ½	48.3	30	50	60	70	100
50	2	60.3	30	50	60	70	100
65	2 ½	73.0	30	50	60	70	100
80	3	88.9	30	50	60	70	100
100	4	114.3	30	50	60	70	100
125	5	139.7	30	50	60	80	100
150	6	168.3	30	50	60	80	100
200	8	219.1	30	50	60	80	100
250	10	273	30	50	60	80	100
300	12	323.9	30	50	70	80	120
350	14	355.6	30	50	70	80	120
400	16	406.4	30	50	70	80	120
450	18	457	30	50	70	80	120
500	20	508	30	50	70	80	120
600	24	610	30	50	70	80	120
700	28	711	30	50	70	80	120
800	32	813	30	50	70	80	120
900	36	914	30	50	70	80	120
1000	40	1016	30	50	70	80	120
1100	44	1118	30	50	70	80	120
1200	48	1220	30	50	70	80	120

Table 12.2-13 Insulation thickness for physical protection

2. In all cases, the maximum surface temperature of pipes that personnel running the facility can come into contact with, shall not exceed 60ºC

12.2.5.6 Fabrication and Erection

Insulation on the valves

The clearance of the valves, including the insulation, shall be taken into account in the design as represented in the **Figure 12.2-5**.

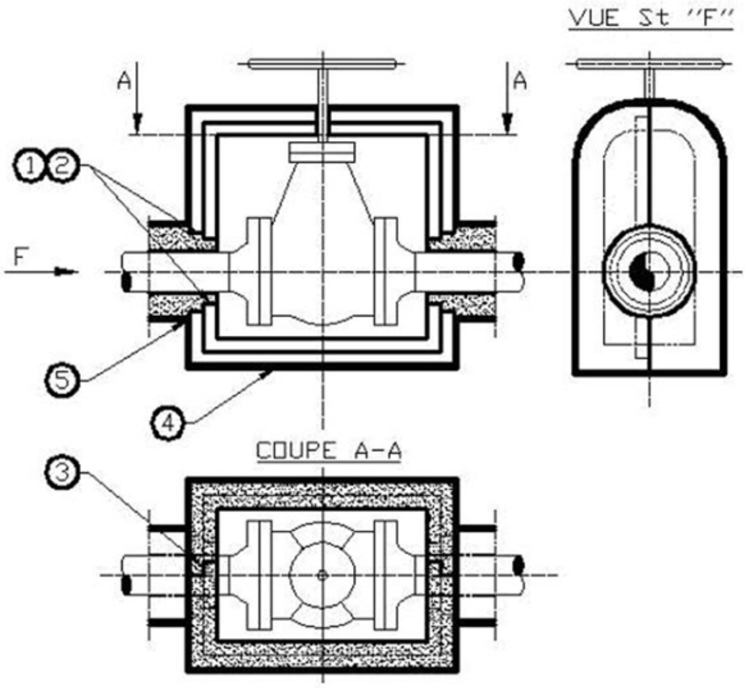


Figure 12.2-5 Insulation on valves

12.2.6 Bends/Elbows

12.2.6.1 Elbows

1. Preferably designers shall use butt welded fittings. Nevertheless, elbow for conventional fluids (without contamination) and services small bore could be socket welded.

2. For radioactive material piping with possibility of contamination, the use of socket welded type components is **prohibited**. Only butt welded type components are allowed.

3. The minimum size of the butt welded elbow clearance should be taken into account in the design (dimension in **Table 12.2-14**).

4. The minimum size of the socket welded elbow clearance should be taken into account in the design (dimension in **Table 12.2-15**).

5. Use of bends is strongly recommended up to DN32 except in particular conditions.

6. The following angles can be used: 15º, 22.5º, 30º, 45º, 60º, 67.5º, 90º.

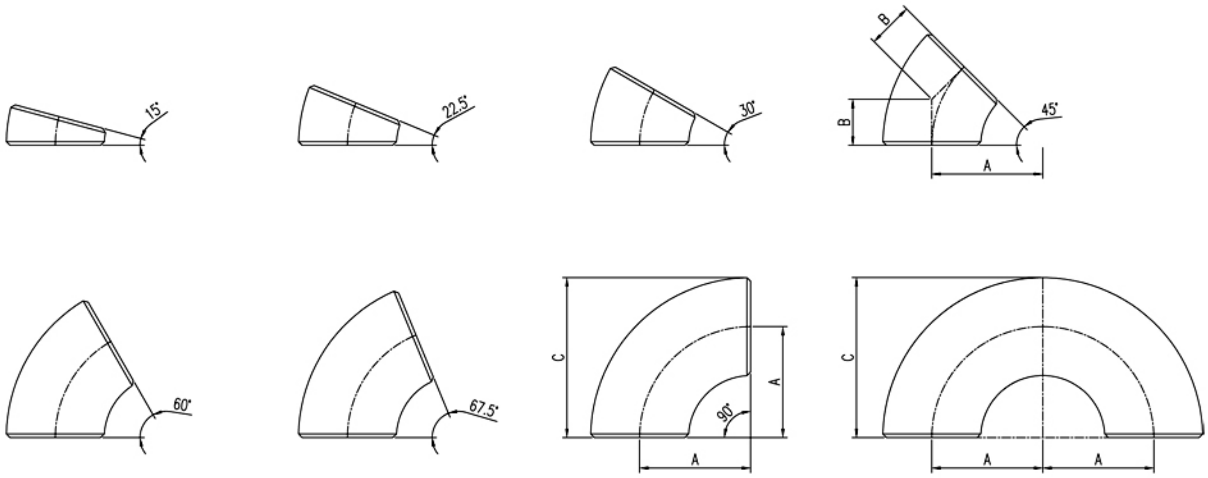
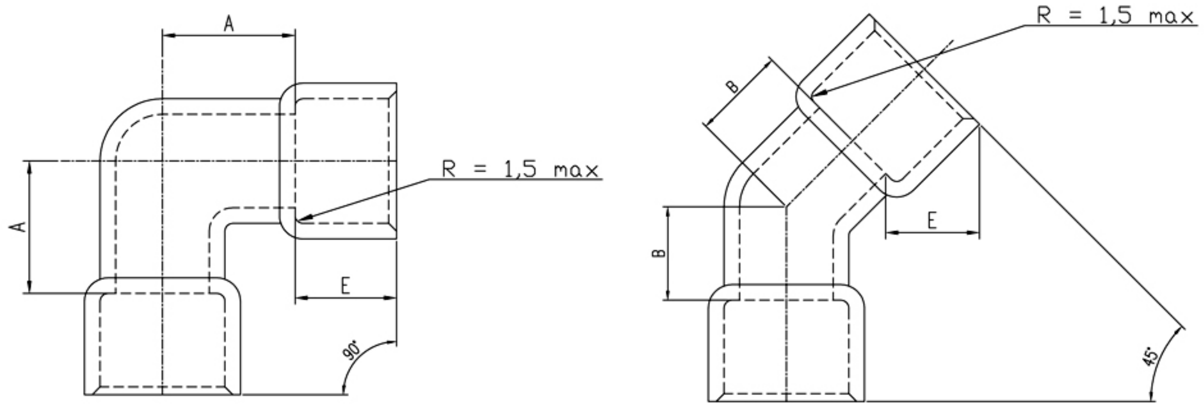


Figure 12.2-6 Butt weld elbows

3D Butt weld elbows according to ASME B16.9					
DN	**NPS**	**OD (mm)**	**C (mm)**	**A (mm)**	**B (mm)**
15	1/2	21.3	49	38	14
20	3/4	26.9	51	38	14
25	1	33.7	55	38	22
32	1 ¼	42.4	69	48	25
40	1 ½	48.3	81	57	29
50	2	60.3	106	76	35
65	2 ½	73.0	131	95	44
80	3	88.9	159	114	51
100	4	114.3	210	152	64
125	5	139.7	260	190	79
150	6	168.3	313	229	95
200	8	219.1	414	305	127
250	10	273.0	518	381	159
300	12	323.9	619	457	190
350	14	355.6	711	533	222
400	16	406.4	813	610	254
450	18	457	914	686	286
500	20	508	1016	762	318
550	22	559	1117.5	838	343
600	24	610	1219	914	381
650	26	660	1321	991	406
700	28	711	1422.5	1067	438
750	30	762	1524	1143	470
800	32	813	1625.5	1219	502
850	34	864	1727	1295	533
900	36	914	1829	1372	565
1000	40	1016	2032	1524	632
1050	42	1067	2133.5	1600	660
1100	44	1118	2235	1676	695
1200	48	1220	2439	1829	759

Table 12.2-14 3D Butt weld elbows

Bends to be used except in the case of a specific requirement.



90° ELBOW 45°ELBOW

Figure 12.2-7 Socket weld elbows

Socket weld elbows								
DN	**NPS**	**E (mm)**	**ISO PN 250**		**ISO PN 240**		**ISO PN 600**	
			A mm	**B mm**	**A mm**	**B mm**	**A mm**	**B mm**
6	1/8	10.0	11.0	8.0	11.0	8.0	-	-
8	1/4	10.0	11.0	8.0	13.5	8.0	-	-
10	3/8	10.0	13.5	8.0	15.5	11.0	-	-
15	1 /2	10.0	15.5	11.0	19.0	12.5	25.0	15.5
20	3 /4	13.0	19.0	12.5	22.5	14.0	28.5	19.0
25	1	13.0	22.5	14.0	27.0	17.5	32.0	20.5

Table 12.2-15 Socket weld elbows

12.2.7 Bends

1. The minimum size of the bend clearance should be taken into account in the design (dimension in **Table 12.2-16**).

2. Preferably the designer should use the 5D bending (regular radius bends **Table 12.2-16**). Only in really dense environments 3D bending (short radius bends **Table 12.2-17**) could be used. In all cases the system engineer should give his agreement.

3. The nominal bend takes into account the nominal fibre and the diameter of the pipes (without the tolerance).

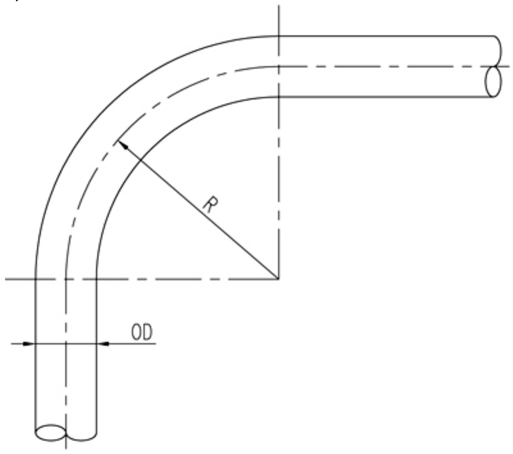


Figure 12.2-8 Bend definition

Regular bends (5D)					
DN	**NPS**	**OD**	**R**	**L1**	**L2**
6	1/8	10.2	51	110	20
8	1/4	13.5	68	110	20
10	3/8	17.2	30	110	20
15	1/2	21.3	45	110	20
20	3/4	26.9	57.5	110	20
25	1	33.7	72.5	110	20
32	1 ¼	42.4	92.5	110	20
40	1 ½	48.3	109	110	20
50	2	60.3	135	140	25
65	2 ½	73.0	365	140	25

Table 12.2-16 Regular bends (5D)

R: bend radius
L1: straight length between two successive bends
L2: straight length between end and tie in (or fillet) weld

The short radius bend will only be used for some restrictive cases with dense environments, and few possibilities of change to the routing of the pipe.

Short radius bends (3D)					
DN	**ND**	**OD**	**R**	**L1**	**L2**
6	1/8	10.2	15	110	20
8	1/4	13.5	24	110	20
10	3/8	17.2	24	110	20
15	1/2	21.3	38	110	20
20	3/4	26.9	38	110	20
25	1	33.7	38	110	20
32	1 ¼	42.4	48	110	20
40	1 ½	48.3	57	110	20
50	2	60.3	76	140	20
65	2 ½	73.0	219	140	25

Table 12.2-17 Short radius bends (3D)

12.2.8 Guidelines on using bends in the design

1. The designer should keep the correct distance between two bends to permit easy erection on site. See **Figure 12.2-9**.

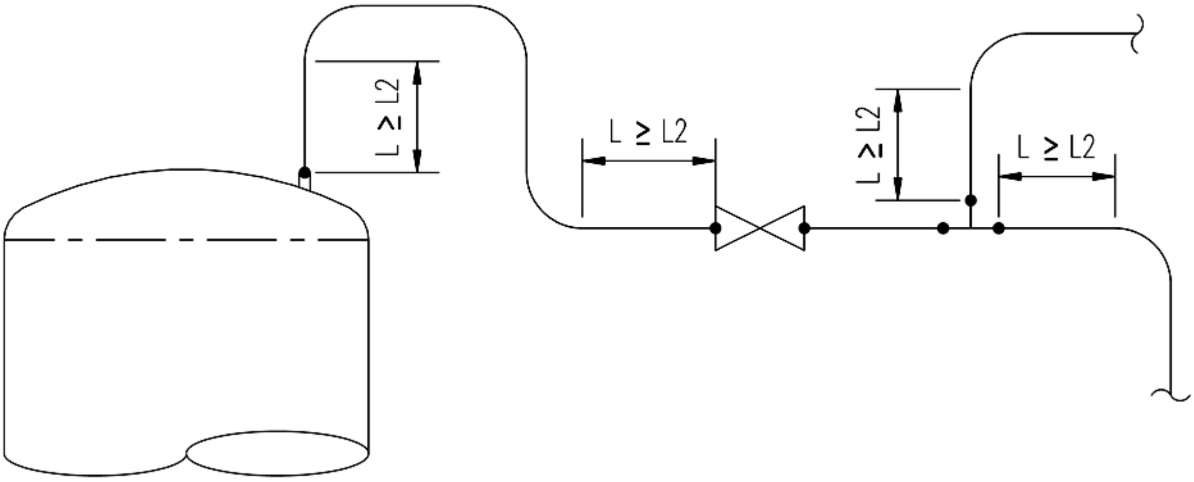


Figure 12.2-9 Distance between bends

2. The designer should check his design taking into account the bend configuration see **Figure 12.2-10** below.

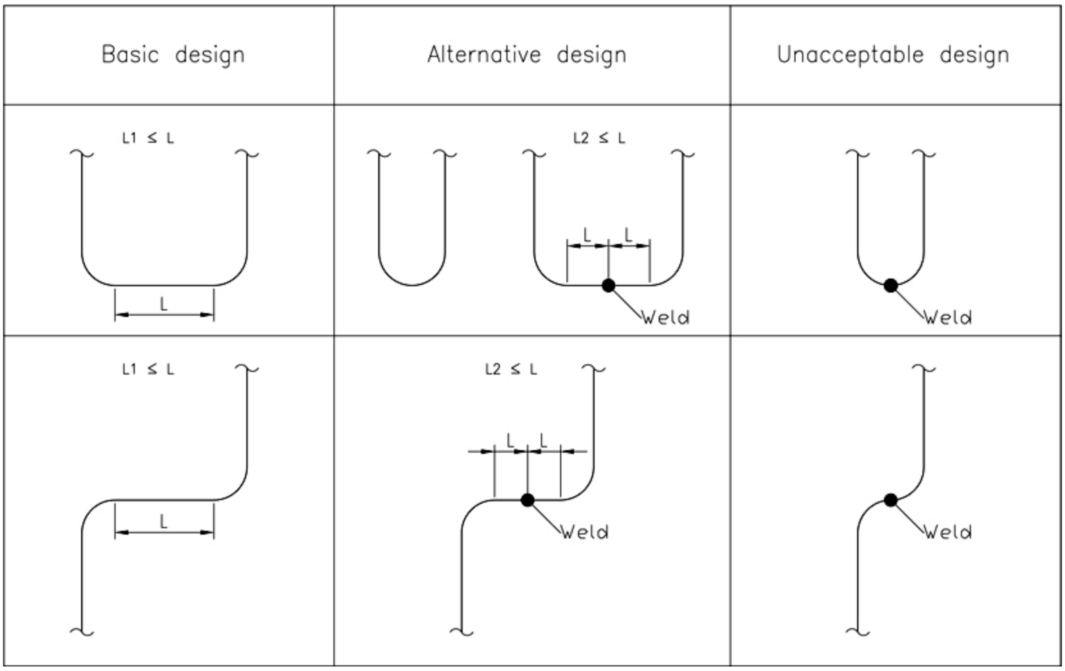


Figure 12.2-10 Bend configuration

12.2.9 Automatic Welding Machine

In order to assure the possibility to use an automatic welding machine, the distances shown in **Table 12.2-18** below shall be kept as clearance.

$Ø_{out}$ (mm)	L (mm)	Ø (mm)
6 to 16	60	85
16 to 32	82	110
32 to 80	82	190
80 to 114	100	280

Table 12.2-18 Clearance for automatic welding machine

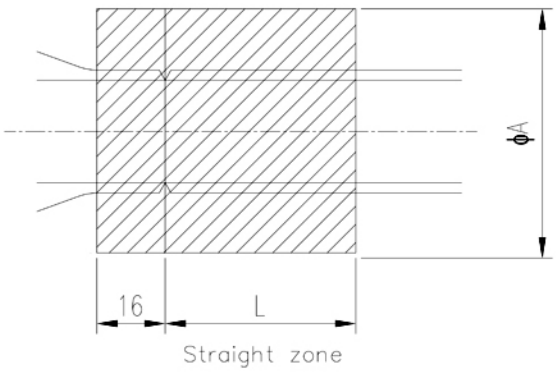


Figure 12.2-11 Welding Machine Clearances

12.2.10 Supports

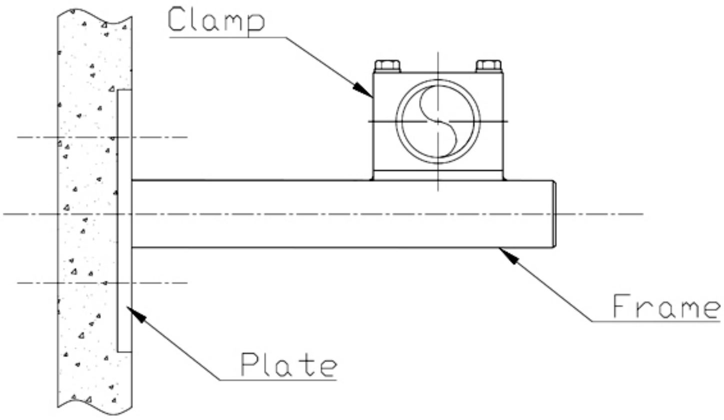


Figure 12.2-12 Support definition

The support is made up of two parts:

- The clamp directly linked to the pipe.
- The frame where the clamp is fixed.

The frame should be fixed on a structural steel frame or directly linked to the concrete by a plate.

Two different types of plate can be used:

- Embedded (the civil company is in charge of providing them)
- Anchored (the system sub-contractor is in charge of providing them)

No shared support.
There must be one support per system.

12.2.10.1 Type of Clamp

12.2.10.2 Horizontal pipe

LG: Longitudinal Guide
AP: Anchor Point

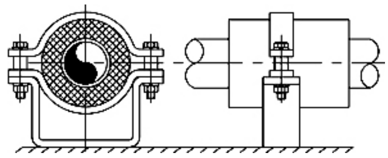
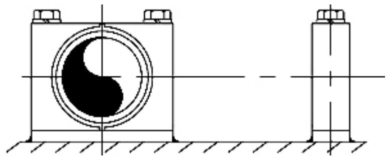
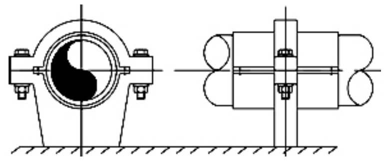
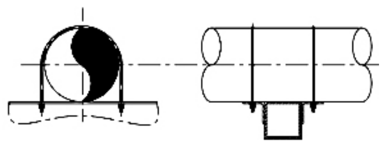
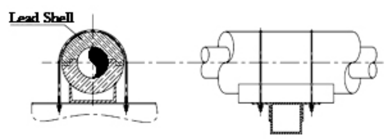
Temperature	DN		Ref. of support	Support preview	Type of connection
	From	To			
0°C to 20°C	15	350	CLA		LG
20°C to 60°C	6	50	CLB		LG AP
	65	200	CLC		LG AP
	250	900	CLD		LG AP
	250	900	CLE		AP

Table 12.2-19 Horizontal Pipe Temperature 0°C to 60°C

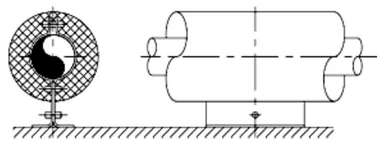
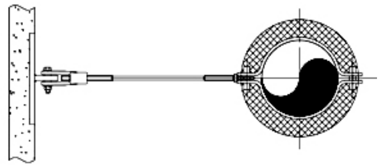
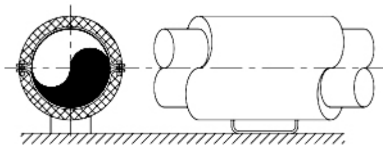
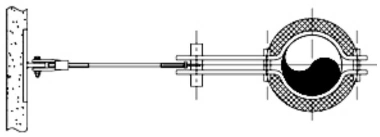
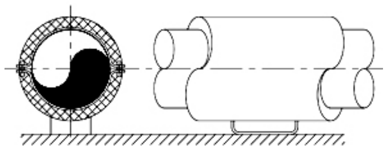
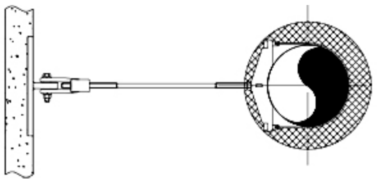
Temperature	DN		Ref. of support	Support preview	Type of connection
	From	To			
60°C to 350°C	15	125	CLF		LG AP
			HLA		Hanger
	150	450	CLG		LG AP
			HLB		Hanger
	500	900	CLG		LG AP
			HLC		Hanger

Table 12.2-20 Horizontal Pipe Temperature 60°C to 350°C

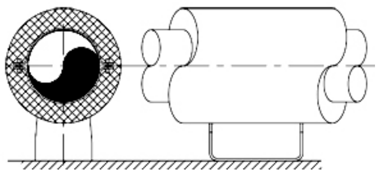
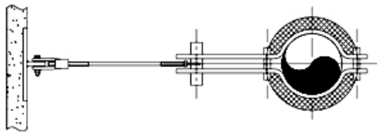
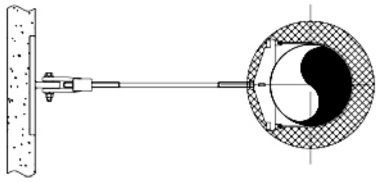
Temperature	DN		Ref. of support	Support preview	Type of connection
	From	To			
350°C to 500°C	15	900	CLH		LG AP
	15	400	HLB		Hanger
	450	900	HLC		

Table 12.2-21 Horizontal Pipe Temperature 350°C to 500°C

12.2.10.3 Vertical pipe

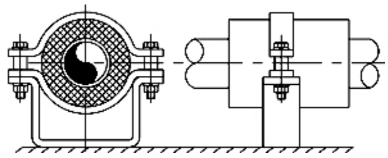
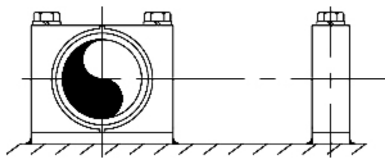
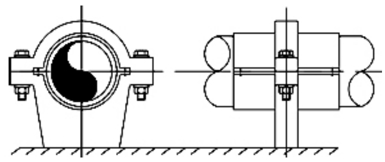
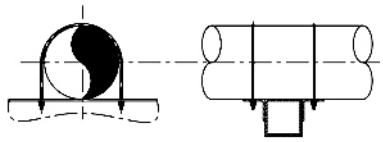
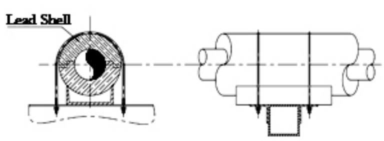
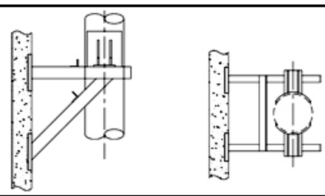
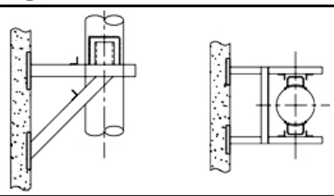
Temperature	DN From	DN To	Ref. of support	Support preview	Type of connection
0°C to 20°C	15	350	CLA		LG
20°C to 60°C	6	50	CLB		LG AP
	65	200	CLC		LG AP
	250	900	CLD		AP
	250	900	CLE		AP
20°C to 60°C	200	1000	CLI		FP
			CLJ		LG

Table 12.2-22 Vertical Pipe Temperature 0°C to 60°C

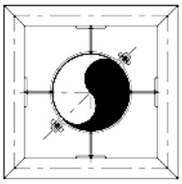
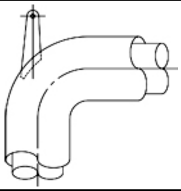
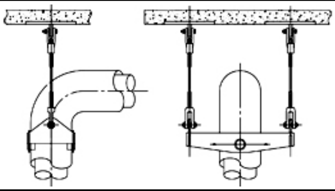
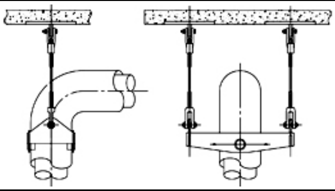
Temperature	DN		Ref. of support	Support preview	Type of connection
	From	To			
60°C to 350°C	40	900	CLK		LG
	32	700	HLD		Hanger
	65	900	HLE		Hanger
350°C to 500°C	65	900	HLE		Hanger

Table 12.2-23 Vertical Pipe Temperature 60°C to 500°C

12.2.10.4 Special support

When pipes up to DN50 are routed together, they can be supported by a special support as follow:

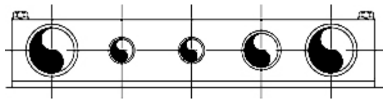
Temperature	DN		Ref. of support	Support preview	Type of connection
	From	To			
20°C to 60°C	6	50	CSA		LG AP

Table 12.2-24 Special support

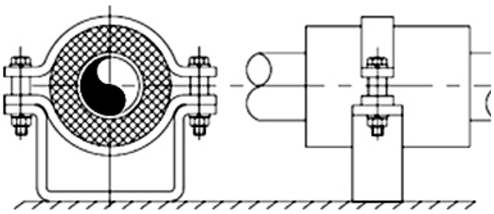


Figure 12.2-13 Clamp CLA

(DN15 to DN350)

Reference	DN	OD (mm)	Mass (kg)
CLA-0015-SS	15	21.3	1.9
CLA-0025-SS	25	33.7	2.1
CLA-0040-SS	40	48.3	4.1
CLA-0050-SS	50	60.3	4.1
CLA-0080-SS	80	88.9	9.5
CLA-0100-SS	100	114.3	14.5
CLA-0125-SS	125	139.7	20.0
CLA-0150-SS	150	168.3	23.0
CLA-0200-SS	200	219.1	32.0
CLA-0250-SS	250	273.0	41.4
CLA-0300-SS	300	323.9	62.4
CLA-0350-SS	350	355.6	76.7

Table 12.2-25 Clamp CLA (DN15 to DN350)

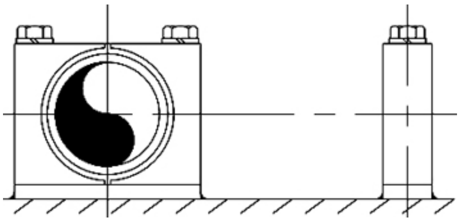


Figure 12.2-14 Clamp CLB

(DN6 to DN50)

Reference	DN	OD (mm)	Mass (kg)
CLB-0006-SS	6	10.2	0.1
CLB-0008-SS	8	13.5	0.1
CLB-0010-SS	10	17.2	0.1
CLB-0015-SS	15	21.3	0.2
CLB-0020-SS	20	26.9	0.2
CLB-0025-SS	25	33.7	0.2
CLB-0032-SS	32	42.4	0.3
CLB-0040-SS	40	48.3	0.3
CLB-0050-SS	50	60.3	0.4

Table 12.2-26 Clamp CLB (DN6 to DN50)

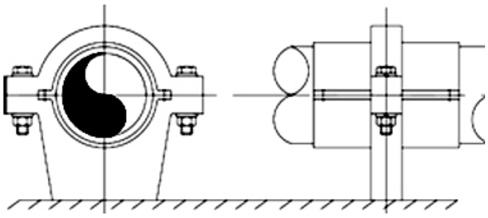


Figure 12.2-15 Clamp CLC

(DN65 to DN250)

Reference	DN	OD (mm)	Mass (kg)
CLC-0065-SS	65	73.0	3.0
CLC-0080-SS	80	88.9	5.0
CLC-0100-SS	100	114.3	11.0
CLC-0125-SS	125	139.7	18.0
CLC-0150-SS	150	168.3	28.0
CLC-0200-SS	200	219.1	33.0

Table 12.2-27 Clamp CLC (DN65 to DN250)

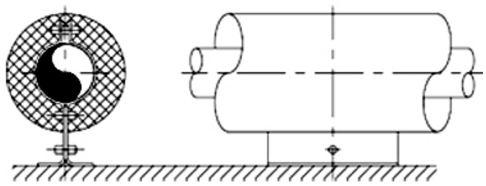


Figure 12.2-16 Clamp CLF

(DN15 to DN125)

Reference	DN	OD (mm)	Mass (kg)
CLF-0015-SS	15	21.3	2
CLF-0020-SS	20	26.9	2
CLF-0025-SS	25	33.7	2
CLF-0032-SS	32	42.4	2
CLF-0040-SS	40	48.3	2
CLF-0050-SS	50	60.3	3
CLF-0060-SS	60	73.0	3
CLF-0080-SS	80	88.9	4
CLF-0100-SS	100	114.3	7
CLF-0125-SS	125	139.7	9

Table 12.2-28 Clamp CLF (DN15 to DN125)

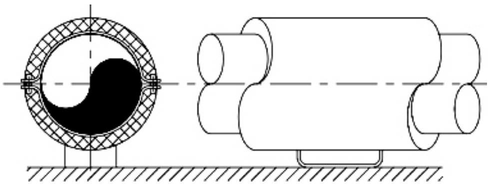


Figure 12.2-17 Clamp CLG

(DN150 to DN900)

Reference	DN	OD (mm)	Mass (kg)
CLG-0150-SS	150	168.3	12
CLG-0200-SS	200	219.1	17
CLG-0250-SS	250	273	25
CLG-0300-SS	300	323.9	27
CLG-0350-SS	350	355.6	34
CLG-0400-SS	400	406.4	47
CLG-0450-SS	450	457	51
CLG-0500-SS	500	508	70
CLG-0600-SS	600	610	107
CLG-0700-SS	700	711	130
CLG-0800-SS	800	813	143
CLG-0900-SS	900	914	177

Table 12.2-29 Clamp CLG (DN150 to DN900)

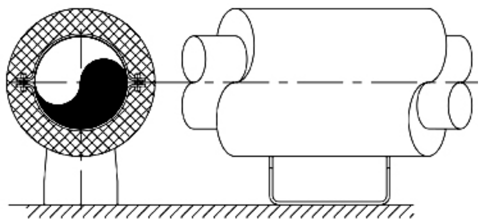


Figure 12.2-18 Clamp CLH

(DN15 to DN900)

Reference	DN	OD (mm)	Mass (kg)
CLH-0015-SS	15	21.3	2
CLH-0020-SS	20	26.9	3
CLH-0025-SS	25	33.7	3
CLH-0032-SS	32	42.4	3
CLH-0040-SS	40	48.3	3
CLH-0050-SS	50	60.3	4
CLH-0060-SS	60	73.0	4
CLH-0080-SS	80	88.9	6
CLH-0100-SS	100	114.3	8
CLH-0125-SS	125	139.7	10
CLH-0150-SS	150	168.3	13
CLH-0200-SS	200	219.1	20
CLH-0250-SS	250	273	28
CLH-0300-SS	300	323.9	32
CLH-0350-SS	350	355.6	46
CLH-0400-SS	400	406.4	64
CLH-0450-SS	450	457	68
CLH-0500-SS	500	508	81
CLH-0600-SS	600	610	120
CLH-0700-SS	700	711	145
CLH-0800-SS	800	813	157
CLH-0900-SS	900	914	195

Table 12.2-30 Clamp CLH (DN15 to DN900)

12.2.10.5 Fixed Hanger Rod

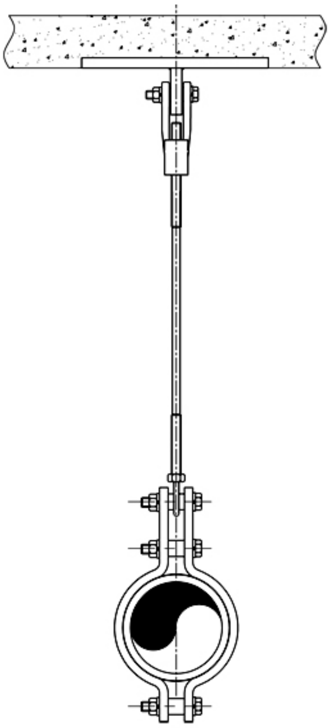


Figure 12.2-19 Hanger rod

Reference	DN	OD (mm)	Mass (kg)
HLA-0015-SS	15	21.3	1
HLA-0020-SS	20	26.9	1
HLA-0025-SS	25	33.7	1
HLA-0032-SS	32	42.4	1.5
HLA-0040-SS	40	48.3	1.5
HLA-0050-SS	50	60.3	2.5
HLA-0065-SS	65	73.0	2.5
HLA-0080-SS	80	88.9	3
HLA-0100-SS	100	114.3	4
HLA-0125-SS	125	139.7	4
HLB-0015-SS	15	21.3	1
HLB-0020-SS	20	26.9	1
HLB-0025-SS	25	33.7	1
HLB-0032-SS	32	42.4	1.5
HLB-0040-SS	40	48.3	1.5
HLB-0050-SS	50	60.3	2.5
HLB-0065-SS	65	73.0	2.5
HLB-0080-SS	80	88.9	3
HLB-0100-SS	100	114.3	4
HLB-0125-SS	125	139.7	4
HLB-0150-SS	150	168.3	5
HLB-0200-SS	200	219.1	7
HLB-0250-SS	250	273	13
HLB-0300-SS	300	323.9	18
HLB-0350-SS	350	355.6	25
HLB-0400-SS	400	406.4	30
HLB-0450-SS	450	457	60
HLC-0500-SS	500	508	100
HLC-0600-SS	600	610	110
HLC-0700-SS	700	711	170
HLC-0800-SS	800	813	270
HLC-0900-SS	900	914	320

Table 12.2-31 Hanger rod

12.2.10.6 Frame

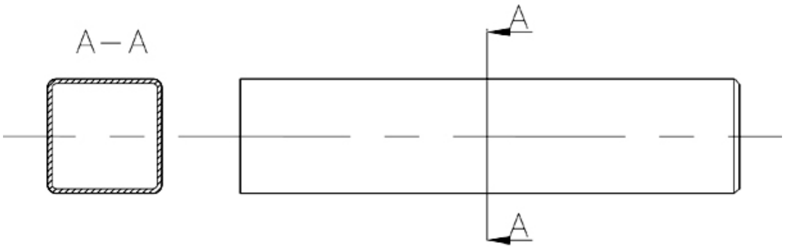


Figure 12.2-20 Square Frame

Reference	Frame dimension
FS-050-SS	50 x 50 x 5
FS-080-SS	80 x 80 x 8
FS-100-SS	100 x 100 x 8
FS-150-SS	150 x 150 x 12
FS-200-SS	200 x 200 x 16
FS-250-SS	250 x 250 x 16
FS-300-SS	300 x 300 x 16
FS-350-SS	350 x 350 x 16
FS-400-SS	400 x 400 x 16

Table 12.2-32 Square Frame dimensions

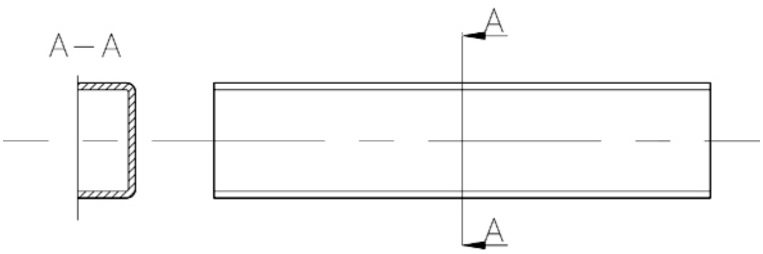


Figure 12.2-21 U Frame

Reference	Frame dimension
FU-080-SS	80 x 80 x 8
FU-100-SS	100 x 100 x 8.5
FU-150-SS	150 x 150 x 10.3
FU-200-SS	200 x 200 x 11.5

Table 12.2-33 U Frame dimensions

12.2.11 Embedded Civil Plate

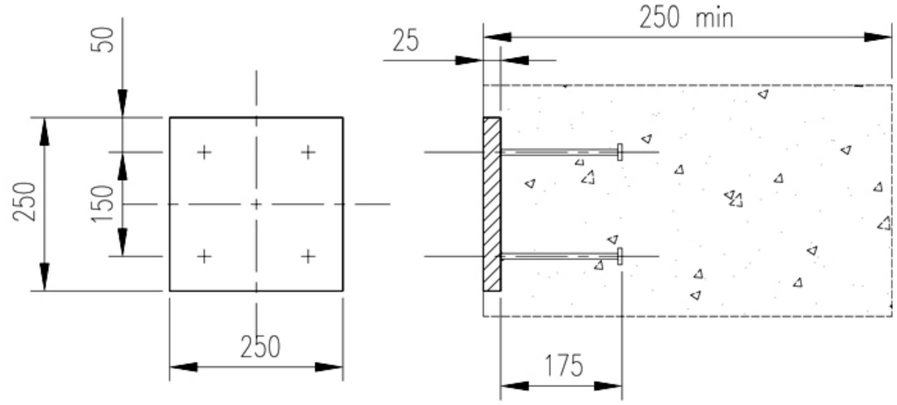


Figure 12.2-22 Embedded plate Type PE-250

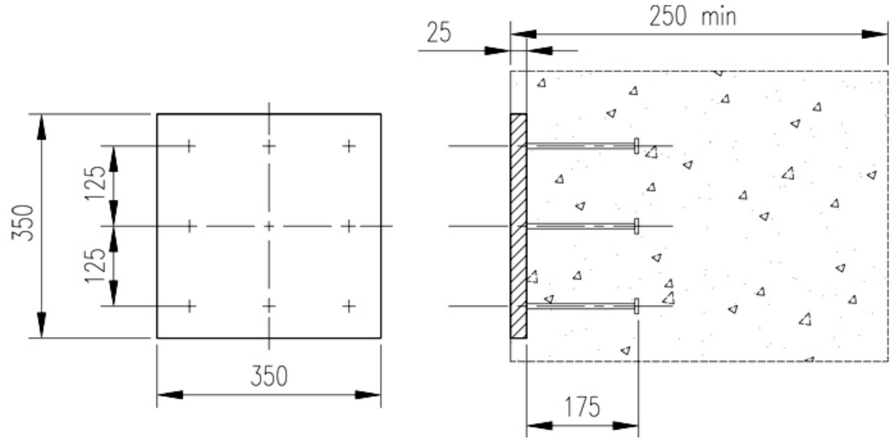


Figure 12.2-23 Embedded plate Type PE-350

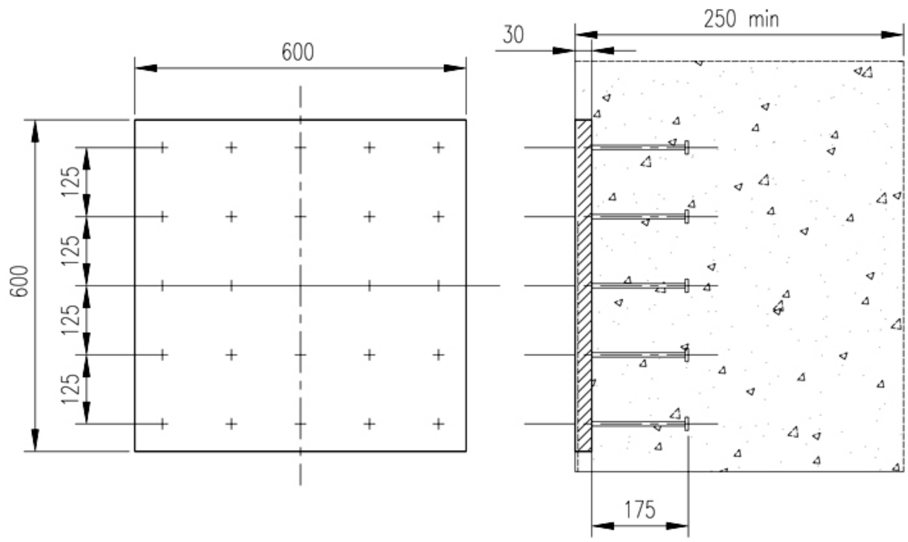


Figure 12.2-24 Embedded plate Type PE-600

12.2.12 Anchored Civil Plate

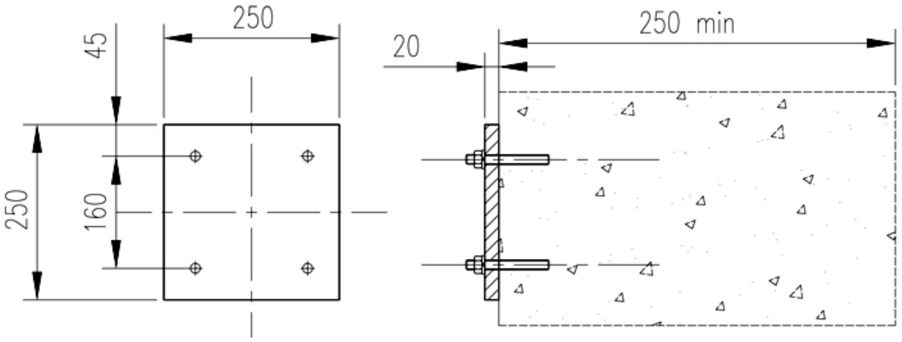


Figure 12.2-25 Anchored plate Type PA-250

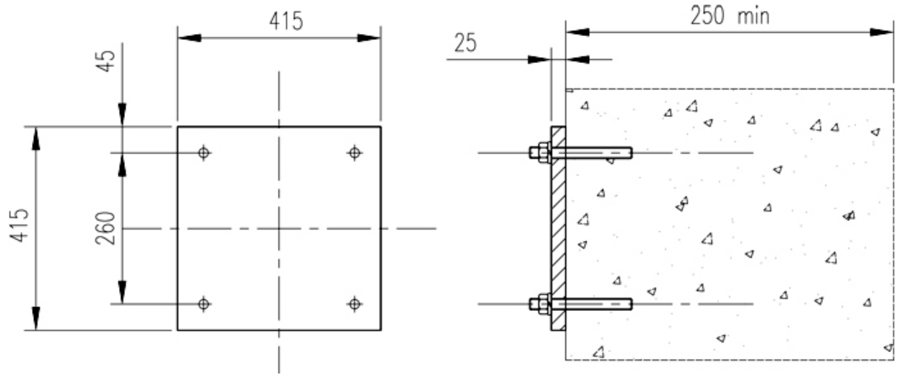


Figure 12.2-26 Anchored plate Type PA-415

12.2.13 Support Estimation

For space reservation during the preliminary layout, the tables below should be followed. This estimation is based on the following rule: the stiffness of the support must be at least 10 times greater than the stiffness of the pipe, considering the span between two supports defined in this document. A stress analysis and calculation shall be performed to confirm them before fabrication and erection.

Note: In the case of multiple supports, the bigger diameter needs to be taken into account. The plates and frames shall be oversized.

The estimation of the frame size and plate is based on the following configuration with different value for the cantilever length L.

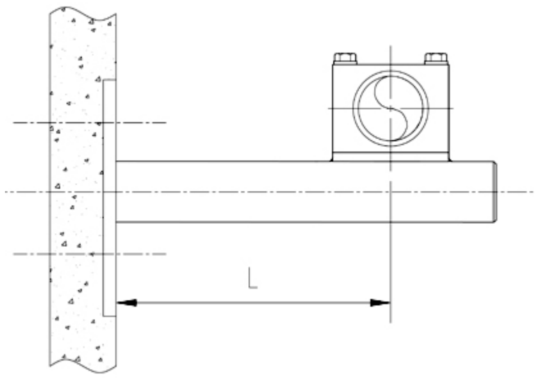


Figure 12.2-27 Cantilever support sizes

Support stiffness (N/mm)						
Section	L (mm)					
	250	500	750	1000	1250	1500
50x50x5	1.18E+04	1.48E+03	4.37E+02	1.85E+02	9.45E+01	5.47E+01
80x80x8	7.74E+04	9.67E+03	2.87E+03	1.21E+03	6.19E+02	3.58E+02
100x100x8	1.61E+05	2.01E+04	5.95E+03	2.51E+03	1.29E+03	7.44E+02
150x150x12	8.13E+05	1.02E+05	3.01E+04	1.27E+04	6.51E+03	3.77E+03
200x200x16	2.57E+06	3.21E+05	9.52E+04	4.02E+04	2.06E+04	1.19E+04
250x250x16	5.27E+06	6.59E+05	1.95E+05	8.24E+04	4.22E+04	2.44E+04
300x300x16	9.41E+06	1.18E+06	3.49E+05	1.47E+05	7.53E+04	4.36E+04
350x350x16	1.53E+07	1.91E+06	5.67E+05	2.39E+05	1.22E+05	7.08E+04
400x400x16	2.32E+07	2.90E+06	8.60E+05	3.63E+05	1.86E+05	1.08E+05

Table 12.2-34 Support stiffness

Cantilever L = 250 mm		
DN	Frame + Plate	
	Gas	Liquid
6	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
8	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
10	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
15	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
20	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
25	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
32	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
40	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
50	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
65	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
80	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
100	FS-050-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
125	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
150	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
200	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250

Table 12.2-35 Preliminary size of the plates and frames L = 250 mm

Cantilever L = 500 mm		
DN	Frame + Plate	
	Gas	Liquid
6	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
8	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
10	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
15	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
20	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
25	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
32	FS-050-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
40	FS-050-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
50	FS-050-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
65	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
80	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
100	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
125	FS-100-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
150	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
200	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
250	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
300	FS-150-SS + PE-350 / PA-415	FS-200-SS + PE-600/ PA-415
350	FS-150-SS + PE-350 / PA-415	FS-200-SS + PE-600/ PA-415
400	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
450	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
500	FS-200-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
600	FS-200-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
700	FS-250-SS + PE-600/ PA-415	FS-300-SS + PE-600

Table 12.2-36 Preliminary size of the plates and frames L = 500 mm

Cantilever L = 750 mm		
DN	Frame + Plate	
	Gas	Liquid
6	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
8	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
10	FS-050-SS + PE-250 / PA-250	FS-050-SS + PE-250 / PA-250
15	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
20	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
25	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
32	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
40	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
50	FS-080-SS + PE-250 / PA-250	FS-100-SS + PE-350 / PA-415
65	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
80	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
100	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
125	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
150	FS-150-SS + PE-350 / PA-415	FS-200-SS + PE-600 / PA-415
200	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
250	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
300	FS-200-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
350	FS-200-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
400	FS-250-SS + PE-600/ PA-415	FS-300-SS + PE-600
450	FS-250-SS + PE-600/ PA-415	FS-300-SS + PE-600
500	FS-300-SS + PE-600	FS-350-SS + PE-600
600	FS-300-SS + PE-600	FS-400-SS + PE-600
700	FS-300-SS + PE-600	Diagonal strut required
800	FS-350-SS + PE-600	Diagonal strut required
900	FS-350-SS + PE-600	Diagonal strut required
1000	FS-350-SS + PE-600	Diagonal strut required
1100	FS-400-SS + PE-600	Diagonal strut required
1200	FS-400-SS + PE-600	Diagonal strut required

Table 12.2-37 Preliminary size of the plates and frames L = 750 mm

Cantilever L = 1000 mm		
DN	Frame + Plate	
	Gas	Liquid
6	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
8	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
10	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
15	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
20	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
25	FS-080-SS + PE-250 / PA-250	FS-100-SS + PE-350 / PA-415
32	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
40	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
50	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
65	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
80	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
100	FS-150-SS + PE-350 / PA-415	FS-200-SS + PE-600/ PA-415
125	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
150	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
200	FS-200-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
250	FS-250-SS + PE-600/ PA-415	FS-300-SS + PE-600
300	FS-300-SS + PE-600	FS-300-SS + PE-600
350	FS-300-SS + PE-600	FS-350-SS + PE-600
400	FS-300-SS + PE-600	FS-350-SS + PE-600
450	FS-350-SS + PE-600	FS-400-SS + PE-600
500	FS-350-SS + PE-600	Diagonal strut required
600	FS-400-SS + PE-600	Diagonal strut required
700	FS-400-SS + PE-600	Diagonal strut required
800	Diagonal strut required	Diagonal strut required
900	Diagonal strut required	Diagonal strut required
1000	Diagonal strut required	Diagonal strut required
1100	Diagonal strut required	Diagonal strut required
1200	Diagonal strut required	Diagonal strut required

Table 12.2-38 Preliminary size of the plates and frames L = 1000 mm

Cantilever L = 1250 mm		
DN	Frame + Plate	
	Gas	Liquid
6	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
8	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
10	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
15	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
20	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
25	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
32	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
40	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
50	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
65	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
80	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
100	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
125	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
150	FS-250-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
200	FS-250-SS + PE-600/ PA-415	FS-300-SS + PE-600
250	FS-300-SS + PE-600	FS-350-SS + PE-600
300	FS-350-SS + PE-600	FS-400-SS + PE-600
350	FS-350-SS + PE-600	FS-400-SS + PE-600
400	FS-350-SS + PE-600	Diagonal strut required
450	FS-400-SS + PE-600	Diagonal strut required
500	Diagonal strut required	Diagonal strut required
600	Diagonal strut required	Diagonal strut required
700	Diagonal strut required	Diagonal strut required
800	Diagonal strut required	Diagonal strut required
900	Diagonal strut required	Diagonal strut required
1000	Diagonal strut required	Diagonal strut required
1100	Diagonal strut required	Diagonal strut required
1200	Diagonal strut required	Diagonal strut required

Table 12.2-39 Preliminary size of the plates and frames L = 1250 mm

Cantilever L = 1500 mm		
DN	Frame + Plate	
	Gas	Liquid
6	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
8	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
10	FS-080-SS + PE-250 / PA-250	FS-080-SS + PE-250 / PA-250
15	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
20	FS-100-SS + PE-350 / PA-415	FS-100-SS + PE-350 / PA-415
25	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
32	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
40	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
50	FS-150-SS + PE-350 / PA-415	FS-150-SS + PE-350 / PA-415
65	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
80	FS-200-SS + PE-600/ PA-415	FS-200-SS + PE-600/ PA-415
100	FS-200-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
125	FS-250-SS + PE-600/ PA-415	FS-250-SS + PE-600/ PA-415
150	FS-300-SS + PE-600	FS-300-SS + PE-600
200	FS-300-SS + PE-600	FS-350-SS + PE-600
250	FS-350-SS + PE-600	FS-400-SS + PE-600
300	FS-400-SS + PE-600	Diagonal strut required
350	FS-400-SS + PE-600	Diagonal strut required
400	Diagonal strut required	Diagonal strut required
450	Diagonal strut required	Diagonal strut required
500	Diagonal strut required	Diagonal strut required
600	Diagonal strut required	Diagonal strut required
700	Diagonal strut required	Diagonal strut required
800	Diagonal strut required	Diagonal strut required
900	Diagonal strut required	Diagonal strut required
1000	Diagonal strut required	Diagonal strut required
1100	Diagonal strut required	Diagonal strut required
1200	Diagonal strut required	Diagonal strut required

Table 12.2-40 Preliminary size of the plates and frames L = 1500 mm

12.2.14 Standard Support

12.2.14.1 Wall mounted

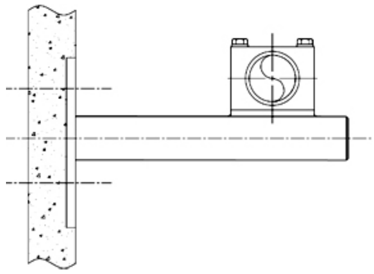


Figure 12.2-28 Cantilever support

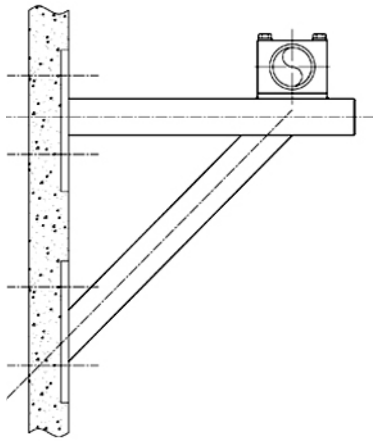


Figure 12.2-29 Braced cantilever support

12.2.14.2 Floor mounted

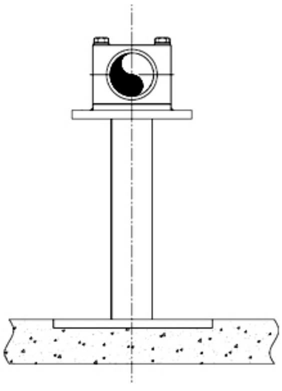


Figure 12.2-30 Column support

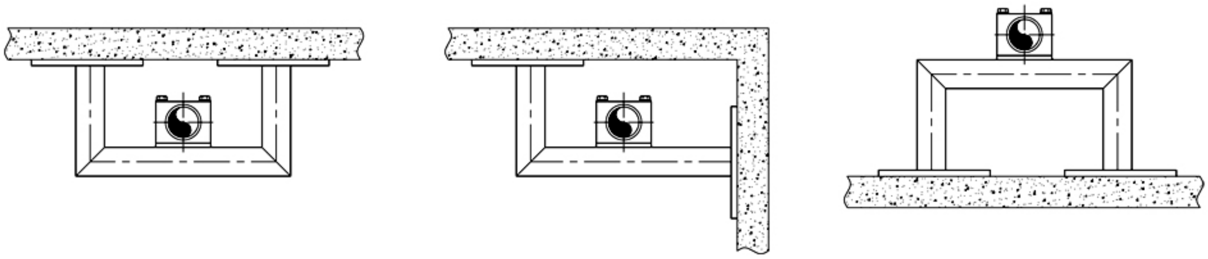


Figure 12.2-31 Plane box frame

12.2.14.3 Ceiling mounted

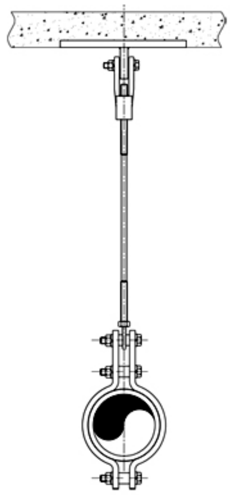


Figure 12.2-32 Single support

12.2.15 The maximum span between Supports

12.2.15.1 Non-seismic horizontal span for pipes

The span for non-seismic spacing should be respected for a preliminary design as indicated in **Table 12.2-41** below. These values are confirmed by detail piping stress analysis.

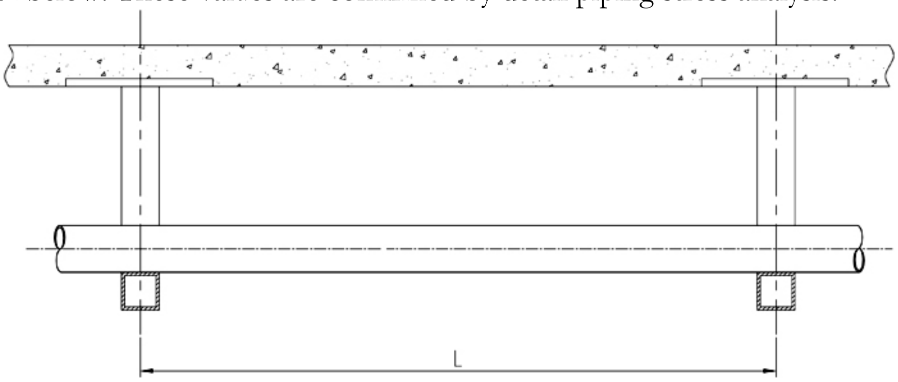


Figure 12.2-33 Span between pipe supports

DN	OD (mm)	WT (mm)	L insulated (m)			L not insulated (m)	
			e_{insul}(*)	Gas	Liquid	Gas	Liquid
6	10.2	2.0	50	0.8	0.8	1.3	1.3
8	13.5	2.3	30	1.1	1.1	1.5	1.5
10	17.2	2.9	30	1.3	1.3	1.8	1.7
15	21.3	3.2	30	1.6	1.5	2.0	1.9
20	26.9	4.0	30	1.9	1.8	2.3	2.1
25	33.7	4.5	30	2.2	2.1	2.6	2.3
32	42.2	5.0	30	2.6	2.4	3.0	2.6
40	48.3	5.6	30	2.8	2.6	3.2	2.8
50	60.3	6.3	30	3.3	3.0	3.6	3.1
65	76.1	7.1	30	3.7	3.4	4.0	3.5
80	88.9	8.0	30	4.1	3.7	4.3	3.8
100	114.3	8.8	40	4.7	4.1	4.9	4.3
125	139.7	10	50	5.2	4.5	5.5	4.7
150	168.3	10	50	5.8	5.0	6.1	5.2
200	219.1	10	50	6.7	5.2	7,1	5.4
250	273.0	10	50	7.5	5,7	7,9	5.8
300	323.9	10	50	8.3	6.0	8.7	6.1
350	355.6	10	50	8.7	6.1	9.1	6.3
400	406.4	10	70	9.1	6.2	9.8	6.4
450	457	10	70	9.5	6.4	10.5	6.8
500	508	10	70	10.0	6.6	11.2	7
600	610	10	100	11.0	6.8	12.2	7.2
700	711	10	100	12.0	7.0	13.4	7.4
800	813	10	100	13.0	7.2	14.5	7.6
900	914	10	100	14.0	7.4	15.4	7.6
1000	1016	10	100	14.8	7.6	16.2	7.6
1100	1118	10	100	15.4	7.6	17.0	7.8
1200	1220	10	100	16.0	7.8	17.6	7.8

(*) insulation taken into account to estimate the total pipe weight

Table 12.2-41 Non-seismic horizontal span between supports

12.2.15.2 Seismic horizontal spacing for pipes

The span for seismic spacing for stainless steel piping should be respected for a preliminary design as indicated in **Table 12.2-42** below:

DN	OD (mm)	WT (mm)	L insulated (m)			L not insulated (m)	
			$e_{insul(*)}$	Gas	Liquid	Gas	Liquid
6	10.2	2.0	30	0.6	0.6	0.8	0.8
8	13.5	2.3	30	0.8	0.8	1.0	1.0
10	17.2	2.9	30	1.0	1.0	1.1	1,1
15	21.3	3.2	30	1.1	1.1	1.2	1.2
20	26.9	4.0	30	1.3	1.3	1.4	1.4
25	33.7	4.5	30	1.5	1.4	1.6	1.5
32	42.2	5.0	30	1.7	1.6	1.8	1.7
40	48.3	5.6	30	1.8	1.8	1.9	1.8
50	60.3	6.3	30	2.1	2.0	2.1	2.1
65	76.1	7.1	30	2.4	2.3	2.5	2.3
80	88.9	8.0	30	2.6	2.5	2.7	2.5
100	114.3	8.8	40	3.0	2.8	3.0	2.8
125	139.7	10.0	50	3.3	3.1	3.4	3.1
150	168.3	10.0	50	3.6	3.4	3.7	3.4
200	219.1	10.0	50	4.2	3.7	4.3	3.7
250	273.0	10.0	50	4.7	4.1	4.8	4.1
300	323.9	10.0	50	5.1	4.4	5.3	4.5
350	355.6	10.0	50	5.4	4.4	5.6	4.5
400	406.4	10.0	70	5.7	4.7	6.0	4.8
450	457	10.0	70	5.7	4.8	6.3	5.1
500	508	10.0	70	6	4.9	6.7	5.2
600	610	10.0	100	6.6	5.1	7.3	5.4
700	711	10.0	100	7.2	5.2	8.0	5.5
800	813	10.0	100	7.8	5.4	8.7	5.7
900	914	10.0	100	8.4	5.5	9.2	5.7
1000	1016	10.0	100	8.9	5.7	9.7	5.7
1100	1118	10.0	100	9.2	5.7	10.2	5.8
1200	1220	10.0	100	9.6	5.8	10.5	5.8

(*) insulation taken into account to estimate the total pipe weight

Table 12.2-42 Seismic horizontal span between supports

12.2.15.3 Non-seismic vertical spacing for piping

The span for non-seismic vertical spacing for stainless steel piping should be respected for a preliminary design as indicated in **Table 12.2-43** below:

DN	OD (mm)	L (m)		DN	OD (mm)	L (m)
6	10.2	1		200	219.1	6
8	13.5	1		250	273.0	7
10	17.2	1		300	323.9	7
15	21.3	2		350	355.6	7
20	26.9	2		400	406.4	7
25	33.7	2		450	457	8
32	42.2	3		500	508	8
40	48.3	3		600	611	8
50	60.3	3		700	712	8
65	76.1	4		800	813	8
80	88.9	4		900	914	8
100	114.3	5		1000	1016	10
125	139.7	5		1100	1118	10
150	168.3	6		1200	1220	10

Table 12.2-43 Non-seismic vertical span between supports

12.2.15.4 Seismic vertical spacing for piping

The span for seismic vertical spacing for stainless steel piping should be respected for a preliminary design as indicated in **Table 12.2-44** below.

DN	OD (mm)	L (m)		DN	OD (mm)	L (m)
6	10.2	1		**200**	219.1	4
8	13.5	1		**250**	273.0	5
10	17.2	1		**300**	323.9	5
15	21.3	1		**350**	355.6	5
20	26.9	2		**400**	406.4	5
25	33.7	2		**450**	457	6
32	42.2	2		**500**	508	6
40	48.3	3		**600**	611	6
50	60.3	3		**700**	712	6
65	76.1	3		**800**	813	6
80	88.9	3		**900**	914	6
100	114.3	4		**1000**	1016	8
125	139.7	4		**1100**	1118	8
150	168.3	4		**1200**	1220	8

Table 12.2-44 Seismic vertical span between supports

12.2.16 Valves Integration/Location

General Valve recommendations (GV):

1. The valve must be positioned so that it is well placed for personnel to dismantle.

2. The vertical position should be used.

3. Dismantling of heavy valves should be only vertically.

4. The best location of the hand wheel is at chest height of the workers.

5. The main parameters for the valve arrangement are:
   - The orientation of the pipe supporting the valve,
   - The direction of the stem.

The integration of the valves shall follow the **Figure 12.2-34**.

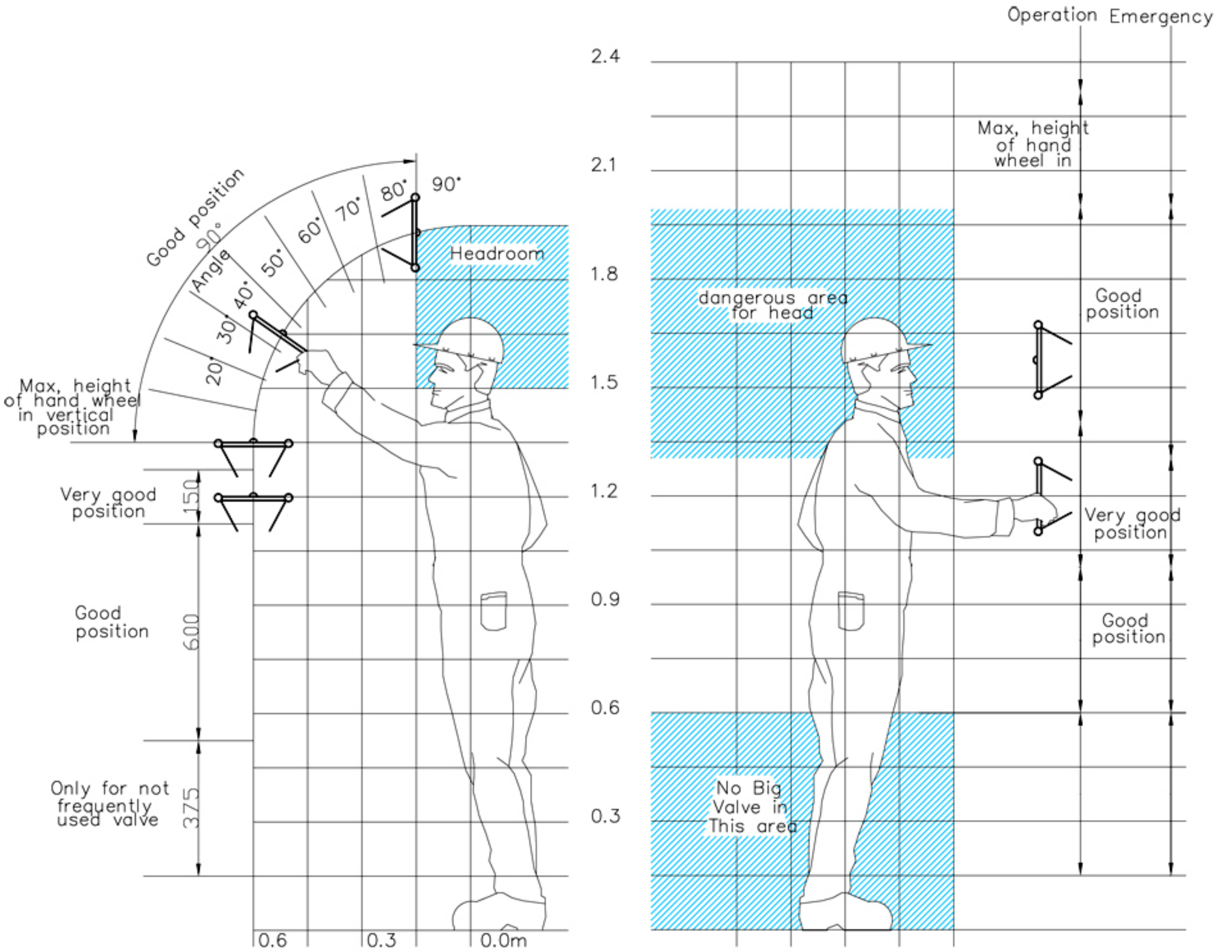


Figure 12.2-34 Valve location for operation and maintenance

Type of valve	Valve Orientation	Stem	Comment
Butterfly valve	Horizontal/vertical	Horizontal	Stem in downward direction to be avoided
Globe valve	Horizontal/vertical	Vertical/Horizontal	Stem in downward direction to be avoided
Gate valve	Horizontal	Vertical	Stem in downward direction to be avoided
Check valve	Horizontal only	Cover in upper position	

Table 12.2-45 Orientation of different valve types

6. Check valve: The minimum clearance distance is 500mm between the top of the valve and the ceiling. This space reservation is necessary for the dressing machine.

12.2.17 Tritium Piping Requirements

To be defined

12.2.18 Vacuum Piping Requirements

Tube will be used instead of pipe up to OD159.

Table 12.2-46 below shows the possible fittings and flange connections.

OD (inch)	OD (mm)	Double ring	VCR	ISO-KF flange	ISO-LF flange
1/4	6.35				
3/8	9.57				
1/2	12.7				
3/4	19.1				
1	25.4				
1 ½	38.1				
2	50.8				
3	76.2				
4 ¼	108				
6 ¼	159				

Table 12.2-46 Preferred tube size for vacuum

Recommended connections.

12.2.19 Cryoline Piping Requirements

1. Use of hanger rod is forbidden for supporting a pipe with an expansion bellow.

2. No pipe can be connected on the expansion below.

3. The number of elbows and welding should be kept as low as possible.

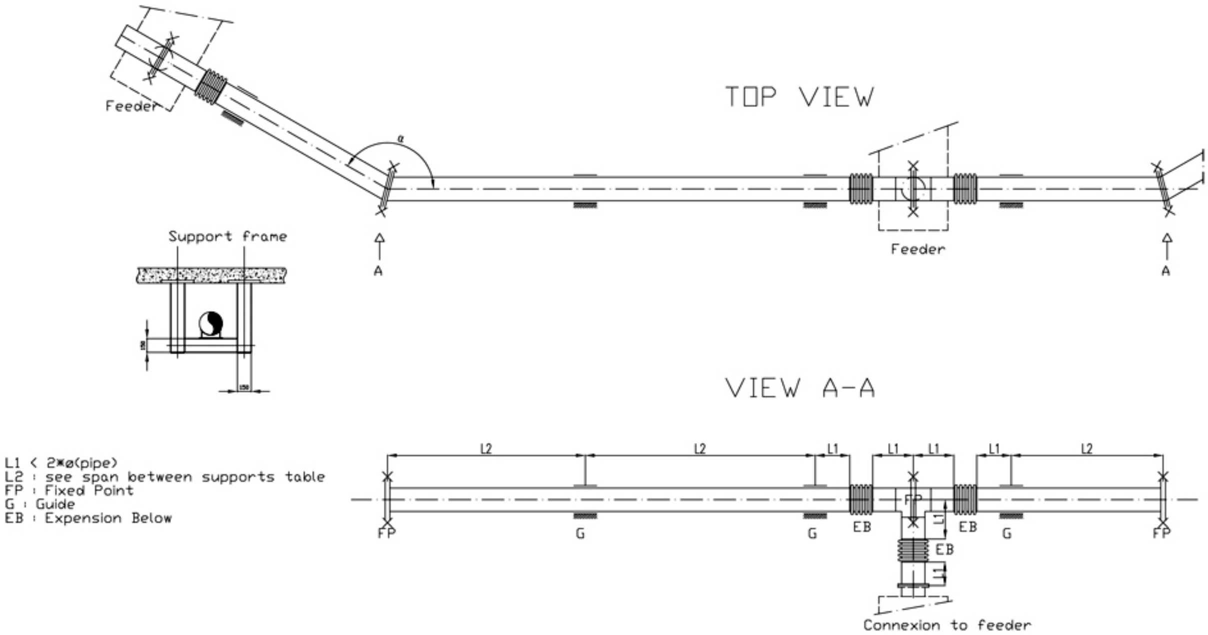


Figure 12.2-35 Support rule for Cryolines

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Report

Leak Testing Policy Document

The scope of this document is to define the roles and responsibilities, methodology and management requirements pertaining to leak testing of vacuum components for use on the ITER project.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Worth L.**	**11 Jun 2014:signed**	**IO/DG/DIP/PSE/FCED/VS**
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Reviewers	**Iseli M.**	**11 Jun 2014:recommended (Fast Track)**	**IO/DG/SQS/NSLE/SAA**
Previous Versions Reviews	**Jourdan T.** **Pearce R.**	**05 Jun 2014:recommended v2.0** **26 May 2014:recommended v2.0**	**IO/DG/SQS/QA** **IO/DG/DIP/PSE/FCED/VS**
Approver	**Orlandi S.**	**17 Jun 2014:approved**	**IO/DG/DIP/PSE**
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Read Access	**RO, project administrator, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: IC_OMPE_WG, AD: Section - Vacuum - EXT, AD: Section - Vacuum, AD: Auditors, AD: ITER Management Assessor**		

Change Log				
Title (Uid)	***Version***	***Latest Status***	***Issue Date***	***Description of Change***
Leak Testing Policy Document (L5P5P2_v2_1)	v2.1	Approved	11 Jun 2014	Updated text with comments from SQS accepted
Leak Testing Policy Document (L5P5P2_v2_0)	v2.0	Approved	26 May 2014	Final Version – replaced “critical” with “key” Slight modification to requirements “nuclear regulator” replaced with “Nuclear Safety Authority”
Leak Testing Policy Document (L5P5P2_v1_2)	v1.2	Signed	19 May 2014	Document updated to reflect comments from review. Policy simplified – no change to requirements or definitions.
Leak Testing Policy Document (L5P5P2_v1_1)	v1.1	Revision Required	24 Apr 2014	Updated as a result of internal review. Once agreed this document will form the basis of the IO leak testing surveillance plan to be developed by PBS 31. It is intended that the leak testing surveillance plan will become part of the MQP documentation to be referenced in system specific surveillance plans.
Leak Testing Policy Document (L5P5P2_v1_0)	v1.0	Signed	24 Oct 2013	

Document Defining the Requirements and Policy for Leak Testing ITER Vacuum Components with respect to Safety and Machine Operations.

Contents

1 Terms and Acronyms

The terms and acronyms, with contextual meaning, which are used throughout this document, are provided in Table 1.

Term/acronym	Contextual meaning
Key Leak Test	A key leak test is a leak test required to demonstrate that a component or system, can meet the leak rate performance required for plasma operations and that the components, or system, can meet its confinement function with respect to leak tightness
Confinement	Confinement is the term used for the physical enclosure of hazardous substances (e.g. tritium)
DA	Domestic Agency
External Intervener	Entity other than the Operator, or its employees, who supplies a PIC. This includes the DAs, Subcontractors (to either the DAs and/or the Operator) and External Service Providers
External Service Provider	Entity, not the Operator, performing surveillance
FAT	Factory Acceptance Test(s) – test required to demonstrate that the component or system meet its specification and can be accepted for delivery to the IO.
IO	ITER International Organization
MIP	Manufacturing Inspection Plan
Operator	The operator of the basic nuclear facility. In this context the IO is the Operator
PIA	Protection Important Activity – Activity required to qualify the PIC for its safety function (e.g. helium leak test to confirm the confinement function of a vacuum boundary)
PIC	Protection Important Component – Component performing a safety function (e.g. a confinement boundary)
Witness	Observe surveillance of the test being performed

Table 1 Terms and acronyms

2 Scope

The scope of this document is to;

- Outline the requirements pertaining to the leak testing of vacuum components.
- Define key leak tests in the context of the IO.
- Define the IO policy regarding the leak testing of vacuum components for use on the ITER project.

3 Requirements

Vacuum leak testing is required to demonstrate that a component or system, can meet the leak rate performance required for plasma operations and that the components, or system, can meet its confinement function with respect to leak tightness.

3.1 Vacuum Requirements

To meet the vacuum requirements for machine operations the acceptable leak rates through vacuum boundaries are defined in the ITER Project Requirements [1] and specifically in the ITER Vacuum Handbook [2]. By satisfying the leak rate requirements as specified [2] it is implicit that the safety requirement concerning leak rates through a confinement boundary can be satisfied.

3.2 Key Leak Tests

A key leak test is defined as a leak test required in order to demonstrate that a vacuum boundary meets the IO Project Requirements [1].

3.3 Regulatory Requirements

As defined in the Order of 7th February 2012 establishing the general rules for basic nuclear installations [3] components which perform a safety function (e.g. provide confinement) are classified as Protection Important Components (PIC). The Order [3] requires that the safety function of a PIC is qualified by analysis and or test. Vacuum components which, in accordance with the ITER Vacuum Handbook [2], must perform a confinement function are PIC.

Qualification of vacuum a boundary which performs a confinement function is defined under the scope of the Order [3] as a Protection Important Activity (PIA).

Under the scope of the Order [3] the Operator must perform surveillance of a PIA.

The Operator may contract external support for surveillance of a PIA to an external service provider but may have to justify this outsourcing to the Nuclear Safety Authority. This justification shall include the reasons why the surveillance of the PIA is to be outsourced, demonstrating that the operator keeps the responsibility and retains the expertise required to ensure control and include a surveillance plan which details the management of the outsourced task and steps to ensure compliance of the PIA with the Order [3].

All PIA leak tests are deemed key.

4 IO Leak Testing Policy

The following leak tests have been defined as key, surveillance of these leak tests is the responsibility of the IO:-

- Leak tests on vacuum components used to qualify a PIC or a PIA.
- Leak testing as part of the Factory Acceptance Test (FAT) of a vacuum component at External Interveners premises.
- Leak testing on delivery at the IO site of vacuum components in compliance with section 25 of the ITER Vacuum Handbook [2].
- Installation leak testing of vacuum components on integration with ITER systems .

4.1 Leak Tests on Vacuum Components to Qualify a PIC or a PIA

The procedures for these key leak tests shall be developed to show that, on execution, the test will demonstrate the performance of the vacuum boundary with the required sensitivity and that the minimum acceptance leak rate is measurable.

4.2 Leak Testing as part of the Factory Acceptance Test (FAT)

Component vacuum boundaries shall be tested for compliance with the ITER Vacuum Handbook [2] prior to delivery to the IO site.

In the case where the entire vacuum boundary of the component can be qualified with a single leak test, this test shall be deemed key.

In the case where the entire vacuum boundary cannot be qualified with a single key leak test (i.e. the system is not complete) the leak tests that must be performed during manufacture to qualify the vacuum boundary are deemed key.

All key leak tests shall be identified in the component MIP [4] as key. The final acceptance of the component shall only be made by the IO on successful completion of all such tests.

4.3 Installation Leak Testing

All vacuum components shall be the subject of at least one leak test which is deemed key. Key installation leak tests shall be performed at the time of component installation or as part of the system integrated commissioning.

5 Bibliography

[1] Project Requirements (PR) (ITER_D_27ZRW8).

[2] ITER Vacuum Handbook (ITER_D_2EZ9UM).

[3] Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN (ITER_D_7M2YKF).

[4] Requirements for Preparing and Implementing a Manufacturing and Inspection Plan (ITER_D_22MDZD).

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MQP Level 3

Working Instruction for Manufacturing Readiness Review

This procedure defines the procedural requirements and methods for conducting a Manufacturing Readiness Review (MRR). In this document MRR designates both:
- the period of preparation of the review to the Authorization To Proceed (ATP) to manufacturing
- the review itself which supports the ATP at the end of the period

Approval Process			
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	Serra G.		**F4E (EU)**
Approver	**Okayama K.**	**16 Apr 2021:approved**	**IO/DG/CNST/CMO**
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Change Log			
Working Instruction for Manufacturing Readiness Review (44SZYP)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	28 Jan 2011	
v1.1	In Work	23 Feb 2011	Minor changes
v1.2	Disapproved	03 Jun 2011	Assigned Reviewers and Approver according to MQP. Added Form of MRR chit and Typical Process of MRR.
v1.3	Signed	26 Jul 2012	- update to comply with MQP Procedure Template - added acronyms list
v1.4	Signed	09 Aug 2012	- update to comply with MQP Procedure Template - added acronyms list
v2.0	Revision Required	08 Feb 2018	Update as per MQP doc Request VQ7WG4. All the document is updated on the latest MQP Documentation Template.
v3.0	Revision Required	09 Apr 2018	Integrated comments from reviewers in particular: - revised section 2: scope: removed reference to Level 2 (not yet approved); clarified scope (limited to manufacturing phase and prior to issue EWP) - revised section 3: definition: removed reference to " installation" - revised section 5: applicable references: rewording for clarifications. In particular relevant to "off-the-shelf" components and design phase status (shall be completed before MRR) - section 7.2.1 (clarification about MRR plan process; to be submitted 6 weeks before (instead of 4) and 7.2.2 (modification/clarification on Panel members with CIO representative added)
v3.1	Approved	11 Jun 2018	This version 3.1 is updated based on comments received from version 3.0 from CIO Deputy Head and from AGN for Design Control Consistency check
v4.0	Approved	18 Nov 2020	As per approved MQP doc Request - 3LGGNB, the main changes are: 1/ Update the chapter scope for the case of IO Works Contractor supplied SSCs 2/ Update the chapters 6 Responsibilities and 7.1 Flow chart about the approver of the MRR report (CAT-2093), 3/ update the chapter 7.2.5 Follow up action to specify the tracking of actions (OFI 2 of 2018 MA Internal audit) 4/ update the appendix 1 to integrate the specific PE/NPE requirements (action from 2020 QIA PE/NPE) 5/ update the list of references The draft with tracked changes is attached to the MQP doc Request - 3LGGNB.
v5.0	Approved	06 Apr 2021	The doc changed based on the doc request https://user.iter.org/default.aspx?uid=4G5HL7, but with the changes as provided by author as following: Section 2 – Deletion of text ; "Any manufacturing activities should be authorized by IO supported by the results of a MRR." Section 2 – "normal" MRR – text replaced by "MRR" Section 5.2 – "Not-critical systems" replaced by "Non-Critical components" – More accurate Section 6 – text modified; "The MRR Chair is responsible to prepare a MRR Report and propose a decision on start/stop work to the DA and IO." changed to "The MRR Chair in conjunction with the panel members is responsible to prepare a MRR Report and propose a decision on start/stop work to the DA or IO as appropriate." – Allows flexibility depending on level of control applied Section 6 – 2nd, 5th & 6th bullet points modified to refer "for Critical components where Full / Partial control by IO has been decided for the MRR

			– brings clarity and allows flexibility where no control applied Section 7.1 – text added below flow chart for clarity as follows ; “Note: The workflow above sets out the general steps to be applied to an MRR. Where necessary the above maybe complemented / further developed by a DA to align with their quality needs. The general provisions however shall be respected in terms of roles and responsibilities where IO has Full or Partial Control for component MRRs, unless specific derogation has been granted by the IO.” Section 7.2.3 & 7.2.4 – MRR Chair responsible for report issuance – text updated accordingly Section 7.2.5 – Responsibility for action follow up – text modified to allow flexibility / bring clarity Section 8 (a) – “Panel” changed to “Chair”

Table of Contents

1 Purpose

This procedure defines the procedural requirements and methods for conducting a Manufacturing Readiness Review (MRR).

In this document MRR designates both:

- the period of preparation of the review to the Authorization To Proceed (ATP) to manufacturing;
- the review itself which supports the ATP at the end of the period.

2 Scope

This document is a MQP level 3 procedure and implements the process requirements from section 3.5.1 ''Planning'' [2] related to ''Manufacturing, Assembly and Installation Process'' of QAP [1] as a level 3 document.

This document provides requirements and methods to implement MRRs of the ITER components, and if deemed appropriate system or subsystem. These process requirements are applicable to DAs (for in-kind procurements) and Suppliers (for in-cash contracts) and subcontractors who perform manufacturing activities.

In particular, in the frame of the ITER project, the ITER Organization (IO) is responsible towards the French Licensing Authorities for the different Protection Important Components (PIC) and, as such, needs to be involved in the approval of all PIC development phases.

Manufacturing Readiness Review (MRR) is the last review before manufacturing and if successful it gives the "go-ahead'' for start the manufacturing of the components as illustrated in the Fig.1.

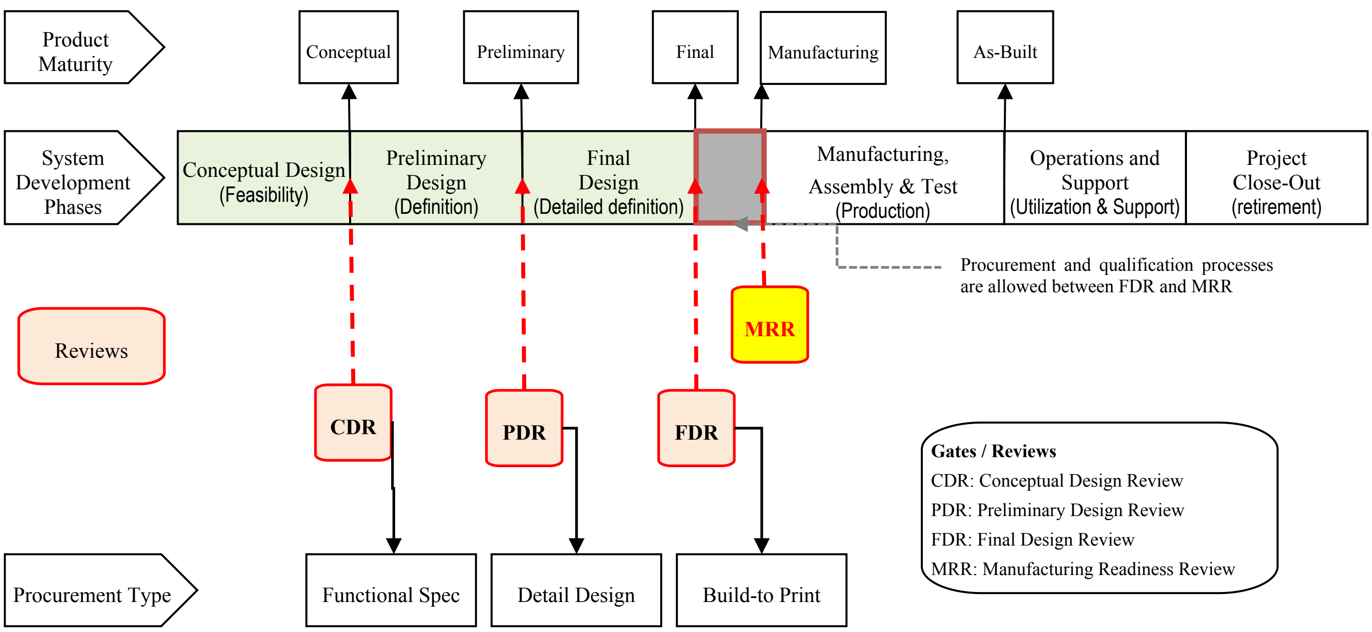


Figure 1 – System life cycle [3]

All MRRs (covering the full Manufacturing scope) should be identified in the IO-Design Review Plan with an indication of their importance (MRR or Simplified MRR), and if it is a Control Point for IO Hold Point (HP) or Authorization To Proceed Point (ATTP).

This procedure describes the general rules for MRRs and specific MRR procedures could be developed by the Project Teams or PBS to better adapt to their specific needs, provided they remain compliant with general provisions from this document including the IO's roles and responsibility.

Process and provision for Manufacturing Readiness Review and Acceptance of Construction Designs execution from BIPS-PT (ref. PBS 61/62/63/65) is covered by [4] and therefore is excluded from the present document.

MRR relates to manufacturing phase/fabrication activities undertaken prior to installation works on the IO site.

MRR can relate to IO DA supplied SSCs or IO Works Contractor supplied SSCs.

In the case of IO Works Contractor supplied SSCs (e.g. fabricated pipework spools intended for installation at the ITER site), the MRR shall be undertaken post issuance of Engineering Work Package (EWP) [5] documentation to IO Construction and review and acceptance / approval of Works Contractor documentation related to the SSCs to be manufactured.

3 Definitions and acronyms

3.1 Definitions

Component: the product to be manufactured as requested in the procurement documentation and that is subject of the MRR. It may be an individual or a group of components of the ITER Facility, and/or parts of components. It includes all requested spare components or parts.

''Delta'' MRR: a partial authorization to start Manufacturing up to defined manufacturing operations.

Manufacturing activities: all activities to be performed in order to manufacture the requested component until its delivery on site. These activities are:

- The fabrication including the acquisition and/or fabrication of all raw materials and parts to manufacture the components, and their assembly into the requested component;
- The inspection and testing [6] to be performed on the raw materials, parts and the manufactured component in order to demonstrate the compliance of the manufactured component with its technical criteria;
- The conditioning and packaging of the manufactured component for its storage and shipping to site including its preservation and handling.

Manufacturing activities requirements: a set of technical requirements that has been propagated from the technical criteria of the component to manufacture and that must be satisfied by the manufacturing activities to ensure that:

- The manufactured component meets their technical criteria at delivery on site (fabrication of the component).
- The technical criteria of the component are not impacted during the execution of their manufacturing activities (protection of the component).

Manufacturing/Fabrication: the processes (e.g. by machining, assembly, etc.) of converting raw materials, components, or parts into finished component that meet the technical criteria specifying its manufacturing design.

Manufacturing Readiness Review: a set of verification activities to be performed before the start of manufacturing activities in order to assure:

- The required activities are adequately and ready to be effectively performed according to approved documents;
- The relevant technical criteria of the manufactured component are specified in approved documents including for on-site storage, on-site assembly and installation, maintenance and preservation after installation, commissioning, operation and maintenance;

It should be noted that through this project gate review, the approved documents which are presented will become ***applicable*** *for the manufacturing phase after acceptance and* *authorization from IO. It is also important to note that even if some approved documents are preliminary version, it will be possible to revise it during the manufacturing process.*

Input Data Package: list of documents with their version number, submitted as input to the MRR (ref. Appendix 1)

Procurement documentation: the set of documents transmitted to the manufacturer of the component concerned by the MRR. This set includes:

- For the Domestic Agencies, the Procurement Arrangement Annex A (for project, process and quality assurance requirements), the PA Annex B (for the component technical requirement) and all their applicable documents;
- For IO's direct contractors, the Technical Specifications of the "In Cash Contracts" (ICP), and all their applicable documents;
- For the manufacturers (when different from above), the Technical Specifications of and all their applicable documents has developed by the DA or IO's direct contractors.

Technical criteria: a characteristic of the component to be manufactured that has been fully propagated during the manufacturing design phase completed prior to the MRR.

- Additional propagation or refinement of these requirements is not required regarding the manufacturing design.
- The criteria include, at the minimum, the component identification and number, classifications, dimensions and weights, materials, surface finish/roughness and cleanliness, handling/lifting features, and marking/label. Each characteristic is complemented as applicable with acceptance criteria and acceptable tolerances.
- Only the relevant technical criteria for the successful manufacture of the component are covered by the MRR, that are criteria that:
    - Will be implemented by the manufacturing activities (fabrication of the component);
    - May be impacted during the execution of the manufacturing activities (protection of the component).
- The identification of all the relevant technical criteria classified as ''Defined Requirements'' is mandatory.

3.2 Acronyms

Acronym	Definition
ATP	Authorization To Proceed
ATTP	Authorization To Proceed Point
DA	Domestic Agency
DR	Deviation Request (as defined in [7])
EWP	Engineering Work Package (as defined in [5])
FDR	Final Design Review (as defined in [8])
HP	Hold Point
ICP	In-Cash procurement contract
IO	ITER Organization
MN	Manufacturer Part Number
MRR	Manufacturing Readiness Review
NCR	Non-Conformance Report (as defined in [9])
PBS	Plant Breakdown Structure
PCR	Project Change Request
PIC	Protection Important Component (as defined in [10])
PNI	Part Number of ITER
QADH	Quality Assurance Division Head
QARO	Quality Assurance Responsible Officer
QC	Quality Class (as defined in [11])
QCRO	Quality Control Responsible Officer
PA	Procurement Arrangement
PARO	PA Responsible Officer
TRO	Technical Responsible Officer
SSC	Systems, Structures or Components
VCM	Verification Compliance Matrix

For a complete list of ITER acronyms and abbreviations see [12].

4 Reference Documents

[1] ITER Quality Assurance Program (QAP) (22K4QX)
[2] Manufacture, Assembly & Construction Planning Procedure (UYULNL)
[3] ITER Systems Engineering Management Plan (SEMP) (2F68EX)
[4] Working instruction for BIPS-PT Manufacturing Readiness Review and Issue of Recommendation for Acceptance of Construction Design by ITER Design Authority (S7HRYX)
[5] WI for Construction Preparation (EWP/CWP/IWP) (UYGEDA)
[6] Procedure for Inspection and Testing (TVL3Y5)
[7] Procedure for the management of Deviation Request (2LZJHB)
[8] Design Review Procedure (2832CF)
[9] Procedure for the management of Nonconformities (22F53X)
[10] Safety Important Functions and Components Classification Criteria and Methodology (347SF3)
[11] Quality Classification Determination (24VQES)
[12] ITER D_2MU6W5 - ITER Abbreviations (2MU6W5)
[13] Procedure for Identification and Controls of Items (U344WG)
[14] ITER Numbering System for Components and Parts (28QDBS)

[15] Requirements for Producing an Inspection Plan (22MDZD)
[16] Work instruction for Producing the Manufacturing & Inspections Plan (UKQG8M)
[17] PE/NPE - Manufacturing Design Controls for PE/NPE (WSJ6VM)

5 Basic Principles

IO as Final Customer and Nuclear Operator decides the level of control on the MRRs and ATPs, depending on the criticality of the project and as identified in IO-Design Review Plan, as follow:

- Full control: IO organizes the MRR and gives the ATP on the basis of this procedure;
- Partial control: IO gives the ATP on the basis of the results of an MRR organized by the DA or the IO-Contractor, using this procedure or an equivalent procedure (demonstrated by a compliance matrix), submitted to IO's for Acceptance for use before proceeding.
- No IO control: IO leaves the MRR and the ATP organization to the provider (DA or IO-Contractor)

MRR's goal is to enable IO (in the case of ICP) and, IO and DAs (in the case of PAs):

1. To confirm that the manufacture of the concerned component is ready to start without incurring unacceptable risks;
2. To give the authorization to proceed with manufacturing.

Each DA or IO's direct contractors for large/complete ICP contracts shall identify the MRRs to be undertaken taking into consideration the following parameters (not exhaustive):

- Size, number and complexity of the component to be manufactured;
- Number of manufacturers used for the PA and ICP contract;
- The graded approach defined by IO, the DA and/or direct contractor.

The outcome of this activity is:

- The number of MRR to be performed per PA/ICP;
- For each MRR, the concerned component(s) and manufacturer(s);
- Target dates for MRR.

A typical process for the preparation and execution of a MRR is shown in the Flow Chart Section 7.

A MRR shall only be executed after:

- the completion of the design phase of the concerned component, including the development of the manufacturing design with the appropriate integration of information from the selected manufacturer;
- the acceptance of the manufacturing design;
- the approval and authorization for use of all the documentation that constitute the Input Data Package for the MRR (see Appendix 1);
- all resources needed to proceed with manufacturing confirmed as are available.

A MRR shall be performed before fabrication starts and after the completion of the qualification phase unless otherwise agreed between IO and DA (in the case of PAs)

The MRR shall review the documents of the Input Data Package in order to verify that the appropriate manufacturing activity requirements have been defined in order to ensure that:

- The technical criteria of the component to be manufactured are not impacted during the execution of their manufacturing activities;
- The manufactured component meets its technical criteria at delivery on site.

It shall verify that all manufacturing activities have been planned and prepared to ensure that the work can be accomplished as specified.
The MRR shall also check that:

- Identification of components and parts will be achieved in consistence with MQP identification procedures [13], [14] during manufacturing
- Preservation has been studied (packing, packaging , handling, protection on site procedures)
- specific procedures and specifications have been prepared to define the installation conditions and tooling as well as maintenance and preservation and spares need after installation

These studies (identification, preservation, installation, maintenance) shall be achieved by the manufacturer with the support of its customer (DA or IO)

In particular the following general points shall be verified during a MRR:

(a) check appropriateness of area and working facilities;

(b) check availability of materials and 'off-the-shelf' datasheets to start work and their compliance to applicable specification and with appropriate traceability;

(c) check availability and approved status of the relevant drawings, including required tolerances, to start work and their compliance to applicable specification;

(d) check availability and approved status of applicable quality and manufacturing documentation (e.g. Quality Plan, Manufacturing Inspection Plans, Non-destructive testing protocols, Welding data package, Process qualification records, etc.)

(e) check availability and appropriateness of machine & tooling and the approval status of manufacturing procedure compliant with manufacturing process qualifications as may be applicable;

(f) check availability and appropriateness of personnel in term of qualifications and number, as may be applicable;

(g) verify by direct evaluation of manufacturing process, facilities, and personnel whether manufacturer has capability to ensure quality of product within required schedule;

(h) verify approval status of all documents and records as appropriate, (e.g. manufacturing procedures, qualification report/certificate, etc.) confirming that manufacturing processes conform to specified (PA or ICP) requirements;

(i) check all documents and records are designated properly with contract / job number, concerned product number, etc.

(j) check availability and use of applicable documentation including standards and codes;

(k) verify by examination of plans and documents whether a suitable QA/QC program has been developed to ensure production monitoring;

(l) check configuration status including NCR and Deviations and Design changes status which should be closed;

(m) check the requirements propagation by VCM fulfilment as specified in 5.1.6

(n) Verify the identification of:

  (i) All the manufacturing activities classified as Protection Important Activity, with their Defined Requirements and imposed Technical Controls and criteria/tolerances.

  (ii) All the relevant technical criteria classified as Defined Requirements.

(o) check of subcontracted operations.

Objective is to:

(i) verify approval status of the manufacturing documentation (ref. Annex 1);

(ii) verify approval status of the preservation documentation (packing, packaging, on-site storage, on site protections);

(iii) verify approval status of installation and maintenance documentation

(iv) making sure that all requirements are considered ant that VCM is fulfilled with evidences

(v) approve or reject the start of manufacturing.

The MRR needs to take into account the graded approach, so that the products that are considered Critical for the ITER project (e.g. the system contains component PIC and/or QC1 or QC2; components or systems that have a relevant financial impact/cost; products that have a complex manufacturing process and involve the different specialities and special processes; Pressure Equipment and/or Nuclear Pressure Equipment) are given high priority.

The necessity and decision on MRR application shall be established during the contract's preparation (PA's or ICP as applicable) with the definition of Control Points. In case of ''off-the-shelf components'' (e.g. raw materials already available from the market / commercial item form manufacturer's catalogue) derogation from MRR execution could be accepted as specified in the relevant contract.

In case a system is not considered Critical (e.g. it does not contains PIC component or QC1 or QC2) implementation of a "simplified MRR" could be agreed with IO as described in Subsection 5.2.

All MRR meetings shall be conducted in a formal way. The comments from the reviewers shall be recorded and related actions shall be tracked.

In case of any need of change detected during an MRR and depending by criticality of impact of this change on design requirements a DR or a PCR shall be issued.

Note: In case of possible issues identified during the MRR the manufacturing shall be "ON HOLD" or may be partially authorized highlighting any outstanding obligation.

In some cases MRRs may be split (''Delta'' MRR) in time for schedule optimization due to phased manufacturing. In this case the criteria above could be applied to the partial MRRs.

5.1 MRR General Content

The MRR shall cover:

5.1.1 Material

- Manufacturing environmental conditions meet product technical requirements (e.g. temperature, humidity, cleanliness class, ventilation, segregation from other material, etc.).
- Production materials used for ITER project are correctly procured, qualified, inspected and stored. Compliance with contractual requirement is confirmed and all material (raw, finish goods, nonconforming product, etc.) are well controlled in production line.
- Appropriate procedure/system for assuring material identification and traceability.
- All products designed for manufacturing shall be designated with type reference codes, i.e. PNI and/or MN.

5.1.2 Personnel

- Personnel who work for ITER project have been trained and evidence that IO requirements, as imposed through the contract documents, are understood is available. Personnel are qualified as may be applicable. In particular the qualified operators for special process (e.g. welding, heat treatment, NDE) are available and sufficient number of resource is allocated.

5.1.3 Machines and Tools

- Machines, jigs, measuring and testing equipment used for IO are qualified and valid for usage, e.g. the equipment list is in place, the maintenance plan is established, the calibration is kept valid, etc.
- Processes: specific manufacturing processes (e.g. heat treatment, welding, coating, cleaning, bending, forming, etc.) have been qualified as may be applicable.

5.1.4 Manufacturing methods

- Check documents relevant to ITER project are approved or accepted by IO as may be applicable (e.g. Quality Plan, the MIPs, manufacturing procedures, the work instructions, manufacturing drawings, etc. including all changes affecting the system).
- Check documents stating compliance of manufacturing processes, facilities and personnel (including applicable approval and qualifications) and whether manufacturer has capability to ensure quality of product within required schedule.

5.1.5 Transportation and ITER site activities

- Check documents describing packing, packaging, transportation, handling and protection on ITER site
- Check relevant documents detailing installation and maintenance on ITER site and particularly specific tooling and spares when needed.
- Check Planned Delivery List describing all items or groups of items to be delivered. Where all items listed in the list designated with PNI's and/or MN.

This specific part of the studies are performed by the IO TRO in case of ICP or DA coordinator in case of PA with the manufacturer inputs

5.1.6 Requirements

- A specific matrix is built for the component to manufacture (DA coordinator or IO TRO) with all the requirements and the evidences coming from the previous design review (FDR) – that is the Verification Compliance Matrix (VCM)
- Check additional technical criteria generated by the manufacturer studies
- Check ITER site activities requirements (preservation, installation, maintenance)
- Check evidences provided by the manufacturer to fulfil all the requirements

All these verification may be done by documentary review and check and/or through on-site verification at manufacturer's premises as may be more appropriate. Adequate traceability and record shall be ensured.

5.2 Simplified MRR

In case of Non-Critical components (e.g. non-PIC component or QC1 or QC2), a "Simplified MRR" process, with no meeting but only review of documents, could be agreed with the IO:

- MRR Responsible party (DA in case of PA or Contractor in case of ICP) shall issue an MRR Plan containing the List of document of the input data package and a detailed checklist of elements to be checked.
- Needed elements are requested from and provided by the Manufacturer.
- DA coordinator and/or IO TRO review the elements described in the MRR Plan and issue final MRR report to give ‘go-ahead’’ or stop decision.

6 Responsibilities

DA in case of PA or the contractor/supplier in case of IO direct contract is responsible for preparation, implementation, and follow-up action of MRR.

IO and DA in case of PA or IO in case of ICP shall select MRR panel members on key MRR identified by IO and designate a chair and a secretary for each of those MRR.

The MRR Chair in conjunction with the panel members is responsible to prepare a MRR Report and propose a decision on start/stop work to the DA or IO as appropriate.

The Manufacturer shall provide all requested information and evidences as requested by the MRR panel and described in MRR plan in order to evaluate and confirm manufacturer readiness including manufacturing area/facilities, machine/tooling, personnel, material, procedure approval status and manufacturing and process qualifications as may be applicable. In particular the Manufacturer shall provide a detailed manufacturing scheduling and approved inspection plan [15].

IO shall be responsible for controlling and supporting DA’s or Supplier/Contractor MRR.

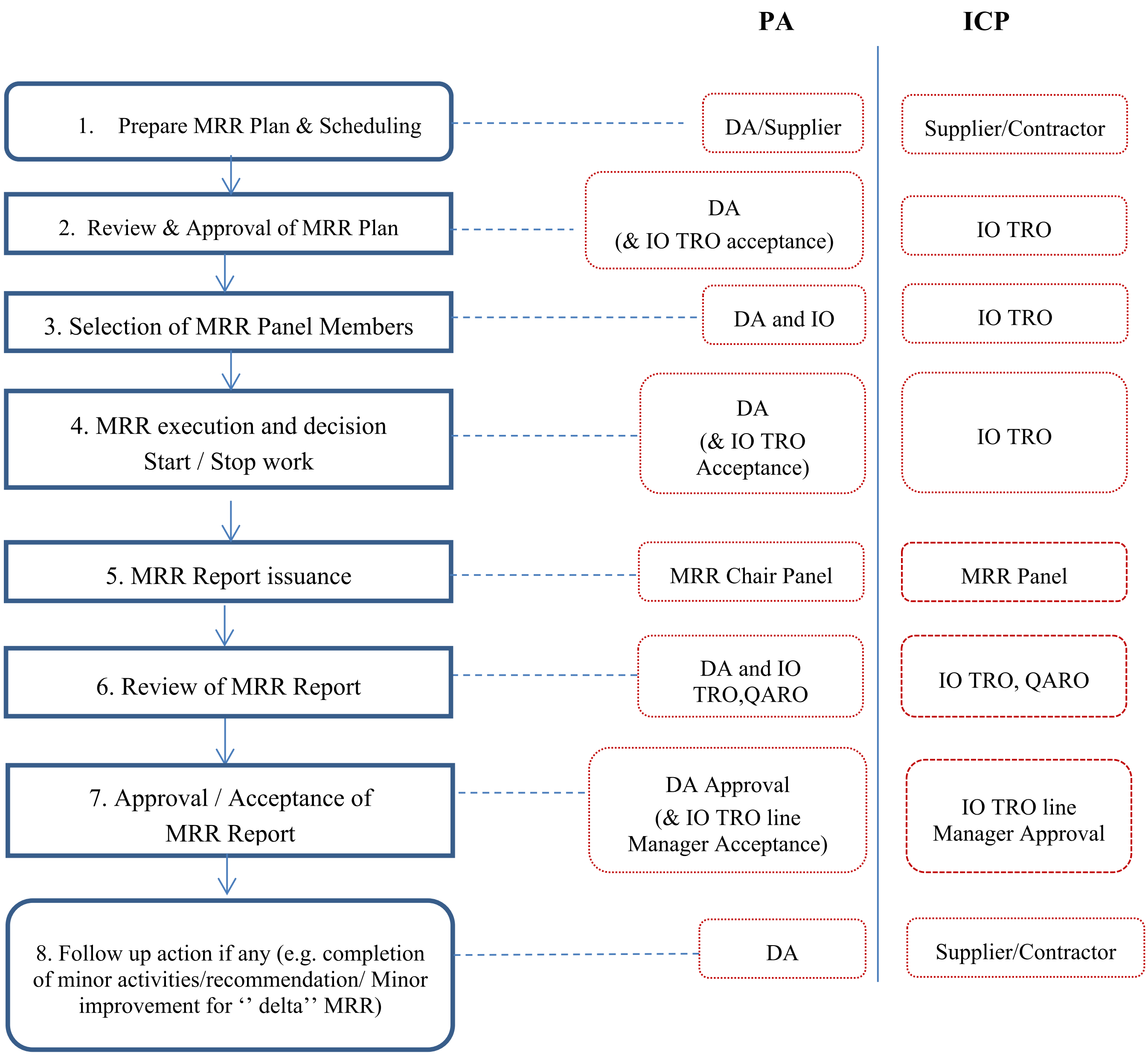
In particular, IO TRO shall:

- Participate in MRR meetings for PIC, Quality Class1, and Quality Class 2 SSCs.
- Review the MRR Plan and MRR Report for Critical components where Full / Partial control by IO has been decided for the MRR
- Be involved in preservation, installation, maintenance studies
- Check the VCM to ensure that all requirements are propagated with related evidences
- The IO QARO should be involved in the review of the MRR plan for Critical components where Full / Partial control by IO has been decided for the MRR and shall review MRR Report to verify adequacy of quality requirements.
- The IO TRO line Manager (e.g. Division Head or Section Leader) shall accept / approve the MRR Report for Critical components where Full / Partial control by IO has been decided for the MRR

7 WORKFLOW

7.1 Flow chart

The MRR workflow is presented below splitting responsible in case of PA and in case of ICP.



Note: The workflow above sets out the general steps to be applied to an MRR. Where necessary the above maybe complemented / further developed by a DA to align with their quality needs. The general provisions however shall be respected in terms of roles and responsibilities where IO has Full or Partial Control for component MRRs, unless specific derogation has been granted by the IO.

7.2 Description

Main steps for MRR implementation as listed in the workflow are described here below:

7.2.1 MRR Plan and scheduling

In the frame of MRR plan preparation or before, the MRR responsible party (the DA or the supplier/contractor) should perform a visit to the manufacturer facilities and subcontractor's facilitates whereas appropriate (e.g. execution of critical operations) in order to verify the manufacturing work area, materials traceability, equipment's and machines, personnel qualifications and resources availability are suitable to accomplish the work in accordance with the applicable requirements.

Prior to performing a MRR, the MRR responsible party, in conjunction with IO, shall prepare a MRR Plan that identifies:

- scope (list of PBS) of the MRR with applicable PA and/or contract documents
- list of equipment in the scope
- MRR panel members and their roles and responsibilities
- Qualification of the Chair
- sub-supplier organization involved in the MRR
- Input data Package: list of documents and items needed to be assessed
- schedule of the MRR
- previous MRR details, if applicable

A MRR pre-meeting may be held by DA, IO and suppliers (for in cash contracts) to prepare the MRR outline or to review adequacy and effectiveness of the proposed MRR Plan.

MRR responsible party shall submit the completed MRR Plan to IO for acceptance at least 6 weeks before the MRR scheduled date.

IO shall review the MRR Plan and provide written comments, if any, to MRR responsible party for resolution and agreement with IO before MRR execution.

Upon IO acceptance of the MRR plan, involved organizations and MRR Panel members shall be notified at least 2 weeks before the MRR is conducted. This notification should be in writing and include information such as the scope and schedule of the MRR, MRR Panel members and complete set of documents to be assessed.

If it is found that a scheduled MRR date cannot be met after the approval of MRR plan, upon written request from DA TRO or Contractor Responsible as may be applicable, IO TRO may authorize a reasonable extension.

7.2.2 Selection of MRR panel members

The MRR panel consists of a Chair and selected experts.

MRR Panel Chair shall be a technical and managerial qualified person who is in charge for:

a) Approve the charge for the review by the TRO
b) Propose name of members for the review panel
c) Approve the meeting(s) agenda
d) Ensure that participants understand what is required to them
e) Ensure that sufficient time is allocated for review activities
f) ensure that the meeting's input package is issued to designated persons;
g) assign tasks to participants in preparation for meetings;
h) chair the review meeting, moderate the discussions ensuring that the focus stays on the manufacturing readiness assessment and that all attendees may provide their input and try to reach consensus in the review team in case of differences of opinion. If consensus cannot be reached, forward minority as well as majority view(s) for decision in the Manufacturing Readiness Review Panel Report;
i) ensure that relevant issues from the meeting are recorded;
j) ensure that actions and recommendations from earlier meetings have been satisfactorily addressed and closed, as appropriate;
k) review and approve the minutes of meeting;
l) ensure that the minutes of meeting are issued to all participants.
m) coordinate the development of Manufacturing Readiness Review Panel Report with the Panel members and approve the report.

In addition to the Chairperson, appointed members should be QARO, SRO, CIO and CST representative and experts as may be proposed by DA, where applicable, and agreed by IO in accordance with the scope of the review. In case of PAs the IO TRO shall be part of the MRR Panel.

The MRR panel members shall be selected considering the type of system or component to be reviewed, its safety and quality classification, and the manufacturing techniques to be used. While selecting MRR Panel members, a special knowledge, prior experience, and education shall be considered. The nature of the MRR may require the assistance of technical specialists. If so, specialists shall be involved in the MRR.

For MRR on PIC, QC1, and QC2 SSCs, the Chair and the Panel shall be independent from the manufacturing design development i.e. not belonging to the Manufacturer's organization.

7.2.3 MRR execution

The MRR panel shall conduct the MRR under the direction of the Chair and in accordance with the approved MRR Plan:

- Prior to starting the MRR, each panel member shall develop a clear understanding of the scope of the MRR, the reliability aspects of the work scope, the requirements and rules applicable to the work to be reviewed, and the communication and reporting agreements made with the organization responsible for performing the work.
- Checklist shall be used and completed. However, a checklist should not preclude the opportunity to verify manufacturing readiness which may have the potential to yield problem. Nor should the checklist prevent the immediate follow-up of an important or significant concern.

IO external expert may participate in MRR for PIC, QC1, and QC2 SSCs. The responsibility for IO external expert is to audit/oversee the process and not to give any Authorization To Proceed.

If any significant conditions adverse to quality are identified, the Chair shall immediately notify to IO TRO of that condition by telephone and/or e-mail. IO TRO shall consult with IO QADH and the appropriate managers as may be the case (e.g. Depending on the pending issue: CST for site activities; CIO for integration and requirements propagation; TED and PED for condition related to the design; etc.)

Results of the MRR shall be documented on the checklist by MRR panel, if applicable.

At the end of the MRR, a time slot should be allocated for the Chairman to debrief MRR meeting's outcome to responsible managers of the applicable organizations and inform if the MRR is successful meaning that nothing is preventing the ATP to be given.

It is IO to give ATP in case of IO Control Point.

Upon the completion of the MRR, DA in conjunction with MRR panel members shall summarize the MRR results in a formal Manufacturing Readiness Review Panel Report.

The Manufacturing Readiness Review Panel Report shall contain the following

- scope of the MRR with applicable PA and/or contract documents;
- MRR panel members;
- Input data Package;
- summary of MRR results and action items to be taken and schedule, if applicable;
- completed checklists;
- appraisal of the review by the Chair, and recommendations for ATP.

MRR Chair shall forward the completed and approved MRR Panel Report to IO TRO for acceptance. The Acceptance of the MRR Panel report constitutes the ''Authorization To Proceed''.

IO is in charge for review and acceptance of the MRR Report as follows:

- IO TRO and any other assigned reviewer (e.g. IO QARO, IO SRO) shall review the report and IO TRO shall accept the Report or reject it notifying his comments.
- The report shall be distributed to applicable organizations within IO for information.

7.2.4 MRR conclusion and final report

Scope of MRR is to confirm or not authorization to start manufacturing.

The MRR Chair (supported by the Panel) shall issue a formal report including recommendations to be carried out along with a clear recommendation on the following possible outcomes:

(i) Successful: there is no objection to deliver the ATP (manufacturing can start).

(ii) Unsuccessful: manufacturing start shall be placed " On HOLD'' until resolution of detected major issues. MRR shall be repeated once available evidences of resolution of detected major issues.

(iii) Conditionally Successful upon the completion of certain minor activities by the Manufacturer in order to comply with a specific recommendation.

(iv) Start of manufacturing activities should neither be stopped nor held unless a major issue is detected. A partial authorization to start could be provided (up to defined manufacturing operation) and a ''Delta'' MRR could be considered at a later date in order to give the opportunity to the Manufacturer to improve the maturity of the manufacturing documentation (any contractual impacts are out of scope of this document) and resolve minor issue, if any.

(v) After due consideration of the MRR conclusions, the IO TRO shall decide the start or otherwise of the manufacturing activities. In case of discrepancy between the IO TRO decision and the MRR conclusions, the IO TRO decision shall be endorsed by the IO QARO and by his/her direct line of management.

7.2.5 Follow-up Action

Prior to the start manufacturing, DA and/or Contractors in case of direct contracts as may be applicable shall resolve unacceptable quality conditions or lack of preservation, installation, and maintenance activities description, resulting from the review. A chit list shall be issued in this case to ensure follow up and closing of all findings. Fabrication shall not start before relevant MRR requested actions are closed, unless otherwise agreed by the DA/IO as applicable depending on the Level Of Control applied to the MRR, e.g. differently authorized by the IO TRO following the process described in Sect. 7.2.4 (v).

A graded approach needs to be used for documenting the open actions after the MRR. DA and/or Contractor shall notify the DA / IO TRO of status of follow-up actions on a periodic basis. The DA / IO TRO shall ensure follow up through periodic progress meetings. For Critical components the IO TRO shall be notified in all cases.

8 Outputs and Records

(a) The MRR Chair is responsible for issuing a MRR Panel Report with a clear recommendation on the outcome of the review.

(b) The IO TRO is responsible for notifying the MRR Panel and all concerned functions (e.g. Project Team; Technical Process Integration, etc.) on the final decision taken and for archiving all review records in accordance with project procedures including the charge, the Review Panel composition, attendees, presentation material, Review Panel reports, approvals to proceed, and declarations of review closure.

NCR, Actions, Checklist and MRR Plan and report shall be recorded in IDM in accordance with relevant process and defined tools.

Type of output	Format	Location of output	Document type	Instructions for identification of the output	Responsible for managing the output	Retention period
MRR Report	*Template*	*IDM PA/ICP folder*	*''R – Report, record, Certificate'' - MRR Report*	*MRR Report*	*IO TRO*	*Project Life*

ANNEX 1 – MRR Input Data Package

The checklists to be used for MRR shall be prepared consistently with importance and complexity of items to be manufactured and may take into account guidance provided in this Annex.

MRR input data package shall include management documents like the following (as a guideline because some documents can be grouped):

- Manufacturing Implementation Plan (covering description points at section 5.1)
- MRR Plan,
- Notification,
- Agenda,
- Presentation,
- Minutes of MRR meeting (record of what has happened during the meeting),
- Panel Report (comments and decisions)

In addition, list of document of the input data package shall be provided. Applicable documents, namely for instance procedure documents, welding documents, Codes, & Standards, tooling related documents, certificate of personnel should be submitted as attachments of Manufacturing Plans.

All documents should be uploaded in IDM (or PLM) or any other agreed tool allowing for review prior to a review meeting, with attendance from IO, DA and Suppliers as may be applicable. All the required documents shall be accepted by IO before manufacturing can commence.

In the frame of PA, the MRR list may be elaborated upon mutual agreement between the DA and the IO and included as part of the review. DA may request MRR Panel members to initiate the checklist relevant to their expert discipline.

Document list below is provided as general guide for required documents to be provided in Data Package for a MRR. This list has to be discussed in the frame of MRR plan review. The list provided here below does not intend to be complete and not all types of documents need to be provided for each MRR depending on item to be reviewed:

1. Engineering	
1.1	List of Deviation Requests if applicable
1.2	Manufacturing drawings (2D) and models (3D) *****
1.3	Assembly drawings at the shop *
1.4	Assembly drawings at the ITER site as may be applicable (e.g. for installation) *****
1.5	Parts and Material list, list of equipment and detailed Bill of material (if necessary)*****
1.6	List of standards, codes and regulations applicable for each step of manufacturing, assembly and integration
1.7	Item Identification & tagging and physical labelling procedure
1.8	Top assembly description and function
1.9	Load analysis as part of the manufacturing process (if necessary)
1.10	Design description and justification of transportation frames
1.11	List of deliverables to be provided by the Manufacturer / Manufacturer Dossier content
1.12	Verification Compliance Matrix (requirements and evidences)
2.Manufacturing processes	
2.1	Manufacturing and Inspection Plan
2.2	Manufacturing schedule and work flow/assembly sequences
2.3	Material procurement technical specification and sub-orders (including e.g. consumables whereas applicable)
2.4	Material management: - identification and control of material - material certificates - material traceability procedure - Storage conditions - Handling procedures
2.5	Manufacturing procedures including special processes (e.g. machining, forming, wiring, brazing, soldering, welding, cleaning, heat treating, others and non-destructive examination, etc.). E.g.: - components processing and assembly specification - cleanliness program - surface treatment program - pipeline inspection program - non-destructive testing program - labelling program (can be included into the tagging & labelling procedure) - coating program - preservation, packaging, storage and transportation program
2.6	Manufacturing working instructions

2.7	Welding data package - Welding procedures/welding Procedure Specification (WPS) - Welding procedure qualification record (WPQR) - Welding quality inspection and procedure plan (WQIPP) - Welding map - Cleaning procedure and requirements for welded parts / components with particular attention on welded joints forming parts of the vacuum boundary according to requirements of ITER Vacuum Handbook.
3.Test methods	
3.1	Control specifications, Testing plan and Test procedures (e.g. Pressure Test Procedure; Helium Leak test procedure; etc.)
3.2	Qualification through Mock-ups and prototype
3.3	Qualification of special processes
3.4	Manufacturing process qualification procedure
3.5	Manufacturing human resources and quality control procedure
3.6	NDE procedures and templates
3.7	Factory acceptance test program identifying all factory acceptance tests as defined at design stage and including details on extent of the tests, type, examinations and inspections of the Items(verification of requirements for acceptance stage)
4.Quality acceptance	
4.1	Quality Plan
4.2	List of Suppliers/Subcontractors and their attributions
4.3	DA, Suppliers and Sub-contractors Quality Plans
4.4	Agreed/Notified Bodies approvals or other third party (where applicable)
4.5	MRR deliverables list (list of documents deliverables to be provided by the Manufacturer)
4.6	Other applicable and/or available documents relevant to manufacturing quality acceptance
5.Tooling	
5.1	List of machines, test equipment and tools including relevant calibration protocols: - the calibration status and records of the machines and tools - Measuring and test equipment qualification and maintenance - Requirements regarding special tooling / spares and any special pieces of equipment or tools needed for packaging, handling, storage, transportation and installation at ITER site.
6.Training and qualification	
6.1	- list of personnel qualifications to perform a special process as may be applicable - list of qualified welders, welding equipment operators, NDE personnel - training records and certificates
7.Transportation and preservation	
7.1	- Packing and packaging procedure - On site preservation procedure - planned delivery list *
8.Installation and Maintenance	

8.1	- Installation and User manual including tooling - Maintenance plan
9. ITER Manufacturer of PE / NPE	
9.1	When ITER acts as Manufacturer of PE/NPE, in accordance with "*Implementation Plan for design and manufacture of PE/NPE (VE2DSP)*" for the MRR IO shall provide documents demonstrating that the manufacturing design of the equipment fit for use and comply with all requirements (called Equipment Design Review). Exhaustive list of documents constituting this Equipment Design Review are defined in chapter 5 of [17].

* items inside list and drawings shall be properly tagged according to [14] .

INSPECTION PLAN

Document Number:				Revision Number:	
ITER Procurement Arrangement Number:		ITER Contract Number:		Title of Item / Identification:	
Name of DA/Supplier:				Name of Supplier/Subcontractor:	

Prepared by (Name & signature)	Approved by DA (Name & signature)	ITER IO QA Acceptance (Name & Signature)	Code*
Position: Date:	Position: Date:	Position: Date:	HP: Hold Point NP: Notification Point W: Witness of Operation S1: 100% Inspection S2: Random Inspection R: Review Report

	Operations (Manufacture, Inspections & Tests, etc.)(2)	Expected Date	Applicable procedures, drawings, instructions, etc	Inspection Body				Records (report, non-conformance number, etc)	Observation(s)
				Supplier	DA	ITER IO	Others[1]		
				Name, Sign & Date	Name, Sign & Date	Name, Sign & Date	Name, Sign & Date		
1					*	*	*		
2									
3									
4									
…									

(1) Others: Third Party Inspection Organization (TPI) or Agreed Notified Body (ANB) or French Safety Authority (ASN), etc. shall be identified
(2) If the operation is a Protection Important Activity (PIA), this PIA shall be identified and a technical control shall be defined.

[Code]

- Hold Point (HP): Identifies an operation that must be signed off by an IO representative before work proceeds beyond this point.
- Authorization to Proceed Point (ATPP): Identifies an operation that must be signed off by a DA representative before work proceeds beyond this point.
- Notification Point (NP): Identifies an operation that must be notified to an IO/DA representative. This notification gives the IO/DA representative the opportunity to arrange an inspection visit if deemed necessary therefore adequate notice must be given to permit arrangements for this visit. In the absence of the appointed representative and with IO/DA documented agreement work can proceed.
- Witness (W): identifies an operation that must be witnessed.
- Surveillance (S1): identifies an operation that requires 100% inspection.
- Surveillance (S2): identifies an operation that requires random inspection or spot checks.
- Review (R): identifies a document or report that must be reviewed.
- Where R/W is used for Radiography, this means that actual radiographs must be checked as well as the reports

[How to fill out the form]

- Operations (Manufacture, Inspections & Tests, etc.): List of operations in sequence expected.
- Expected date: An approximation of the date when an operation is scheduled (estimated month).
- Applicable procedures, drawings, instructions etc: All documents giving reference requirements and acceptance criteria which will be used for the designated operation, such as Welding Procedure Specifications, Welding Plans, Welding Inspection Record Sheets, NDE Procedures, Pressure/Leak Test procedures, etc.
- Identify any other organization employed to perform inspection activities.
- Records (report, non-conform. Number, etc.): Documented products issued during the operation. It is also recommended to include identification number of documentation.
- Observation(s): Any special issues or clarifications raised during inspection for reference or information.

IDM UID
4CK4MT
VERSION CREATED ON / VERSION / STATUS
07 Jan 2025 / 4.1 / Approved
EXTERNAL REFERENCE / VERSION

MQP Level 3

ITER System Design Process (SDP) Working Instruction

The System Design Process-Working Instruction (SDP-WI) provides guidelines to the System -ROs for the planning of their documents during the design development phases and up to Manufacturing Readiness Review (MRR).

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Lebourgeois T.**	**07 Jan 2025:signed**	**IO/DG/ESD/DO/ICAS**
Co-Authors			
Reviewers	**Bartels H.- W.** **Carlier E.** **Vanpoperynghe Y.**	**07 Jan 2025:recommended** **07 Jan 2025:recommended** **15 Jan 2025:recommended**	**IO/DG/SID/CID** **IO/DG/SID/CID/DIS** **IO/DG/SID/CID/SIS**
Approver	**Orlandi S.**	**16 Jan 2025:approved**	**IO/DG/CP**
Information Protection Level: Non-Public - Unclassified *RO: Khomutnikov Aleksei*			
Read Access	**GG: MAC Members and Experts, AD: ITER, AD: External Collaborators, AD: External Management Advisory Board, AD: Nuclear Safety Inspectors, AD: OBS - Quality Management Division (QMD), AD: DA, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: CMS staff and EXT, AD: IO_Director...**		

#drn#

Change Log			
ITER System Design Process (SDP) Working Instruction (4CK4MT)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	21 Apr 2011	
v1.0	Approved	05 Jul 2011	First version
v2.0	In Work	02 Oct 2019	As per approved MQP doc request https://user.iter.org/default.aspx?uid=X45X3C the changes are: - Aligned with Technical Document Families and covered documents (TDFC). - Better integrated within the Design Control document structure. - Added Manufacturing Design and Preparation phase documents.
v2.1	Approved	04 Oct 2019	Technical change: update of the document numbers in the tables 1 and 2
v3.0	In Work	11 Sep 2020	As per approved MQP doc request https://user.iter.org/?uid=3JH453 there are no changes to the document but this review is to have DAs in the loop for impact assessment and make the documents Annex A PA AD through the MPA.
v3.1	In Work	01 Dec 2020	As per approved MQP doc request https://user.iter.org/?uid=3YWWSB the changes are: - Table 9: 2 documents merged (Engineering Analysis and Calculation Report), some clarification - Appendix 3: link to the new document containing the former Appendix 3.
v3.2	Revision Required	03 Dec 2020	Corrected bad pdf formatting in Appendix 2
v3.3	Approved	08 Mar 2021	Main changes made to address previous version comments: - Completed and improved few definitions (architecture, part definitions) - Added references to BOM and Identification of items procedures - Aligned with the new SIRO's role Please refer the attached track change version for changes made.
v4.0	Revision Required	20 Dec 2024	As per CWH2TR and further communication the changes are: -update as per IO Re-org -update due to changes of ICP document types in 2023 (TDF -> TDT) -update to align with other MQP Procedures (Design Review Procedure, L2 Design Control Procedures, SEMP..)
v4.1	Approved	07 Jan 2025	- Chapter 7.1: correction of RACI information for Design Integration Reviews - Appendix 1: clarification of requirements regarding CMM during Final Design

Table of Contents

1 Purpose

The **System Design Process**-Working Instruction (SDP-WI) provides guidelines to the System[1]-ROs for the planning of their documents during the design development phases and up to Manufacturing Readiness Review (MRR).

During these phase activities, the Design Development process covers the production of engineering deliverables describing and demonstrating the functionality and performance of the system model. It covers also the plans, instructions and procedures controlling the –abilities (manufacturability, assembly and installation-ability, testing and commissioning-ability, operability, maintainability, disposability of the system…) after the MRR until the end of the system product lifecycle.

The detailed description and maturity content of all engineering deliverables [Generic Document Titles -GDTs] and their procedures can be found in the Technical Document Types Cards (TDTC) [R7].

Note that in case of conflict the SDP-WI content has precedence over the TDTCs content.

The selection of each technical document shall be tailored to the complexity of the system, its criticality (e.g. according to their quality class [R9] or safety classes [R10] or to the maturity of involved technology), and the already achieved design development stage.

2 Scope

The SDP-WI shall be applied by any System-RO for preparation of the Conceptual Design, Preliminary Design, Final Design and Manufacturing Design phases.

This set of documents is defined at System level but as recommended by the Systems Engineering approach, each lower PBS node should also be defined by same document-types (i.e. sub-SRD, sub-Design Description (DDD), sub-Justification documents should be created at sub-system level, and so on…), down to the lowest Configuration Item [R2].

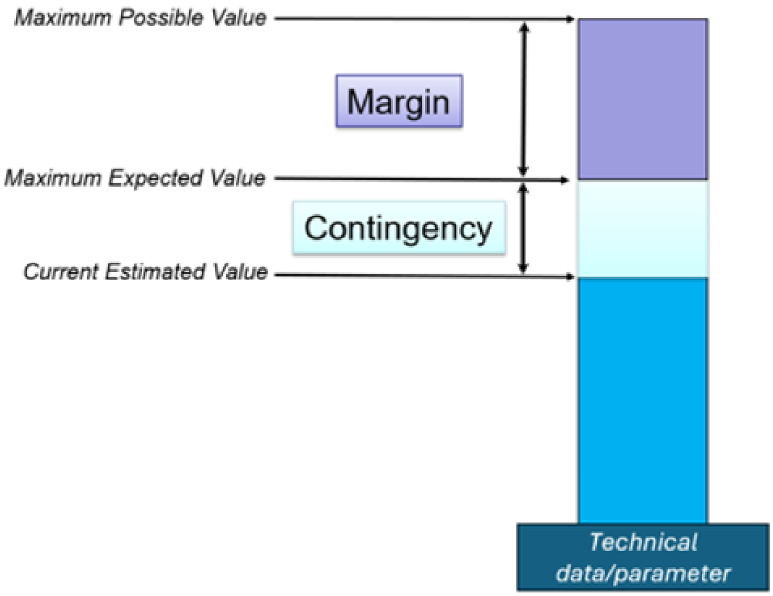
Note 1: The process is generic enough to be understood and tailored for any discipline (mechanical, electrical, I&C, etc...). Depending on the discipline deliverables may be called using a different terminology but should always correspond to a certain TDT/GDTs.

[1] See Definitions

3 Definitions and acronyms

3.1 Definitions

Term and definition
Configuration Management (CM) Relevance A document is CM relevant at a given gate when it is a reference against which the product(s) of any following phase is/are verified. The document is placed under Configuration Control (i.e. part of the Technical Baseline) after the gate closure. An update of such document will require a PCR.
Configuration Item (CI) A basic unit of Configuration Management (CM) for which a relevant authority exists and decides to control its definition as well as to closely monitor its changes. CIs may vary widely in complexity, size and type and may represent an entire system, a subset of it, or a component.
Component An ITER Component is a major piece of equipment uniquely located within an ITER System, such as a pump or a tank, which is tagged with a Functional Reference (FR).
Design Justification Document: Document that supports the justification of a design solution, i.e. documents providing evidence that the requirements in the technical requirement specification are satisfied.
Design Solution: Set of documents which describes the Functional and Physical Architecture of the considered SSC and which drives the realization, operation and maintenance, disposal of equipment satisfying the requirements as indicated in the technical requirement specification.
Function: A task to be performed by the system to achieve a required outcome or satisfy an operational need. Functions are captured in the context of performance requirements. (NB: not to be mixed with performance baseline)
Generic Doc Title (GDT): Name of each type of technical document, defined as outputs of MQP procedures and organised in Technical Document Types (TDT).
Manufacturing Design (MD): Set of Detailed Design documents produced by the Manufacturer which provides confidence in the Manufacturer's capability to satisfy Client's Procurement Specification. MD content is detailed in Appendix 1 of Working Instruction for Manufacturing Readiness Review (44SZYP). MD is an input to the shop floor and/or procurement work and does not therefore necessarily include detailed fabrication methods (*fabrication sequences, task lists and shop floor travellers)* used by the machine operators to implement MD's fabrication requirements.

Margin / Contingency **Margin** is the difference between the maximum possible value and the maximum expected value. **Contingency** is the difference between the current estimated value and the maximum expected value. **Current estimated value**: it is the value of the technical data/parameter known at date **Maximum expected value**: it is the most extreme value of the technical data/parameter that the design team expects will be observed as the design is refined and become more mature. It is based on the return of experience of the design teams. **Maximum possible value**: it is the maximum expected value increased by the margin. It acts as a buffer to provide "design place" for a less mature design and to account for uncertainties. 
Part: a single item which generally cannot be further disassembled.
System: A set of components which interact according to a design so as to perform a specific (active) function, in which an element of the system can be another system, called a subsystem. NOTE: At ITER, "system" sometimes designates the top-level ITER systems, corresponding to PBS Level 1 or sometimes level 2 and which have a toplevel SRD (System Requirement Documents), also called Configuration Items Level 1. Currently around 90 "systems" are defined to cover the ITER Facility The lower-level systems are called sub-systems and have dedicated sub-SRD (sub-System Requirement Document), also called Configuration Items Level 2.
System-RO: The System Responsible Officer (SysRO) is in charge of the full life cycle of the system. It is by default the Project Leader of the delivered system. Project Leader (SysRO) may nominate staff(s) for SysRO duties with associated responsibilities and authorities to one or more employees of the ITER Organization who have the competence necessary to accomplish the tasks under her/his OBS. Outside Project Leader OBS, CPL can nominate staff for those roles in collaboration with the Project Leader (SysRO).

Technical Document: Any container of (technical) information which:

- gives information about the technical aspects and technical management of system and enabling systems for each lifecycle phase,
- is subject to versioning and applicability, as well as to a given workflow towards approval (this is also valid for drawings, schematics and 3D data),
- and can be easily allocated to one of the Technical Document Type (TDT) & to one GDT.

3.2 Acronyms

See also ITER Abbreviations 2MU6W5

ATP	Authorisation-to-Proceed
CI	Configuration Item
CIC	Controls & Integrated Commissioning Program
CIDH	Central Integration Division Head
CM	Configuration Management
CMM	Configuration Management Model
COTS	Commercial Off-The-Shelf
CWP	Construction Work Package
DA	Domestic Agency
DCM	Design Compliance Matrix
DDD	System Design Description Document
DECO	Design Coordinator (from Design Office)
DIR	Design Integration Review
DIRO	Design Integration RO
DP	Design Plan
DPP	Document Production Plan
FAR	Functional Analysis Report
FBS	Functional Breakdown Structure
FS	Functional Specification
GDT	Generic Document Title
HAZOP	Hazard and Operability Study
HIRA	Hazard Identification and Risk Assessment
ICD	Interface Control Document
IS	Interface Sheet
PA	Procurement Arrangement
PBS	Product Breakdown Structure
PCR	Project Change Request
PE/NPE	Pressurized Equipment/Nuclear Pressurized Equipment
PIC	Protection Importance Component
PM	Program Manager
PR	Project Requirements
QARO	Quality Assurance Responsible Officer
RO	Responsible Officer
ROX	Return Of Experience (also REX)
RPM	Requirement Propagation Matrix
RQ	Requirement
RQM-RO	Requirement Responsible Officer
SIRO	System Integration RO
SOA	Sign-Off Authority
SDP	Systems Design Process
SDR	System Design Review

SEMP	Systems Engineering Management Plan
SIS SL	System Integration Section Leader
SLS	System Load Specification
SRD	System Requirement Document
SRO	Safety Responsible Officer
SSC	System Structure and Component
s-SRD	Sub- System Requirement Document (Children of an SRD)
TDT(C)	Technical Document Type (Card)
VCM	Verification Compliance Matrix

4 Reference Documents

[R1] ITER Systems Engineering Management Plan - ITER-SEMP (2F68EX)
[R2] ITER Configuration Management Implementation Plan (CMIP) (27LHHE)
[R3] Sign-Off Authority for Project Documents (2EXFXU)
[R4] Design Planning Procedure (U34ACR)
[R5] Design Input Control Procedure (U34CSG)
[R6] Design Development Procedure (U34DDZ)
[R7] Technical Document Types (TDT) Cards (BFF8H7) (folder)
[R8] Design Interface Control Procedure (28VNJG)
[R9] Quality Classification Determination (24VQES)
[R10] Safety Important Functions and Components Classification Criteria and Methodology (347SF3)
[R11] Data supplied by the IO operator to NPE manufacturer (VHBYMG)
[R12] Design Review Procedure (2832CF)
[R13] Implementation plan for design & manufacture of PE/NPE (VE2DSP)
[R14] PE/NPE - Manufacturing Design Controls for PE/NPE (WSJ6VM)
[R15] Procedure for Identification and Controls of Items (U344WG)
[R16] Work Instruction for Creation of Part Number of ITER, PNI and Cataloguing (UYGU3S)
[R17] Work Instruction for Generation of ITER Bill of Materials (BOM) (VXMR6K)
[R18] Yearly Design Review Plans (UZ9ZJG)
[R19] ITER Procedure for Performing Hazard and Operability (2F5L5M)
[R20] Identification of Occupational Health & Safety Requirements related to Design (TME48W)
[R21] Project Requirements (PR) (27ZRW8)
[R22] Project Change Procedure (22F4E5)
[R23] Design Integration Review Procedure (3CNWMT)

5 Basic principles

5.1 Roles for System Design Development

Generic roles established in Design Input Control Procedure [R5] and Design Development Procedure [R6] are transposed at System level the following way:

1. **Design Coordinator**:

The Design Coordinator is the person responsible for the execution of the System design and the execution of the SDRs

2. **Design Developer:**

The **Developer** of the **System Design** is the technical person who supports the Design Coordinator to produce the System Design Documentation.

3. **Design Approver:**

The Design Approver is the duly authorized person to approve the system design on behalf of his/her organization. Within the IO, the System Design Approver is the Program Manager of the related system.

5.2 Context

The ITER Systems Engineering Management Plan - ITER-SEMP [R1] define the systems engineering technical phases (Conceptual Design, Preliminary Design…), and the main objectives of each technical phases. During each technical phase, a set of technical documents (system requirements, design description, justification….) shall be developed to help maturing the design.

The **main objectives, inputs and outputs** of the design phases (Conceptual Design, Preliminary Design, Final Design and Manufacturing Design) are detailed in **Appendix 1.**

5.3 Preparation for System Design Development

The Design Development process is applied during each design phase, and the output controlled through 'phase reviews gates" [R1].

In each design phase, the Design Development process is applied recursively (progressively down the PBS levels) and till the required document maturity as detailed in this document is achieved.

5.3.1 Design planning

Each design phase starts with the definition/update of the Design Plan (DP) for the management of the phase and the identification of the documents (DPP) to be produced or refined during the phase.

Below is reminded the set of input for the System Design Development (*output of the System Design Plan [R4]):*

Description	Main Documents	Complementary documents (*)	Doc.# (Table 9)
Plan Activity	**System Design Plan (DP)**		7.1
Plan Deliverables		**System Document Production Plan (DPP)**	N.A.

(*) documents included in or separate from main document but referenced in it

Table 1 – Inputs from Design planning

5.3.2 Design Development Input Requirements

Below is reminded the set of design input requirements (*outputs of the System Design Input Control process [R5]*):

Description	Main Documents	Complementary documents	Doc.# (Table 9)
Specify System Requirements	**System Requirement Document**		1.1
		ICD/IS	1.2/1.3
		CMM	1.4
		ITER Load Specification	1.5
		ITER Concept of Operations	5.1

Table 2 – Inputs for Design Development

Note: Design input requirements for the other design phases include the baseline documents validated after the previous Design Reviews.

6 Process application during each design phase

The System Design Development process comprises 3 sub-activities [R6]:

1. Develop Architecture Definition (Physical & Functional)
2. Perform analyses and calculations (to support functional and physical decomposition, optimization of the architectures, trade-off analyses and to verify the preferred solution)
3. Specify the System Design Solution.

The System Design Development process is applied in each design phase as detailed **on Figure 1**.

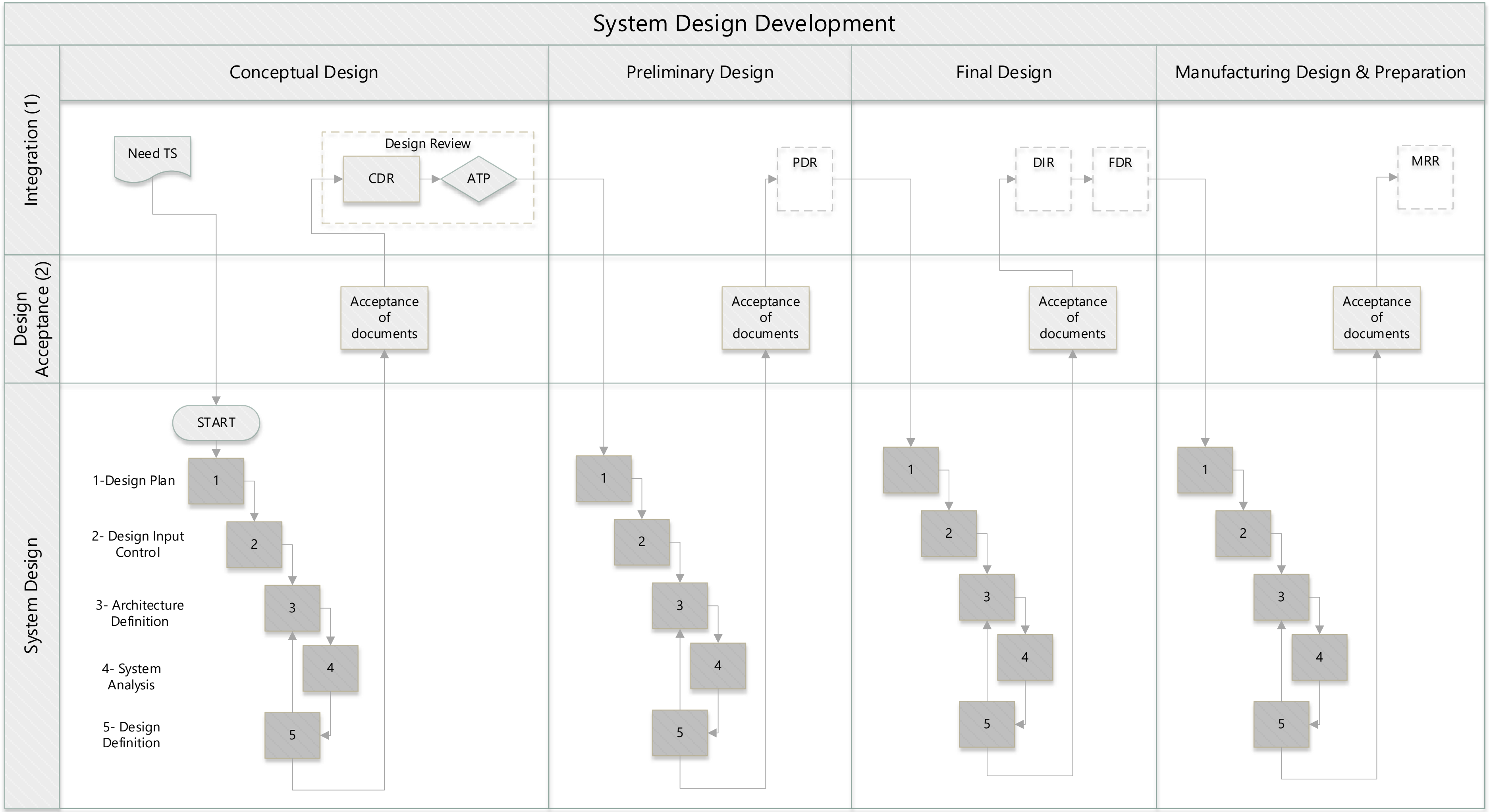


Figure 1: Process application during design activity phases

(1): Design Integration Review, Interface Review and System Design Review

(2): In case of Procurement

Note: The System Functional Solution Definition process [R6] is first applied in the Conceptual Design to decompose the System Functions down to the level necessary to identify a lower-level function which can be achieved by a feasible SSC. A feasible SSC is either an SSC existing on the market (Catalogues- Commercial Off-The-Shelf components - COTS) or an SSC which can be reasonably fabricated based on the Design Developer's experience (Return Of Experience - ROX).

In the Preliminary and Final Design, the System Functional Solution Definition process is applied at lower levels of the product to refine the sub-system and component design up to the component level (Detailed Design with Component Technical Specification).

For a system in development, most technical data/parameters carry both margin and contingency.

Generally speaking, the current maximal of a data/parameter change as the design of the system matures, and the margins and contingencies can be reduced as the design of the system reaches the Final Design Stage.

NB: Hidden margins shall be excluded to avoid stacking conservatisms that could lead to over costs and potential non feasibilities (exceeding the technical or regulatory constraints).

Once documents and documents maturity (also called "passing gate" criteria) are achieved for a given gate review, the System-RO shall organize (or make it organized) a System Design Review [R12] or an MRR for validation and authorization for use of the design package, according to the ITER Design Review Plan [R18] and Configuration Management Implementation Plan-CMIP [R2].

Note: A Review of Interfaces and/or a Design Integration Review (DIR) is/are organized before the FDR to check the correct development of Interfaces and/or the Integration of the Design in its environment.

6.1 Conceptual Design

The System-RO shall apply the Design Development process (Figure 1) for the objectives defined on **Table 5** in Appendix 2 and produce design documents for "Conceptual Design" maturity as detailed in the summary **Table 9** in Appendix 2**.**

During Conceptual Design, focus is finalisation of requirements, Functional analysis and search for solutions for the higher levels of the PBS (system, sub-system, up to critical components) and demonstrate feasibility of the system.

6.2 Preliminary Design

The System-RO shall apply the Design Development process (Figure 1) for the objectives defined on **Table 6** in Appendix 2 and produce design documents for "Preliminary Design" maturity as detailed in the summary **Table 9** in Appendix 2.

6.3 Final Design

The System-RO shall apply the Design Development process (Figure 1) for the objectives defined on **Table 7** in Appendix 2 and produce documents for "Final Design" maturity as detailed in the summary **Table 9** in Appendix 2.

6.4 Manufacturing Design

The System-RO shall apply the Design Development process (Figure 1) for the objectives defined on **Table 8** in Appendix 2 and produce documents for "Manufacturing Design" maturity as detailed in the summary **Table 9** in Appendix 2.

Note: When IO is acting as manufacturer, the design of PE/NPE is developed during the manufacturing design phase. See [R13]and [R14].

7 Responsibilities

7.1 System Design developed internally

The SDP-WI is implemented using the RACI matrix below:

Description	RO (Doer /writer)	Accountable (Approver)	Consulted (Contributor/ Reviewer)	Informed (User)
Generate SRD	SIRO & System-RO	Design Approver	SRO, Design Coordinator, Transverse Functions RO	RQM-RO
Develop Interfaces documents	SIRO & System-RO	SIS SL	Interfacing Systems (1)	
Develop System Design documents incl. Verification	Design Developer	Design Approver or delegate	SIRO, DIRO, SRO, QARO, DECO, Discipline Expert	
Organize Design Integration Review	DIRO (or SIRO if solely functional)	DIS SL	Design Team and other IO Stakeholders (see [R23])	
Organize System Design Review	Design Developer	Design Coordinator	IO Stakeholders (see [R1])	Interfacing Systems
Authorization To Proceed after Design Review close-out.	Design Developer	CID Head	Design Approver, Design Coordinator, SIRO, CIC Program Manager	

(1) When the interfacing system is procured by a DA/Contractor, DA/Contractor TRO shall be reviewer [R8]

Table 3 -RACI matrix for internal design

For the full detail of Sign-off of each design output, please refer to Project SOA [R3].

7.2 System Design developed through Procurement

The design development work (specified in a procured work package) for a given activity phase may be executed by other design development teams in other Organizations (Domestic Agencies-DA or IO Contractors). In that case the work is formalized through a procurement scheme (IO-direct contract or a Procurement Arrangement) signed by both parties.

During the procurement activities, performed mainly at sub-system level or below, the monitoring of the procured work is delegated to an IO-PA-TRO or an IO-Contract-TRO (who may be also the IO-System RO).

When preparing the design procurement scheme the IO-PA-TRO/ IO-Contract-TRO should ensure that the planning of the work and list of deliverables is compliant with the IO's rules.

During execution of the procured design activities, the IO-PA-TRO implements a Surveillance Plan and produces documentation related to the monitoring of the activities, review and acceptance/approval of deliverables according to approved procedures. He/she shall ensure the consistency and propagation of the System RQs to all the lower-level specifications and the compliance of delivered design with the RQs identified in the Procurement Technical Specification.

Appendix 1: Design Activity Phases: inputs, outputs and objectives

A- Conceptual Design (CON)

<table>
<tr><th colspan="2">Conceptual Design Activity Phase</th></tr>
<tr><td>Phase Inputs</td><td>

Inputs from upper level:

Technical rules to be followed (codes & standards, handbooks, etc.)
Allocations of Requirements to the systems (via SRDs) with relevant physical envelopes/space reservations (CMMs) and interface design specifications (ICDs) and preliminary PBS tree

Workplan (Design Plan/DPP for the Conceptual Design Activity phase). The plan shall clearly define the scope (system i.e. Configuration Item Level 1 or Level 2) and the boundaries.

</td></tr>
<tr><td>Main Objectives</td><td>

To produce the documents for the considered system (Configuration Item) and maturity relevant for the Conceptual Design Activity phase as indicated in the Design Plan.
To consolidate design inputs and interfaces:

Finalisation of the systems requirements (SRDs), including reference to all complimentary applicable documents (handbooks…)
Boundaries of the system have been established, interfaces are properly and exhaustively identified through Interface Control Documents (ICD); ICD shall contain the work plan to specify all interface requirements (in IS) at the different interface points. In addition, allocation for main balances shall be defined with services systems and interfaces with more developed systems shall be defined with a sufficient detail level to avoid delay of their design.
Physical interfaces requirements: CMMs of systems [mainly for Building Integration]

To outline at least one feasible design solution:

Description of the proposed concept solution and its functioning (functional diagrams)
Identification and localisation of main components (system layout drawing / 3D models)

To identify via the Design Compliance Matrix (DCM) which:

Requirements have already been considered in the Design (and those which were not for risk assessment)
Design options are assessed in terms of risks and the selected design solutions/options are justified and supported by necessary analyses

To identify impact of non-achievable requirements (draft PCR), with:

</td></tr>
</table>

	○ Identification of modifications needed to SRD ○ Identification & assessment of impacts on Overall project requirements (PR) [R21].
Phase Outputs (Maturity Level)	• As a result of the Conceptual Design Activity phase: The system requirements are complete and the system is deemed **feasible.** The System Design Definition shall meet the requirements and is achievable at an acceptable risk and cost. • SRD, Interfaces and CMM are developed, • Functional Specifications (for FS PAs) and outline drawings of sub-systems are available with their traceability matrices to SRD (RPM, DCM). • System Architecture and system decomposition is prepared. • This Phase is terminated with the approval of the Close-out Report of the Conceptual Design Review (CDR), giving the Authorisation-to-Proceed (ATP) to the next activity phase (Preliminary Design).
Notes	*Non-achievable requirements may be accepted provided that their impact has been assessed, the change to the SRD identified and the impacts of the system requirements on the overall project assessed, as per PCR procedure [R22].*

Table 5 – Conceptual Design Activity Phase: inputs, outputs and objectives

B- Preliminary Design (PRE)

<table>
<tr><th colspan="2">Preliminary Design Activity Phase</th></tr>
<tr><td>Phase Inputs</td><td>Consolidated Technical/Engineering data (system + Plant levels) produced by all systems during the CON phase
Workplan (Design Plan and DPP for the Preliminary Design Activity phase). The plan shall clearly define the scope (system i.e. Configuration Item Level 1 or Level 2) and the boundaries, especially if the scope is smaller than previous phase (Conceptual design).</td></tr>
<tr><td>Main Objectives</td><td>To produce the documents for the considered system (PBS node) scope and maturity relevant for the Preliminary Design Activity phase as indicated in the Design plan.
At the beginning of the Preliminary Design Activity phase, to select a design option if various solutions were defined during Conceptual Design
To refine the Conceptual Design to confirm the technical feasibility and the robustness of selected design solution, considering costs and schedule constraints. Evidence is given in:
An update of the Design Description (DDD), considering carefully margins and contingencies.
Functional Diagrams (P&ID, SLD, I&C architecture, etc)
An update of the physical representation of the system
An update of the System Load Specification,
An update of the definition justification documents, referring to a first consistent set of justification notes demonstrating that the technical objectives of the systems requirements will be met (analyses, return of experience, tests, simulations) and that manufacturability, on-site delivery (for High Exceptional Loads), assembly/installation and start-up and maintenance of the system have been addressed
To allocate system requirements to the subsystems (e.g. in s-SRD) to comply with the general architecture of the system.
To fully define Interface requirement specifications that are necessary to perform, or that have an impact, on the Final Design activities (exhaustive and with appropriate maturity). An Interface Requirement defines the functional and physical requirements and constraints that exist at a common boundary between two SSC. The Interface Requirements are recorded in Interface sheets.
To plan the future steps of justification in a consistent way (in particular all the tests on mock-ups/prototype for design qualification/verification should be planned in Verification/Qualification Plan)
To re-assess the technical risks of the selected solution and provide mitigation plan before going to the detailed design (Risk/Hazard Analysis Report) [R19] [R20].
To check that the proposed design solution definition still meets the RQs (DCM for SRD/s-SRD)</td></tr>
</table>

Phase Outputs (Maturity Level)	System Design with the preliminary design maturity: • General architecture (Functional: FBS, Physical PBS-GBS) is consolidated and the main (or critical) components described adequately NB: Level of details in the Design of PBS elements varies with each system or component depending on the level of risk (mature/COTS or to-be-developed technology) • All the Interface Requirements shall be fully defined. • 3D model / System Layout Drawing • System Load Specification is consolidated • Justification documentation, including verification plan are prepared ➢ This Phase is closed with the approval of the Close-out Report of the Preliminary Design Review (PDR), giving the Authorisation-to-Proceed (ATP) to the next activity phase (Final Design).

Table 6 – Preliminary Design Activity Phase: inputs, outputs and objectives

C - Final Design (FIN)

Final Design Activity Phase	
Phase inputs	• Technical/Engineering data produced during the PRE phase • Workplan (Design Plan and DPP for the Final Design Activity phase). The plan shall clearly define the scope (system i.e. Configuration Item Level 1 or Level 2) and the boundaries, especially if the scope is smaller than previous phase (Preliminary design).

Main Objectives	• To produce the documents for the considered system (PBS node) scope and maturity relevant for the Final Design Activity phase as indicated in the Design Plan.
	• To refine the design to a level where the final definition of the product (PBS element) is sufficiently complete to allow starting the manufacturing design & preparation phase (subsystem/component specifications are detailed enough to be "understandable" by the manufacturer).
	• To update all ICD/IS according to refined design definition
	• To have a complete and approved CMM (under config branch)
	• To build a complete set of justifications demonstrating that:
	  o Component specifications and design are justified (supporting analyses, return of experience, tests and explanations)
	  o The specification of the qualification process is fixed (test objectives, logical sequencing, expected results, etc.)
	• To develop documentation covering the following aspects of the system: manufacturability, on-site delivery, assembly/installation, commissioning, operation and maintenance of the system

Phase Outputs (Maturity Level)	• Complete definition of the system (DDD, diagrams, 3D models (DM/CM), drawings, component lists, etc) • Detailed definition of the composing PBS elements (i.e. Functional References) ready for manufacturing/detailed design. • Full set of justification documents (including DCM, Structural Integrity Reports, etc) • Plans for next phases (manufacturing, installation, commissioning, operation and maintenance) ➢ This Phase is closed with the approval of the Close-out Report of the Final Design Review (FDR), giving the Authorisation-to-Proceed (ATP) to the next activity phase (Manufacturing Design and Preparation).
Note	*When IO is the manufacturer of the PE/NPE to be designed, as part of the Final Design process, IO acting as Operator shall establish PE/NPE specific documents [R11].*

Table 7 – Final Design Activity Phase: inputs, outputs and objectives

D - Manufacturing Design & Preparation

Manufacturing Design & Preparation Activity Phase	
Phase inputs	• Detailed definition of the composing PBS elements (Functional References) ready for manufacture studies, • Workplan (Design Plan and DPP for the Manufacturing Design and Preparation Activity phase). The plan shall clearly define the scope (system i.e. Configuration Item Level 1 or Level 2) and the boundaries, especially if the scope is smaller than previous phase (Final design).

Main Objectives	• To produce the documents for the considered scope and maturity relevant for the Manufacturing Design and Preparation Activity phase as indicated in the Design Plan.
	• To refine the design definition (Manufacturing Design) to a detailed level for the workshop execution (manufacturing drawings, fabrication, factory acceptance tests, data sheet for COTS, Manufacturing and Controls procedures, Weld Plan, tooling, trainings, materials certificates, tagging procedure)
	• To generate Manufacturing-Bill of Materials (M-BOM) [R17] and deliverable list.
	• To generate Manufacturing Implementation Plan (MIP).
	• To build a complete set of justifications demonstrating that:
	  o Manufacturing design is compliant with the Manufacturing requirements (Compliance Matrices - VCM),
	  o Manufacturing Design is justified (supporting analyses, return of experience, tests and explanations),
	  o Component Qualification is finalised (in particular for PIC)
	  o Manufacturing processes are qualified

Phase Outputs (Maturity Level)	Manufacturing design: • Manufacturing Inspection Plan • Detailed definition of the composing products/equipment's and their identification following [R15] [R16], ready for procurement (for COTS) or actual fabrication. • Detailed definition of the welded joints (welding maps…) • Material certificates • Manufacturing Procedures, NDT procedures, tagging procedures • Factory Acceptance Test Plan and procedures, • Qualified manufacturing, coating and assembly processes and tools • Qualification of operators Requirements for the preservation of the product and its qualification over the product lifecycle. ➢ This Phase is closed with the approval of the Close-out Report of the Manufacturing Readiness Review (MRR), giving the Authorisation-to-Proceed (ATP) to the next activity phase (Manufacturing).
Note	*According to Implementation Plan [R13] and procedure [R14], when IO acts as manufacturer of PE/NPE it performs* • *a PE/NPE Technical Review of the inputs supplied by IO operator prior to the manufacturing design* • *and a PE/NPE Technical Review of the outputs of the manufacturing design.*

Table 8 – Manufacturing Design & Preparation Activity Phase: inputs, outputs and objectives

Appendix 2: Summary of the System Design Documents and maturity at gates (Table 9)

Table 9 gives the design documents to be typically developed or updated during the system design development phase up to MRR.

The details of these documents are given in **Appendix 3** and can also be found in [R7].

This documentation covers all the design development (definition, justification) of the system itself but also:

- design management documents (which control the production of design development documents),
- documents defining the input requirements,
- documents (implementation plans and procedures) which control the implementation of the design solution during the future phases of production or utilization of the system products.
- documents linked to the procurement activity.

The list shows for each gate the maturity level (or passing gate criteria) of the documents:

☒ : Not Required
PL: PreLiminary
CS: ConSolidated
CP: ComPlete
UD: UpDate of CP if needed
IfU: If Useful
S: At any Stage

Note 1: This list gives the main documents to be developed. It is expected that in addition to the cited documents the System-RO opens the TDTC / related MQP procedures and assesses which GDT should be produced as output of his/her work.

Note 2: This list is applicable for all systems, whatever the engineering discipline (mechanical, electrical, building, process, I&C, etc.). Some documents are specific to discipline work, they are not all indicated here and should be prepared according to the discipline's templates (codes, handbooks, guidelines etc…) shown in the TDTCs.

Note 3: Depending on the complexity of the system and the criticality of the discipline to be treated, it may be agreed that certain documents with preliminary status are replaced by a Section in the DDD,

Note 4: The reference documents and their relevant sections should be used extensively in the text of technical documents to avoid duplication and maintenance of information.

Appendix 2: Summary of the System Design Documents and maturity at gate (Table 9)

Doc. #	[Design Aspect] and System Design Documents	Procedure /Guideline	CDR	PDR	FDR	MRR	ICP Doc Types	TDTC UID
1.	**Design Requirements**							
1.1	System Requirements Document (SRD or Sub SRD) (1)	25DSU2	CP	UD	UD		System Requirements Document-SRD Sub-System Requirements Document-sSRD	BXPZJS BXQ4VC
1.2	Interface Control Document (ICD)	28VNJG	CP	UD	UD		Interface Control Document-ICD	BZVDCD
1.3	Interface Sheet (IS)		PL	CS	CP		Interface Sheet-IS	BZKUP3
1.4	Configuration Management Model-CMM	V2ERKH	PL	CS	CP	If U	Not Applicable	WA46NH
1.5	System Load Specification	22MAL7	PL	CS	CP		Load Specification	WBBFYH
	Design Description							
1.6	System Design Description (DDD)	2M24AM	PL	CS	CP		System Design Description-DD	BXQ6H5
1.7	System Layout Drawing	See TDTC	PL	CS	CP		System Layout Drawing	WA9HY6
1.8	Building Drawing	See TDTC	PL	CS	CP	UD	Site & Building Drawing	W9ZKZY
1.9	Process Flow Diagram (PFD)	T7GQGS	CP	UD	UD		Process Flow Diagram-PFD	BK6T9E
1.10	Piping and Instrumentation Diagram (P&ID)			PL	CP		Piping and Instrumentation Diagram-PID	C7Z4TS
1.11	Single Line Diagram (SLD)		PL	CP	UD		Single Line Diagram	C7Z3TJ
1.12	Cabling Diagram-CBD			PL	CP	UD	Cabling Diagram-CBD	C7YW7M
1.13	Detailed Wiring Diagram-WD				PL	CP	Detailed Wiring Diagram-WD	BK6V8E
1.14	Instrumentation and Control Document (PCDH Deliverables) (2)	27LH2V		PL	CS	CP	Instrumentation and Control Document	C94MZN
1.15	Instrumentation and Control - Physical and Functional Architecture			PL	CP	CP	Instrumentation and Control - Physical and Functional Architecture	C8D6LA BXQF2A
1.16	Equipment or Component List	See TDTC	PL	CS	CP	UD	Component list	WBXM7R
1.17	Bill Of Material-BOM	See TDTC		PL	CS	CP	Bill of Material - BOM	W9ZCNP
1.18	System Detailed Performance Definition	See TDTC	If U	If U	If U		Technical Requirements Specification	WBYZ5V
1.19	Component Technical Specification			PL	CP	UD	Technical Requirements Specification	WBYZ5V
1.20	Assembly Drawing	See TDTC		PL	CP	UD	Assembly Drawing	CBU322

Appendix 2: Summary of the System Design Documents and maturity at gate (Table 9)

							Isometric Drawing	CBU3LR
							Support Drawing	CBU3KA
1.21	Cubicle Internal Definition	7KLR8R			CP	UP	Cubicle Internal Definition	BK6VFR
2.	**[Definition Justification]**							
2.1	Design Justification Plan	See TDTC	PL	CP	UD		Verification and Validation Plan	WCJ4P2
2.2	Design / Verification Compliance Matrix (DCM/VCM)	473LQM	PL	CS	CP	UD	Compliance Matrix - DCM or VCM or ICM	C7YUNE
2.3	Interface Compliance Matrix	3L775F			CP		Compliance Matrix - DCM or VCM or ICM	C7YUNE
2.4	Functional Analysis Report - FAR	See TDTC	PL	CP	UD		Functional Analysis	WBBZYV
2.5	Structural Integrity Report	35BVV3	PL	CS	CP		Structural Integrity Report	C7ZZBT
2.6	Calculation report (3)	See TDTC			CP	If U	Calculations	C826XY
2.7	Engineering Analysis (4)	See TDTC	PL	PL	CP	If U	Engineering Analysis	C824CS
2.8	Qualification Plan	XB5ABP		PL	PL	CP	Qualification Plan-QP	C94HZF
2.9	Qualification Summary Report for PIC Components	XB5ABP				CP	Qualification Synthesis Report for PIC Component	C94L6Z
2.10	Acceptance Plan (FAT, SAT)	See TDTC			PL	CP	FAT & SAT Plan and Procedure	CBUJD9
2.11	Factory Acceptance Test Procedure	See TDTC				CP	FAT & SAT Plan and Procedure	CBUJD9
2.12	System Commissioning Plan	VVSZNU		PL	CP		Commissioning Plan	WBYPHH
2.13	Commissioning Test Procedure	X8KGJE			PL		Commissioning Test Procedure	WBY7QR
2.14	Requirement Validation Matrix	7WT3PG		PL	CP		Compliance Matrix - DCM or VCM or ICM	C7YUNE
2.15	ROX and Research and Development Report	See TDTC	If U	If U	If U	If U	ROX and Research and Development Report	WCJ2U9
3.	**[Manufacturing]**							
3.1	Manufacturing execution document (manufacturing procedure, test procedure…) (5)	See TDTC				CP	Manufacturing execution document	CBQCMG
3.2	Part Drawing	See TDTC			PL[6]	CP	Part Drawing	WAD9FG
3.3	Manufacturing Process Qualification Records	See TDTC				CP	Manufacturing execution document	CBQCMG
4.	**[Assembly and Installation]**							
4.1	Installation Drawing	See TDTC			CP		Installation Drawing	CBU2MH

Appendix 2: Summary of the System Design Documents and maturity at gate (Table 9)

4.2	Assembly or Installation Plan (*part of Construction Work Package Description-CWP*)	See TDTC		PL	CP		Installation Execution Document	CBUK45
5.	**[Operation and Maintenance]**							
5.1	Concept of Operations	XA95GG		PL	CP		Concept of Operations	WA44CK
5.2	Operation and Maintenance Manual	See TDTC			If U	PL	Equipment Operation and maintenance Manual	WNMXF4
5.3	System Maintenance and In-Service Inspection Plan	See TDTC		PL	CP		System Maintenance and In-Service Inspection Plan	WBZZXJ
6.	**[Decommissioning]**							
6.1	Decommissioning Plan	TYHA8S		PL	CP		Decommissioning Document	WA8RU6
7.	**[Product Lifecycle Records]**							
7.1	Design Plan	U34ACR	S	If U	If U		Design Plan	WBZTQN
7.2	Issue or Risk or Opportunity Analysis Report	22F4LE	S	S	S	UD	Not Applicable	N.A.
7.6	Quality Plan	22MFMW	If U	If U	If U	If U	DA-Suppliers Quality Plan DA Quality Plan Contractors Quality Plan	N.A.

Table 9 – Summary of the System Design Documents and maturity at gates

(1) The maturity for Sub-System Requirements Document-sSRD is Consolidated at CDR and Complete at the PDR

(2) Includes:

- Specifications of I&C controller type (slow/fast), (conventional/interlock, Safety) and network interface configuration. [D5],
- List of signals connected to the plant system I&C including name, type, sampling rate, allocation to I&C cubicle [D6],
- List of the data at Central I&C interface [D7],
- Hardware configuration of I&C cubicles showing the cubicle interfaces with Central I&C infrastructure, buildings, power supply and HVAC. [D8],
- Description of plant system state machines (PSOS) with transitions and state variables. The deliverable includes the PSOS/COS mapping table. [D9]

(3) Document type for final version of Computational Fluid Dynamics-CFD Analysis Report, Contamination Analysis Report, Electromagnetic-EM Analysis Report, Nuclear Analysis Report, Seismic Analysis Report, Structural and Thermal Analysis Report, Functional Analysis Report-FAR.

(4) Document type for any Engineering Analysis such as 0D or 1D Thermohydraulic Analysis Report, ALARA Analysis Report, Analysis Model, Checklist for Analyses or Calculations, Constructability Analysis Report, EEE NRC Analysis Report, Fire Protection Analysis Report, Hazard Analysis Report (HIRA, HAZOP), Human Factors and Organizational Performance Report, Investment Protection Analysis Report, Logistics Analysis Report, Maintainability Analysis Report, Manufacturability Analysis Report, Nuclear Safety Analysis Report, Operation Analysis Report, RAMI Analysis Report - including FMEA or FMECA, Remote Handling Analysis Report, Scoping Calculation Report, Simulation Analysis Report, Task Analysis Report.

(5) Document type for manufacturing input documents such as Calibration Plan (Manufacture), Data Sheet, , List of Manufacturing Tools and Equipment, Manufacturing Flow or Assembly Sequence, Manufacturing Instruction or Procedure, Manufacturing Plan, Manufacturing Process Qualification Report, Non-destructive Examination Procedure, Test Procedure, Training

Appendix 2: Summary of the System Design Documents and maturity at gate (Table 9)

or Qualification Record, Welding Data Input Package (for Manufacture), Welding Map (for Manufacture), Welding Procedure Specification-WPS, Welding Procedure Qualification Record-WPQR (for Manufacture), Material Property Report, Brazing Procedure Qualification Record-BPQR, Brazing Procedure Specification-BPS.

Appendix 3: Documents detailed contents and maturity at gates

For detailed descriptions of the above defined System design documents in Appendix 2 please refer to UID ITER_D_43S7GL