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POWER PLANT PHYSICS & TECHNOLOGY DEPARTMENT

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DRAFT DDC Part 1
General Information

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Work Package	*WPMAT*	**Date**	*31st Oct. 2016*
Project Leader	*Michael Rieth*		
TS Title	*DDC – DEMO Design Criteria*		
TS Ref. No.	*EDDI-1.3.3-T003*	**TS IDM-link**	*EFDA_D_2N3M6L*
Task Owner	*Manminder Singh Kalsey*		
RU(s)	CCFE		

Report Review & Approval	
IDM role	**Name(s)**
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Reviewer(s)	*Mike Fursdon, Jarir Aktaa, Mike Gorley*
PMU Reviewer	*Eberhard Diegele, Matti Oron-Carl*
Approver	*Michael Rieth*

X Study / Assessment | Procurement / Commissioning of Hardware | Industry

Use of Facility | Other *{please specify}*

[1] One *Deliverable Report* shall be submitted for each deliverable e.g. Study Report, Commissioning Report, Final Assessment Report, Technical Acceptance Report, Procurement Report, etc.

Executive Summary
This is the DEMO Design Criteria v1.0. It is a work in progress, and as such shall be updated regularly. It is intended to be written in the format that would be released once it is fully populated and reviewed. Notes are written in red as additional guidance and explanation. The red notes shall be removed once the DDC is released with approved design rules. **This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.**

Comments (shortcomings, deviations, etc.)
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Table of Contents

References

1 Introduction

The DEMO Design Criteria (DDC) provides rules for the assessment of Plasma Facing Components (PFC's) for DEMO.

This Design Criteria comprises the following Parts:

Part 1: General Information: *providing required background information, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 2: Design Assessment: *providing required operating conditions, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 3: Material Data: *the required physical property data along with the associated design allowable.*

Part 4: Example Calculations: *design assessment of a DEMO PFC is presented, demonstrating how an assessment should be carried out using ANSYS.*

Part 5: Rule Justifications: *explanations provided for why new or modified rules are adopted in the DDC.*

1.1 Included Components

The DDC currently covers the following key Plasma Facing Components (PFC). The main reason for focusing on these PFC's it is these components that will need to operate in a unique and challenging environment. This unique environment is not fully covered by existing design CODES, and hence the need for the DDC was established.

Note: All other DEMO components may be validated by using appropriate established CODES (ie AFCEN, ASME or equivalent).

It must be noted that although this design criteria is intended to cover the listed components (below), it is important that the criteria does not confine the design process to specific geometries and materials. Hence this criteria does not refer to components directly but breaks down components into the following functional elements:

- Structural
- Armour
- Joints

More details of these functional elements can be found in 6.1.

1.1.1 Divertor

The Divertor is a plasma facing component that is positioned inside the Vacuum Vessel. The primary functions of the Divertor are:

- Define the boundary of the plasma
- Enable the control of impurities

- Provide a means for non radiant power fraction exhaust
- Provide a means for helium ash exhaust
- Protect the vacuum vessel by absorbing neutrons

In order to deliver the required functionality, the Divertor will sustain the following environmental effects and loading:

- High heat flux
- Plasma induced surface erosion
- Neutron induced irradiation

1.1.2 Blanket

The Blanket is a plasma-facing component that lines the majority of the vacuum vessel. The primary function of the blanket is to extract the energy released from a fusion reaction. This is executed through absorbing fusion neutrons into a fluid medium and then using this absorbed energy to generate electricity. In addition the blanket provides the following functionality:

- Generate (breed) tritium by reaction of the fusion neutrons with lithium.
- Act as a neutron multiplier, compensating for neutron loss and thus sustaining the fusion reactions.
- Protect the vacuum vessel by absorbing fusion bi-product neutrons and also the VV from plasma heat, plasma particle.

In order to deliver the required functionality, the Blanket must sustain the following environmental effects and loading:

- High heat flux
- Plasma induced surface erosion
- Neutron induced irradiation

2 Definitions and Abbreviations

2.1 Definitions

In order to remove ambiguity from the assessment of DEMO components, the following definitions will apply. Effort has been made to ensure that these definitions have a precision of meaning that is both easily understood and are unambiguous.

Allowable Stress Design (ASD)

An assessment procedure which compares calculated to allowable stresses for each category of stress which may arise in a structure from individual and combined applied loads.

Damage

The reduction in component life.

Damage Mechanism

The mechanism that results in damaging the component.

Design Criteria

A set of rules, that if followed, should ensure that the structural integrity of the assessed components remain intact.

Excessive Deformations

Deformations, either elastic or inelastic, resulting from the application of loads and temperatures which prevent any portion of the component structure from performing its intended function.

Fail-safe

The design philosophy under which the failure of any single structural component will not endanger lives or property when it fails.

Failure

When a component is no longer able to sustain its required design loads it is deemed to be classed as a failure.

Failure Mechanism

The mechanism that results in a component failure.

Limit State Design (LSD)

Design assessment method where the structure is designed to safely withstand all loads likely to act on it throughout its life. This design philosophy employs the use of Partial Safety Factors.

Load and Resistance Factor Design (LRFD)

An alternative name for Limit State Design.

Safe-Life

The design philosophy under which crack propagation to failure will not occur in the expected operating environments during the specified service life of the reactor; also the period of time for which the integrity of the structure can be ensured in the expected operating environments.

Structure

All components and assemblies designed to sustain loads or pressures, provide stiffness and stabililty, or provide support of containment.

Strain Softening

TBD

Strain Hardening

TBD

System

A major combination of components and assemblies that functions as a unit.

Fail-Safe

A design philosophy under which the failure of any single structural component will not degrade the strength or stiffness of the remainder of the structure to the extent that it cannot complete the remainder of the pulse.

2.2 Abbreviations

DDC	*DEMO Design Criteria*
PFC	*Plasma Facing Components*
ALM	*Additive Layer Manufacturing*
ASME	*American Society of Mechanical Engineers*
ASSY	*Assembly*
ASTM	*American Society for the Testing of Materials*
BPVC	*Boiler and Pressure Vessel Code (an ASME design code)*
CCFE	*Culham Centre for Fusion Energy, Great Britain (formerly UKAEA)*
EB	*Electron Beam*

ELI	*Extra Low Interstitial*
Eqpt	*Equipment*
GMAW	*Gas Metal Arc Welding*
HAZ	*Heat Affected Zone*
HCPB	*Helium Concept*
HIP	*Hot Isostatic Pressing (a type of joining process)*
HVOF	*High Velocity Oxy-Fuel Spraying*
MAG	*Metal Active Gas (a type of welding process)*
NADCAP	*National Aerospace & Defence Contractors Accreditation Programme*
NDT	*Non-Destructive Testing*
PBF	*Powder Bed Fusion (a type of additive manufacturing process)*
PECS	*Pulsed electric Current Sintering (a type of joining process)*
PPS	*Pre-Production Samples*
R&D	*Research and Development*
S/Steel	*Stainless Steel*
TIG	*Tungsten Inert Gas (a type of welding process)*
TSC	*Thermal Spray Coating*
WPBB	*Work Package Breeder Blanket*
WPS	*Welding Procedure Specification*

3 Loading and Stress Classifications

3.1 Load Classifications

The loading seen on a Fusion component is complex and generally consists of multiple loads being applied at the same time (load combinations). The application of a single load is rarely seen, however for the purpose of a structural integrity assessment the classification of singular loads into Primary and Secondary Loads is needed.

3.1.1 Primary Loading

A primary load is not self-limiting and must be equilibrated by internal forces in the structure. As plasticity develops, a stage is reached where no further redistribution of internal forces is possible and plastic collapse is inevitable.

The following are examples of Primary loads seen in a Fusion reactor:

- Gravity
- Coolant pressure
- Vacuum
- Seismic
- Electro-magnetic

3.1.2 Secondary Loading

Secondary loading is self-limiting or self-equilibrating so that local deformation leads to a reduction of the associated stress. Failure occurs when the deformation is large enough to cause plastic collapse or instability from the primary loading.

The following are examples of Secondary loads seen in a Fusion reactor:

- Heat Flux
- Coolant Heat Transfer
- Swelling
- Baking
- Residual stresses

3.2 Load Types (For Partial Factors design assessment)

Due to differing levels of statistical reliability of loading data, it will eventually be necessary to provide a further level of load classifications (beyond primary and secondary loading). This additional classification allows lower factors of safety (FOS) to loadings of higher certainty. For example, gravity would only require a small FOS (if any) as it has a high level of certainty, however in contrast Seismic loading would require a larger FOS due to its low level of certainty. This shall be detailed further if the DDC adopts the Partial Factor Design assessment philosophy.

3.3 Stress Classifications

The stresses induced in a structure are a result of the load combinations applied. Definitions are provided below.

3.3.1 Primary Stress

Primary stress is the stress that in induced in the structure as a result of the applied primary loads.

3.3.2 Secondary Stress

Secondary stress arises from secondary loading.

3.3.3 Peak Stress

This is the total stress minus the Primary and Secondary stresses. It is either derived from a stress concentration factor (SCF) or from a sufficiently fine numerical meshing method such as Finite Element Analysis.

4 Operating Conditions

During operation, DEMO components shall be subjected to various operating conditions that are made up of load combinations. These operating conditions shall be classified into categories based on both the probability of occurrence and consequences of failure.

The Operating Condition categories have a direct link to the safety factors applied in the structural design assessment. These safety factors have a critical role to play, and if inappropriate can result in either excessive or under conservatism, neither of which are desirable when assessing the validity of DEMO designs. Therefore the process of determining Operating Condition Categories is under review.

Note: Note, it has been recommended that a full review of component classifications and their relation to the DDC design classifications should be carried out. It has been noted that DEMO SIC classifications have been proposed, it is likely that the PFC's could contain multiple SIC classifications, how this shall be handled from a design criteria prospective needs to be clearly defined. In addition, other classifications need to be taken into consideration (ie Remote Handling, Vacuum, Quality) together with the required level of availability (investment protection).

In the absence of further guidance it is recommended to follow the recommended design Code (RCC-MRx, ASME or SDC-IC).

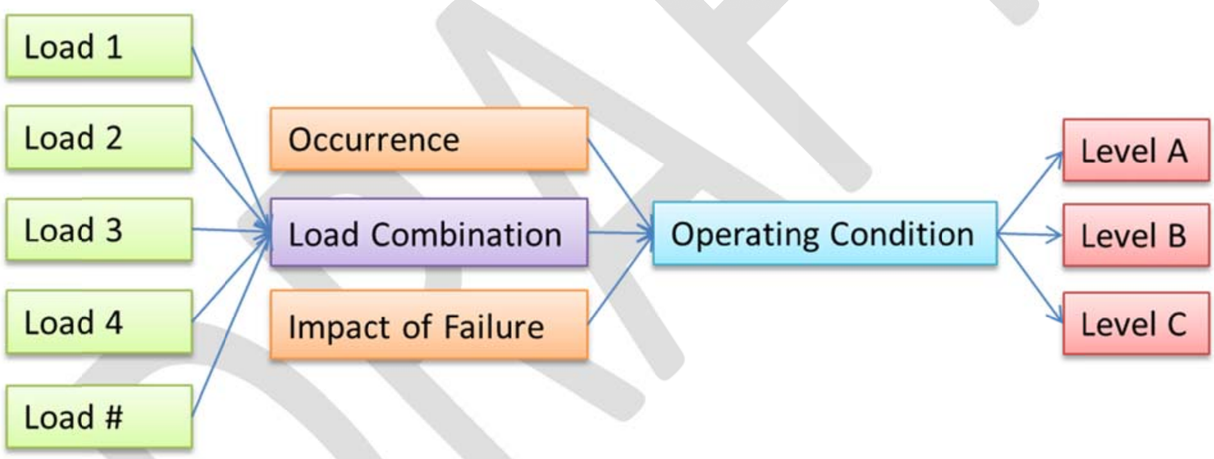

Figure 1: Operating Condition interaction diagram

5 Damage Mechanism Descriptions

The key damage mechanisms relevant to PFC's are defined in this section. Only damage mechanisms are listed here, however all of these damage mechanisms have the potential to cause failure and hence if left unresolved can also become failure mechanisms.

Most of the damage mechanisms listed would evolve quite quickly into a failure mechanism and hence it is very difficult to build into the design a degree of damage tolerance. However, some of the more complex damage mechanisms (Fatigue, Creep & Swelling) have the potential of having an appreciable period before causing a failure, hence these damages could be tolerated for a period of time. The design assessment found in Part 2 shall assess the ability of designs to withstand these damage mechanisms during the planned component life.

Note: This section intends to provide a clear unambiguous description of the applicable damage mechanisms. It is also intended that physical examples are provided preferably from the Fusion industry. This shall provide the DEMO designer with a greater understanding of the type of damage mechanisms we are intending to design against.

5.1 Monotonic Damage

5.1.1 Plastic Collapse

5.1.1.1 Description of Damage

If a structure made of an elastic and ductile material is subjected to a proportional and steadily increasing loading, initially the structure behaves elastically and the deformation is reversible. At higher loading, irreversible plastic deformations occur such that, if the loading were removed, the structure would not return to its original dimensions or shape. If the loading were continually increased, the structure would ultimately reach plastic collapse. This is an overall structural behaviour, as opposed to a local material instability.

5.1.1.2 Affected Materials

- CuCrZr
- Eurofer

5.1.1.3 Appearance or Morphology of Damage

Gross permanent deformation.

5.1.2 Plastic flow localisation

5.1.2.1 Description of Damage

In a material with very low strain hardening capability, plastic strain may not be readily homogenized, and the structure may fail by the localization of plastic flow. Plastic flow localization appears as a large strain within a narrow band, inclined at an angle to the load. It is a type of plastic instability (under load-control), precipitated by small surface notches or irregularities. Like necking, plastic flow localization is essentially a nonlinear phenomenon and must be avoided even under strain-controlled loading. This type of damage may lead to early cracking even when the material has significant local ductility as measured by reduction in area.

Both necking and plastic flow localization are affected by the strain hardening capability of a material, which is closely tied to its uniform elongation. Both appear in an irradiated material with low uniform elongation.

5.1.2.2 Affected Materials

- CuCrZr
- Eurofer

5.1.2.3 Appearance or Morphology of Damage

TBD

5.1.3 Exhaustion of Ductility

5.1.3.1 Description of Damage

Reduced ductility is associated with a low elongation (strain) at rupture. This can precipitate cracking in regions of high elastic follow-up or stress concentration, such as the root of a notch, where the strains may be locally high. This type of damage must be distinguished from the damage of "fast fracture" (below). Exhaustion of ductility is a limit of a continuum analysis of a homogeneous material. Fast fracture is associated with propagation of cracks.

5.1.3.2 Affected Materials

- CuCrZr
- Eurofer
- Tungsten

5.1.3.3 Appearance or Morphology of Damage

TBD

5.1.4 Brittle Fracture (TBC JA)

5.1.4.1 Description of Damage

Brittle fracture is a breakage or cracking of a material into discernible parts, from which no deformation can be identified (a clean break). It is characterized by rapid crack propagation with low energy release and without significant plastic deformation.

5.1.4.2 Affected Materials

- Tungsten
- Eurofer
- CuCrZr

5.1.4.3 Appearance or Morphology of Damage

- Sudden fracture is often the first indication of damage so this is by far the most dangerous failure mechanism. Pre-critical cracks may be found during routine maintenance checks.
- Failure Cracks will typically be straight, non-branching, and largely devoid of any associated plastic deformation beyond the crack initiation point (although fine shear lips may be found along the free edge of the fracture, or localised necking around the crack).
- Microscopically, the fracture surface will be composed largely of cleavage, with limited intergranular cracking and very little microvoid coalescence.

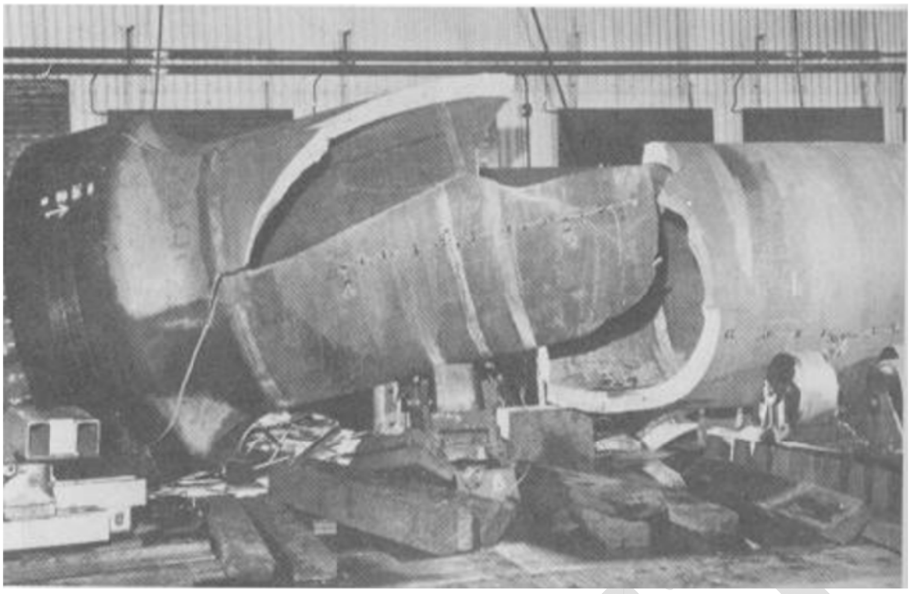

Figure 2: Example Brittle Fracture failure.

5.1.5 Thermal Creep

5.1.5.1 Description of Damage

At high temperatures, metal components can slowly and continuously deform under load below the yield stress. This time dependent deformation of stressed components is known as creep and can eventually lead to failure.

5.1.5.2 Affected Materials

- CuCrZr
- Eurofer

5.1.5.3 Appearance or Morphology of Damage

- The initial stages of creep damage can only be identified by scanning electron microscope metallography. Creep voids typically show up at the grain boundaries and in later stages form fissures and then cracks.
- At temperatures well above the threshold limits, noticeable deformation may be observed.

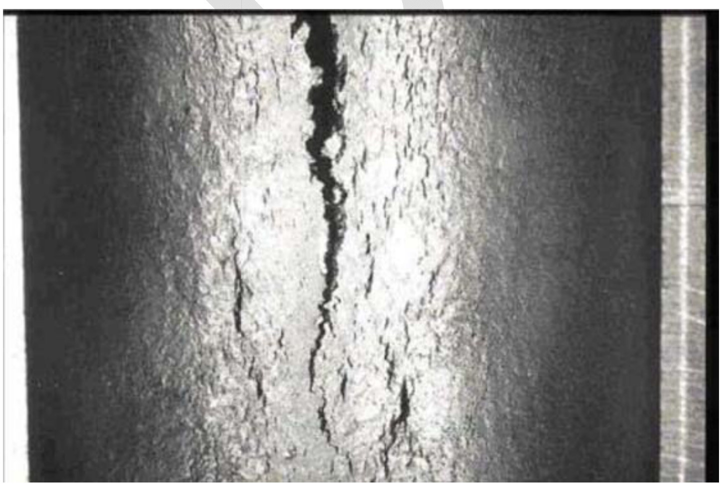

Figure 3: Example Creep Rupture failure.

5.2 Cyclic Damage Mechanisms

5.2.1 Ratcheting

5.2.1.1 Description of Damage

Continuous growth on both loading and unloading steps. Failure from instability or structure becoming too thin to support primary loads.

5.2.1.2 Affected Materials

All ductile materials. Initial residual stress from manufacture can be ignored.

5.2.1.3 Appearance or Morphology of Damage

Thinning and growth of vessels plus potential crack growth.

5.2.2 Fatigue **(TBC MF)**

5.2.2.1 Description of Damage

Fatigue is the result of cyclic thermal or mechanical loading. Damage is in the form of voids or cracks that may occur where relative movement or differential expansion is most highly constrained.

5.2.2.2 Affected Materials

All

5.2.2.3 Appearance or Morphology of Damage

- Cracks usually initiate on the surface of the component.
- Thermal fatigue cracks propagate transverse to the stress and they are usually dagger-shaped, transgranular, and oxide filled. However, cracking may be axial or circumferential, or both, at the same location.

Figure 4: Example Fatigue Failure

5.3 Environmental Damage Mechanisms

5.3.1 Neutron induced Swelling

Neutron induced swelling is the increase of volume and decrease of density of materials subjected to intense neutron radiation. Neutrons impacting the materials lattice rearrange its atoms, causing buildup of dislocations, voids.

5.3.1.1 Description of Damage

5.3.1.2 Affected Materials

5.3.1.3 Appearance or Morphology of Damage

5.3.2 Corrosion

5.3.2.1 Description of Damage

Corrosion is the gradual destruction of materials (usually metals) by chemical and/or electrochemical reaction with their environment.

5.3.2.2 Affected Materials

5.3.2.3 Appearance or Morphology of Damage

Figure 5: Example Corrosion

5.3.3 Erosion Corrosion

5.3.3.1 Description of Damage

Erosion corrosion is the gradual degradation of material caused by the action of surface interactions such as fluid flow.

5.3.3.2 Affected Materials

5.3.3.3 *Appearance or Morphology of Damage*

Figure 6: Example Erosion Corrosion damage.

5.4 Compound Damage Mechanisms (TBC)

5.4.1 Stress Corrosion Cracking

5.4.1.1 *Description of Damage*

5.4.1.2 *Affected Materials*

5.4.1.3 *Appearance or Morphology of Damage*

5.4.2 Creep Fatigue (TBC JA)

5.4.2.1 *Description of Damage*

5.4.2.2 *Affected Materials*

5.4.2.3 *Appearance or Morphology of Damage*

5.5 Modifying Effects (TBD)

5.5.1 Radiation induced material property changes

5.5.2 Thermally induced material property changes

6 Design Assessment Philosophy

6.1 Component Functional Elements

6.1.1 Structural Element

The structural element is the backbone of the component primarily providing structural strength. In the case of the PFC's it is likely that the structural element shall also retain the flow and pressure of a cooling fluid.

6.1.2 Armour Element

The armour element plates the structural element as is the plasma facing aspect of a PFC. This element is subject to high heat fluxes and plasma erosion.

6.1.3 Joint Element

The joint element ensures that the Structural Element and the Armour Element remain intact throughout the planned component life.

6.2 Design Life Target

Traditionally four different design life philosophies are applied in the design of safety critical components in the engineering industry. These philosophies are known as:

- Infinite-Life
- Safe-Life
- Damage Tolerant
- Fail-Safe

The fusion industry has tended to adopt the Safe-Life Design philosophy where components are designed to survive the expected loading without seeing any appreciable damage initiation (failure is assumed when damage is first formed). Although this conservative approach is acceptable in most cases, the DEMO PFC's operate in a very challenging environment where designing to a Safe-Life Design Philosophy may not be possible. For this reason the DDC utilises a combination of Safe-Life, Damage Tolerant and Fail-Safe Philosophies detailed below and in Figure 7.

- Structural Element, Safe-Life and if required Damage Tolerance.
- Armour Element, Safe-Life and if required Damage Tolerance shall be utilised. However, if required Fail-Safe philosophy is acceptable where if the failure of the Armour must not result in the failure of the structure. *Note: This may change following a review of the results from the Armour Assessment task.*

- Joint Element, Safe Life. *Note: This may change following a review of the results from the Joint Assessment task.*

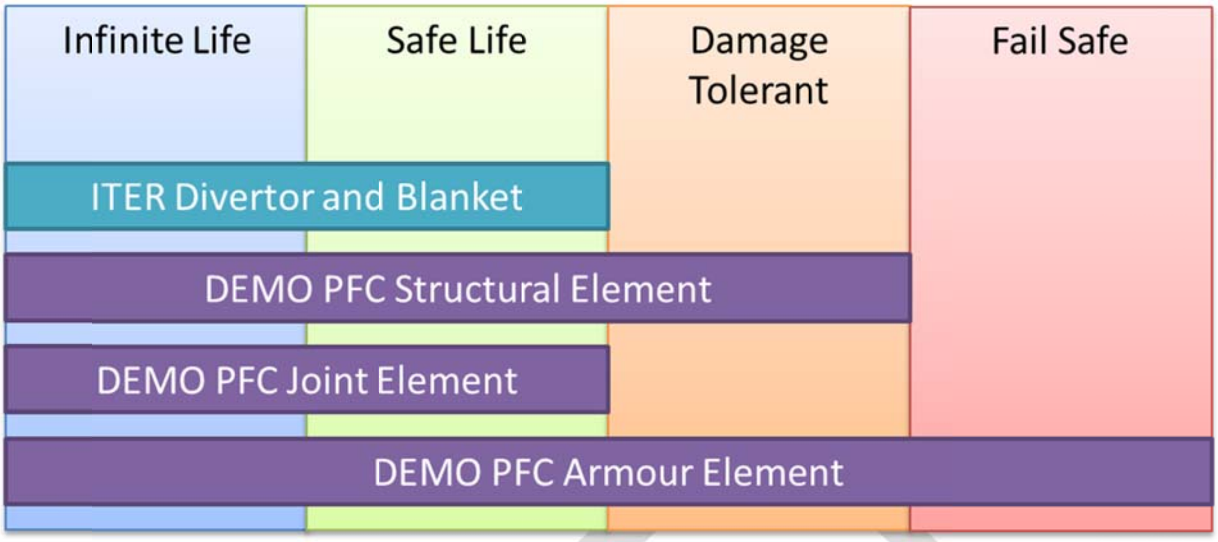

Figure 7: Design Life Target

6.3 Design Assessment

The design assessment process is primarily intended to demonstrate that the proposed design will not fail during the target design life. This is done by predicting the response of a design to the expected operating conditions, and determining if this response would result in causing a failure.

There are a number of numerical methods that can be used in this assessment process, details of which can be seen in Figure 8. Traditionally, the Nuclear Fission industry has utilised the deterministic allowable stress approach as the main method to assess safety critical components. Likewise, the Nuclear Fusion industry has moved in the same direction. In addition to the well established allowable stress approach, the plastic design approach is also occasionally used, however this is often seen as an inaccessible route due to the complexity and the lack of clear guidance on how to use this route to assess components.

Historically, the allowable stress route found in Nuclear Codes have been developed from the pressure vessel industry and are appropriate for simple cases like cylindrical shells under axisymmetric quasi-static loads. However, these rules are not relevant to complex 3D studies. In the Fusion industry, in particular with the PFC's, using the traditional Nuclear allowable stress rules can be unnecessarily conservative and difficult to apply, in particular the application of stress linearisation is time consuming and sometimes not relevant.

In the near term, the DDC shall utilise Plastic Design route as this is seen to be more appropriate to PFC geometry than the Allowable Stress Design route.

In longer term, the possibility of utilising the more advanced Partial Factor Design route shall explored, and if deemed to be relevant and beneficial shall be adopted.

Note: With regards to the more advanced fully Probabilistic methods, ASME have been involved in developing a system based Code called RIM (Risk Informed Methodology), this should be investigated to determine if it is applicable to the DDC.

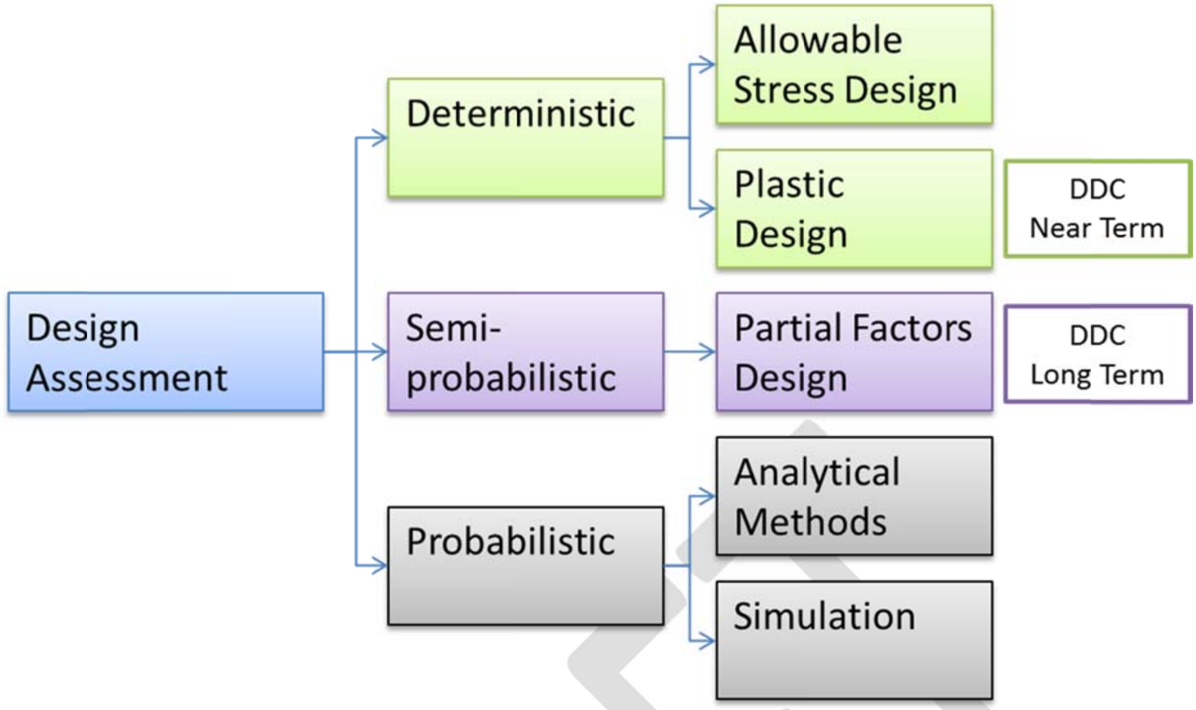

Figure 8: Design Assessment Techniques

The design assessment criteria can be found in Part 2.

The material data required to carry out this assessment can be found in Part 3.

To ensure a consistent design assessment of DEMO PFC's, example calculations have been provided in Part 4.

The justification for any rule modifications shall be provided in Part 5.

Note: It is recognised that both Divertor and Blanket designers are developing conceptual designs that need to be assessed to determine if the desired level of structural integrity is achieved. Until the DDC is reviewed, approved and released it is recommended that the ITER SDC-IC, RCC-MRx or ASME design Codes should be used as these are deemed to be the most appropriate for DEMO PFC's.

Note: The DDC shall provide Plastic Design Rules for all of the identified damage mechanisms.

In the cases where the rules in the available C&S are deemed to be sufficient and easy to follow, a reference shall be provided (the DDC shall not cut and paste work that exists elsewhere).

In the cases where the rules in the available C&S are deemed to be sufficient but are not easy to follow or are open to interpretation. The DDC shall attempt to re-write the rules in a clear and unambiguous way.

In the case where new rules are required. The DDC shall attempt to convey the new rules in a clear and unambiguous manner.

POWER PLANT PHYSICS & TECHNOLOGY DEPARTMENT

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DRAFT DDC Part 2
Design Assessment

		Deliverable-ID[1]	*MAT-1.3.3-T003-D002*
Work Package	*WPMAT*	**Date**	*31st Oct. 2016*
Project Leader	*Michael Rieth*		
TS Title	*DDC – DEMO Design Criteria*		
TS Ref. No.	*EDDI-1.3.3-T003*	**TS IDM-link**	EFDA_D_2N3M6L
Task Owner	*Manminder Kalsey*		
RU(s)	CCFE		

Report Review & Approval	
IDM role	**Name(s)**
Author	*Manminder Singh Kalsey*
Co-author(s)	*TBD*
Reviewer(s)	*Mike Fursdon, Jarir Aktaa, Mike Gorley*
PMU Reviewer	*Eberhard Diegele, Matti Oron-Carl*
Approver	*Michael Rieth*

X Study / Assessment   Procurement / Commissioning of Hardware   Industry

Use of Facility   Other *{please specify}*

[1] One *Deliverable Report* shall be submitted for each deliverable e.g. Study Report, Commissioning Report, Final Assessment Report, Technical Acceptance Report, Procurement Report, etc.

Executive Summary
This is the DEMO Design Criteria v1.0. It is a work in progress, and as such shall be updated regularly. It is intended to be written in the format that would be released once it is fully populated and reviewed. Notes are written in red as additional guidance and explanation. The red notes shall be removed once the DDC is released with approved design rules. **This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.**

Comments (shortcomings, deviations, etc.)
This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.

Table of Contents

References

1 Introduction

This Part of the DDC provides the design assessment criteria and procedure for the assessment of DEMO PFC's. This design assessment is primarily intended to demonstrate that the proposed design will not fail during the target design life. This is done by predicting the response of a design to the expected loading, and determining if this response would result in causing a failure. This Part needs to used in conjunction with the other Parts where the following information can be found:

Part 1: General Information: *providing required background information, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 3: Material Data: *the required physical property data along with the associated design allowable.*

Part 4: Example Calculations: *design assessment of a DEMO PFC is presented, demonstrating how an assessment should be carried out using ANSYS.*

Part 5: Rule Justifications: *explanations provided for why new or modified rules are adopted in the DDC.*

2 Loads and Operating Conditions

During operation, DEMO PFC's shall be subjected to various operating conditions that are made up of load combinations. These operating conditions shall be classified into categories based on both the probability of occurrence and consequences of failure. Each operating condition must be identified and classified as I (Operational), II (Likely), III (Unlikely) and IV (Extremely Unlikely). These operating condition classifications (I, II, III and IV) are related to A, B, C, D criteria levels in this document, which are used to categorize load factors and design limits that will be applied in the analysis of the respective operation condition. More details of this can be found in Part 1 Section 4.

2.1.1 Loads

The loads include, but are not limited to, the following:

a) Internal and external pressures.

b) Electromagnetic loads due to:

- disruptions,
- Vertical Displacement Events,
- Magnet faults.

These loads include reaction forces at the support points, including dynamic effects.

c) The weight of the component and its contents, and the static and dynamic loads due to its contents (fluid interaction) under each condition analysed.

d) Forces resulting from weight, thermal expansion, pressure and dynamic loads (anchor displacements) which originate outside the zone studied and which are applied at its boundaries.

e) Loads resulting from earthquakes and consequent vibrations, if any.

f) Temperature effects, either constant or transient.

g) Irradiation-induced swelling effects.

h) Pressure of explosion, if occurs in the vacuum vessel (including dynamic effects).

2.1.2 Load Factors

Factors are applied to loads to account for the differing levels of statistical reliability of the loading data.

TBD based on AMECFW work package.

2.1.3 Load Combinations & Associated Operating Conditions

TBD based on AMECFW work package.

3 Criteria Levels

TBD based on AMECFW work package.

4 PFC Design Assessment

The design assessment of the DEMO PFC's intends to demonstrate that the component shall retain its structural integrity for the required operational duration. This section provides design rules to ensure that the potential damage mechanisms do not cause an unplanned failure.

Although it is recommended that the PFC should be modelled and assessed in its entirety, each of the elements will not be subject to the complete range of damage mechanisms. The following table highlights the damage mechanisms that need to be assessed for each element.

Note: It is recognised that both Divertor and Blanket designers are developing conceptual designs that need to be assessed to determine if the desired level of structural integrity is achieved. Until the DDC is approved and released it is recommended that the ITER SDC-IC or the RCC-MRx should be used as these are deemed to be the most appropriate for DEMO PFC's.

Note: The DDC shall provide Plastic Design Rules for all of the identified damage mechanisms.

In the cases where the rules in the available C&S are deemed to be sufficient and easy to follow, a reference shall be provided (the DDC shall not cut and paste work that exists elsewhere).

In the cases where the rules in the available C&S are deemed to be sufficient but are not easy to follow or are open to interpretation. The DDC shall attempt to re-write the rules in a clear and unambiguous way.

In the case where new rules are required. The DDC shall attempt to convey the new rules in a clear and unambiguous manner.

Damage Mechanisms	Structural Element	Armour Element	Joint Element
Monotonic Damage			
Plastic Collapse		Potentially relevant	n/a
Plastic Flow Localisation		Potentially relevant	n/a
Exhaustion of Ductility		Potentially relevant	n/a
Brittle Fracture			Potentially relevant
Thermal Creep		Potentially relevant	n/a
Cyclic Damage			
Ratcheting		n/a	Potentially relevant
Fatigue			
Environmental Damage			
Swelling		n/a	Potentially relevant
Corrosion		n/a	Potentially relevant
Erosion			Potentially relevant
Compound Damage			
Stress Corrosion Cracking		n/a	Potentially relevant
Creep Fatigue		Potentially relevant	n/a

Table 1: Damage mechanisms that need to be assessed by each PFC element.

To ensure that the irradiation damage/benefit is captured, all damage mechanisms should be assessed using both the start of life and end of life material properties. *Note: It is understood that in most cases, end of life material properties are not available, in these circumstances the DDC shall attempt to supply predicted end of life material properties. If however, the DDC is unable to provide predicted end of life material properties than a comprehensive surveillance programme must be specified.*

4.1 Monotonic Damage Mechanism

4.1.1 Plastic Collapse

This design rule has originated from ASME VIII Division 2. Minor text modifications have been made, however the technical content remains the same.

Note: This design rule is awaiting load factors before it becomes usable. Once these have been defined, it needs to be reviewed. Validation may not be required as it is an established design rule.

4.1.1.1 Overview

Protection against plastic collapse is evaluated by determining the plastic collapse load of the component using an elastic-plastic stress analysis. The allowable load on the component is established by applying a design factor to the calculated plastic collapse load.

4.1.1.2 Numerical Analysis

The plastic collapse load can be obtained using a numerical analysis technique (e.g.finite element method) by incorporating an elastic-plastic material model to obtain a solution. The effects of non-linear geometry shall be considered in this analysis. The plastic collapse load is the load that causes overall structural instability. This point is indicated by the inability to achieve an equilibrium solution for a small increase in load (i.e. the solution will not converge).

4.1.1.3 Acceptance Criteria

The acceptability of a component using an elastic-plastic analysis is determined by satisfying the following criteria.

A global plastic collapse load is established by performing an elastic-plastic analysis of the component subject to the specified loading conditions. The plastic collapse load is taken as the load which causes overall structural instability. The concept of Load and Resistance Factor Design (LRFD) is used as an alternate to the rigorous computation of a plastic collapse load to design a component. In this procedure, factored loads that include a design factor to account for uncertainty, and the resistance of the component to these factored loads are determined using an elastic-plastic analysis (see Table (TBD).

4.1.1.4 Assessment Procedure

The following assessment procedure is used to determine the acceptability of a component using an elastic-plastic stress analysis.

Step 1. Develop a numerical model of the component including all relevant geometry characteristics. The model used for the analysis shall be selected to accurately represent the component geometry, boundary conditions, and applied loads. In addition, refinement of the model around areas of stress and strain concentrations shall be provided. The analysis of one or more numerical models may be required to ensure that an accurate description of the stress and strains in the component is achieved.

Step 2. Define all relevant loads and applicable load cases. The loads to be considered in the design shall include, but not be limited to, those given in Table (TBD).

Step 3. An elastic plastic material model shall be used in the analysis. The von Mises yield function and associated flow rule should be utilized if plasticity is anticipated. A material model that includes hardening or softening, or an elasticperfectly plastic model may be utilized. When using this material model, the hardening behavior shall be included up to the true ultimate stress and perfect plasticity behavior (i.e. the slope of the stress-strain curves is zero) beyond this limit. The effects of non-linear geometry shall be considered in the analysis.

Step 4. Determine the load case combinations to be used in the analysis using the information from Step 2 in conjunction with Table (TBD) Each of the indicated load cases shall be evaluated. The effects of one or more loads not acting shall be investigated. Additional load cases for special conditions not included in Table (TBD) shall be considered, as applicable.

Step 5. Perform an elastic-plastic analysis for each of the load cases defined in Step 4. If convergence is achieved, the component is stable under the applied loads for this load case. Otherwise, the component configuration (i.e. thickness) shall be modified or applied loads reduced and the analysis repeated.

4.1.2 Plastic Flow Localisation

This design rule has been sourced from the ITER SDC-IC. Text and technical modifications have been made the justifications of which can be found in Part 5.

Note: This damage mechanism requires additional work, this shall be carried out in 2017, it is envisaged that a design rule shall be written and reviewed by the end of 2017. To fully validate this rule may require additional time, depending on available test data.

4.1.2.1 Overview

Protection against plastic flow localisation is evaluated by demonstrating that the specified loadings do not allow for the onset of strain softening. The magnitude of local damage is predicted using an elastic-plastic stress analysis, and compared with the associated design allowable.

4.1.2.2 Numerical Analysis

The peak total strain can be obtained using a numerical analysis technique (e.g.finite element method) by incorporating an elastic-perfectly plastic material model to obtain a solution. The effects of non-linear geometry shall be considered in this analysis.

4.1.2.3 Acceptance Criteria

The acceptability of a component using an elastic-plastic analysis is determined by satisfying the following criteria:

The peak total strain is calculated by performing an elastic-plastic analysis of the component subject to the specified loading conditions. The peak total strain needs to be lower than the minimum strain at rupture. In this procedure, factored loads that include a design factor to account for uncertainty, and the resistance of the component to these factored loads are determined using an elastic-plastic analysis.

4.1.2.4 Assessment Procedure

The following assessment procedure is used to determine the acceptability of a component using an elastic-plastic stress analysis.

Step 1. Develop a numerical model of the component including all relevant geometry characteristics. The model used for the analysis shall be selected to accurately represent the component geometry, boundary conditions, and applied loads. In addition, refinement of the model around areas of stress and strain concentrations shall be provided. The analysis of one or more numerical models may be required to ensure that an accurate description of the stress and strains in the component is achieved.

Step 2. Define all relevant loads and applicable load cases. The loads to be considered in the design shall include, but not be limited to, those given in Table (TBD).

Step 3. An elastic perfectly plastic material model shall be used in the analysis. The von Mises yield function and associated flow rule should be utilised if plasticity is anticipated. The effects of non-linear geometry shall be considered in the analysis.

Step 4. Determine the load case combinations to be used in the analysis using the information from Step 2 in conjunction with Table (TBD). Each of the indicated load cases shall be evaluated. The effects of one or more loads not acting shall be investigated. Additional load cases for special conditions not included in Table (TBD) shall be considered, as applicable.

Step 5. Perform an elastic-plastic analysis for each of the load cases defined in Step 4.

Step 6. Evaluate the peak "total strain" against the design allowable "uniform elongation".

4.1.3 Exhaustion of Ductility

This design rule has been sourced from the ITER SDC-IC. Text and technical modifications have been made the justifications of which can be found in Part 5.

Note: This damage mechanism requires additional work, this shall be carried out in 2017, it is envisaged that a design rule shall be written and reviewed by the end of 2017. To fully validate this rule may require additional time, depending on available test data.

4.1.3.1 Overview

Protection against exhaustion of ductility is evaluated by demonstrating that the specified loadings do not cause local damage due to the exhaustion of ductility. The magnitude of local damage is predicted using an elastic-plastic stress analysis, and compared with the associated design allowable.

4.1.3.2 Numerical Analysis

The peak total strain can be obtained using a numerical analysis technique (e.g.finite element method) by incorporating an elastic-perfectly plastic material model to obtain a solution. The effects of non-linear geometry shall be considered in this analysis.

4.1.3.3 Acceptance Criteria

The acceptability of a component using an elastic-plastic analysis is determined by satisfying the following criteria:

The peak total strain is calculated by performing an elastic-plastic analysis of the component subject to the specified loading conditions. The peak total strain needs to be lower than the minimum strain at rupture. In this procedure, factored loads that include a design factor to account for uncertainty, and the resistance of the component to these factored loads are determined using an elastic-plastic analysis (see Table (TBD)).

$\varepsilon t < \varepsilon r$

4.1.3.4 Assessment Procedure

The following assessment procedure is used to determine the acceptability of a component using an elastic-plastic stress analysis.

Step 1. Develop a numerical model of the component including all relevant geometry characteristics. The model used for the analysis shall be selected to accurately represent the component geometry, boundary conditions, and applied loads. In addition, refinement of the model around areas of stress and strain concentrations shall be provided. The analysis of one or more numerical models may be required to ensure that an accurate description of the stress and strains in the component is achieved.

Step 2. Define all relevant loads and applicable load cases. The loads to be considered in the design shall include, but not be limited to, those given in Table (TBD).

Step 3. An elastic perfectly plastic material model shall be used in the analysis. The von Mises yield function and associated flow rule should be utilised if plasticity is anticipated. The effects of non-linear geometry shall be considered in the analysis.

Step 4. Determine the load case combinations to be used in the analysis using the information from Step 2 in conjunction with Table (TBD). Each of the indicated load cases shall be evaluated. The effects of one or more loads not acting shall be investigated. Additional load cases for special conditions not included in Table (TBD) shall be considered, as applicable.

Step 5. Perform an elastic-plastic analysis for each of the load cases defined in Step 4. For each load combination.

Step 6. Evaluate the peak “total strain” against the design allowable “strain to rupture”.

4.1.4 Brittle Fracture

This design rule has been sourced from the ITER SDC-IC. Text and technical modifications have been made the justifications of which can be found in Part 5.

Note: This damage mechanism has been drafted, however, it needs to be reviewed, and if required modified by the Damage Mechanism Expert.

4.1.4.1 Overview

Protection against brittle fracture is evaluated by demonstrating that the specified loadings do not cause a pre-existent crack to propagate to failure. The magnitude of defect stress intensity is predicted using an elastic-plastic stress analysis, and compared with the associated design allowable.

4.1.4.2 Numerical Analysis

The J-Integral can be obtained using a numerical analysis technique (e.g.finite element method) by incorporating an elastic-perfectly plastic material model to obtain a solution. The effects of non-linear geometry shall be considered in this analysis.

4.1.4.3 Acceptance Criteria

The acceptability of a component using an elastic-plastic analysis is determined by satisfying the following criteria:

The J-integral is calculated by performing an elastic-plastic analysis of the component subject to the specified loading conditions. The calculated J-Integral needs to be lower than the critical J-Integral. In this procedure, factored loads that include a design factor to account for uncertainty, and the resistance of the component to these factored loads are determined using an elastic-plastic analysis (see Table (TBD)).

$J < Jc$

4.1.4.4 Assessment Procedure

The following assessment procedure is used to determine the acceptability of a component using an elastic-plastic stress analysis.

Step 1. Develop a numerical model of the component including all relevant geometry characteristics. The model used for the analysis shall be selected to accurately represent the component geometry, boundary conditions, and applied loads. In addition, refinement of the model around areas of stress and strain concentrations shall be provided. The analysis of one or more numerical models may be required to ensure that an accurate description of the stress and strains in the component is achieved.

Step 2. Define all relevant loads and applicable load cases. The loads to be considered in the design shall include, but not be limited to, those given in Table (TBD).

Step 3. An elastic perfectly plastic material model shall be used in the analysis. The von Mises yield function and associated flow rule should be utilised if plasticity is anticipated. The effects of non-linear geometry shall be considered in the analysis.

Step 4. Determine the load case combinations to be used in the analysis using the information from Step 2 in conjunction with Table (TBD). Each of the indicated load cases shall be evaluated. The effects of one or more loads not acting shall be investigated. Additional load cases for special conditions not included in Table (TBD) shall be considered, as applicable.

Step 5. Perform an elastic-plastic analysis for each of the load cases defined in Step 4. For each load combination.

Step 6. Identify the location where brittle fracture is most likely to occur. This location is likely to be where the maximum principal stress occurs.

Step 7. Introduce a defect of size ??? and shape ??? into the FE model at the location identified in the previous step.

Step 8. Perform an elastic-plastic analysis for each of the load cases defined in Step 4. For each load combination, using the FE model containing the defect.

Step 9. Evaluate the peak "J-Integral" predicted at the defect against the design allowable "Critical J-Integral".

4.1.5 Thermal Creep

This design rule has been sourced from the ITER SDC-IC. Text and technical modifications have been made the justifications of which can be found in Part 5.

Note: This damage mechanism has been drafted, however, it needs to be reviewed, and modified by the Damage Mechanism Expert.

4.1.5.1 Overview

Protection against local cracking caused by thermal creep is evaluated by demonstrating that the specified loadings do not cause a crack to initiate due to an accumulation of creep damage. The magnitude of stress intensity and temperature is predicted using an elastic-plastic stress analysis, and compared with the associated creep rupture curves. From this a Creep Damage usage fraction is calculated.

4.1.5.2 Numerical Analysis

The stress intensity and temperature can be obtained using a numerical analysis technique (e.g.finite element method) by incorporating an elastic-perfectly plastic material model to obtain a solution. The effects of non-linear geometry shall be considered in this analysis.

4.1.5.3 Acceptance Criteria

The acceptability of a component using an elastic-plastic analysis is determined by satisfying the following criteria:

The Creep Usage Fraction (Wt) is calculated by performing an elastic-plastic analysis of the component subject to the specified loading conditions at different time intervals. The calculated accumulated Creep Usage Fraction needs to be less than 1. In this procedure, factored loads that include a design factor to account for uncertainty, and the resistance of the component to these factored loads are determined using an elastic-plastic analysis (see Table (TBD)).

$$Wt < 1$$

4.1.5.4 Assessment Procedure

The following assessment procedure is used to determine the acceptability of a component using an elastic-plastic stress analysis.

Step 1. Develop a numerical model of the component including all relevant geometry characteristics. The model used for the analysis shall be selected to accurately represent the component geometry, boundary conditions, and applied loads. In addition, refinement of the model around areas of stress and strain concentrations shall be provided. The analysis of one or more numerical models may be required to ensure that an accurate description of the stress and strains in the component is achieved.

Step 2. Define all relevant loads and applicable load cases. The loads to be considered in the design shall include, but not be limited to, those given in Table (TBD).

Step 3. An elastic perfectly plastic material model shall be used in the analysis. The von Mises yield function and associated flow rule should be utilised if plasticity is anticipated. The effects of non-linear geometry shall be considered in the analysis.

Step 4. Determine the load case combinations to be used in the analysis using the information from Step 2 in conjunction with Table (TBD). Each of the indicated load combinations shall be evaluated. Additional load cases for special conditions not included in Table (TBD) shall be considered, as applicable.

Step 5. Perform an elastic-plastic analysis for each of the load combinations defined in Step 4.

Step 6.

Step 7.

Step 8.

Step 9.

4.2 Cyclic Damage Mechanisms

4.2.1 Ratcheting

This design rule has been developed new for the DDC.

Note: This damage mechanism shall be drafted following a review of the 2016 task specification. It shall then need to be reviewed, modified and validated, this shall happen in 2017.

4.2.1.1 Overview

4.2.1.2 Numerical Analysis

4.2.1.3 Acceptance Criteria

4.2.1.4 Assessment Procedure

4.2.2 Fatigue

Note: This damage mechanism shall be drafted in 2017 following a review of the 2016 task specification. It shall then need to be reviewed, modified and validated, an initial draft is expected in

2017. A number a developments are expected in proceeding years, the rule shall be updated accordingly.

4.2.2.1 Overview

4.2.2.2 Numerical Analysis

4.2.2.3 Acceptance Criteria

4.2.2.4 Assessment Procedure

4.3 Environmental Damage Mechanisms

Note: Currently no work has been carried out on these damage mechanisms within the DDC project. These items shall need to be planned into future activities.

4.3.1 Swelling

4.3.2 Corrosion

4.3.3 Erosion

4.4 Compound Damage Mechanisms

4.4.1 Stress Corrosion Cracking

Note: Currently no work has been carried out on this damage mechanism within the DDC project. This item shall need to be planned into future activities.

4.4.2 Creep Fatigue

Note: This damage mechanism shall be drafted in 2017 following a review of the 2016 task specification. It shall then need to be reviewed, modified and validated, an initial draft is expected in 2017. A number of developments are expected in proceeding years, the rule shall be updated accordingly.

POWER PLANT PHYSICS & TECHNOLOGY DEPARTMENT

Report IDM reference No.	EFDA_D_2N3M6L	Version: see IDM

DRAFT DDC Part 3
Material Data

		Deliverable-ID[1]	*MAT-1.3.3-T003-D002*
Work Package	*WPMAT*	**Date**	*31st Oct. 2016*
Project Leader	*Michael Rieth*		
TS Title	*DDC – DEMO Design Criteria*		
TS Ref. No.	*EDDI-1.3.3-T003*	**TS IDM-link**	EFDA_D_2N3M6L
Task Owner	*Manminder Kalsey*		
RU(s)	CCFE		

Report Review & Approval	
IDM role	**Name(s)**
Author	*Manminder Singh Kalsey*
Co-author(s)	*TBD*
Reviewer(s)	*Mike Fursdon, Jarir Aktaa, Mike Gorley*
PMU Reviewer	*Eberhard Diegele, Matti Oron-Carl*
Approver	*Michael Rieth*

X Study / Assessment Procurement / Commissioning of Hardware Industry

Use of Facility Other *{please specify}*

[1] One *Deliverable Report* shall be submitted for each deliverable e.g. Study Report, Commissioning Report, Final Assessment Report, Technical Acceptance Report, Procurement Report, etc.

Executive Summary
This is the DEMO Design Criteria v1.0. It is a work in progress, and as such shall be updated regularly. It is intended to be written in the format that would be released once it is fully populated and reviewed. Notes are written in red as additional guidance and explanation. The red notes shall be removed once the DDC is released with approved design rules. This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.

Comments (shortcomings, deviations, etc.)
This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.

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References

1 Introduction

This Part of the DDC provides the required material data required to perform the design assessment found in Part 2. This includes all of the physical data required to set up a FEA model to perform an elasto-plastic analysis, along with the design allowables required to demonstrate a required level of structural integrity. This Part needs to used in conjunction with the other Parts where the following information can be found:

Part 1: General Information: *providing required background information, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 2: Design Assessment: *providing required operating conditions, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 4: Example Calculations: *design assessment of a DEMO PFC is presented, demonstrating how an assessment should be carried out using ANSYS.*

Part 5: Rule Justifications: *explanations provided for why new or modified rules are adopted in the DDC.*

Note: The need for this Part is currently under review. It may be possible and potentially more efficient to include all of this data within the material properties handbook. This would have the benefit of reducing the number of documentations that need to be managed, hence reducing resource overhead and potential for data errors and inconsistencies creeping in. However, until a formal decision has been made, an attempt has been made to create the Part 3 structure.

1.1 Included Materials

This part of the DDC includes data for the following materials:

- CuCrZr – grade TBD
- Eurofer – grade TBD
- Tungsten – grade TBD

Both Physical data and Design Allowable data are supplied in un-irradiated and irradiated states. Any missing data is clearly highlighted.

1.1.1 Physical Data

The following physical data is supplied for each of the materials:

- Coefficient of thermal expansion
- Young's modulus
- Poisson's ratio
- Mass density
- Thermal conductivity
- Specific heat
- Monotonic stress-strain curves
- Cyclic stress-strain curves

1.1.2 Design Assessment Data

The following design assessment data is supplied for each of the materials:

- TBD

2 CuCrZr (TBD)

2.1 Physical Data

2.2 Design Assessment Data

3 Eurofer (TBD)

3.1 Physical Data

3.2 Design Assessment Data

4 Tungsten (TBD)

4.1 Physical Data

4.2 Design Assessment Data

POWER PLANT PHYSICS & TECHNOLOGY DEPARTMENT

Report IDM reference No.	*EFDA_D_2N3M6L*	Version: see IDM

DRAFT DDC Part 4
Example Calculations

		Deliverable-ID[1]	*MAT-1.3.3-T003-D002*
Work Package	*WPMAT*	**Date**	*31st Oct. 2016*
Project Leader	*Michael Rieth*		
TS Title	*DDC – DEMO Design Criteria*		
TS Ref. No.	*EDDI-1.3.3-T003*	**TS IDM-link**	*EFDA_D_2N3M6L*
Task Owner	*Manminder Singh Kalsey*		
RU(s)	CCFE		

Report Review & Approval	
IDM role	**Name(s)**
Author	*Manminder Singh Kalsey*
Co-author(s)	*TBD*
Reviewer(s)	*Mike Fursdon, Jarir Aktaa, Mike Gorley*
PMU Reviewer	*Eberhard Diegele, Matti Oron-Carl*
Approver	*Michael Rieth*

X Study / Assessment — Procurement / Commissioning of Hardware — Industry

Use of Facility — Other *{please specify}*

[1] One *Deliverable Report* shall be submitted for each deliverable e.g. Study Report, Commissioning Report, Final Assessment Report, Technical Acceptance Report, Procurement Report, etc.

Executive Summary
This is the DEMO Design Criteria v1.0. It is a work in progress, and as such shall be updated regularly. It is intended to be written in the format that would be released once it is fully populated and reviewed. Notes are written in red as additional guidance and explanation. The red notes shall be removed once the DDC is released with approved design rules. **This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.**

Comments (shortcomings, deviations, etc.)
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References

1 Introduction

This Part of the DDC provides example design assessment of DEMO PFC's using the design rules found within the DDC. This design assessment is primarily intended to demonstrate that the proposed design will not fail during the target design life. This is done by predicting the response of a design to the expected loading, and determining if this response would result in causing a failure. This Part needs to used in conjunction with the other Parts where the following information can be found:

Part 1: General Information: *providing required background information, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 2: Design Assessment: *providing required operating conditions, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 3: Material Data: *the required physical property data along with the associated design allowable.*

Part 5: Rule Justifications: *explanations provided for why new or modified rules are adopted in the DDC.*

Note: This Part of the DDC will only become relevant once the proceeding Parts have been finalised reviewed and released. Information within this document is only included to provide an indication of the structure that will be contained within this document.

Note: The DIV team have already created a good plastic analysis procedure. That report has been used as an appropriate lead for the structure of this example calculation.

2 Divertor DDC Assessment (TBD)

This section provides an example DDC assessment of a Divertor.

2.1 Problem Definition (TBD)

This section defines the key parameters of the example calculation. This includes the following information:

- Component Geometry
- Component Materials
- Loads and Load combinations

2.2 Model Definition (TBD)

This section provides an example of how to set up a finite element analysis of the Divertor. This includes the following information:

- Boundary conditions
- Mesh Definition
- ANSYS workbench model structure

2.3 Design Assessment (TBD)

This section demonstrates how to assess if the Divertor shall maintain it's structural integrity based on all of the design rules found within the DDC.

3 Blanket DDC Assessment (TBD)

This section provides an example DDC assessment of a Blanket.

3.1 Problem Definition (TBD)

This section defines the key parameters of the example calculation. This includes the following information:

- Component Geometry
- Component Materials
- Loads and Load combinations

3.2 Model Definition (TBD)

This section provides an example of how to set up a finite element analysis of the Blanket. This includes the following information:

- Boundary conditions
- Mesh Definition
- ANSYS workbench model structure

3.3 Design Assessment (TBD)

This section demonstrates how to assess if the Blanket shall maintain it's structural integrity based on all of the design rules found within the DDC.

POWER PLANT PHYSICS & TECHNOLOGY DEPARTMENT

Report IDM reference No.	EFDA_D_2N3M6L	Version: see IDM

DRAFT DDC Part 4
Example Calculations

		Deliverable-ID[1]	DRAFT 1
Work Package	*WPMAT*	**Date**	*31st Oct. 2016*
Project Leader	*Michael Rieth*		
TS Title	*DDC – DEMO Design Criteria*		
TS Ref. No.	*EDDI-1.3.3-T003*	**TS IDM-link**	EFDA_D_2N3M6L
Task Owner	*Manminder Singh Kalsey*		
RU(s)	CCFE		

Report Review & Approval	
IDM role	**Name(s)**
Author	*Manminder Singh Kalsey*
Co-author(s)	*TBD*
Reviewer(s)	*Mike Fursdon, Jarir Aktaa, Mike Gorley*
PMU Reviewer	*Eberhard Diegele, Matti Oron-Carl*
Approver	*Michael Rieth*

X Study / Assessment   Procurement / Commissioning of Hardware   Industry

Use of Facility   Other *{please specify}*

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Executive Summary
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Comments (shortcomings, deviations, etc.)
This document is not complete and has not been reviewed and as such shall not be taken in precedent over established Codes and Standards.

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References

1 Introduction

This Part of the DDC provides a justification for the design assessment philosophy found in Part 1. It also provides a justification for all of the new damage mechanism assessment rules found in Part 2. Where necessary, the justifications are supported with validations that demonstrate the benefits of the new design rules over existing design rules. This Part needs to used in conjunction with the other Parts where the following information can be found:

Part 1: General Information: *providing required background information, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 2: Design Assessment: *providing required operating conditions, including definitions, load classifications, operating conditions, damage mechanism descriptions and design assessment philosophy.*

Part 3: Material Data: *the required physical property data along with the associated design allowable.*

Part 4: Example Calculations: *design assessment of a DEMO PFC is presented, demonstrating how an assessment should be carried out using ANSYS.*

Note: This document shall be populated as and when new design rules have been entered into the DDC Part 2 and are ready for release to the design teams. It shall provide additional technical information that may not be required to perform a design assessment, but is required to understand the reasons behind the change from existing design rules. In addition, any validation work carried out shall be placed in this Part.

2 Design Philosophy (TBD)

3 Load Factors (TBD)

4 Design Rules (TBD)