APPENDIX E Glossary

The following is a general purpose glossary for the field of controlled fusion and plasma physics.

Additional heating: Usually with reference to a plasma which is initially heated by a toroidal current induced in the plasma (ohmic heating), additional heating designates other means of heating a plasma (absorption of electromagnetic waves or of injected fast neutral particles).

Advanced Tokamak Scenarios: Tokamaks normally generate natural profiles of plasma current and plasma pressure. Using external non-inductive current drive and local control of the current and pressure profiles can allow access to enhanced regimes and even steady state operation, generally referred to as Advanced Tokamak Scenarios.

ALCATOR C-MOD: High field, high density tokamak at MIT (USA) with an elongated, diverted plasma.

Alfvén gap modes: The toroidal nature of tokamak plasmas produces gaps in the otherwise continuous spectrum of Alfvén waves, populated by discrete, weakly damped Alfvén gap modes. Under certain conditions these modes can be destabilised by resonant energy transfer from energetic particles, e.g. α-particles from fusion reactions.

Alfvén waves: A fundamental plasma wave, which is primarily magneto-hydrodynamic in character with an oscillation of the magnetic field and, in some cases, plasma pressure. In tokamaks, these waves are typically strongly damped. See also fast Alfvén wave.

Alfvén velocity: The velocity of propagation of Alfvén waves in the direction of the magnetic field; it is proportional to the magnetic field strength, and inversely proportional to the square root of the mass density.

alpha particle, or α-particle He^4: The nucleus of the helium atom, composed of two protons and two neutrons, is one of the two products of the DT fusion reaction (the other one is a neutron). The α-particles, being electrically charged, are trapped by the magnetic confinement field and therefore can release their energy to the plasma contrary to the neutrons which escape from the plasma and transfer their energy in the blanket surrounding the plasma core. The plasma heating which is provided by these α-particles as they slow down due to collisions is essential for achieving ignition.

Alternative lines: Magnetic confinement development other than the tokamak.

Analytic/Computational modelling: Analytic: algebraic solution of basic equations. Computational: numerical solution of basic equations.

Anomalous transport: Measured heat and particle loss is anomalously large compared with collisional theory of heat transport in toroidal plasmas.

ASDEX-Upgrade: Medium-sized Tokamak at Garching (Association Euratom-IPP, Germany) with an elongated, diverted plasma.

Aspect ratio: The ratio between the large radius and the small radius of a torus.

Auxiliary heating: See additional heating.

Ballooning instability: A local instability which can develop in the tokamak when the plasma pressure exceeds a critical value; it therefore constrains the maximum β that can be achieved. It is analogous to the unstable bulge which develops on an over-inflated tyre.

Beta (β): Ratio of plasma pressure to magnetic field pressure. One of the figures of merit for magnetic confinement: the magnitude of the magnetic field pressure determine the cost of the field coil that generates it; since fusion reactivity increases with the square of the plasma pressure, a high value of ß indicates good performance. The highest values achieved in tokamaks reach 40% (START).

Beta-normalised (β_N): The ratio of plasma current (in MA) to the product of minor radius (in m) and magnetic field (in T) characterises the limit to the achievable β imposed by ideal MHD. Beta-normalised is the ratio of β (as a percentage) to the above ideal MHD parameter. Generally β_N ~3 should be achievable, but techniques for obtaining higher values have been observed experimentally.

Blanket: A structure containing lithium or lithium compounds surrounding the

plasma core of a fusion reactor. Its functions are to breed tritium, via lithium-neutron reactions, and to absorb most of the fusion energy to be used for electricity generation.

Bootstrap current: Theory developed in 1970 predicted that a toroidal electric current will flow in a tokamak which is fuelled by energy and particle sources that replace diffusive losses. This diffusion driven "Bootstrap current", which is proportional to β and flows even in the absence of an applied voltage, could be used to provide the poloidal magnetic field: hence the concept of a Bootstrap tokamak, which has no toroidal voltage. A Bootstrap current consistent with theory was observed many years later on JET and TFTR; it now plays a role in optimising advanced tokamaks.

Breakeven: The fusion performance of a power plant is denoted by Q, which is the ratio of the power released by fusion reactions to that used to heat the plasma. As a convention, scientific breakeven corresponds to Q=1 and ignition to Q=infinity. A fusion power plant would operate at Q~50.

Breeding ratio: The number of tritium atoms produced in the blanket of a fusion power station per tritium nucleus burned in the fusion plasma.

Burn: The fusion process of consuming DT fuel in a reactor, releasing energy.

CCE-FU: The Consultative Committee for the Euratom Specific Research and Training Programme in the field of Nuclear Energy, Fusion. Formerly the CCFP.

CCFP: Consultative Committee for the Fusion Programme. Advisory body to the Commission (in French CCPF, in German BAPF). Renamed under the 5th Framework Programme as the CCE-FU (q.v.).

CEA: Commissariat à l'Energie Atomique, France. Partner in the Association EURATOM-CEA which operates the TORE SUPRA tokamak.

CFI: Committee on Fusion-Industry.

CFP: Community Fusion Programme. Renamed under the 5th Framework Programme as the "Key Action Fusion".

Charge exchange measurement: Measures the plasma ion temperature. Neutral atoms in the plasma (for example from a neutral beam) donate electrons to hot plasma ions, which are thereby neutralised. These hot atoms are no longer confined by the magnetic field and leave the plasma. Their energy is measured by a neutral particle analyser.

CIEMAT: Centro de Investigaciones Energéticas Medioambientales y Tecnológicas, Spain. Partner in the Association EURATOM-CIEMAT. Operates the flexible heliac stellarator TJ-II.

Classical transport: Collisions between the individual particles of a plasma allow them to move across the magnetic field. Theories which describe this mechanism are called "classical" (or "neo-classical" when additional effects due to the toroidal geometry are included). The measured heat and particle transport is usually higher than predicted by these theories.

Collisionality: Non-dimensional parameter, which is the inverse ratio of the mean free path of plasma particles between collisions to a characteristic length of the magnetic field configuration.

Compact torus: Class of closed magnetic configurations in which no material elements (coils, conductors or walls) need to link through the bore of the plasma torus. Thus the vessel of compact tori can be spherical or cylindrical.

COMPASS: COMPact ASSembly, a tokamak for studies of plasma stability, at Culham, UK (Association EURATOM-UKAEA). Originally with circular vessel (COMPASS-C), now with D-shaped vessel (COMPASS-D).

Confinement time: In a fusion plasma neither particles nor energy are perfectly confined. Particle confinement time is the time during which the particles, on average, stay confined. The energy confinement time, which is usually shorter than the particle confinement time, is defined in steady state as the ratio of the plasma energy content to the total power input to the plasma and is a measure of how fast a plasma would cool if there were no heating.

CRPP: Centre de Recherches en Physique des Plasmas. Fusion laboratories of the Association EURATOM-Swiss Confederation at the Ecole Polytechnique Fédérale de Lausanne and the Paul-Scherrer Institute, Villigen (CRPP-Fusion Technology).

Current drive (non-inductive): In a tokamak, plasma current can be driven inductively, with the toroidal plasma acting as a secondary winding of a transformer whose primary coil is at the central column of the device. Continuous

current cannot be driven by transformer action. 'Non-inductive' current drive methods are applied either by injecting particles with directed momentum into the plasma or by accelerating electrons by electromagnetic waves so that they carry the current. Also being applied to control instabilities and to optimise confinement by modifying the current profile. The bootstrap effect also drives current.

Current profile (current distribution): The distribution of current density across the minor radius of the plasma.

Current ramp-up (down): The increase (decrease) of plasma current either at the start of operation or during operation.

Cyclotron frequency: Charged particles in a magnetic field have a natural frequency of gyration in the plane perpendicular to the magnetic field - the cyclotron frequency. For electrons in a tokamak, the cyclotron frequency is typically a few tens of GHz (28 GHz per Tesla), and for ions, a few tens of MHz (7.5 MHz per Tesla for deuterium).

Cylindrical approximation: An approximation to the true tokamak geometry in which the torus is straightened, so that the toroidal direction becomes the cylinder axis. There are two directions of symmetry: along the axis (the 'toroidal' direction) and about the axis (the 'poloidal' direction).

DCU: Dublin City University, Ireland. Partner in the Association EURATOM-DCU.

DEMO: Demonstration Reactor (the first device in the European fusion strategy intended to produce significant amounts of electricity).

Deuterium: A stable isotope of hydrogen, whose nucleus contains one proton and one neutron. In heavy water, normal hydrogen is replaced by deuterium. Sea water contains, on average, 34g deuterium per m^3. Deuterium plasmas are used routinely in present-day experiments; in a fusion power plant the plasma will consist of a mixture of deuterium and tritium which fuse more readily then two deuterium nuclei.

DG Research (DG RTD): The Directorate-General of the European Commission, Brussels, responsible for Research and Development**.** Formerly DG XII.

Diagnostic: Apparatus used for measuring one or more plasma quantities (temperature, density, current, etc.).

Diffusion, thermal (or particle): The random flow of heat (or particles) in the presence of a thermal (or density) gradient.

DIII-D: The largest operating US tokamak, run by General Atomics, San Diego. It has a flexible configuration and studies core and divertor physics with intense additional heating.

D-He^3: Deuterium-^{3}Helium: A potential fuel for fusion with low release of neutrons, but which would require a much higher fusion triple product ($nT\tau$) than DT to reach ignition. ^{3}Helium is an isotope of helium which is not available in appreciable quantities on Earth.

Disruption, Disruptive instability: A complex phenomenon involving MHD instability which results in a rapid release of energy to the wall and strong electromechanical forces in a tokamak. Plasma control may be lost, triggering a VDE (q.v.). This phenomenon places a limit on the maximum density, pressure and current in a tokamak.

Distribution function: Describes both the space and velocity distribution of plasma particles.

Divertor: A magnetic field configuration with a separatrix, affecting the edge of the confinement region, designed to remove heat and particles from the plasma, i.e. divert impurities and helium ash to divertor plates in a target chamber. Alternative to using a limiter to define the plasma edge.

Double null: See Single/double null divertors.

Drift kinetic theory: Kinetic theory which describes plasma processes which have spatial scales much greater than the particle Larmor radii.

Drift orbits: Particle motion is tied to straight magnetic field lines. However, electric fields and gradients of the magnetic field give an additional drift perpendicular to the magnetic field creating drift surfaces displaced from the magnetic surfaces.

Driven current: Plasma current produced by a means external to the plasma, inductively or non-inductively.

Driver: In inertial confinement fusion, the laser or particle beam system used to compress a target pellet.

DTE: The deuterium-tritium experiment at JET which in 1997 set new records for

fusion power production. Followed the Preliminary Tritium Experiment of 1991.

ECCD: Electron Cyclotron Current Drive. Non-inductive current drive technique using directed electron cyclotron resonance waves.

ECE: Electron Cyclotron Emission. Radiation emitted by electrons as a result of their cyclotron motion around magnetic field lines. Used to measure electron temperature.

ECH: Electron-Cyclotron Heating. Radio wave heating near the resonance frequency (or its multiple) of the electron gyration in a magnetic field. In present and future machines ECH is at typically 60-170 GHz, depending on the magnetic field strength in a machine.

EFDA: European Fusion Development Agreement. The new organisational framework of the EU fusion activities on the exploitation of the JET Facilities, international collaboration (including ITER) and supporting technology. EFDA replaces the NET agreement.

EFET: European Fusion Engineering & Technology: a fusion technology oriented European Economic Interest Grouping.

Electron temperature: A measure of electron thermal energy in units of degrees or electron volts (1 eV ~ 10^4 degrees Kelvin).

ELM: Edge localised mode. An instability which occurs in short periodic bursts during the H-mode in divertor tokamaks. It modulates and enhances the energy and particle transport at the plasma edge. These transient heat and particle losses could be damaging in a reactor.

ENEA: Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, Italy. Partner in the Association EURATOM-ENEA.

Energetic particle: In terms of energy, the particles in a plasma can be divided into two classes. The more numerous thermal particles are characterised by a temperature typically in the range 1-30 keV for modern tokamaks. The less numerous class of energetic particles has significantly higher energy up to several MeV. Energetic particles can be created by electric fields, fusion reactions, neutral beam injection or RF heating.

Error fields: The magnetic coils of a tokamak are designed to give the desired magnetic field configuration. The finite number of coils and imperfections in their construction lead to unwanted deviations from this configuration known as error fields. These could lead to disruptions and are of particular concern for larger tokamaks.

EXTRAP T-II: External Trap II, a medium-sized reversed field pinch (RFP) at the Royal Institute of Technology, Stockholm (Association EURATOM-NFR), built for RFP transport and shell stabilisation studies in support of RFX.

EURATOM: European Atomic Energy Community.

Faraday rotation: The rotation of the plane of polarisation of light passing through a magnetised plasma.

Fast Alfvén wave: The fast Alfvén wave exists over a broad frequency spectrum, from the ion cyclotron range of frequencies (ICRF) where its character is electromagnetic, down to magnetohydrodynamic frequencies. Its velocity is comparable to the Alfvén velocity. The fast Alfvén wave is used routinely for high-power (~20MW) ICRF heating on JET, as it is efficiently absorbed in the plasma by the mechanism of ion cyclotron resonance. Although usually stable in tokamaks, the wave can be excited by energetic ion populations.

Fast wave current drive: Current drive produced by a fast wave. The wave can penetrate the plasma more easily than a lower hybrid wave.

Feedback: Use of measurements of plasma parameters to control the parameters, shape or profiles of the plasma to obtain desired conditions.

Field lines, Flux surfaces: Imaginary lines marking the direction of a force field. In a tokamak these define a set of nested toroidal surfaces, to which particles are approximately constrained, known as flux surfaces.

Field reversed configuration: A compact torus with a strongly elongated plasma. The plasma is contained in a cylindrical vessel inside a straight solenoid. The confining magnetic field usually has only a poloidal component. Not to be confused with reversed field pinch.

FIR: Far infra-red (e.g. wavelength ~ 0.2 to 1mm). FIR lasers are used to measure the magnetic field and plasma density.

"**Fishbones**": Rapid bursts of MHD activity sometimes observed when neutral beam heating is used in tokamaks (fishbone refers to the shape of the bursts

in oscillating magnetic field when plotted as a function of time).

First wall: The first material boundary that surrounds the plasma. Today, the first wall in all machines is protected by low-Z materials (such as carbon tiles, boron or beryllium coating).

Flat-top current: Constant current during quasi-stationary operating conditions.

Fokker-Planck Code: A computer code to calculate the velocity distribution of plasma particles allowing for collisional relaxation and plasma heating. Calculates distribution functions (q.v.).

FOM: Stichting voor Fundamenteel Onderzoek der Materie (Foundation for basic investigations of matter), The Netherlands. Partner in the Association EURATOM-FOM.

FPC: The Fusion Physics Committee, a sub-committee of the CCE-FU which reports to it principally on the physics aspects of the programme. Formerly the Programme Committee (PC).

FTC: The Fusion Technology Committee, a sub-committee of the CCE-FU which reports to it principally on technology activities and contributions to international collaborations. Formerly the Fusion Technology Steering Committee (FTSC).

FTU: Frascati Tokamak Upgrade, a high density, high current tokamak at Frascati, Italy (Association EURATOM-ENEA).

Fusion triple product: Product of (ion) density, (ion) temperature and energy confinement time. A measure of the proximity to break-even and ignition.

Fusion product: The product of a fusion reaction, for example an α-particle or neutron in a deuterium-tritium plasma.

Fusion reactivity: Fusion reaction rate. For present typical tokamak conditions, it increases with the square of the density and the ion temperature of the plasma.

Full wave theory: Wave theory which includes complete accounting of wave energy (transmitted, reflected and absorbed, including energy transferred to other waves) for studying RF heating.

FZK: Forschungszentrum Karlsruhe, Germany. Partner in the Association EURATOM-FZK, active in fusion technology and, with the development of gyrotrons, in plasma engineering.

FZJ: Forschungszentrum Jülich GmbH, Germany. Partner in the Association EURATOM-FZJ, operating the tokamak TEXTOR.

GSI: Gesellschaft für Schwerionenforschung, Darmstadt, Germany. Studying heavy-ion physics, and driver physics with possible application for inertial confinement fusion.

Gyro-kinetic theory: Version of kinetic theory in which the Larmor radius is not assumed to be small. An essential theory for investigating fine-scale instabilities which might be responsible for driving turbulence, which may in turn be responsible for anomalous transport.

Gyrotron: Device used for generating high power microwaves in the electron cyclotron range of frequencies (50 - 200 GHz). This UHF wave is mostly used to heat the plasma at the electron cyclotron resonance frequency. It also could be used to diagnose the plasma.

Heliac: Stellarator configuration with a central toroidal coil around which the plasma column is wound helically. Because of its high capability of investigating a wide range of stellarator configurations, it is used for TJ-II.

Helias: Optimised stellarator configuration, used with modular coils for Wendelstein VII-X (Germany) and SHEILA (Australia).

H-mode: A High confinement regime that has been observed in tokamak plasmas. It develops when a tokamak plasma is heated above a characteristic power threshold, which increases with density, magnetic field and machine size. It is characterised by a sharp temperature gradient near the edge (resulting in an edge “temperature pedestal”), ELMs and typically a doubling of the energy confinement time compared to the normal “L” regime. Today, a variety of high confinement modes have been identified in divertor and in limiter configurations (e.g. the I-mode), which, in part, have been obtained by special tailoring of the radial plasma current profile.

H-transition (or L-to-H transition): Transition into the H-regime from the L-regime, usually quite sudden, at a certain threshold power of additional heating and specific plasma parameters.

Halo currents: See Vertical Displacement Event.

Helicity injection: The helicity of a toroidal plasma is related to a linkage of toroidal and poloidal magnetic fluxes, and is approximately conserved throughout a discharge. If additional helicity can be injected, the plasma current could be sustained or even increased.

Helium ash: Fusion reactions in a deuterium-tritium plasma produce energetic α-particles (helium nuclei), which heat the plasma as they slow down. Once this has happened, the α-particles have no further use: they constitute helium ash, which dilutes the fuel and must be removed to maintain a burning plasma.

High beta (β): Condition in which the plasma energy is a significant fraction of the energy in the magnetic field. An alternative measure is the ratio between the plasma energy and the energy in the poloidal magnetic field, the poloidal β.

High field ECH launch: Electron cyclotron waves can be launched from the inside of the plasma torus. This allows higher density plasma to be heated.

Hydrogen: The lightest element; the nucleus consists of only one proton, the atomic shell of one electron. Isotopes of hydrogen, with one or two additional neutrons in the nucleus, are deuterium and tritium respectively.

IAEA: International Atomic Energy Agency (of the United Nations), Vienna, Austria. The ITER-EDA is undertaken under the auspices of the IAEA.

ICE: Ion Cyclotron Emission. Observed in JET and TFTR as a suprathermal signal, apparently driven by collective instability of energetic ion populations such as fusion products and injected beam ions.

ICF: Inertial Confinement Fusion. Intense beams of laser light or light or heavy ion beams are used to compress very rapidly and heat tiny target pellets of fusion fuel to initiate fusion burn in the centre. Sufficient fusion reactions must occur in the very short time before the fuel expands under its own pressure. The inertia of the pellet's own mass determines the time scale during which fusion reactions occur, hence the name inertial confinement.

ICRH: Ion Cyclotron Resonance Heating by launching waves into the plasma in the range of the ion cyclotron frequency (radio frequency, typically at several tens of MHz).

ICRF: Ion Cyclotron Resonance Frequencies.

Ideal: In the context of MHD, 'ideal' implies that the magnetic field and the plasma always move together. For this to occur, the electrical resistivity of the plasma must be negligible.

Ideal internal kink modes: An MHD instability of the central region of a tokamak. This, or its close relative the resistive internal kink mode, may be involved in the Sawtooth disruptions which occur in most Tokamaks.

IEA: International Energy Agency (of the OECD), Paris, France. Implementing agreements for international collaboration on specific topics in fusion have been set up in the frame of the IEA.

Ignition condition: Condition for self-sustaining fusion reactions: heat provided by fusion α-particles replaces the total heat losses. External sources of plasma heating are no longer necessary and the fusion reaction is self-sustaining. Ignition is not required for energy gain in a power station. Retaining a level of external heating or current drive will be required to control the plasma pressure and current profiles, to optimise the performance, leading to a so-called "driven burn".

Impurities: Ions, other than the basic plasma ion species, which are unwanted as they lose energy by radiation and dilute the plasma.

Impurity screening: The prevention of impurities from entering the plasma.

Internal kink: A type of MHD instability that can occur within the central region of the plasma (where $q < 1$) reducing the peak temperature and density.

Internal Reconnection Event (IRE): An instability which breaks magnetic field lines and reconnects them with a different topology to reduce the system to a lower energy state - associated with the operating limits of spherical tokamaks.

Ion Bernstein wave: A wave which only exists in a hot plasma and is supported by the ions. It propagates at right angles to the magnetic field, when it is undamped, at harmonics of the ion cyclotron frequency. There is also an electron Bernstein wave which propagates at harmonics of the electron cyclotron frequency.

Ion Cyclotron Current Drive (ICCD): Non-inductive current drive using ICRH.

Ion Cyclotron Resonance Heating (ICRH) / Ion Cyclotron Resonance Frequencies (ICRF): Additional heating method using RF waves at frequencies (~ 20-50 MHz) matching the frequency at which ions gyrate around the magnetic field lines.

IPP: Max-Planck-Institut für Plasmaphysik, Garching, Germany. Partner in the Association EURATOM-IPP, operating the tokamak ASDEX-Upgrade and the stellarator Wendelstein VII-AS. Also has sites in Berlin and in Greifswald, where the construction of the large superconducting stellarator Wendelstein VII-X is in progress.

IR: Infra Red part of the electromagnetic spectrum.

IRE: Internal Reconnection Event.

IST: Instituto Superior Técnico, Portugal. Partner in the Association EURATOM-IST.

ISTTOK: Small tokamak, for study of non-inductive current drive, at the Instituto Superior Técnico (IST), Lisbon, Portugal.

ITER: International Thermonuclear Experimental Reactor (the next step as a collaboration between EURATOM, Japan, the Russian Federation and originally the USA, under the auspices of the IAEA). After a conceptual design phase - CDA (1988-1990), now under engineering design activities (ITER-EDA, 1992-2001). TAC, Technical Advisory Committee. See also Next Step.

JAEC: Japan Atomic Energy Commission, Tokyo, Japan.

JAERI: Japan Atomic Energy Research Institute. Headquarters in Tokyo, Japan.

JET: Joint European Torus. The largest tokamak in the world, sited at Abingdon, UK. Operated as a Joint Undertaking (JET Joint Undertaking), until the end of 1999. The scientific exploitation of the JET facilities is now guaranteed by the Euratom fusion Associations within the EFDA framework. The operation of the facility is the responsibility of the Association Euratom-UKAEA.

JT-60U: Japanese tokamak at Naka. The largest Japanese tokamak and second largest operating experiment after JET, but not designed for use with D-T fuel.

keV: Kilo-electronvolt. Energy which an electron acquires passing a voltage difference of 1000 volts. Also used to measure the temperature of a plasma (1 keV corresponds to 11.8 million degrees Kelvin).

Kinetic instability: Oscillation which is unstable as a result of the energy distribution of ions or electrons.

Kinetic theory: A detailed mathematical model of a plasma in which trajectories of electrons and ions are described. More complex than fluid and two-fluid theories, it is necessary in the study of RF heating and some instabilities, particularly when energetic particles are involved.

L-H transition: Change from L regime to H regime (usually quite sudden).

L-mode: As opposed to the H mode. Regime with degradation of confinement, in additionally heated plasmas, with respect to plasmas heated ohmically by the plasma current.

Langmuir probe: Electrical probe inserted into the edge of a plasma for measurements of density, temperature and electric potential.

Larmor radius: Radius of the gyratory motion of particles around magnetic field lines.

Large scale ideal modes: A large scale mode has a wavelength which is a significant fraction of the plasma dimensions and assumes ideal MHD.

Laser ablation: Use of lasers to produce a sudden influx of impurities into the plasma from a solid surface.

Last closed flux surface: The boundary separating those magnetic field lines that intersect the wall (open lines) from the magnetic field lines that never intersect the wall (closed lines).

Lawson criterion: The value of the confinement time multiplied by the ion density (at the required temperature) which must be exceeded in a fusion reactor to reach ignition.

Limiter: A material surface within the tokamak vessel which defines the edge of the plasma and thus avoids contact between the plasma and the vessel. A pumped limiter can also be used to remove heat and particles and is an alternative exhaust system to the divertor.

LLNL: Lawrence Livermore National Laboratory, Livermore, USA.

Locked modes: MHD modes that cease rotating (though they can still grow).

Low-activation materials: Materials which do not develop high, long-lived radioactivity under neutron irradiation.

Low aspect ratio: Low ratio of major to minor radius of the torus.

Lower hybrid current drive (LHCD): Non-inductive current drive using lower hybrid waves.

Lower hybrid heating (LHRH): Plasma heating by radio frequency waves at the "lower hybrid" resonance frequency in the plasma. Typical frequencies are a few GHz.

Lower hybrid (LH) wave: A plasma wave of frequency between the ion and electron cyclotron frequencies. It has a component of electric field parallel to the magnetic field, so it can accelerate electrons moving along the field lines.

Magnetic axis: The magnetic surfaces of a tokamak form a series of nested tori. The central 'torus' defines the magnetic axis.

Magnetic Confinement Fusion (MCF): Confinement and thermal insulation of a plasma within the reactor core volume by the action of magnetic fields. In toroidal magnetic confinement, usually both toroidal and poloidal components of the magnetic field are needed (the field lines are threaded like the filaments of a cable which is bent into a ring).

Magnetic islands: Islands in the magnetic field structure caused either by externally applied fields or internally by unstable current or pressure gradients. See tearing magnetic islands.

Magnetic surfaces (flux surfaces): In toroidal magnetic confinement, the magnetic field lines lie on nested toroidal surfaces. The plasma pressure, but not the amplitude of the magnetic field, is a constant on each magnetic surface.

Magneto-acoustic cyclotron instability: This instability results from an exchange of energy between the fast Alfvén wave (or magneto-acoustic wave) and an ion Bernstein wave which has a source of free energy through the presence of a population of energetic (non-thermal) ions, e.g. fusion products. The instability occurs for propagation perpendicular to the equilibrium magnetic field.

Major radius: The distance from the tokamak symmetry axis to the plasma centre.

Marfe: A localised and radiating thermal instability sometimes observed near the edge of tokamak plasmas.

Marginal Stability: Close to the transition from stability to instability.

MAST: Mega Amp Spherical Tokamak at Culham (Association EURATOM-UKAEA), twice as big as START. Began operation in 1999.

MeV: Mega-electronvolt, unit for nuclear energies. Energy which an electron acquires passing a voltage difference of 1 million volts.

MHD (Magnetohydrodynamics): A mathematical description of the plasma and magnetic field, which treats the plasma as an electrically conducting fluid. Often used to describe the bulk, relatively large-scale, properties of a plasma.

MHD instabilities: Unstable distortions of the shape of the plasma/magnetic field system.

Microinstabilities: Instabilities with characteristic wave-lengths similar to the ion Larmor radii, rather than to the tokamak dimensions. These are thought to be responsible for the fine scale turbulence in tokamaks, and hence anomalous transport.

Minor radius: Half the small diameter of the tyre-shaped toroid.

Mirnov coils: Pick-up coils at the edge of the plasma for measuring the time variation of magnetic fields arising from instabilities.

Mirror: A linear magnetic confinement concept with a weaker magnetic field in a central region and with strong fields at both ends which reflect contained particles by the mirror effect. Some variants exist to increase the magnetic field in all directions from the centre or to improve the closure of the bottlenecks. The Tandem Mirror confinement concept also involves electrostatic fields.

MIT: Massachusetts Institute of Technology, Boston, USA. Operates the high-field divertor tokamak ALCATOR C-MOD.

Mode: A resonant wave or oscillation in a plasma. Also used as a synonym for an operating regime.

Mode number: Characterises the wavelength of a mode.

Monte Carlo code: A statistical technique used in numerical calculations where

events may occur many times, each with a certain probability.

Motional Start Effect (MSE): The measurement of shifts and splitting of spectral lines emitted from particles moving in a local electric field. This can be interpreted to give the local magnetic field inside the tokamak if the particle velocity is known, and is a major diagnostic on some tokamaks to deduce the current profile.

MPQ: Max-Planck-Institut für Quantenoptik, Garching, Germany. Active, within its programme, in ICF (laser fusion) related physics. Partially supported by Euratom, for a “keep in touch activity” in ICF.

Negative ion beam: To produce neutral beams, negative ions (obtained by the addition of electrons to neutral atoms) are accelerated and then neutralised before entering the plasma. The efficiency of creating neutral beams from positive ions is too low at the beam energy required for a fusion power station, of the order of 1 MeV.

Neo-classical theory: Classical collisional plasma transport theory, corrected for toroidal effects. The neoclassical theory predicts the existence of the bootstrap current.

Neo-classical tearing mode: The magnetic island produced by a tearing mode perturbs the bootstrap current which further amplifies the island and degrades confinement or leads to a disruption.

NET: Next European Torus, a design for the Next Step which had been prepared by the NET team (located at the Association EURATOM- IPP in Garching) and which has largely influenced the ITER design. The European ITER contributions in physics and technology were organised by the NET team, until its replacement by EFDA in 1999.

Neural network: A computer algorithm that uses incoming data to derive plasma parameters, having previously been "trained" on a series of examples of a non-linear input-output mapping.

Neutrons: Neutral particles in the nucleus. Products of Deuterium-Tritium and other fusion reactions.

Neutral beams: Since charged particles cannot easily penetrate the magnetic confinement fields of the plasma, high energy beams of neutral atoms are injected into the plasma for fuelling, heating and current drive. Within the plasma, the atoms of the beam are ionized and are then confined.

Neutron multiplier: The fusion of deuterium and tritium consumes one tritium nucleus per reaction, producing one neutron. Since in the blanket of a power station not every neutron reacts with lithium to produce a new tritium atom, a neutron multiplying element may be used in the blanket to enhance the tritium production so as to make the power station self-sufficient in tritium supply.

Next Step: The next experimental device in the strategy of the European Fusion Programme. Presently pursued via the ITER EDA, with a European activity as a fall-back option. The generic name for an experimental reactor with a long pulse burning plasma at high fusion gain.

NFR: Naturvetenskapliga Forskningsrädet (Natural Science Council), Sweden. Partner in the Association EURATOM-NFR.

NIFS: National Institute for Fusion Science, Nagoya, Japan.

NRIM: National Research Institute for Metals, Sakura-mura, Japan.

Non-inductive heating and current drive: See additional heating and current drive.

NSTX: Spherical tokamak at Princeton, USA. A similar size to MAST, but of different design. Started operation in 1999.

Ohmic heating (OH): The resistive heating resulting from a current flowing within the plasma corresponding to the heating of a wire by a current flowing through it. Ohmic heating in a tokamak is insufficient to reach thermonuclear temperatures since, contrary to a wire, the resistance of a plasma decreases strongly with increasing temperature, thus making Ohmic heating weak at high temperatures.

ORNL: Oak Ridge National Laboratory, USA.

Operating limits: See tokamak operating boundaries.

Optimised shear: Adjusting the current profile to optimise tokamak.

PbLi: Eutectic lithium-lead alloy considered for use as blanket breeding material.

Peeling mode: An edge MHD instability which exists when the current density at the plasma edge is non-zero. It may be associated with ELMs.

Pellet: In inertial confinement concepts, the fuel is contained in tiny spheres, called pellets, which are compressed by laser or particle beams. In magnetic fusion, pellets of frozen hydrogen, deuterium, tritium, accelerated up to several kilometres per second, are used to refuel the plasma and to obtain very high densities.

PIREX: Proton Irradiation Experiment, material test facility (Association Euratom-Switzerland, CRPP-FT, PSI, Villigen, CH).

Plasma: State of matter above a few thousand degrees where atoms are broken into their constituents, ions and electrons, thereby creating an electrically conducting medium. Plasmas can therefore interact strongly with electric and magnetic fields.

Plasma confinement: Retention of plasma energy or particles within a given region, including the heat and particle losses from the plasma.

Plasma parameters: Physical quantities which characterise the plasma and which must be measured experimentally, such as current, density, temperature, confinement time, beta.

Plasma pressure: Proportional to the product of plasma density and temperature. There is an electron and an ion pressure and the plasma pressure is the sum of the two. In magnetic confinement devices, this pressure is counterbalanced by magnetic pressure.

Plasma shape: Describes the plasma vertical cross-section, circular, elongated, D-shape, diverted, single null, double null.

Polarimetry: Measurement of the rotation of the plane of polarisation of light passing through a magnetically confined plasma; used to measure the local magnetic field and thus the safety factor (see Faraday rotation).

Poloidal field: Component of the magnetic field perpendicular to the toroidal direction and the major radius. The poloidal field is essential for confinement and is generated in a tokamak by the plasma current and the external coils.

Power threshold: The L-H transition and improved performance regimes related to reversed shear occur when the power exceeds a certain threshold value - the power threshold.

PPPL: Princeton Plasma Physics Laboratory, New Jersey, USA.

Preliminary Tritium Experiment (PTE): Three plasma discharges on JET, November 1991, into which a significant amount of tritium was injected for the first time in a tokamak. The power liberated from fusion reactions (~ 2MW for ~ 2 seconds) was in accordance with expectations. Followed by the more ambitious DTE in 1997.

Profile: Variation of plasma parameters with minor radius.

Profile control: Controlling the profiles of pressure, density or current, in order to control instabilities.

PSI: Paul-Scherrer-Institut, Villigen, Switzerland, active, in muon physics among others fields. The Association EURATOM-Swiss Confederation has their fusion technology activities working in superconductor and materials technology located at Villigen.

Pumped divertor: Divertor field lines directed into a pumped chamber surrounding the target plate.

q, q_{95}: See Safety factor.

Q: Ratio of fusion power to total additional heating power. At $Q=\infty$, no external power is required and the plasma is said to be ignited. A power station should operate with $Q\sim50$ to be economical.

Radial electric field: Arises when there is a charge imbalance in the plasma.

Radio frequency (RF) heating: Heating with waves in the radiofrequency range at resonance frequencies of the plasma (see ECH, ICRH, LHH).

Reflectometry: Use of reflected microwaves to measure plasma density.

Relaxation: The evolution of a plasma to a lower energy state.

Resistive ballooning modes: A class of ballooning mode which would be stable in the absence of resistivity, but can be unstable in its presence. Related to tearing modes, but topologically different.

Resistive instability: Instability due to diffusion and rearrangement of magnetic field lines. When the plasma resistivity is small, these instabilities have a slow growth rate.

Resistivity: The tendency to resist the flow of electric current, thereby dissipating energy. Plasmas are very good conductors of electric current, so that their resistivity can often be neglected. In this case, 'ideal' magnetohydrodynamics may be applied.

Resonant ions/electrons: Resonance occurs when one of the characteristic frequencies of particle motion in the plasma (for example, the cyclotron frequency) matches the frequency of some applied perturbation (for example, an RF wave).

Resonant magnetic perturbation (RMP): An externally applied magnetic perturbation matched to the spatial structure and optionally the frequency and phase of an instability.

Reverse Field Pinch (RFP): A toroidal magnetic confinement device, similar to a tokamak, in which the poloidal and toroidal fields are of comparable magnitude. Capable of higher plasma current and pressure for a given external magnetic field. They require a conducting shell close to the plasma for stabilisation.

Reverse (magnetic) shear: In a tokamak the current density is usually greatest at the magnetic axis, in which case the safety factor increases from the centre to the edge of the plasma. Using non-inductive current drive and/or the bootstrap current the current density can be made to increase away from the centre. In this “reverse shear” case, the safety factor has a minimum away from the plasma centre. Using reverse or low shear (“optimised shear”) some tokamaks, notably DIII-D and TFTR in the US and more recently JT-60U in Japan and JET, have shown greatly improved plasma performance. Reverse shear is an attractive option for advanced tokamak scenarios.

RF: Radio-Frequency.

RFX: Reversed Field pinch Experiment at CNR-Padova, Italy (Association EURATOM-ENEA).

RISØ: Forskningscenter Risø, Denmark. Partner in the Association EURATOM-RISØ.

Rotational transform: Measure of the ratio of poloidal to toroidal flux defining the pitch of the helical field lines. The q-value of the tokamak is proportional to the reciprocal of the rotational transform.

RTP: Rijnhuizen Tokamak PETULA, for study of transport in a plasma, at Nieuwegein (Rijnhuizen), the Netherlands (Association EURATOM-FOM). Ceased operation in 1998, the activities of the Association being transferred to TEXTOR, as part of the Tri-lateral Euregio Cluster.

Runaway electron: An electron with a very high energy has a decreasing probability of colliding with another charged particle and of losing its energy. Such a particle then gains more and more energy in the electric field of a tokamak, reaching 10's of MeV.

Safety factor: Number of turns the helical magnetic field lines in a tokamak make round the major circumference for each turn round the minor circumference, denoted q. Has no connection with the ordinary sense of “safety” other than q=1 surfaces are ideally unstable. For diverted plasmas q goes to infinity at the separatrix, so instead q_{95} is used to describe the safety factor near the edge, which is the safety factor of the plasma surface which contains 95% of the poloidal flux.

Sawtooth: A cyclically recurring instability which causes an energy loss from the central region of tokamak discharges. The temperature periodically falls abruptly, then slowly recovers. The jagged trace produced by plotting temperature against time gives the instability its name.

Sawtooth crash: The rapid collapse of the central temperature in a tokamak during a sawtooth cycle.

Scaling laws: Empirical or theoretical expressions for how various plasma phenomena (eg confinement, power threshold, etc) vary with tokamak parameters. They are particularly used for predicting the performance of future tokamaks.

Scrape-off-layer (SOL): The residual plasma between the "edge" of the plasma (defined by the limiter radius or the separatrix) and the tokamak vessel wall.

Semi-empirical: A theoretical approach in which the behaviour of some key quantities is deduced from experiment, rather than a priori.

SEAFP: The Safety and Environmental Assessment of Fusion Power is an extensive study conducted by several teams in the associated laboratories, NET, industry and the JRC, published in June 1995.

SEAL: The Safety and Environmental Assessment of Fusion Power Long-term is a programme, launched in 1995, being undertaken for the European Commission in the framework of the Fusion Programme.

Separatrix: Magnetic surface at which the rotational transform vanishes and the safety factor becomes infinite.

Shear: The safety factor usually varies from magnetic surface to magnetic surface across the plasma cross-section; this variation is measured by the non-dimensional quantity called "shear". Also refers to the variation of plasma flow (flow shear). If the type of shear is not specified, it usually means magnetic shear.

Single/double null: Points of zero poloidal magnetic field where the separatrix crosses itself are the X-points or nulls. Usually sited above and/or below the plasma. Tokamak divertor configurations have either one or two nulls.

Single fluid model: The set of equations which represent a plasma as a magnetised, electrically conducting fluid with the usual fluid properties of viscosity, thermal conductivity, etc. The possibility of distinct behaviour of electrons and ions (i.e. 2 "fluids") is excluded.

Small aspect ratio: Same as Low aspect ratio.

Spectroscopy: The detection and analysis of the spectrum of radiation emitted by a plasma. This can yield information about temperatures, impurities, rotation, using different parts of the electromagnetic spectrum (IR, visible, VUV, XUV, etc.)

Spherical tokamak (ST): A very low aspect ratio tokamak - it appears almost spherical, though topologically it remains a torus with a centre column. The spherical tokamak is being further investigated, with a larger experiment, MAST.

Spheromak: A spherical plasma in which comparable toroidal and poloidal currents flow. The toroidal current is not driven by transformer action.

Stability theory: The theory of how small perturbations to a system evolve in time. Spontaneous growth is due to instability. Instabilities can saturate at some small amplitude, in which case they may degrade confinement, or grow uncontrollably, in which case the equilibrium is lost leading to a disruption.

START: Small Tight Aspect Ratio Tokamak, a "spherical" tokamak with a very small aspect ratio at the Association EURATOM-UKAEA (Culham). This very fat ring-shaped configuration showed experimentally a lesser tendency to disruptions and is efficient in its use of magnetic energy. Ceased operation in 1998, replaced by MAST.

Start-up assist: Assisting plasma formation to cross a range of plasma temperature at which impurities radiate strongly, with the aim of minimising the start-up delay and transformer requirements, usually using ECH.

STC: Scientific and Technical Committee, advisory committee set up by the EURATOM Treaty, competent for nuclear programmes.

Steady state power plant: A continuously (as opposed to cyclically) operated power plant.

Stellarator: Closed configuration having the shape of a three-dimensionally distorted ring in which the plasma is confined principally by an externally generated magnetic field (produced by non-planar coils outside the plasma vessel). The coils can be arranged in a modular fashion. Stellarators do not need a transformer; they need an additional heating system for the plasma start-up. Due to the fact that no toroidal plasma current is needed to maintain the confinement configuration, they naturally provide steady state operation.

SULTAN: Supra Leiter Test ANlage. Large Superconductor Test Facility, CRPP at PSI Villigen, Switzerland (Association EURATOM-Swiss Confederation).

Super Alfvénic velocity: A velocity greater than the Alfvén velocity. In a tokamak, only energetic particles have super Alfvénic velocities; because they satisfy this condition, they may resonantly transfer their energy to magnetohydrodynamic modes, which may grow as a result (eg TAE modes).

Superthermal radiation: Electromagnetic radiation produced by energetic particles, as opposed to thermal particles.

Survey spectrometer: An instrument which gives information concerning the radiated spectrum over a large range of frequencies.

TAE modes: Toroidal Alfvén Eigenmodes. One class of Alfvén gap modes.

Target plates: See Divertor.

TCV: ”Tokamak à Configuration Variable”, for study of elongated and strongly shaped plasmas, at Lausanne, Switzerland (Association EURATOM-Swiss Confédération).

TEKES: Technology Centre Finland. Partner in the Association EURATOM-TEKES.

Tearing magnetic islands: The disturbance caused by a tearing mode which alters the topology of the confining magnetic field and causes transfer of heat across the affected region.

Tearing mode: A class of resistive MHD instability which has been predicted theoretically in tokamaks and positively identified in experiments.

Temperature pedestal: In an H-mode discharge there is a region of steep temperature gradient at the plasma edge. The temperature at the top of this steep gradient region is the temperature pedestal.

Tesla: Unit of magnetic field strength (more exactly the magnetic induction). $1T = 1Vs/m^2 = 10{,}000$Gauss.

TEXTOR: Torus Experiment for Technology Oriented Research. Tokamak at Jülich, Germany (Association EURATOM-FZJ). Refurbished and upgraded, in 1994, as TEXTOR-94.

TFTR: “Tokamak Fusion Test Reactor” at Princeton, the largest US device with a major campaign using deuterium-tritium fuel from 1993 - 1997. Ceased operation in March 1997.

Thermal cycling: Successive heating and cooling of materials can lead to cracks or rupture, particularly at boundaries between materials that expand at different rates.

Thermal particles: As a result of collisional energy exchange, the energy of most plasma particles falls within a Maxwellian distribution which is described by a single temperature (typically 1-30keV for tokamaks). These are the thermal particles, as distinct from energetic particles which lie outside the thermal distribution.

Thomson scattering diagnostic: Diagnostic to measure temperature and density by detecting laser light scattered and Doppler shifted by the thermal plasma electrons.

Tight aspect ratio: Same as Low aspect ratio.

TJ-II: A heliac stellarator at Madrid, Spain (Association EURATOM-CIEMAT). (TJ-IU was a torsatron at CIEMAT, built and operated in preparation for TJ-II).

Tokamak: Magnetic configuration with the shape of a torus. The plasma is stabilised by a strong toroidal magnetic field. The poloidal component of the magnetic field is produced by an electrical current flowing toroidally in the plasma. This current is induced via transformer action and, for steady state, must be maintained by non-inductive current drive and by self-generation of bootstrap current inside the plasma.

Tokamak operating boundaries: The set of plasma parameters, beyond which it is impossible to operate a tokamak. Careful choice of plasma cross-sectional shapes and current and pressure profiles can increase the operating regime.

TORE SUPRA: Large tokamak with superconducting toroidal magnetic field coils and a circular plasma cross-section at the Association EURATOM-CEA in Cadarache, France.

Toroidal Alfvén Eigenmodes: See TAE modes.

Toroidal field: The component of the magnetic field along the major circumference of the torus. The largest magnetic field component in a tokamak.

Toroidal stability: Stability analysis taking account of effects due to the toroidal geometry. These are sometimes neglected to identify possible instabilities, but must usually be included for accurate predictions of stability boundaries.

Toroidal turbulence code: A turbulence code which includes effects due to the toroidal geometry.

TOSKA: Large facility testing for superconductors (Association EURATOM-FZK, Karlsruhe, Germany).

Transformer drive: The use of a transformer action to produce plasma current.

Transport: The processes by which particles and energy move across magnetic surfaces.

Transport barrier: In certain operational scenarios (e.g. the H-mode or ITB-mode) a region of low transport exists giving rise to a steep local pressure gradient. Such a region is referred to as a transport barrier.

Transport scaling: The magnitude of heat transport may be expressed, empirically

or theoretically, in terms of a simple functional dependence on a few plasma parameters. This allows us to model how the heat transport varies (scales) in response to changes in the value of these parameters.

Trapped particles: The outside (large major radius) of a tokamak plasma has a lower magnetic field than the inside. Particles with low velocity parallel to the magnetic field compared with the velocity perpendicular to the magnetic field may not enter the higher field (inside) region and become trapped on the outside. They are not free to circulate toroidally but instead bounce back and forth, performing so-called banana orbits.

Tri-lateral Euregio Cluster (TEC): A collaboration between the Associations Euratom-FZJ, -FOM and –Etat Belge, to exploit the TEXTOR tokamak at FZJ, Julich, Germany.

Tritium: An isotope of hydrogen, whose nucleus consists of one proton and two neutrons. Tritium does not occur naturally, because it is unstable to radioactive decay with a half-life of 12.3 years. Due to its rapid decay, tritium is almost absent on earth. For a fusion reactor, tritium will be produced in the breeding blanket surrounding the core of a fusion power station. Special tritium-handling technology is required whenever the use of deuterium-tritium plasmas is contemplated and has been developed on TFTR and JET.

Tritium inventory: The amount of tritium contained in a fusion power station or in a specified part of it.

Turbulence: Randomly fluctuating, as opposed to coherent, wave action. For example, the turbulent water beneath a waterfall can only be described in terms of its averaged properties, such as the scale and duration of fluctuations; whereas a more systematic description can be given to waves on the surface of a still pond.

Turbulent transport: Anomalous heat transport associated with plasma turbulence.

Two-fluid model and multi-fluid model: The extended set of equations which represent a plasma as interpenetrating and interacting fluids of electrons and ions, impurity ions etc.

UKAEA: United Kingdom Atomic Energy Authority. Partner in the Association EURATOM-UKAEA which operates the tokamak COMPASS-D and the spherical tokamak MAST. Also charged with the operation of the JET facilities under EFDA.

Vertical Displacement Event (VDE): An event which arises when control of the plasma is lost and the plasma moves vertically. It can lead to a “halo current” in components which surround the plasma resulting in large, potentially damaging, forces on these components. The forces are much larger in larger tokamaks and are therefore a particular concern for JET and ITER.

VUV: The “Vacuum Ultra Violet” range of the electromagnetic spectrum.

Warm plasma refuelling: Fuelling of plasma using medium energy particles or particle clusters.

WEC: World Energy Council.

WENDELSTEIN VII-AS: Advanced stellarator, in operation at Garching, Germany (Association EURATOM-IPP).

WENDELSTEIN VII-X: Large advanced stellarator, optimised to produce a reactor-relevant plasma configuration, designed at Garching. Construction in progress at Greifswald, Germany (Association EURATOM-IPP) with first operation scheduled for 2006.

X-point: See single/double null.

XUV: The “Extreme Ultra Violet” range of the electromagnetic spectrum. Shorter wavelengths than VUV.

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