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Fusion Energy Devices and the ASME BPVC

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Regulatory Landscapes: US

Fusion Regulation: Current Frameworks and Divergence

- **United States – 10 CFR Part 30 Framework**
- **Fusion is currently regulated under 10 CFR Part 30**, which governs byproduct materials (e.g. tritium, activated components), similar to particle accelerators—not under 10 CFR Parts 50/52 used for fission reactors
- This approach reflects fusion’s **lower radiological hazard profile**:
 - No criticality risk
 - No spent nuclear fuel
 - No long-term high-level waste
 - Hazards (e.g. tritium, activated dust) are **static or decay naturally**
- **Radiation dose limits** for fusion facilities can be maintained within existing 10 CFR Part 20 thresholds:
 - Annual effluent: 10 mrem
 - Direct dose in any hour: 2 mrem
 - Accident dose: 1,000 mrem
- **Part 30 includes a graded approach** to licensing based on hazard level, avoiding arbitrary thresholds for tritium inventory
- **Fusion-specific ‘rule making’** is being developed via a new volume of NUREG-1556 to ensure consistency across Agreement States.

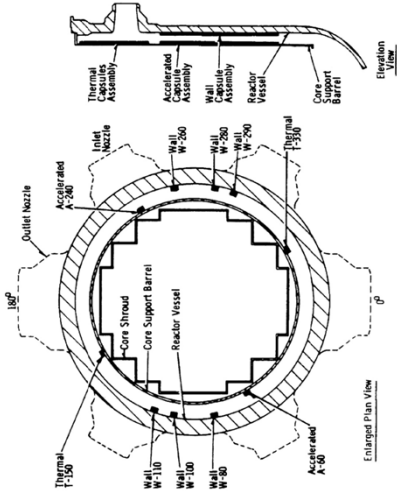


Fusion vs Fission: Technical and Regulatory Differences

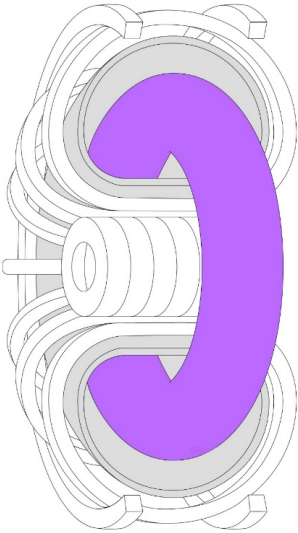
Fusion Isn't Fission: Why Codes Must Evolve

Aspect	Fission Power Plant	Fusion Power Plant
Energy Source	Splitting heavy nuclei (e.g. U-235)	Fusing light nuclei (e.g. deuterium, tritium)
Fuel Type	Enriched uranium or MOX	Deuterium and tritium (often bred in blanket systems)
Criticality Risk	Yes – requires active control to prevent runaway reactions	No – fusion reactions are inherently self-limiting
Waste Profile	Long-lived radioactive waste (spent fuel)	Short-lived activated materials; tritium handling
Failure Modes	Core meltdown, loss of coolant accident	Component degradation (e.g. blanket failure, tritium leakage)
Component Environment	Uniform reactor core conditions	Radial build with diverse conditions (cryogenic magnets, high-pressure blankets, etc.)
Materials Challenges	High-temperature corrosion, neutron embrittlement	High neutron flux, liquid metal corrosion, irradiation-induced creep
Commercial Status	Operational fleet worldwide	Multiple companies building proof-of-concept plants; some targeting grid delivery by 2030

- With multiple fusion companies targeting **electricity delivery by 2030**, and a bold decadal-vision from **US Congress**, a robust, scalable code is essential.



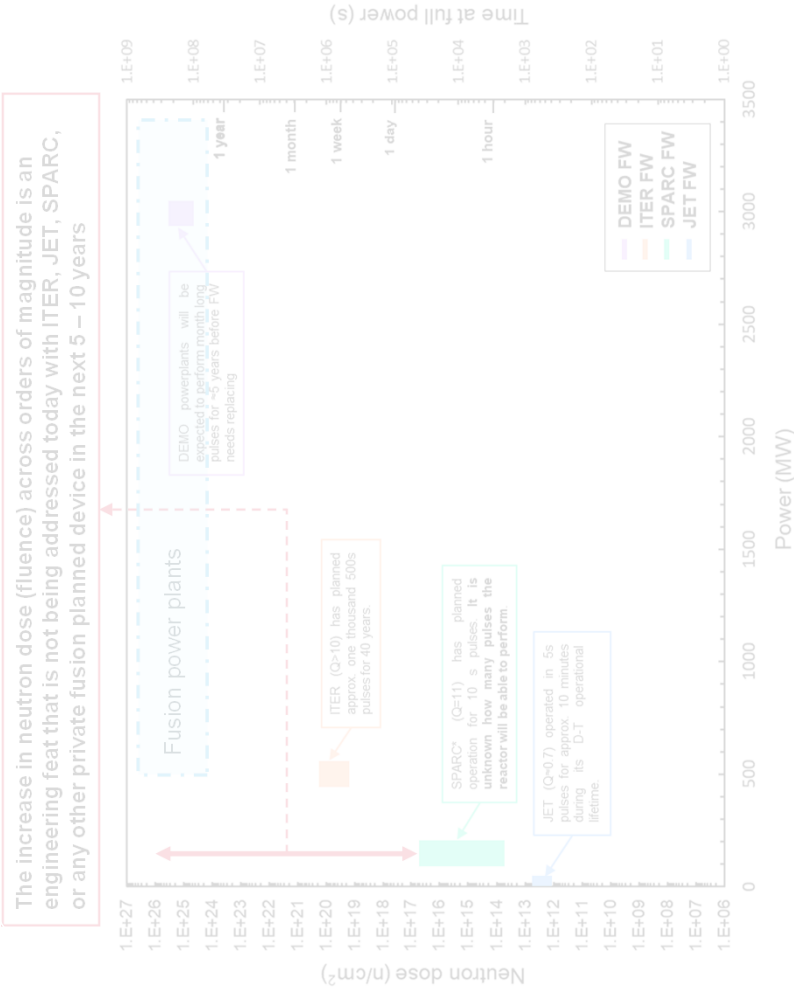
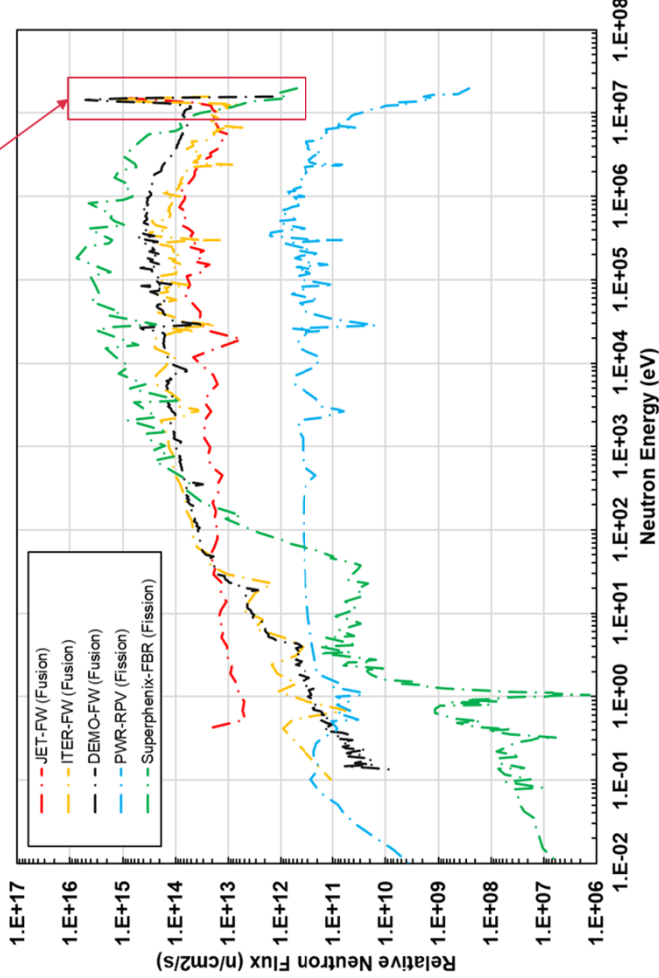
*Taken from ASTM STP 1603, 2018, Westinghouse



A Major Challenge – Neutron dose to in-vessel components

Neutrons cause materials to degrade (change in yield strength, embrittlement, swelling, transmutation, helium embrittlement). Fusion energy produces a **high neutron flux and fluence** that cause the effects above to dominate the engineering challenges and **undermines the safe operation of reactors**.

14.1 MeV peak, specific to fusion and no testing facility can currently replicate it for materials testing



Breeder Blanket – Safety vs Investment

Lifetime-Limiting Components: Protecting Investment

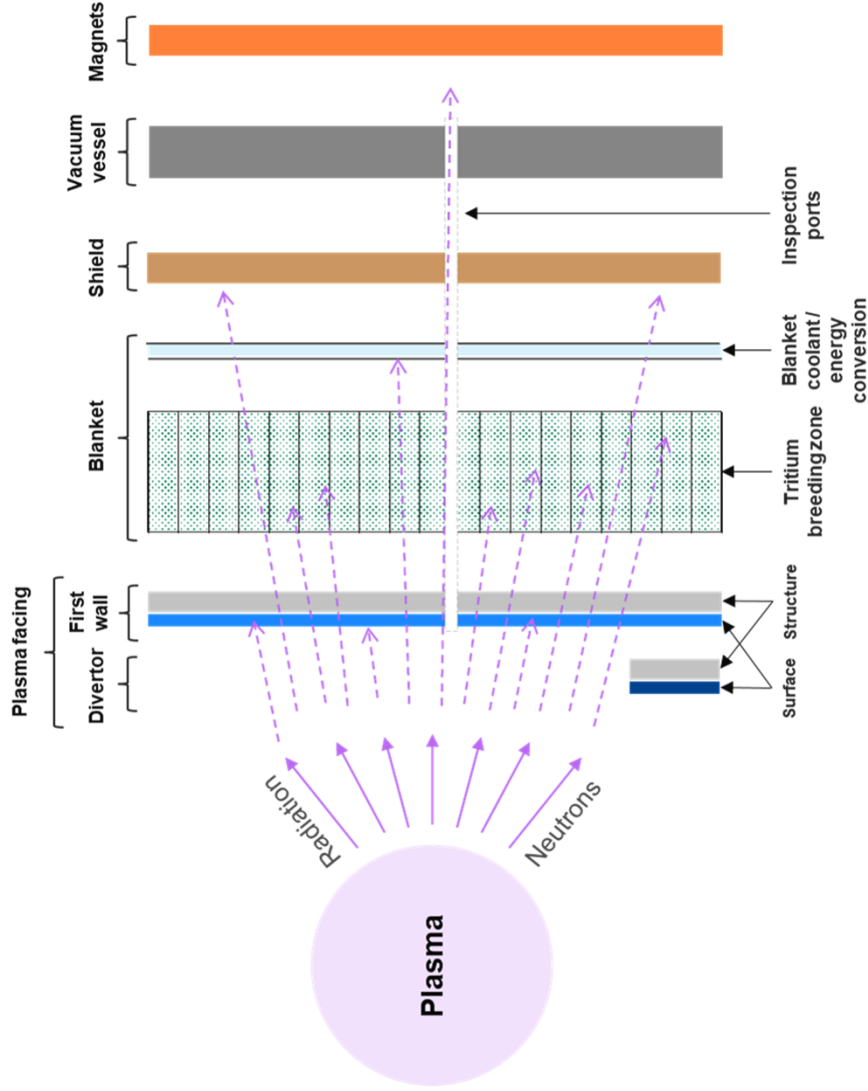


Table: General power plant environmental conditions

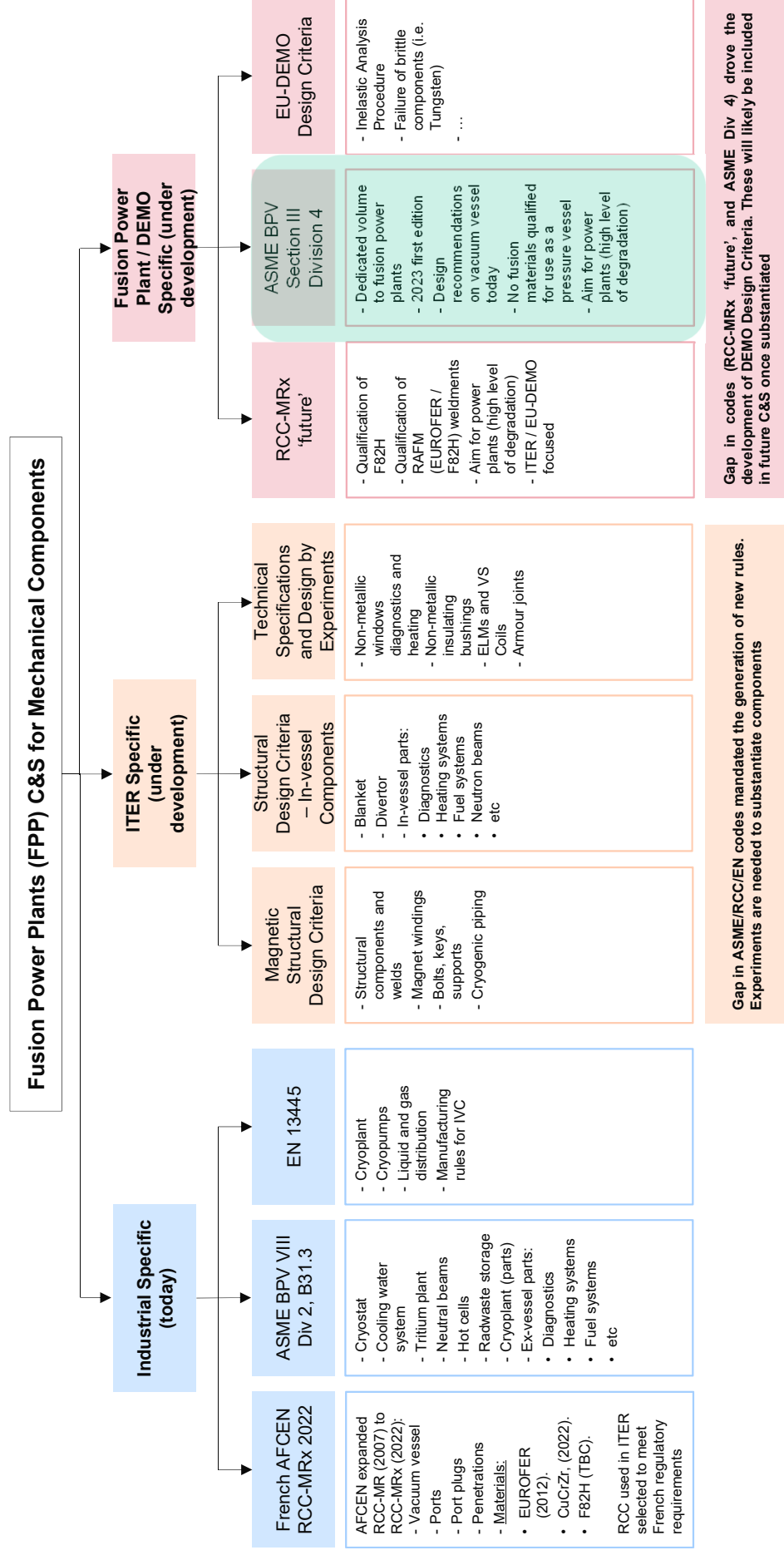
	Plasma facing	Breeder blanket	Vacuum vessel	Magnet structure
Neutron irradiation	High	Very high	Low	Very low
Expected life	Short	Medium	Forever	Forever
Temperature	High	Medium	Low	Cryo
Pressure	High coolants	High coolants	Medium coolants	0.6 MPa liquid He
Mechanical loading	Low	High creep / fatigue	High loading	Very high loadings
Expected failure modes	Creep, ratcheting etc	Creep, ratcheting, embrittlement	Ductile failure	Fast fracture
Tolerability of failure	Maybe some	Maybe fewer or none?	No	No

Strict high demands on quality requirements of components to ensure operational and/or safety requirements

Existing Standards Landscape

Current Codes in Use: ASME BPVC, RCC-MRx, EN 13445

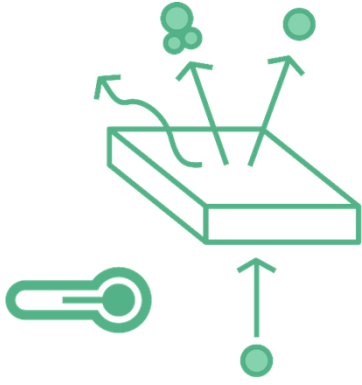
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What's Missing?: Environmental Effects

Closing the Gaps: Irradiation, Corrosion, and Design Complexities

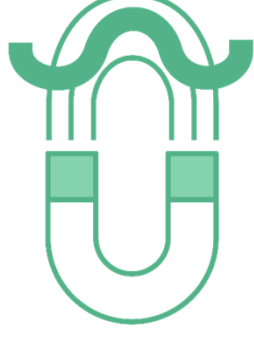
- Current applicable codes lack provision for the following fusion-specific conditions:



**High-Temperature
Neutron Irradiation**



**Liquid Metal
Corrosion**



**Fusion Specific
Loadings (MHD)**



**Complex Failure
Modes (e.g.
Embrittlement)**

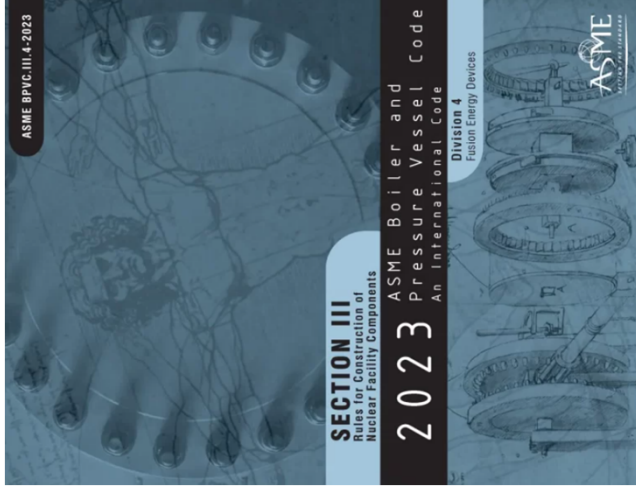
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ASME Section III Division 4 Roadmap

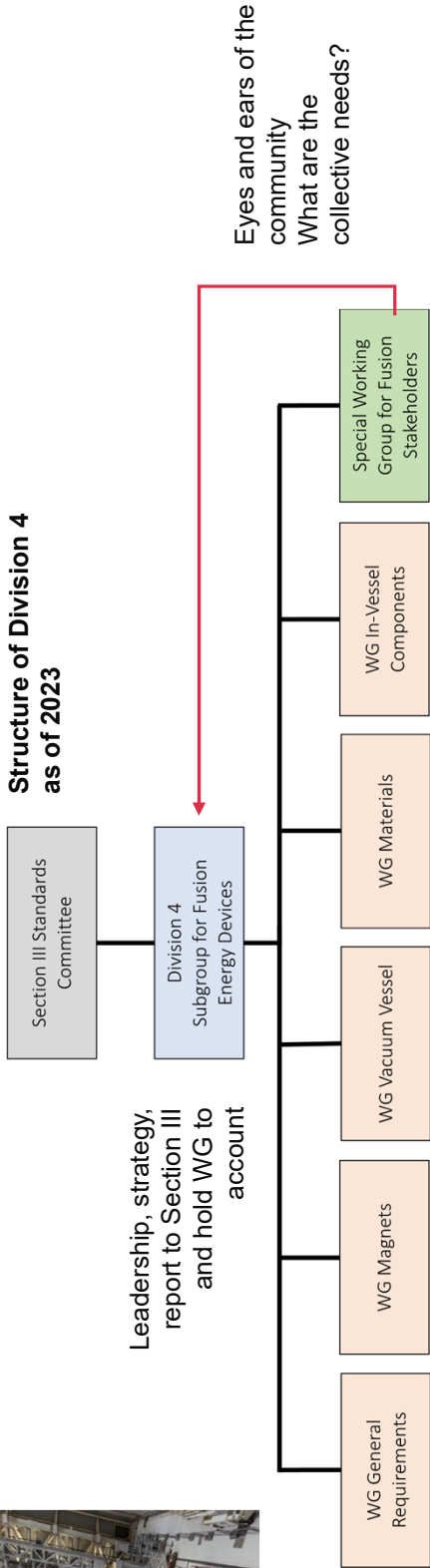
Section III – Rules for Construction of Nuclear Facility Components, Division 4 – Fusion Energy Devices

Section III Charter: “To develop, review, and maintain, [...] rules governing the construction of [...] Division 4 components for fusion devices [...]. [...] [These rules focus on assuring the pressure boundary integrity and the structural integrity](#), as applicable, of the component or item being constructed.

Division 4 Charter: “The Subgroup shall develop rules for the construction of fusion-energy-related components such as vacuum vessel (vacuum or target chamber), cryostat and superconductor structures and their interaction with each other. [...] [The rules shall contain requirements for materials, design, fabrication, testing, examination, inspection, certification, and stamping.](#)”



Building the Fusion Code: ASME BPVC Section III Division 4



ASME BPV Section III Division 4 WG Materials (future vision)

Base Material	Spec No	Product Form	Types / Grades
Austenitic stainless steel	TBD	Same as Div 1/Div 5	316LN-(IG)
Reduced-activation steel	TBD	Plate, pipe?	EUROFER97, F82H-IEA
Vanadium alloys	TBD	TBD	V-4Cr-4Ti, V15Cr-4Ti ?
Copper alloys	TBD	TBD	CuCrZr?
Ceramics	TBD	TBD	SiC _f /SiC?

Division 4 Fusion Stakeholders are supporting the collection of interest on Types / Grades required

Specifications are needed for all listed Base Materials

Product Forms must be defined for more novel materials of interest

Summary & Call to Action

Special Working Group for Fusion Stakeholders Meeting Highlights

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- ~30 attendees spanning a wide range of stakeholders
 - **Fusion technology developers:** Commonwealth Fusion Systems, EX-Fusion, Kyoto Fusionneering, Tokamak Energy, Type One Energy, Zap Energy
 - **Public fusion programmes:** KEA (K-DEMO), QST (JA DEMO), UKAEA (STEP)



UK Atomic Energy Authority



- 2 new SWG FS members (total 18 members) - Commonwealth Fusion Systems, UKAEA

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Slide provided by Dr R. Holmes, Kyoto
Fusionneering, Chair of SWG Fusion
Stakeholders

Update Brief / Stakeholder Engagement of Note

Update 1: Division 4 WG General Requirements

- Ballot 24-2913 for major change in Division 4 structure to be a deterministic component code for fusion energy devices

Update 2: Collaboration with JSME in discussion

- Large input on superconducting structure component code based on ITER experience

Update 3: Drafting underway in WG GR on populating subsection FA

Update 4: WG Materials sitting first time this Code Week

- US DOE funded (\$20m) [IMPACT FIRE](#) award UT-Knoxville and ORNL to code qualify RAFM steel for BPV Section III Division 4 – started March 2025 for 4 years

- Subsection FA – General Requirements - o Subpart A – Metallic Materials - o Subpart B – Non-Metallic Materials - o Subpart C – Magnetic Components
- Subsection FB – Class A Metallic Pressure Boundary Components - o Subpart A – Low Temperature Service - o Subpart B – Elevated Temperature Service - o Subpart C – Cryogenic Temperature Service
- Subsection FC – Class B Metallic Pressure Boundary Components - o Subpart A – Low Temperature Service - o Subpart B – Elevated Temperature Service - o Subpart C – Cryogenic Temperature Service
- Subsection FF – Supports o Subpart B – Low Temperature Service
- Subsection FG – Class CM Core Components - o Subpart A – Low Temperature Service - o Subpart B – Elevated Temperature Service - o Subpart C – Cryogenic Temperature Service
- Subsection FH – Class NM Non-Metallic Pressure Boundary Components - o Subpart A – Low Temperature Service - o Subpart B – Elevated Temperature Service - o Subpart C – Cryogenic Temperature Service
- Subsection FM – Magnetic Components - o Subpart A – Low Temperature Service - o Subpart B – Elevated Temperature Service - o Subpart C – Cryogenic Temperature Service

Mandatory Appendices
Mandatory Appendix I – Placeholder

Nonmandatory Appendices
Nonmandatory Appendix A – Vacuum Vessel Design Methodology
Nonmandatory Appendix B – Guidelines for Materials Qualification
Nonmandatory Appendix C – Environmental Damage Considerations

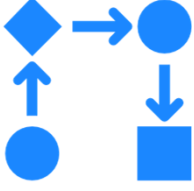
One of the biggest challenges in making fusion energy commercially viable is the lack of nuclear-code-qualified high-temperature structural materials that can be used in fusion reactors. [IMPACT](#) aims to create a process and database for the first-ever American Society of Mechanical Engineers Boiler and Pressure Vessel code qualification for a fusion material and to demonstrate how these new materials can more quickly move from code qualification to engineering application.

Going forward

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Division 4 serves the fusion
community.



The (draft) rules evolve over time



To get involved, please join the
ASME Code Weeks (free).

If you are interested and want to contribute experience from fission industry to the code development, please contact **Dr Emily Rose Lewis**: emily.lewis@oxfordsigma.com



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Fusion Energy Devices and the ASME BPVC: Towards a Fit-for-Purpose Regulatory Framework

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2	Issue 2 – Removing supplementary slides	23-Sept-2025	Emily Lewis	Bradley Young Alasdair Morrison
3				
4				
5				