ASME FE.1-2018

Draft Standard for Trial Use

Rules for Construction of Fusion Energy Devices

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The American Society of Mechanical Engineers

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This Draft Standard for Trial Use will be revised following the conclusion of the Trial-Use Period. There will be no written interpretations of the requirements of this Draft Standard for Trial Use issued.

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FOREWORD

There is an ongoing effort within The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Committee on Construction of Nuclear Facility Components (Section III) to develop rules for the construction of fusion energy devices. The Standards Committee of Section III, Division 4 and its Subgroup on Fusion Energy Devices (FED) are developing these new fusion Code rules. These rules cover fusion-energy-related components such as vacuum vessels, cryostats, and superconducting magnet structures and the interactions of these components. Related support structures, including metallic and nonmetallic materials, containment or confinement structures, and in-vessel components such as fusion-system piping, vessels, valves, pumps, and supports, are also covered. The rules contain requirements for materials, design, fabrication, testing, examination, inspection, certification, and stamping.

ASME BOILER AND PRESSURE VESSEL COMMITTEE ON CONSTRUCTION OF NUCLEAR FACILITY COMPONENTS (BPV III)

(The following is the roster of the Committee at the time of approval of this Draft Standard.)

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SUBSECTION FA
FUSION ENERGY DEVICE FACILITIES

SUBPART FAA GENERAL REQUIREMENTS

ARTICLE FAA-1000 INTRODUCTION

FAA-1100 GENERAL

FAA-1110 Scope

The rules of Subsection FA, Subpart FAA constitute the general requirements associated with fusion components used in the construction of fusion devices and their supporting systems. Only those fusion components that are serving a pressure boundary and/or structural integrity function (see FAA-2120) are covered by these rules. Items that are specifically excluded are electrical components and superconducting strand. It is understood that these rules were developed to document rules for construction that are not adequately addressed within existing Divisions of Section III of the ASME Boiler and Pressure Vessel Code (BPVC) or other existing codes and standards used in the nuclear industry.

(a) The General Requirements of ASME FE.1 are provided in ASME BPVC, Section III, Subsection NCA, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered FAA paragraphs or subparagraphs or new numbered FAA paragraphs or subparagraphs.

(b) ASME BPVC, Section III, Division 1 terminology may differ from that in ASME FE.1 (e.g., Class 1 and Class 2 versus Class A and Class B), but the application and use of these rules are identical for ASME FE.1 construction except where otherwise noted.

(c) References to Appendices are to each respective Subsection of this Draft Standard, unless otherwise stated.

FAA-1120 Definitions

Definitions of key terms specific to this Draft Standard are included in Article FAA-9000 or noted within the applicable text. The definitions in Article FAA-9000 shall prevail should a conflict exist with definitions found in ASME BPVC, Section III, Subsection NCA or in other documents referenced in this Draft Standard. Unless a term is defined in Article FAA-9000, the definition in ASME BPVC, Section III, Subsection NCA, Article NCA-9000 shall apply.

FAA-1130 Limits of These Rules

The rules of this Draft Standard for fusion components provide requirements for new construction and include consideration of mechanical and thermal stresses due to cyclic operation and high-temperature creep. These rules address the thermal and radiation effects on materials produced during the fusion activity. The rules do not cover deterioration that may occur in service as a result of corrosion, erosion, thermal embrittlement, or instability of material. These effects shall be taken into account with a view to realizing the design or the specified life of the components and support identified.

The rules are not intended to be applicable to valve operators, controllers, position indicators, pump impellers, pump drivers, or other accessories and devices, unless they are pressure-retaining parts or act as support structures or supports. If such items are in a support load path, the provisions of FAA-1100 apply.

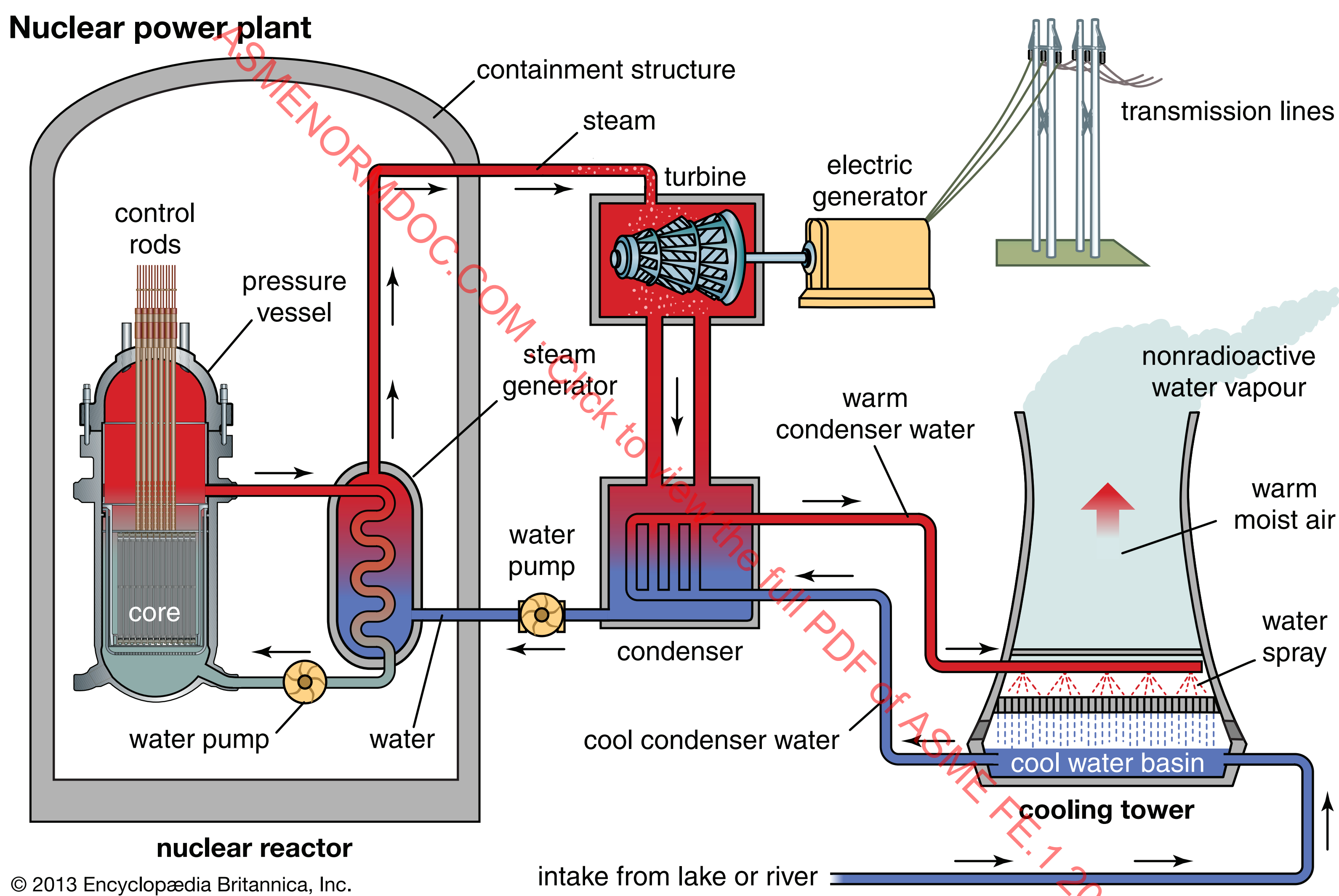
The rules of this Draft Standard do not apply to instruments, or permanently sealed fluid-filled tubing systems furnished with instruments, but they do apply to instrument, control, and sampling piping when specified in a Design Specification.

FAA-1300 FUSION TECHNOLOGIES

Subsection FA provides the rules for construction of nuclear fusion devices and their supporting systems. Nuclear fusion and nuclear fission are two different types of energy-releasing reactions in which energy is released from high-powered atomic bonds between the particles within a nucleus. The main difference between these two processes is that fission is the splitting of an atom into two or more smaller ones, whereas fusion is the fusing of two or more smaller atoms into a larger one.

Nuclear fission is a technology that has been in use since the 1950s. Figure FAA-1300-1 illustrates a typical light water fission system. There is potential for new developments in nuclear energy technology to enhance nuclear energy's role in a sustainable-energy future.

Figure FAA-1300-1 A Typical Light Water Fission System

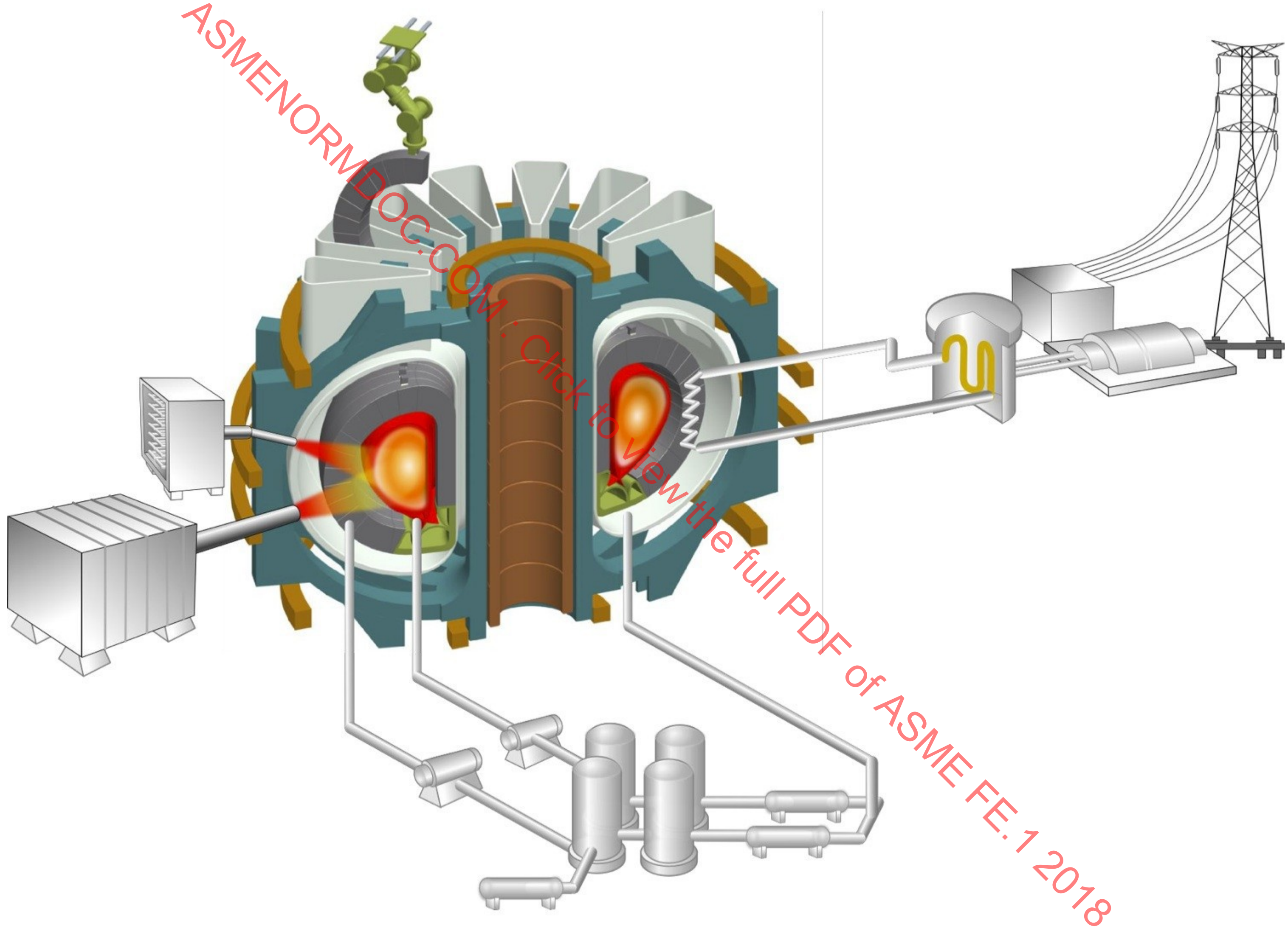


GENERAL NOTE: Image courtesy of Encyclopaedia Britannica, Inc., copyright 2013; used with permission.

Nuclear fusion is a process in which light nuclei, usually deuterium and tritium, collide and join together to form a heavier nucleus. When this happens, a considerable amount of energy is released. To overcome the electrostatic repulsion of these light nuclei so they will collide and fuse, extreme energy is imparted to the nuclei by radio-frequency heating, ohmic heating, neutral beam heating, or other means. These high-energy nuclei are called plasma ions. These plasma ions are confined by magnetic fields in a tokamak system so their velocity energy allows them to collide. Figure FAA-1300-2 illustrates a theoretical magnetic confinement-based fusion system.

Another fusion system is to freeze deuterium and tritium atoms into small pellets, and then heat and compress the frozen pellets with lasers or X-rays so that the inertia of the pellet mass allows atom collisions and fusion. Deuterium fuel is abundant in water, and tritium can be bred from lithium.

Figure FAA-1300-2 A Theoretical Magnetic Confinement-Based Fusion System



GENERAL NOTE: Image courtesy of the National Fusion Research Institute of Korea (NFRI).

ARTICLE FAA-2000
CLASSIFICATION OF COMPONENTS AND SUPPORTS

FAA-2100 GENERAL REQUIREMENTS

FAA-2120 Purpose of Classifying Items in a Fusion Power Plant

Construction rules are specified for items that are designated Code Classes A and B. These Code classes are to be applied to the classification of items in fusion energy devices and their supporting systems. Class A component rules address those items deemed to be serving a pressure boundary and/or structural integrity function, and Class B rules address those items deemed not to have a pressure boundary function but that do serve a structural integrity function. These classifications reflect the risk-based approach derived from safety criteria established for fusion-based devices. Items not in the two classifications listed above may be addressed in either these Draft Standard rules or appropriate non-nuclear codes and standards.

This Draft Standard recognizes the different levels of importance associated with the function of each item within fusion systems as related to the safe operation of the nuclear facility. The Code classes allow a choice of rules that provide assurance of structural integrity and quality commensurate with the relative importance assigned to the individual items of the nuclear facility.

FAA-2130 Classifications and Rules of ASME FE.1

FAA-2131 Code Classes of ASME FE.1. ASME FE.1 provides rules for the construction of items in the following Code classes:

(a) Class A, which includes Class A components, supports for Class A components, and support structures

(b) Class B, which includes Class B components and supports for Class B components

ARTICLE FAA-7000
REFERENCE STANDARDS

FAA-7100 GENERAL REQUIREMENTS

The standards and specifications referenced in the text of this Draft Standard associated with fusion components are listed in Table FAA-7100-1, unless they are already listed in ASME BPVC, Section III, Divisions 1 and 2 or ASME BPVC, Section III, Subsection NCA, Table NCA-7100-2. The standards and specifications associated with nonmetallic components are addressed in their respective Subparts of Subsection FA. Where reference is made within ASME FE.1 to requirements that are part of the ASME BPVC, the BPVC Sections are not included in Table FAA-7100-1. International standards, such as from the International Organization for Standardization (ISO) or the International Atomic Energy Agency (IAEA), may be used if specified by standards and specifications referenced in other codes and standards.

Table FAA-7100-1 Standards Referenced in ASME FE.1 Associated With Fusion Components

Standard ID	Published Title	Referenced Edition	Subsection Applicability
The American Society of Mechanical Engineers (ASME)			
ASME NQA-1	Quality Assurance Requirements for Nuclear Facility Applications	2015	All
American Society for Nondestructive Testing (ASNT)			
SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing	2011	All

ARTICLE FAA-8000 CERTIFICATES, NAMEPLATES, CERTIFICATION MARK, AND DATA REPORTS

FAA-8100 AUTHORIZATION TO PERFORM ASME BPVC ACTIVITIES

The rules for certificates, nameplates, the Certification Mark, and Data Reports for fusion components, supports, and support structures under ASME FE.1 shall be the same as the rules established for ASME BPVC, Section III, Division 1 metallic components and metallic core support structures. The only changes shall be the use of ASME FE.1 terminology rather than Division 1 terminology (e.g., Class A and Class B rather than Class 1 and Class 2) and the specification of the ASME FE.1 Subpart used.

Authorization to use the official Certification Mark or to certify work by other means provided in Subpart FAA (see ASME BPVC, Section III, Subsection NCA, Table NCA-8100-1) will be granted by the Society for a 3-yr period pursuant to the provisions set forth in ASME BPVC, Section III, Subsection NCA.

ARTICLE FAA-9000
GLOSSARY

FAA-9100 INTRODUCTION

This Article defines selected terms used in this Draft Standard for pressure boundary components, supports, and support structures. The definitions in this Glossary shall prevail should a conflict exist with definitions found in ASME BPVC, Section III, Division 1 or other documents referenced in this Draft Standard. Unless defined below, the definitions in ASME BPVC, Section III, Subsection NCA, Article NCA-9000 shall apply.

FAA-9200 DEFINITIONS

controlled nuclear fusion: the process of fusing nuclei together at a controlled rate. When fusing light nuclei such as deuterium (D) and tritium (T) isotopes, there is some excess mass that is converted to kinetic energy of the reaction products. For D + T, a helium nucleus and a neutron are produced in the fusion reaction. The kinetic energy of these fusion reaction products can be captured by slowing the reaction products in a material so that kinetic energy is converted to heat energy. The heat energy can be used for producing electricity or other industrial uses. The tokamak system is in contact with the fluid and maintains the internal or external fluid pressure.

inertial confinement: a nuclear fusion method in which frozen pellets in a vacuum chamber are rapidly compressed with great force by laser beams, X-ray beams, or ion beams.

ITER: an international organization that manages the International Thermonuclear Experimental Reactor (ITER) project.

magnetic confinement: a nuclear fusion method in which nuclei in a vacuum chamber are guided at high velocity by magnetic fields and heated by microwave energy and/or other means so that the high velocity of the nuclei overcomes electrostatic repulsion and fusion reactions occur.

pressure boundary: area on the surface of a component that has been designed to accept the stresses created by internal or external forces as defined in the Design Specification. (See FAA-2120.)

tokamak: a fusion system using the magnetic confinement method.

SUBPART FAB
MAGNETIC CONFINEMENT

ARTICLE FAB-1000
INTRODUCTION

FAB-1100 SCOPE

There are several methods to accomplish controlled nuclear fusion, two of which are discussed within this Draft Standard. One method is magnetic confinement, in which nuclei in a vacuum chamber are guided at high velocity by magnetic fields and heated by microwave energy and/or other means so that the high velocity of the nuclei overcomes electrostatic repulsion and fusion reactions occur. Another method, inertial confinement, uses tiny frozen pellets in a vacuum chamber; the pellets are rapidly compressed with great force by laser beams, X-ray beams, or ion beams. The beams ionize some molecules and the compression force creates a shock wave in the pellet; this overcomes electrostatic repulsion and the atoms fuse. Both magnetic confinement and inertial confinement control the fusion reaction by the amount of mass and the amount of energy input to the process, either by heating or by compression.

FAB-1200 MAGNETIC CONFINEMENT

The tokamak, or system of magnetic confinement used in today's experimental devices and that may be used in future power facilities, uses both resistive and superconducting magnets. The major systems that can make up the tokamak include

(a) resistive and superconducting magnets, including but not limited to the following:

(1) toroidal field (TF) coils

(2) poloidal field (PF) coils

(3) central solenoid (CS) coils

(4) correction coils (CC)

(b) vacuum vessel (VV)

(c) in-vessel coil systems

(d) in-vessel components, including blanket and divertor

(e) cryostat

(f) VV overpressure suppression system

(g) thermal shields

Each of these major systems consists of other subsystems and components that together form a major part of the tokamak.

The tokamak has a confinement structure that also serves as a radiation-shielding barrier; the cryostat and the VV provide the vacuum boundaries. The primary purpose of the cryostat is to provide the environment for the thermal isolation of the superconducting magnets. The VV is located inside the magnet system and provides the first confinement barrier for the in-vessel radiological inventory.

The thermal shield is mounted between the VV and the superconducting magnets on the inside, and the cryostat and the magnets on the outside. All of these components are mounted inside the cryostat. Inside the VV, the internal replaceable components include blanket modules and divertor cassettes.

FAB-1210 Magnet System

The magnet system for the ITER tokamak consists of TF coils, a CS, PF coils, and, if necessary, CCs. The TF coils determine the basic toroidal segmentation of the machine and are chosen to meet the number and size requirements of access ports. A typical magnet system is shown in Figure FAB-1210-1.

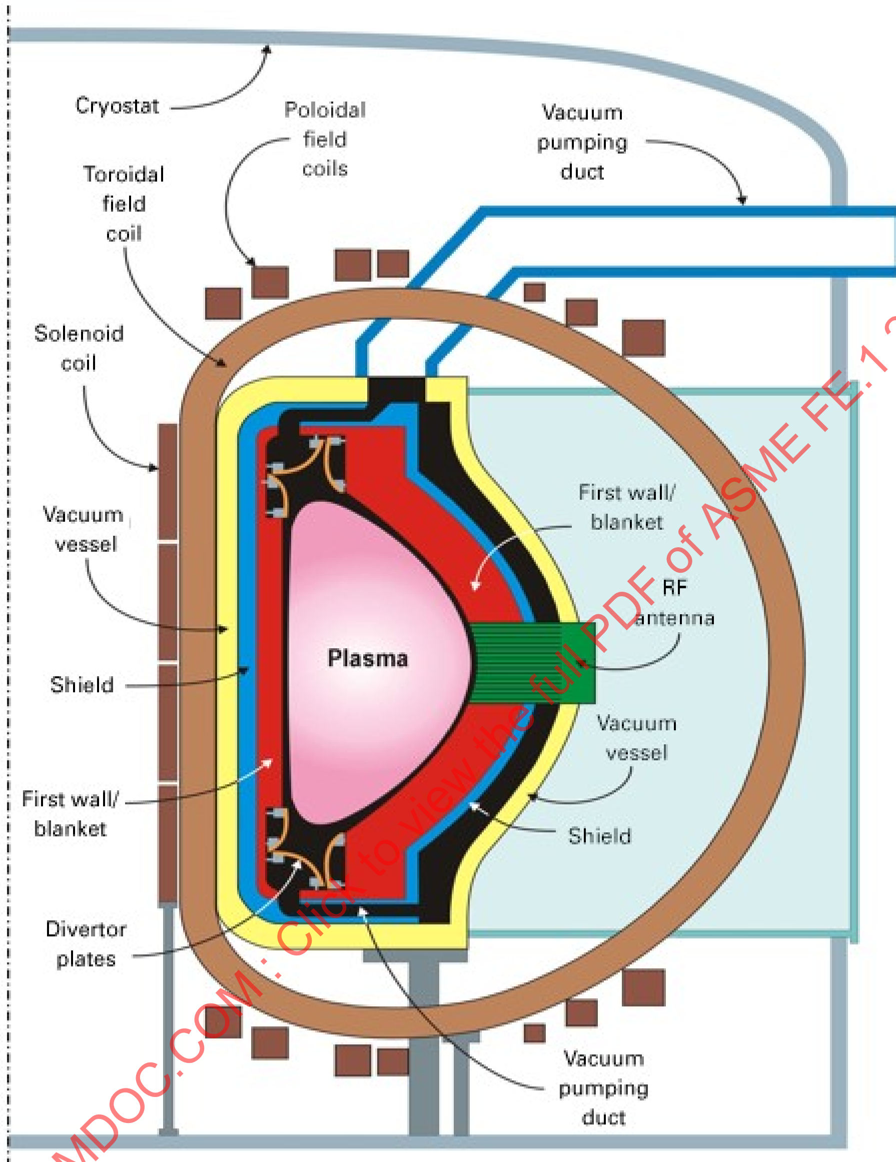
The TF coil case encloses the winding pack and is the main structural component of the magnet system. The TF coil case and the winding pack are structurally linked.

The CS assembly consists of a vertical stack of winding pack modules, which is supported from the bottom of the TF coils through its preload structure. The number of CS modules is designed to satisfy the plasma-shaping requirements.

The PF coils are attached to the TF coil to allow for radial displacements. The PF coils provide suitable magnetic fields for plasma shaping and position control.

Outside the TF coils are located, if necessary, independent sets of CCs, each consisting of coils arranged around the toroidal circumference. These coils may be used to correct error fields (particularly toroidal asymmetry) arising from positioning errors in the TF coils, CS, and PF coils.

Figure FAB-1210-1 Example of a Magnet Confinement System in an ITER Machine



GENERAL NOTE: Image adapted from Quora, https://www.quora.com/What-are-the-pros-and-cons-of-controlled-nuclear-fusion-with-inertial-confinement-like-NIF-National-Ignition-Facility-versus-magnetic-confinement-like-ITER-or-TOKAMAK.

The gravity supports are composed of pedestals with flexible elements to allow radial displacements. The magnets are supported fully independently of the vessel and associated components.

(a) The magnet system provides the following:

(1) TF coils for the magnetic field that gives the designer-specified plasma safety factor during the various phases of operation.

(2) TF coil structures that are integrated with the PF coil supports and the CS structures to restrain the electromagnetic loads on the coils under normal operating and fault conditions. The TF coil structures also resist the gravity and seismic loads of the magnet system.

(3) CS for the majority of the magnetic flux change needed to initiate the plasma, generate the plasma current, and maintain this current during the operation time. The CS contributes to the fields needed to control the plasma.

(4) PF coils for the magnetic fields that shape the plasma and control its position during the various phases of operation.

(5) CCs that compensate for field errors due to design asymmetries and geometric tolerances in the machine.

(b) The magnets must withstand the following conditions:

(1) electromagnetic loads acting on the magnets

(2) the weight of the magnets

(3) seismic loads on the magnets

(4) forces applied during installation and assembly of the magnets

(5) helium coolant pressure loads

FAB-1220 Magnet Structures

In a tokamak, the TF magnet is subjected to two main force systems. The in-plane loads are generated by the interaction of the current in the TF coils with the toroidal field. The out-of-plane loads are generated by the interaction of the current in the TF coils with the poloidal field. In most instances, the TF coil cases are the main structural component of the magnet system, and they provide support against the TF coil in-plane as well as out-of-plane loads.

FAB-1221 Magnet Structural Arrangement. The TF coil casing encloses the winding pack and is the main structural component of the magnet system. The TF coils are structurally linked. The coil case is fabricated from an engineering material, such as stainless steel or an equivalent material. The TF coil structures support the self-equilibrating electromagnetic forces acting between the TF coils, the CS, the PF coils, the CCs, and the VV during normal operation, plasma disruption, and fault events.

FAB-1300 VACUUM VESSEL

FAB-1310 Functional Requirements

The vacuum vessel

(a) provides a hazardous materials confinement barrier and withstands postulated accidents without losing confinement

(b) is designed to remove the nuclear heating and maintain the surface heat flux within the allowable temperature and stress limits

(c) is designed to remove the decay heat of in-vessel components, even in conditions when the other cooling systems are not functioning

(d) provides a pressure boundary consistent with the generation and maintenance of a high-quality vacuum

(e) supports in-vessel components to specified tolerances and their loads under normal and off-normal operations

(f) together with the in-vessel components, maintains a specified toroidal electrical resistance and contributes to plasma stability by providing a conductive shell tight fitting to the plasma as far as practically feasible

(g) together with the blanket, divertor, and ancillary equipment in ports, provides adequate radiation shielding for the superconducting coils and reduces activation inside the cryostat and at connecting ducts (end parts of the port extensions) to facilitate remote handling and decommissioning

(h) provides access ports or feed-throughs for in-vessel component service and maintenance, maintenance and inspection equipment, fueling and pumping systems, diagnostics, and plasma heating equipment and test blanket

The main components that make up the VV are the main vessel, the port structures, and the VV supporting system. The tokamak VV is a torus-shaped structure with shielding and coolant. The basic vessel design is an all-welded structure. Only the inner shell serves as the first confinement barrier when the double-wall structure is employed. The VV is divided into sectors joined by welding.

FAB-1320 Vessel Shells

The main vessel may consist of inner and outer shells, ribs and gussets, blanket module supporting structures, in-wall shielding, splice plates, port stubs, and special thick-wall components, such as the divertor support structures. Stiffening ribs between the shells provide the required mechanical strength and separate the shells of the structure.

The inner and outer shells and stiffening ribs are joined by welding. Each sector is subdivided into half-sectors, and these subdivisions are connected with pressure-tight central poloidal ribs.

FAB-1330 Port Structures

The VV may have upper, equatorial, and lower port structures, including local penetrations. There are ports for additional plasma heating systems, remote maintenance access to facilitate in-vessel component replacement and/or diagnostics, and vacuum pumping, etc. Between these ports, there are local penetrations for the divertor piping, the in-vessel viewing, and glow discharge.

The conducting shells that aid the plasma vertical stability may be mounted to the VV.

Most of the port components can be either single- or double-wall construction with stiffening ribs between the shells. Some components of the ports have a single-wall construction as a part of the structure. The connecting ducts may be composed of thinner shells with reinforcing beams. Local penetrations are usually thin shells.

FAB-1340 Supports and Mechanical Interfaces

A tokamak VV is vertically supported by sliding VV supports. These supports are horizontally restrained against fast displacements taking place during seismic events or fast transients but are free to move during thermal expansion. The VV is also restrained vertically in the upward and downward directions.

Tokamak blanket modules may be attached directly to the VV by a set of blanket module supports mounted to blanket module support structures located in the VV.

FAB-1341 Divertor Attachment. Divertors are supported by structures integrated with the shell of the VV.

FAB-1342 Port–Cryostat Interfaces. The port structures interface with the cryostat with bellows between the port-connecting ducts and the cryostat vessel. The local penetrations also interface with the cryostat with bellows.

FAB-1350 Cooling

The VV's primary heat transfer system consists of multiple loops so as to have redundancy of cooling capability.

The independent loops feed coolant to sectors of the VV to minimize the effect of faults. This limits the maximum possible VV temperature rise resulting from a coolant leak in one of the VV loops. During normal operation, the total heat deposition in the VV is mainly due to nuclear heating, and the heat is nonuniformly deposited in the VV.

During baking, the coolant temperature is increased to achieve the required baking conditions of the main vessel and ports.

FAB-1351 VV Coolant Routing. The coolant is supplied and flows within an internal supply structure. This structure distributes the coolant to channels on both the inboard and outboard sides of the vessel to provide a flow in the channels.

FAB-1360 Loading Conditions

The loads acting on the VV can be divided into four categories.

(a) Inertial Loads. These loads are due to accelerations due to gravity and seismic events.

(b) Electromagnetic (EM) Loads. These loads act on nearly all conductive structures during fast transients [e.g., plasma disruptions, plasma vertical displacement events (VDEs), and magnet current fast discharge].

(c) Pressure Loads. These loads include coolant and incidental VV internal and external pressure.

(d) Thermal Loads. These loads are caused by temperature gradients inside the VV structure caused by nuclear heating and thermal radiation, or by the temperature difference between the VV coolant and the blanket coolant.

Other types of loads are piping loads attached to the ports, coolant loop loading, and accident loads.

FAB-1400 IN-VESSEL COMPONENTS

FAB-1410 Divertor

(a) The divertor is a plasma-facing component that is positioned in the VV. The primary functions of the divertor are to

(1) define the boundary of the plasma
(2) enable the control of impurities
(3) provide a means for nonradiant power fraction exhaust
(4) provide a means for helium ash exhaust
(5) protect the VV by absorbing neutrons
(6) perform the heat transfer function

(b) To deliver the required functionality, the divertor shall sustain the following environmental effects and loading:

(1) high heat flux
(2) plasma-induced surface erosion
(3) neutron-induced irradiation

(c) The geometrical design and features of the divertor can vary depending on the exact reactor application, e.g., a single-null or double-null configuration. However, most designs rely on active cooling. The divertor consists of a structural element that contains the coolant and an armor element that provides the required protection from the plasma interception.

FAB-1420 Blanket

(a) The blanket is a plasma-facing component that lines the majority of the VV. 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:

(1) generates tritium by reaction of the fusion neutrons with lithium or lithium compounds

(2) acts as a neutron multiplier, compensating for neutron loss and thus sustaining the fusion reactions

(3) protects the VV by absorbing fusion by-product neutrons and protects the VV from plasma heat and plasma particles

(b) To deliver the required functionality, the blanket shall sustain the following environmental effects and loading:

(1) heat flux

(2) plasma-induced surface erosion

(3) neutron-induced irradiation

(4) EM loads in plasma operation and from plasma transients

(c) The geometrical design and features of the blanket can vary depending on the blanket's exact reactor application. However, most designs rely on active cooling within a metallic structure.

FAB-1421 Blanket Coolant Manifolds. Coolant manifolds are routed over the vessel's plasma-side surface, branching to blanket modules. The coolant manifolds are routed by the cooling circuit.

SUBSECTION FB
PRESSURE BOUNDARY COMPONENTS

SUBPART FBA MAGNET

ARTICLE FBA-1000 INTRODUCTION

FBA-1100 SCOPE

FBA-1110 Aspects of Construction Covered by These Rules

(a) Subsection FB contains rules for the material, design, fabrication, examination, testing, overpressure relief, marking, stamping, and preparation of reports by the Certificate Holder of items that are intended to conform to the requirements for Class A construction.

(b) The rules of Subsection FB cover the requirements for strength and pressure integrity of items, the failure of which would violate the pressure-retaining boundary. The rules cover initial construction requirements but do not cover deterioration that may occur in service as a result of corrosion or instability of material.

ASME BPVC, Section III, Subsection NCA, NCA-1130 gives further limitations to the rules of this Subsection.

FBA-1120 Temperature Limits

The rules of Subpart FBA shall not be used for items that are to be subjected to metal temperatures that exceed the temperature limit in the Owner's Design Specification.

FBA-1130 Boundaries of Jurisdiction Applicable to This Subsection

FBA-1131 Boundary of Components. The Design Specification shall define the boundary of a component.

FBA-1132 Boundary Between Components and Attachments

FBA-1132.1 Jurisdictional Boundary. The jurisdictional boundary shall be defined in the Design Specification.

FBA-1140 Electrical and Mechanical Penetration Assemblies

Electrical and mechanical penetration assemblies shall be constructed in accordance with the rules for vessels, except that the design and the material performing the electrical conducting and insulating functions need not meet the requirements of this Subsection.

ARTICLE FBA-2000
MATERIAL

FBA-2100 GENERAL REQUIREMENTS FOR MATERIAL

FBA-2110 Scope of Principal Terms Employed

(a) The term "material" or "pressure-retaining material" as used in this Subsection is defined in (c) below.

(b) The term "material organization" is defined in ASME BPVC, Section III, Subsection NCA, Article NCA-9000.

(c) The term "material" as used in this Subsection applies to items such as vessel shells, heads, and nozzles; pipes, tubes, and fittings; valve bodies, bonnets, and disks; pump casings and covers; and bolting that joins pressure-retaining items.

(d) The requirements of this Article make reference to the term "thickness." For the purpose intended, the following definitions of nominal thickness apply:

(1) plate: the plate thickness is the dimension of the short transverse direction.

(2) forgings: the thickness is the dimension defined as follows:

(-a) hollow forgings: the nominal thickness is measured between the inside and outside surfaces (radial thickness).

(-b) disk forgings (axial length less than the outside diameter): the nominal thickness is the axial length.

(-c) flat ring forgings (axial length less than the radial thickness): for axial length ≤2 in. (50 mm), the axial length is the nominal thickness. For axial length >2 in. (50 mm), the radial thickness is the nominal thickness.

(-d) rectangular solid forgings: the least rectangular dimension is the nominal thickness.

(3) castings

(-a) thickness, *t*, for fracture toughness testing is defined as the nominal pipe wall thickness of the connecting piping.

(-b) thickness, *t*, for heat treatment purposes is defined as the thickness of the pressure-retaining wall of the casting, excluding flanges and sections designated by the designer as non–pressure retaining.

FBA-2120 Pressure-Retaining Material

FBA-2121 Permitted Material Specifications

(a) Pressure-retaining material shall conform to the requirements of one of the specifications for material given in ASME BPVC, Section II, Part D, Subpart 1, Tables 2A and 2B, including all applicable footnotes in the tables, or to those material specifications listed in this Article and to all of the requirements of this Article that apply to the product form in which the material is used.

(b) The requirements of this Article do not apply to material for items not associated with the pressure-retaining function of a component, such as shafts, stems, trim, spray nozzles, bearings, bushings, springs, and wear plates, nor to seals, packing, gaskets, valve seats, and ceramic insulating material and special alloys used as seal material in electrical penetration assemblies.

(c) Material made to specifications other than those specified in the Design Specification may be used for the following applications:

(1) safety valve disks and nozzles, when the nozzles are internally contained by the external body structure

(2) control valve disks and cages, when the valves function for flow control only

(3) line valve disks in valves whose inlet connections are NPS 2 (DN 50) and smaller

(d) Material for instrument line fittings and valves NPS 1 (DN 25) and smaller may be made to specifications other than those specified in the Design Specification.

(e) Welding and brazing material used in the manufacture of items shall comply with the Design Specification except as otherwise permitted in ASME BPVC, Section IX, and shall also comply with the applicable requirements of this Article. The requirements of this Article do not apply to material used as backing rings or backing strips in welded joints.

(f) The requirements of this Article do not apply to hard surfacing or corrosion-resistant weld metal overlay that is 10% or less of the thickness of the base material.

FBA-2122 Special Requirements Conflicting With Permitted Material Specifications. Special requirements stipulated in this Article shall apply in lieu of the requirements of the material specification whenever the special requirements conflict with the material specification requirements (see ASME BPVC, Section III, Subsection NCA,