IDM UID
REYV5V

VERSION CREATED ON / VERSION / STATUS
05 Apr 2016 / 2.3 / Approved

EXTERNAL REFERENCE / VERSION

Memorandum / Note

Chemical composition and impurity requirements for materials

The requirements on the limit on impurities in steel are not properly specified in the baseline. This document:summarizes current status of general requirements in the various ITER documentsprovides information about current status of procurement for various PBSprovides requirements for further impurities content and chemical composition for components which are still under development.

Approval Process			
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Previous Versions Reviews	**Sannazzaro G.** **Alekseev A.** **Walsh M.** **Orlandi S.** **Choi C.- H.**	**24 Feb 2016:recommended v2.2** **10 Mar 2016:recommended v2.2** **11 Feb 2016:recommended v2.2** **10 Feb 2016:recommended v2.2** **10 Feb 2016:recommended v2.2**	**IO/DG/COO/CIO/AS** **IO/DG/COO/TED** **IO/DG/COO/TED/PPD** **IO/DG/COO/PED** **IO/DG/COO/TED/VSD**
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Document Security: Internal Use *RO: Barabash Vladimir*			
Read Access	**AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: Auditors, AD: ITER Management Assessor, project administrator, RO**		

Change Log			
Chemical composition and impurity requirements for materials (REYV5V)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	12 Oct 2015	
v1.0	Signed	29 Oct 2015	file uploaded
v2.0	Signed	12 Jan 2016	Comments from reviwers are included.
v2.1	In Work	08 Feb 2016	Updated based on discussion during meeting 02/02/2016.
v2.2	Revision Required	10 Feb 2016	Editorial comments from Michael LOUGHLIN.
v2.3	Approved	05 Apr 2016	Comments of reviewers have been included. See answer on comments in attached file to this IDM version

Chemical composition and impurity requirements for materials (update of Project Requirements)

Support of PCR 722 [S5M7NM]

Project Issue Management / PIM-169: The requirements on the limit on impurities in materials (REYV5V)

Table of Contents

1 Purpose

The purpose of the document is to identify all existing requirements for materials and impurities in steels and alloys with the goal to minimize activation of the materials in ITER and provide requirements for chemical composition and impurities for materials for components which are still under design development:

- the limit on impurity content for the ongoing procurement is not going to be changed,
- for the procurement not yet started the limit on the impurity content are set up with the same logic (to ensure a consistent approach based to the ALARA principle).

RPrS gives requirements on the effect of activation of neutron irradiated materials (contact dose rate, average annual individual effective dose to exposed workers, collective dose for personal) and specifies cobalt impurity content for zones exposed to neutron fluxes such as for austenitic steel for vacuum vessel.

The limits for impurities in materials as specified in section 7.2 of this document are proposed to be implemented as Project Requirements for further procurement. SRDs shall be updated accordingly.

The materials impurities requirements defined in this document are consistent with the requirements in on-going PAs and are not going to affect them.

The selection of the limits of impurities is based on ALARA principles adopted in RPrS and PR.

The limit for impurities in materials shall be used in activation calculations.

In case the materials impurity content is assayed, the assayed values shall be taken into account in activation calculations instead of the defined limits.

This document is in response to Project Issue Management PIM-169.

2 Scope

ITER is INB 174 in accordance French regulation [ITER_D_MU6PP3].

The scope of this document is related to all systems structures and components (SSC) of ITER which are subject to neutron irradiation which leads to activation of materials.

3 Definitions

ALARA	As Low As Reasonable Achievable
RPrS	Preliminary Safety Report (Rapport Preliminaire de Sûreté)
PR	Project requirements

ESPN	Équipement Sous Pression Nucléaire (Nuclear Pressure Equipment)
FMA-VC waste	French abbreviation for "Faible et Moyenne Activité à Vie Courte" (meaning low and intermediate-level short-lived or type A waste)
MA-VL waste	French abbreviation for "Moyenne Activité à Vie Longue" (meaning intermediate-level long-lived) or type-B waste)
PA	Procurement Arrangement
ACP	Activated Corrosion Product
SSC	Systems, Structures and Components
SDDR	Shut-Down Dose Rate

For a complete list of ITER abbreviations see: ITER_D_2MU6W5 - ITER Abbreviations.

4 References

1. Preliminary Safety Report (RPrS) (3ZR2NC v3.0) (current)
2. Project Requirements (PR) (27ZRW8 v5.3) (current)
3. Radioprotection guide for ESPN application (2LTQ96 v1.1) (current), J Elbez-Uzan
4. Order 2005 December 12 for nuclear pressurised equipment (ESPN) EN (ITER_D_2229CW v1.1) (new updated version of Order of 30.12.2015)
5. Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN (7M2YKF v1.6) (current)
6. STAC Oct 2015 report RVZHE4 v. 1.1, STAC Action 109.

5 Generic requirements from main documents (Ref. 1 – 4)

Some elements in materials subjected to neutron irradiation undergo nuclear reactions and become radioactive. Activation of materials depends on chemical composition, in many cases main alloying elements are responsible for activation (e.g. Ni, Mn) and to change those elements is not possible due to intrinsic material properties requirements. In many cases activation of materials depends on the so-called "controlled impurities content" (e.g. Co, Ta, U with maximum values determined by As Low As Reasonably Achievable (ALARA) principle).

ITER nuclear analysis identified that the following elements (impurities) shall be controlled in materials for the ITER components: cobalt, niobium and tantalum.

- Radiological Protection: the above mentioned elements (Co and Ta) are powerful gamma emitters. A small variation in the content of these elements could have a large impact on the collective dose of ITER.
- Radioactive Waste: Dismantling of ITER will be carried out by host country. The amount and toxicity of the waste has been already transmitted to ASN. Variations in the amount of above mentioned elements could affect to the classification of the waste. Limiting Nb for the main vessel allows keeping waste classification as FMA-VC category. In-vessel components will be classified as MA-VL waste in any case due to contribution of other alloying elements
- Radioactive Contamination: in the same direction of above aspects, the toxicity of materials created during operation (e.g. dust created by machining) could be increased due to the content of above mentioned elements.

In some cases other elements, present as impurities, are important for specific application, e.g. uranium content in beryllium, cobalt and nickel in aluminium alloys.

In the following Chapters 5.1 – 5.4 the generic requirements from the referenced documents are reported in Italic font and blue colour.

5.1 Preliminary Safety Report (RPrS) (3ZR2NC v3.0) [Ref. 1]

ITER_D_3ZR2NC v3.0
VOLUME I - DESCRIPTION OF THE FACILITY AND ITS ENVIRONMENT
Chapter 13: Operating feedback for design 23/55

1.6.5 Other wastes

In order to minimize material activation and hence the waste quantity and its categorisation, measures have been taken in the specification of the impurity content in materials.

These are particularly related to the following elements:

- *Cobalt – reduced levels of cobalt in structural and confinement materials will achieve a significant reduction in contact dose and quantities of activated corrosion products generated,*
- *Niobium (for the material for the vacuum vessel) – reduced levels of niobium in structural and confinement materials will achieve a reduction in the quantities of activated waste.*

A specific austenitic steel (SS 316 L(N) type) referred to as ITER Grade (IG) has been developed as the main structural material for the vacuum vessel with a low level (0.05% compared with the standard 0.25%) of cobalt (Co).

Reduction of the cobalt and niobium levels has no impact on the properties (especially mechanical) of the structural steel. In addition, reduction of these elemental levels will also limit the production of long life activation products, such as ^{60}Co. This has a positive impact on waste and its categorisation

ITER_D_3ZR2NC v3.0
VOLUME I - DESCRIPTION OF THE FACILITY AND ITS ENVIRONMENT
10/31 Chapter 14: Permanent shutdown and decommissioning

2.3 MEASURES TAKEN AT THE DESIGN LEVEL

The vacuum vessel and the in-vessel components use austenitic steels with a low cobalt (Co) impurity level. The reduced Co content does not affect the mechanical properties of the steel, but makes it possible to limit the formation of medium-lived radioactive products including ^{60}Co. The latter is mainly formed through reactions of high-energy neutrons with the steel and can contribute to the dose received by personnel during operations,

ITER_D_3ZR2NC v3.0
VOLUME II – PRELIMINARY SAFETY DEMONSTRATION
Chapter 2: Normal operation study 24/86

2.4.1.3 Choice of materials

The materials selected and their specifications may have implications on occupational exposure and waste classification (see Chapter I-14 "Final shutdown and decommissioning"). This choice primarily applies to austenitic steel, the main material used in the facility structures, circuits and equipment. Its composition, in terms of elements and impurities,

has an influence on the nature and quantity of activation products formed under irradiation from the plasma's high-energy neutrons.
From the activation of materials exposed to neutron flux, assessment of the radiological hazard resulting from alloying elements and impurities content in materials shows that the most significant isotopes contribution to the dose to personnel are:

- *cobalt isotopes (58Co and 60Co) from Co impurities in stainless steels, copper alloys and beryllium,*
- *manganese isotopes (54Mn and 56Mn) from stainless steels and beryllium,*
- *tantalum isotopes (182Ta) and Tungsten isotopes (187W) produced from Tungsten activation.*

All elements, except cobalt, are elements resulting from the activation of the main alloying elements and cannot be markedly changed without having an impact on the stainless steel properties. The effect of cobalt in irradiated stainless steel, copper alloys and beryllium leads to an increase in the decay heat and residual dose rate. Because activated cobalt will be the main contributor to doses from activated corrosion products in the water cooling systems and from the dust collected in the vacuum vessel, it will primarily impact the occupational dose.

In order to minimize cobalt isotopes, it is necessary to use steels with a very low cobalt impurity level when exposed to the neutron flux (e.g. maximum cobalt impurity is specified at 0.05% for stainless steel exposed to neutron flux). Reducing this content has no impact on the steel properties (particularly mechanical properties) and limits the formation of these cobalt isotopes.

Niobium does not contribute significantly to dose rates. Nevertheless, niobium impurity specifications are also established for waste characterization. Niobium is used as an alloying element for stabilizing austenitic structures and avoiding intergranular corrosion. The relevant of niobium is determined by its initial concentration in the reference steel, together with the long half live of the daughter radioisotopes, and by a potential reduction in the waste masses of the vacuum vessel (by separating the front part of the outboard vacuum vessel).

Finally, specifications for limiting actinides impurities in beryllium (30 ppm of U in beryllium) are also established for radiation protection and waste characterization issues.

ITER_D_3ZR2NC v3.0
VOLUME 1 - DESCRIPTION OF THE FACILITY AND ITS ENVIRONMENT
Chapter 6.1: Systems of the Tokamak

For many components (e.g. in-vessel and port mounted equipment, IC systems, launchers, plugs, diagnostics) the following design criteria and performance parameters are established:

1.5 DESIGN CRITERIA AND PERFORMANCE PARAMETERS

… the nuclear shielding provided … is consistent with an activation level dose rate of 100 µSv/hr, 10^6 s after shut down…

ITER_D_3ZR2NC v3.0
VOLUME I - DESCRIPTION OF THE FACILITY AND ITS ENVIRONMENT
Chapter 9.2: Radiological zoning 5/61

2.1 APPLICABLE LIMITS

The objectives adopted for ITER in terms of exposure of personnel to ionizing radiation are shown in the table below:

Maximum annual individual effective dose	As low as reasonably possible and under all circumstances < 10 mSv per year
Average annual individual effective dose to exposed workers	≤ 2.5 mSv per year
Individual effective dose due to incident situation	< 10 mSv

ITER_D_3ZR2NC v3.0
VOLUME II – PRELIMINARY SAFETY DEMONSTRATION
Chapter 2: Normal operation study 21/86

2.2.2 Collective exposure

Considering the experience and targets for the above-mentioned facilities and the fact that ITER will be a one-of-a-kind experimental facility, a maximum annual collective dose objective for personnel classified as radiation workers has been set at an average of 500 mSv/yr throughout the ITER operating lifetime.

3.2 ESTIMATED DOSE

Dose rates in these studies have been assumed at values that may be observed only after long activation periods (i.e. at ITER end of life), and in any case much lower than the radiological zoning for the different green or yellow zones (e.g. 10 Sv/h in green zones and 100 Sv/h in yellow zones when the bioshield is removed).

5.2 Project Requirements (PR) (27ZRW8 v5.3) [Ref. 2]

7.6 Radiation protection
The As Low As Reasonably Achievable (ALARA) principle shall be applied to minimize occupational doses. [PR1997-R]

8.2.5 Activation
Materials which are subject to neutron irradiation shall be selected taking into account their possible activation during ITER operation. [PR2182-R]
Depending on operational conditions (such as maximum expected neutron flux and fluence) and allowable dose rate, the requirements for specific impurities in chemical composition of materials which give significant contribution to activation of materials shall be established.

These limits on impurities' concentration shall be technically feasible and reasonably achievable. [PR1478-R]

Where the use of lower-activated materials will allow a reduction in contact dose and decay heat and to a decreased activation of waste, they should be selected. [PR2183-P]

5.3 ESPN, ANNEX 4 - Requirements for determining radiation protection requirements [Ref. 4]

1. Materials

Materials shall be chosen taking account of their possible activation and the release of corrosion products that may, following activation, necessitate radiation protection measures during operation.

2. Design

The design of all equipment that, during operation, has to be exposed to corrosion, erosion, internal abrasion or other chemical attacks shall be subject to appropriate measures in order to limit as far as possible the release of products and to avoid the equipment being activated.

3. Method of inspection and maintenance

Equipment shall be designed so that all operations laid down in implementation of Title III of this Order can be carried out in such a way as to ensure, in compliance with the principles and rules laid down by the Public Health Code and the Employment Code, that persons carrying out or monitoring these operations are protected against radiation.

5.4 Radioprotection guide for ESPN application (2LTQ96 v1.1) – J Elbez-Uzan, [Ref. 3]

These guidelines present ITER recommendations for design and manufacturing of Nuclear Pressurised Equipments in application of articles 6 and 7 of the Order of 12th December 2005, and Annex 4 to this Order concerning radiation protection as state in article 9 of this Order. They take into account the disposals and requirements as stated in articles 6 and 7 of the cited Order. These are general recommendations to be applied and developed case by case for each ESPN in ITER taking into account their specific functions and radioactive fluid.

1.3 Radioprotection requirements

In addition to the present recommendations, principals for radioprotection given by the regulation have to be followed in ITER:

- *Justification*
- *Optimisation*
- *limitation*

In particular the optimisation approach has to be applied in order to

-Integrate in the design the elements required for keeping As Low As Reasonably Achievable the exposure of personnel to ionising radiations during the operation phase of ITER as well as during maintenance phases, inspections and dismantling
-To limit the amount of waste and their activity during operation and dismantling.

From the point of view of the concrete objectives of these guidelines, this document provides the general approach to be applied for the design of ESPN:

- *Limitation of the activation of the equipments*
- *Design requirements for inspection means, maintenance and periodic in-service inspections of the equipments*

Case by case guidelines have to be developed in order to serve the purposes of providing to the manufacturer the data concerning the radioactive nature of the fluids in the pressurised equipment in allowing to perform the corresponding risk analysis.

6.1 Limitation of the activation of the equipments

6.1.1 Choice of material: general approach
The choice of materials for ESPN equipment is based on requirements for appropriate properties (in particular ones related to workers doses) and performance at all operating conditions.

The main radioprotection guidelines for materials for ESPN equipments are driven by the following requirements as far as possible:

1- Use of materials with lower activation under neutronic flux (in particular under 14 MeV neutrons from Deuterium-Tritium reaction in the plasma chamber), the main reasons are:

- *reduced contact dose during maintenance and decommissioning;*
- *lower decay heat;*
- *reduced activities of nuclides which are detrimental for waste classification during operation and decommissioning.*

2- Use of corrosion and erosion resistant materials which are under neutron irradiation and are in contact with coolant fluid to reduce the quantity of Activation Corrosion Products (ACP). Selection of appropriate water chemistry is required for limiting release of corrosion products.

6.2.1 Limit the hot spots generation
The equipment design will have to facilitate, as much as possible, the absence of activated material retention zones to prevent "hot spots". In order to avoid this problem, purges and draining must be installed in the low points of equipment.

6 Definition of impurity content in steels and alloys in Procurement Arrangements

Table 1 below shows the list of materials and requirements for impurities for various PBS systems. The limits for impurities have been specified in Procurement Arrangements.

For many systems procurements of materials are ongoing.

For some systems design is still under development: systems marked in yellow in Table 1 are under development.

For on-going procurements there is no proposal for changes for chemical composition and impurities.

For new procurement arrangements the ALARA principles which are declared in high level documents are applicable. Some clarification requirements are included in chapter 7.2 of this document.

Summary of current status of chemical composition and impurities requirements is in:
Chemical compositions of materials representing the components included into basic model for nuclear analysis of ITER (HTN8X3) (being updated).

Table 1. List of materials and impurities for various SSC

PBS	System	List of materials	Requirements for Impurities Co/Nb#/(Ta) Max Wt.%	Comments
11	Magnet system Procurement is On-going No change	316LN (high N), JJ1, Nb3Sn, Cu NbTi, Cu Jacket 316LN (high N) 316LN (high N) 316LN, 316L, Alloy 718, grade 660, Feeders (steel 1.4435) Epoxy, glass	Co = max 0.10% Nb = max 0.05% Ta = max 0.01 or 0.05 or n/s** (shall be assumed max 0.01 % if not specified)	PAs: https://user.iter.org/?uid=2LZR86 Note: PAs do not include requirements for welds There are DRs – increase Co content for small amount.
15 - VV	Vacuum Vessel Procurement is On-going No change	316L(N)-IG grade, Steel type 316L (1.4404) steel type 304, 304L (1.4307), Grade 660, polyimide, Al bronze, Alloy 718; 304B4 and 304B7, Ferritic steel 430 Fasteners XM-19, 660, Alloy 625	Co = max 0.05% Nb = max 0.01% Ta = max 0.01% In main steels	PAs: https://user.iter.org/?uid=2LKBVN For small amount of materials see for details: 2M2F8H v1.8 For small amount- Co max 0.20%.
15-IV	In-vessel coil system	Steel 316L, pure Cu, MgO, Alloy 718, steel 660, Al bronze	To be specified* (similar to VV and blanket)	TS is under preparation
16	Blanket system Procurement is On-going No change	Beryllium (S-65, TGP-56FW), CN-G01 CuCrZr, Cu, 316L(1.4404), 316L(N)-IG, Al bronze, grade 660, Alloy 718, XM-19, insulation coating, friction coating	U = max 0.0030% in Beryllium Co = max 0.05% Nb = max 0.10% Ta = max 0.01% In main steels For small amount- Co max 0.20% (incl. weld filler and alloy 718)	PAs: https://user.iter.org/?uid=GE39ML
17	Divertor Procurement is On-going No change	Tungsten, CuCrZr, Cu, 316L(N)-IG, 316L (1.4404), XM-19, alloy 718, Alloy 625, Grade 660, Al bronze	Co = max 0.05% Nb = max 0.10% Ta = max 0.01% In main steels	PAs: https://user.iter.org/?uid=2LAE7P See: 7A9DTH v5.0

PBS	System	List of materials	Requirements for Impurities Co/Nb#/(Ta) Max Wt.%	Comments
			For small amount- Co max 0.20%. (incl. weld filler and alloy 718)	
18	Fuelling &Wall cond.	To be specified*	To be specified*	To be specified in PA
22	Machine assembly	Not applicable	Not applicable	Not applicable
23	Remote handling	To be specified*	To be specified*	Port Cell Rails and any/all new RH requirements
24-CR Procurement is On-going No change	Cryostat system	Steel type 304 & 304L Bolts grade 660 SA-533, Type D, Class 2 SA-508 Grade 3, Class. 2 B8 bolting Note: Alloy 625 is proposed for bellows.	Co = max 0.10% Nb = max 0.10% Ta = n/s** (shall be assumed max 0.01 % if not specified)	PA: https://user.iter.org/?uid=34EWCQ Weld filler: Co max 0.20%. Note: For Alloy 625 - Assessment is needed: Ni- 58%, Co, Ta – to be specified
24-TCPH	Cryostat system	To be specified*	To be specified*	To be specified in PA by SD and CIO
24-VP	VVPSS system	To be specified*	To be specified*	To be specified in PA by SD and CIO
26 Procurement is On-going No change	Cooling water system	Piping and valves: Steel TP304L or/and TP316L	Co = max 0.20% Nb = max 0.10% Ta = max 0.05% Weld filler: Co max to be specified	For pipes outside the Cryostat, port cell, bioshield, and outside the L3 shielded compartment (N55B8R, R33QMX)
		Piping and valves: Steel TP304L or/and TP316L	Co = max 0.05% Nb = max 0.10% Ta = max 0.0% Weld filler: Co	For pipe inside the Cryostat, port cell, bio-shield, and inside the L3 shielded

PBS	System	List of materials	Requirements for Impurities Co/Nb#/(Ta) Max Wt.%	Comments
			max to be specified	compartment. Applies to pipes in locations requiring frequent access for maintenance or locations requiring long duration activities. (N55B8R, R33QMX)
		316L and /or 304L for other systems in PHTS (IBED): heat exchanges, pumps, etc.	To be specified*	To be specified by SD and CIO
27	Thermal shield system Procurement is On-going No change	Steel 304LN (EN 1.4311), TP304L, 316L, 316LN Some small amount of Ti-6Al-4V, Alloy 718, 316LN, steel 660, insulation G10, bolting B8M (316), 304B4 (enriched boron)	Co = max 0.10% Nb = max 0.10% For small amount- Co max 0.20%. Ta assumed max 0.01 % For very small some materials – n/s**	PA: https://user.iter.org/?uid=3NS22D (A4PYRQ_1.1, 2NAJL7) Note: ANS material to be specified, PA dos not include requirements for filler
31	Vacuum system Procurement is On-going No change	Austenitic steels, Other functional materials	Co – 0.05% for flanges, 0.10% max for other components Ta – max 0.01% Nb = max 0.01%	EMEHC6 NC5N3T R5WMSL Pipes for PBS 31 – see requirements for PBS 26
32	Tritium plant	Austenitic steels Other functional materials	To be specified*	To be specified* by SD and CIO
34	Cryogenic system	Austenitic steels Other functional materials	Not specified	Functional PA by SD and CIO
51	IC&CD	Austenitic steels Other functional materials	To be specified*	To be specified* by SD and CIO
52	EC&CD	Austenitic steels Other functional materials	To be specified*	To be specified* by SD and CIO

PBS	System	List of materials	Requirements for Impurities Co/Nb#/(Ta) Max Wt.%	Comments
53	Neutral beam Procurement is On-going No change	Austenitic steel, Copper and alloys Functional materials Ceramic	Co = max 0.05% Nb = max 0.01% Ta = max 0.01% (Co ≤ 0.01% for magnetic shield) Specific functional materials are foreseen (e.g. CoSm, silver brazing alloy)	Similar to PBS 15-VV and PBS 16/17
54	LH&CD	Austenitic steels Other functional materials	To be specified*	To be specified by SD and CIO
55	Diagnostic	Port plugs: 316L(N), 316L (1.4404), Al bronze, grade 660 Other materials are under investigation Functional materials Other steel structures in VV and Cryostat	Co = max 0.03% Nb = max 0.01% Ta = max 0.01% In main steels As for VV	See note: it was proposed to assess difference between 0.03 and 0.05% max Co.
56	Test blanket system	Various materials: Eurofer, IN, KO, CN RAFM steels	For RAFM steel Co < 0.005%, But Ta – range: 0.02 – 0.15% for various RAFM steels	Austenitic piping as for PBS 26 Other materials: to be specified
57	IVVS	To be specified*	To be specified*	To be specified
58	Port Plug Test Facility	Not applicable	Not applicable	Not applicable

* To be specified - based on requirements of this document.

** n/s - not specified

\# Nb content in structural steels; not a limit for conductor material and for alloys where Nb is alloying element (e.g. alloy 718, Alloy 625, XM-19).

7 Requirements

7.1 On-going Procurement Arrangements and Direct Contacts

The requirements specified in on-going Procurement Arrangements and Direct Contacts for impurities important for radiation protection shall be followed.

Final certificates for materials shall include the specified impurities.

The final values of impurities shall be taken into account for assessment of contact dose in areas where frequent maintenance is needed for justification of allowable dose rates and total dose.

7.2 New Procurement Arrangements and Direct Contacts

Limits for impurities content (in some case also for alloying elements) are radiation protection requirements.

There requirements are related to PBS: 15-IV, partly 23, partly 24 (TCPH), 24-VP, 26, 51, 52, 54, 55, 57, 23.

The areas where neutron irradiation for materials activation is important and where human access is needed shall be identified by each related PBS.

This includes but not limited to:

> VV port plugs, port cells, bellows in port cells, cooling and vacuum pipes in port cells, port interspaces, diagnostic components, neutral beams, heating systems, in-vessel viewing system, etc.

The requirements are based on ALARA requirements defined in PR and consistent with existing procurements. The requirements are clarified in this document and shall propagate to relevant SRDs.

For minimising the shutdown dose rate (SDDR) the following materials selection shall be made in this order:

1. Aluminium alloys (with limit of Co and Ni)
2. Carbon steels and iron
3. Austenitic steels with low cobalt and tantalum
4. Nickel alloys
5. Others (silver, materials with high cobalt, content, etc.)

Lower preference material (e.g. iron rather than Aluminium) will be selected if a technical justification is demonstrated.

7.2.1 Austenitic stainless steels

For austenitic stainless steels the following are requirements:

- Co – max 0.050 wt. %
- Ta – max 0.010 wt. %

(Nb – max 0.10 wt. %)

The same values are requirements for austenitic stainless steels outside of bio-shield where frequent maintenance is needed. This shall be defined in relevant SRDs.

For other locations impurities shall be defined based on waste assessment.

7.2.2 Weld filler materials for steels

The requirements related to base steel shall be applied for welding filler materials.

Importance of contribution of weld filler materials with increased Co content shall be analysed. Typically (as for Vacuum Vessel and Cryostat) cobalt content max 0.20 wt. % is specified and accepted. If needed – Ta content shall be clarified. It shall be analysed by SD and Nuclear integration. In some cases filler materials could be considered as small quantity in addition to main materials, in this case specific analysis shall be performed.

7.2.3 Brazing alloys

The requirements related to base materials shall be applied for brazing alloys.

In some cases brazing alloys could be considered as small quantity in addition to main materials, in this case specific analysis shall be performed.

7.2.4 Ni based alloys (e.g. Alloys 718, 625)

Use of Alloys 718, 625 shall be carefully assessed, generally these materials are not recommended in machine where the human access is foreseen irrespectively of the content and amount of impurities in it. Ni content in these alloys is one of main contributors to SDDR.

The SDDR analysis shall be performed for justification of use of these materials.

From materials production point of view the following shall be taken into account during assessment:

1. Alloy 718:

- Ni – 50.0 – 55.0 wt. %
- Co – max 0.10 wt. % (standard specification includes Co max 1.0 wt. %)
- Ta – max 0.010 wt. % (specification includes range of values for Nb + Ta)
- Nb is alloying element - 4.70 – 5.50 wt.%

2. Alloy 625:
- Ni – min 58.0 wt. % (normally > 60%)
- Co – max 0.10 wt. % (standard specification includes Co max 1.0%)
- Ta – max 0.010 wt. % (specification includes range of values for Nb + Ta)
- Nb is alloying element: 3.15 – 4.15 wt.%

Summaries of cobalt and tantalum content based on literature search are presented in:
- Summary of Co and Ta content in Alloy 718 (ITER_D_RHWTEL)
- Summary of Co and Ta content in Alloy 625 (ITER_D_RHWK97)

7.2.5 Other materials

Other materials (e.g. Al bronze, pure Cu, grade 660 steel,) may be needed to be used for SSC.

These materials shall follow the requirements:
- Co – max 0.050 wt. %
- Ta – max 0.010 wt. %

Amount of Nb in these materials (if Nb is impurity) shall be max 0.010 or 0.10 wt. % (depending on location).

7.2.6 Small quantity of materials

In many cases ITER components include small quantity of materials. For such cases many times it was stated that procurement of these materials with very stringent radiation protection requirements is almost impossible due to cost and procurement schedule.

For such cases chemical composition and impurities (Co, Ta, Nb) content shall be measured and their quantity assessed and their influence on radiation performance shall be assessed by issuing Deviation Request (22F53X). The DR shall be accompanied by compensatory measures. Deviation Requests shall be accepted by SD and CIO (Nuclear Integration).

7.2.7 Impurities in Aluminium alloys for heating and diagnostic systems

Aluminium alloys are considered as low activation materials with lower contact dose rate.

However, during activation assessment, the possible impurities (Co, Ni, Ta, etc.) in these alloys shall be taken into account in areas where materials activation is important and where human access is needed.

The following maximum content of these impurities is considered as reasonable and achievable:
- Co – max 0.025 wt. %
- Ni – max 0.025 wt. %

The limit for the quantity of impurities will be assessed by IO-CT and IO-DAs based on ALARA principles before the procurement of material.

7.2.8 Impurities in carbon steels

Generally Co, Ta, Nb impurities are not included in chemical composition requirements in carbon steels (e.g. EN grade S235J used in port cells).

However, in places where contact dose rates and total doses are important, the following limits shall be established:

- Co – max 0.010 wt. %
- Ni – max 0.050 wt. %

7.2.9 Tungsten impurity in austenitic steel

Generally tungsten impurity is not included in chemical composition requirements in austenitic steels (316L, 304L, etc.). During some analysis it was found that W plays important role directly after shutdown.

Based on limited data the content of W impurity could be as much as 0.025 wt. %.

This value is recommended for neutronic analysis based on case by case.

7.2.10 Activation due to neutron from ^{17}N isotopes outside of bio-shield

Water irradiated in side of vacuum vessel will have significant amount of isotopes ^{17}N. Despite of low half-life the activation of components outside of cryostat is possible and could be significant. Lower Co (0.050 wt. % max) and Ta (0.010 wt.% max)content as specified by PBS 26 is needed in locations requiring frequent access for maintenance or locations requiring long duration activities.

7.2.11 Limit for impurities for materials in contact with water coolant

To limit the production of Activated Corrosion Products from materials which in contact with water coolant and under neutron irradiation in-side of cryostat the requirement is: Co - 0.050 wt. % max and Ta - 0.010 wt. % max. Depending on design (percentage of wetted area for wrought material) the limit of these impurities for weld filler materials shall be established case by case.

7.2.12 New materials with higher content of alloying and impurity elements important for activation

Several new materials are being proposed for application in ITER due to some functional requirements.

- Use of Kovar alloy in WAV system in Upper Port plugs. This material has as main element 17 wt. % of Co and 28 wt. % of Ni.
- Nilo Invar alloy (Cobalt content is not specified in standard specification, but Ni content is ~42 wt. %)
- Etc.

The assessment of use of these materials shall be done in the form of Deviation Request (22F53X) and approved by SD and CIO (Nuclear Integration in Analysis Section/Division).

8 Summary

RPrS gives requirements on effect of activation of neutron irradiated materials (contact dose, average annual individual effective dose to exposed workers, collective dose for personal) and specifies cobalt impurity content for austenitic steel for vacuum vessel.

The main safety requirements listed in RPrS are:

- Contact dose rate in accessible areas: ALARA and in any case :
    - $\leq$ 100 µSv/hr at 10^6 sec after shutdown for yellow zones,
    - < 10 µSv/hr at 10^6 sec after shutdown for green zones,
- Average annual individual effective dose: ALARA and in any case $\leq$ 2.5 mSv/year
- Collective dose for personal: ALARA and in any case < 500 mSv/year averaged

The impurities in materials must be controlled in order to minimize activation of the materials and allow or facilitate human access operations in compliance with the safety requirements listed above.

The limits for impurities in materials as specified in section 7.2 of this document are proposed to be implemented as Project Requirements to satisfy the safety requirements for further procurements.

The document supporting PCR 722 is a translation of the existing safety requirements and ALARA principles into practical requirements on impurity content in materials for components where SDDR is important.

- **For On-going PAs:**
    - No change of requirements for components whose procurement is already on-going (requirements are already specified in the procurement agreement documentations)

- **For new PAs and new procurements:**
    - Definition of areas where SDDR shall be strictly controlled. This shall be defined by each related PBS.
    - The requirements for design and materials selection to reduce SDDR shall be identified.
    - After acceptance of PCR the requirements shall be implemented procurement (PAs, contracts). SRD shall be updated accordingly.
    - All other radiological aspects (waste, etc.) need to be studied.

The assessment of use of materials in case of deviations shall be done in the form of Deviation Request (22F53X) and approved by SD and CIO (Nuclear Integration in Analysis Section/Division). **The DR shall be accompanied by compensatory measures.**

For materials in which impurity content is assayed, the reported values shall be taken into account in activation calculations.