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Wendelstein 7-X receives final EURATOM approval

W7-X recommended for preferential support

At its meeting on 28 September 1995, the Consultative Committee on the Fusion Programme (CCFP) unanimously recommended that the EURATOM Commission award Phase II approval to the Wendelstein 7-X project, basic device plus Stage I heating. This is the final step necessary for the Commission to grant preferential support to the investment cost of the project.

As a preferentially supported project, Wendelstein 7-X will receive a contribution to the capital investment cost of 45% from EURATOM. The remaining contribution is to be shared in the ratio of 9 to 1 between the Federal Republic and the Bundesland Mecklenburg Vorpommern, where the project is to be located at the IPP Branch Institute, Greifswald.

EURATOM assessment procedures comprise two phases. The scientific aim is evaluated in Phase I, and the technical feasibility, including the organization, the financing, and the time schedule, in Phase II. A few weeks after final Phase I approval for W7-X in May 1994, the Phase II application was submitted to EURATOM. Over a period of nine months, the EURATOM Ad-Hoc Group and its six subgroups thoroughly examined the proposal. Many and very detailed questions were discussed at 17 meetings, mostly together with the proponents. At the end of this rather active period, the Ad-Hoc Group recommended on September 8, 1995, without any restriction or reservation, that Phase II approval be awarded to the project. This report was passed to the Programme Committee, which followed this recommendation on September 11–12, 1995. The final recommendation to the Commission was given by the CCFP on September 28, 1995.

The design of the W7-X project together with the construction of the buildings is expected to start now, and it is hoped that the experimental setup will be ready for the first plasma shot in mid-2004.

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In this issue . . .

The possibility of a geometrical mechanism of "self-healing" phenomena in Helias-type systems.

Self healing may be due to a shift in the geometry. 2

Superconductor development for W7-X

The NbTi cable-in-conduit conductor for W7-X and results of ongoing tests with planar coils are described. 3

Spanish contributions to the Tenth International Conference on Stellarators: TJ-I U and TJ-II

Paper summary. 5

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The possibility of a geometrical mechanism of "self-healing" phenomena in Helias-type systems

Recently, numerical simulations of the island structure evolution with increasing plasma pressure have been performed [1, 2] using the HINT code [3]. It was shown that magnetic islands that appear in the vacuum equilibrium of the Helias stellarator can, in some cases, disappear as the plasma pressure increases [1,2]. The authors of Ref. [1] called this phenomenon "self-healing." One could gain an impression that phenomena similar to self-organization take place here.

Meanwhile, the analysis of one series of numerical experiments in Ref. [2] has shown that observed "self-healing" can be explained simply by the disappearance of the corresponding resonant magnetic surface because of a change in the rotational transform profile when the plasma pressure increases. However, in another series of calculations, the islands also disappear even though the corresponding resonance surface remains in plasma. To explain this case, the authors of Ref. [4] suggest the mechanism of compensation of the resonant vacuum magnetic field harmonic $\sim \exp\, i(m\theta - n\zeta)$ by that created by internal surface currents. Such a current is formally permissible by the magnetic differential equation using the *a* parameter, which determines the equilibrium longitudinal current density, $\boldsymbol{j} = \alpha \boldsymbol{B}$. In magnetic (Boozer) coordinates this equation acquires the form

$$\iota \frac{\partial \alpha}{\partial \theta} + \frac{\partial \alpha}{\partial \zeta} = -\frac{dp}{d\Phi}\left[F\frac{\partial}{\partial \theta} - J\frac{\partial}{\partial \zeta}\right]\left(\frac{1}{B^2}\right) \equiv iC(a,\theta,\zeta)$$

where θ, ζ are the poloidal and toroidal magnetic angle coordinates; ι is the rotational transform; p, Φ, F, and J are the plasma pressure, toroidal flux, and poloidal and toroidal currents, respectively; and a is a flux surface label.

As was emphasized in Ref. [4], the Fourier components of the solution,

$$\alpha = \sum_{m,n} \alpha_{mn}(a) e^{i(m\theta - n\zeta)} \quad ,$$

have the following appearance at

$$C = \sum_{m,n} C_{mn}(a) e^{i(m\theta - n\zeta)} \quad ,$$

$$\alpha_{mn} = \frac{C_{mn}}{m\iota - n} + C_0 \delta(m\iota - n) \quad .$$

Thus, at proper choice of amplitude C_0, the resonance magnetic field on the corresponding resonance magnetic surface can be eliminated [4].

It seemed us that there is a more simple mechanism of eliminating the resonance component of $1/B^2$ and the corresponding island structure, without internal surface currents in plasma. This mechanism is connected only with the changing of system geometry. Namely, changing the magnetic surface geometry changes the Fourier spectrum of $1/B^2$. For example, adding a vacuum homogeneous transverse magnetic field will shift the magnetic surfaces and change the $1/B^2$ spectrum. This mechanism in our opinion can explain in more simple way the "self-healing" described in Ref. [1].

Indeed, the vacuum configuration in Ref. [1] where the "self-healing" takes place has island chains on the ι = 5/6 and ι = 5/5 resonance surfaces, i.e., corresponding to the $(1/B^2)_{6,5}$ and $(1/B^2)_{5,5}$ Fourier components. With pressure growth, the magnetic surface's cross sections are deformed. Relations between the plasma a, θ, ζ and vacuum ρ, ϑ, ζ magnetic coordinates can be written for our purposes in the following simple form:

$$\rho = a + \Delta \cos\theta \quad ,$$

$$\vartheta = \theta + \lambda \sin\theta \quad .$$

Here $\Delta(a)$ is the toroidal shift and $\lambda(a)$ is the parameter of transition to magnetic coordinates. We shall consider Δ/a and λ as small quantities. Substitution of Eqs. (3) and (4) into the vacuum term $(1/B^2)_{5,5} \exp i(5\vartheta - 5\zeta)$, where $(1/B^2)_{5,5}$ is a function of ρ, leads to the appearance of a $(1/B^2)_{6,5}$ component because ofthe coordinate transformation. Taking this effect into account, the observed "self-healing" phenomena in Ref. [1] can be explained as follows. Let's introduce the following notations:

$$(1/B^2)_{6,5} = (1/B^2)^{v}_{6,5} + (1/B^2)^{p}_{6,5} \quad ,$$

where the first term is the vacuum resonance harmonic, which could be considered as a constant in spite of an increase in the growth of the plasma pressure for small Δ/a and λ; the second term is connected with the coordinates transformation. When the configuration without an island chain m/n = 6/5 is considered in Ref. [1], the corresponding resonance term $(1/B^2)^{p}_{6,5}$ appears in $1/B^2$ because ofthe effect of the coordinate transformation. When the vacuum configuration has an m/n = 6/5 island chain with a phase opposite to the first case (as occurs in Ref. [1]), it means that $(1/B^2)^{v}_{6,5}$ has opposite sign to the $(1/B^2)^{p}_{6,5}$. Plasma pressure increase leads to the growth of $(1/B^2)^{p}_{6,5}$; thus, for some β the value of the $(1/B^2)_{6,5}$ becomes equal to zero.

It is clear that the coordinate transformation can also be realized in vacuum configuration, for example by adding a transverse magnetic field. Thus, the proposed mechanism of "self-healing" can be checked in a pure vacuum configuration using integration over magnetic field lines.

If the suggested mechanism is valid, the "self-healing" phenomenon must be considered as an accident, rather than being intrinsic to Helias or another 3-D configuration. Nevertheless, it does not mean that it cannot be used for configuration improvement as was suggested in Ref. [1].

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Superconductor development for W7-X

An overview of engineering aspects for W7-X was given in *Stellarator News* Issue 39, May 1995. In the present contribution, the R&D for the coil development of this experiment is addressed, concentrating on the conductor development and results of planar test coils as obtained so far in an ongoing investigation.

The superconducting coils for W7-X will be wound from a NbTi cable-in-conduit conductor, designed for a nominal current of 16 kA at 6.2 T and 3.8°K He-cooling inlet temperature. The design value for the average axis field strength for W7-X was set to 3.3 T to ensure a sufficient safety margin for the magnet. When operating the experiment at the resonance field of 2.5 T for ECRH at 140 GHz in the "Standard Case," each of the 50 nonplanar coils (120 windings) requires a conductor current of about 12 kA at an overall current density of 38.4 MA/m^2, referred to the winding pack dimensions. Under these conditions, a maximum local field of about 4.8 T occurs at the coil bore near the indented region of the bean-shaped plasma cross section. Twenty ancillary coils (36 windings each) use the same conductor and allow for a wide parameter variation in W7-X. Under all experimental conditions, the peak axis fields are more than 10% below the above design value.

Discussions of an easy manufacture procedure for the modular coils at reasonable machining effort and comparatively low cost had led to the choice of a cable-in-conduit multifilamentary NbTi superconductor with copper stabilization encased in an aluminum alloy conduit. This choice was already made at an early stage of the W7-X project. While the superconducting cable, twisted for reducing AC losses, is flexible *per se*, the conduit should be soft for winding the coils but rigid during operation of the magnet. Certain aluminum alloys are ideally suited for this purpose before and after a heat treatment. Such a heat treatment is required after winding the coils anyway to cure the glass-fiber epoxy insulation. The conduit has to be He-tight for cooling with supercritical helium. The "void fraction" of the conductor is important to ensure a sufficient helium flow rate at a reasonable pressure drop along the cooling length. If the void fraction is too large, stability problems canarise because of possible motion of the strands in the cable under the electromagnetic forces and the resulting frictional heat.

Apart from specific requirements of superconductivity, the winding process for the W7-X coils is similar to that successfully used in the coil construction of the W7-AS experiment: coil winding in a soft state using a prefabricated mold to achieve a highly reproducible shape, followed by a heat treatment curing of the complete coil. The W7-X coils will be embedded in a stainless steel case; an intercoil support structure is being optimized to reduce stresses due to the electromagnetic forces, to save weight, and to provide sufficient access to the experiment for diagnostics, heating, and supply lines.

Two types of superconductor for the coil development were obtained from industry, type “A” with 144 filaments of 27 µm diameter per strand, using “co-extrusion” to apply the aluminum cladding, and (from another company) type “B” with 48 filaments of 46 µm diameter, using “conform cladding” of another aluminum alloy. Both conductors utilize 192 strands of commercially available NbTi/Cu superconductor; void fractions in the cable amount to 34% and 38%, respectively. Initial short-sample tests demonstrated for both conductor types a reasonably small amount of degradation (around 10% to 15% reduction of critical current, measured at 4.2°K and up to 8 T background field). Strand measurements of material taken from wound and cured conductor samples were compared to data obtained from virgin strands and showed that the conductor can be bent at the minimum radius of curvature occurring in W7-X coils, which amounts to about 20 cm. Other tests demonstrated the performance of current and helium supply leads, especially the feasibility of helium-tight welding between the connection elements and the conductor conduits. These tests were mainly performed at the Forschungszentrum Karlsruhe (FZK), which had been the agent for the EURATOM Coil of the Large Coil Test at Oak Ridge.

It was also agreed with FZK to perform tests of planar coils on their facility STAR, which can provide a background field up to 8 T. Three coils, labeled STAR I–III, were wound so far. Two were made successively from a total production length (about 400 m) of the conductor type “A”; the third coil was wound by the same company at a later time from 200 m of type “B.” This length matches the cooling length of the W7-X modular coil design. The dimensions of all three coils are identical; their bore size is chosen to be identical to the smallest radius of curvature in the nonplanar modular coils of W7-X.

The STAR I coil could not be investigated because of a rather simple fault. Oil was used in the co-extrusion process of the first production length of the type “A” conductor. In efforts to remove this oil, some inadequate steps were taken thatblocked the helium transfer through the conductor, and the coil had to be abandoned.

The STAR II coil was wound from the second half of the type “A” conductor. The oil could be sufficiently removed. Many test runs were made at various experimental conditions. The lowest temperature measured during these tests in STAR was about 5°K. Typical quench currents up to 17 kA were obtained. Values ranged between 13.6 and 15.5 kA at increased current ramp-up speeds and varied helium flow rates. The quenches originated, as expected, in the high-field zone of the coil, where the conductor curvature is also maximum. A safety discharge of the STAR II coil was performed at 14 kA without a quench; the time constant of the discharge circuit being chosen a factor 3 shorter than in W7-X. The strands of the type “A” conductor, measured after the full coil production process, showed at 6 T and 4.2°K a degradation related to the values for the virgin strands by 35%, of which 8% were measured just after the co-extrusion process, whereas the remaining was the consequence of an additional improper heat treatment, which will be avoided in future. The coil reached in STAR on its “load line” (field versus current) a quench current of 17 kA at 5.8 T and 4.8°K, which is 5% below that current expected from the degraded strands, or equivalent to a temperature increase of 0.2°K in the space of current, temperature, and field values. For the W7-X magnet, to be cooled at an inlet temperature of 3.8°K, a corresponding temperature margin of 0.9°K would result if operated at the design current of 16 kA.

The STAR III coil was wound using the type “B” conductor. Strands of this conductor, measured after the full cable production process, showed at 6 T and 4.2 K a degradation by 11.4%; values between 5.5% at 5.5 T and 8.5% at 8 T are reported in [1]. The STAR III coil was tested at similar temperatures as were available in the STAR II investigation. The choice not to improve the cooling capabilities of the STAR test bed was made for two reasons: mainly to achieve test results at the earliest possible time, and secondly to compare results under nearly identical conditions. In a large series of experiments, a maximum quench current of 18 kA at 6.1 T and 5.0°K was obtained with the STAR III coil, which lies 8% below the expected one along the load line. This corresponds to a temperature difference of 0.5°K. For the W7-X magnet under the design values of 16 kA and 6 T, this would yield a temperature margin of 1.5°K above the helium inlet temperature of 3.8°K, at the high-field side of the coil. A temperature increase of about 0.6°K is expected along the cooling channel of the W7-X coils towards lower field values. Becausefor the experimental parameters envisaged in W7-X the coil currents and associated peak fields at their surfaces are considerably lower than these design values, the safety margin in operation temperature is even larger.

As a consequence of the results obtained so far, and in view of the schedule for the construction phase of the Wendelstein 7-X experiment, the following activities are in progress:

➟ The DEMO coil, a full-size demonstration coil for W7-X, is being constructed by industry. It will utilize the type “A” conductor with a more detailed quality control as compared to that of the production phase for the first 400 m. This coil will be investigated at the Forschungszentrum Karlsruhe in the background field of the EURATOM LCT Coil.

- An "advanced conductor" with improved stability, see [2], will be produced in parallel for a STAR IV coil.
- The STAR IV coil will be investigated in addition to the DEMO coil test.
- An evaluation of the STAR and DEMO coil tests will be the starting point for industrial production of the conductor for the W7-X series coils.
- If necessary, a STAR V coil will be built using the chosen superconductor and investigated for proof-of-principle prior to the W7-X series coil production, thus providing several valid solutions for the total length of about 60 km of superconductor to be used in the construction of the 50 nonplanar and 20 ancillary W7-X coils.

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Spanish contributions to the Tenth International Conference on Stellarators: TJ-I U and TJ-II

Seventeen papers (seven oral contributions and ten posters) were presented by CIEMAT members and collaborators at the Tenth International Conference on Stellarators, most of them focusing on results from TJ-I U torsatron or TJ-II heliac. Two of them dealt with results obtained in W7-AS in collaboration with members of IPP Garching. Five more papers were presented by close collaborators of CIEMAT on different topics concerning CIEMAT devices, ATF results, and heliac reactor studies. This summary outlines the main results obtained in TJ-I U, our current device, and TJ-II, our near-future one, as well as the rest of the contributions presented by our group.

Magnetic surface mapping results in TJ-I U were presented by J. Qin. More than 100 magnetic configurations were measured, covering ranges of the rotational transform $\iota = 0.1$–0.6 and 15 cm horizontal shift of magnetic axis. The shape of magnetic surfaces can be changed from bean-shaped to almost circular. In addition to well-defined, nested and closed magnetic surfaces, low- and high-order rational "surfaces" with $\iota = n/m$, $n = 1, 2, 3, 4$ and $m = 2, 3, 4, ...,$ up to $m = 19$ have been observed. Low order island structures with $\iota = 1/2, 1/3, 1/4$ and $1/5$ have also been observed. A theoretical model that includes not only the ideal coils but also error fields has been developed. It fits the experimental data remarkably well, and thus it is reliable in representing almost any real magnetic configuration with full field operation.

The fueling system of TJ-I U was discussed by F. Tabarés. Particle balance during the gas injection was used to infer the fueling efficiency of the puffed gas under different experimental conditions. A low fueling efficiency for H_2 injection was measured for 28-GHz heated discharges, in spite of their low electron density. This fact is consistent with the high transparency of the plasmas for the H atoms generated through electron impact from molecules, together with low recycling. During the 37.5–GHz heating campaign, a more complex gas-injection system allowed the production of true density plateau even within the short duration of the plasma pulses. A higher fueling efficiency was also observed when compared with the previous campaign. The injection of small amounts of He into the plasma provided a first estimate of the electron temperature in the outer half of the plasma and allowed a first estimate of the energy confinement time. The obtained value is close to that expected from the standard scaling laws.

B. Zurro reported spectroscopic studies on ion heating, rotation, and impurity emission asymmetries in TJ-I U.

The proton temperature was deduced from the analysis of the H_a line wings. The impurity ion used for Doppler studies was O V. The observation was almost tangential, through the same quartz window used for microwave heating power injection; therefore, the reported parallel rotation and ion temperature could be affected by the heating wave electric field. The absolute values of O V ion temperature and central proton temperature, in the density range $2–7 \times 10^{12}$ cm^{-3}, range between 50 and 100 eV, higher than theoretically estimated and also higher than perpendicular proton temperatures measured by a charge-exchange neutral spectrometer ($T_i \simeq 30–40$ eV). Further experiments are being done to elucidate this problem.

First results from a microwave scattering diagnostic for TJ-I U plasmas were presented by K. Likin. The microwave power (140 GHz, 0.4 W) is launched into the plasma with a horn antenna and a focusing mirror. Three lens-horn antennae receive the scattered microwave power (center of scattering volume located about mid-radius) corresponding to plasma density fluctuations with wave numbers 6, 14, and 22 cm^{-1}. The first results obtained show that fluctuations rise in the leading front of the plasma density increase. The frequency spectra have features up to 200 kHz and are similar to the ones observed in other stellarators like L-2 and ATF.

Edge turbulence studies were reported by M.A. Pedrosa. Langmuir probes were used to obtain radial profiles of density, potential, and electron temperature, as well as their fluctuations levels. The existence of two different propagation modes in the proximity of the last closed magnetic surface (LCMS) was observed. Inside the LCMS, the high-frequency fluctuations propagating in the ion drift direction strongly decay. Particle transport due to this mode of propagation are relevant, not only in the plasma bulk side of the LCMS due to the reduction of fluctuation levels and the decorrelation between ion saturation current and floating potential, but also in the scrape-off layer (SOL) because of the unfavorable coupling between those magnitudes. Under some plasma conditions the main part of the turbulent particle transport could be imputed to a quasicoherent mode probably related to the magnetic configuration.

The analysis of plasma turbulence requires special tools because the usual linear methods (e.g., spectral analysis) do not reveal any information about the phase coupling among different spectral components. B. Ph. van Milligen presented a study of the usefulness of wavelet bicoherence as a nonlinear analysis tool for the analysis of turbulence. To demonstrate its potential, it was applied to numerical models of chaos and turbulence and to real measurements. When applied to a model of drift wave turbulence relevant to plasma physics, it detected a highly coherent structure associated with a rational surface. Analyzing reflectometry measurements from W7-AS it detected a strong increase in nonlinear phase coupling coinciding with the L/H transition.

A comparative study of experimental results on edge plasma turbulence characteristics in three stellarators, W7-AS, ATF, and TJ-I U, was presented by T. Estrada. Plasma turbulence in ECRH plasmas was characterized using Langmuir probes (ATF and TJ-I U) and reflectometry measurements (W7-AS). The location of the velocity shear layer was used as the reference point for comparisons. The nonlinearity of the plasma turbulence was characterized by means of bicoherence analysis. In spite of the differences between W7-AS and ATF (shear, curvature, etc.), the level of plasma fluctuations is comparable in both machines, about 5–10% in the plasma bulk side of the velocity shear layer. This result could indicate the existence of a common drive for the turbulence. However, the outcome of the nonlinear plasma analysis is different in these two cases: whereas the bicoherence in the plasma edge is small in W7-AS, it is significantly high in ATF. This result could be understood in terms of the dependence of the strength of the nonlinear coupling on the magnetic shear. But, while the measured fluctuation level in the plasma bulk side of the velocity shear layer is larger in TJ-I U than in W7-AS and ATF, the value of bicoherence in TJ-I U is comparable to the one obtained in ATF. This result calls into question the interpretation of the ATF/W7-AS comparison in terms of the influence of magnetic shear on nonlinear coupling.

C. Hidalgo reported measurements of the statistical properties of the time-resolved radial turbulent flux in the plasma boundary region of TJ-I tokamak and TJ-I U torsatron, by means of Langmuir probes. The strong similarity of the above-mentioned statistical properties supports the universal character of the plasma turbulence in magnetic confinement devices. These results emphasize the relevance of comparative studies between the structure of plasma turbulence in tokamak and stellarator plasmas to test edge turbulence models critically.

R. Balbín presented measurements of electron temperature fluctuations, by means of the fast swept probe technique, and turbulent transport in the boundary region of W7-AS. Temperature fluctuations levels (10–20%) are similar to the level of density fluctuations. Statistically significant correlation between density and electron temperature fluctuations has been measured. This result indicates that radiative instabilities are not likely the dominant mechanism to explain edge turbulence in W7-AS. Because of the zero phase between density and electron temperature fluctuations, the transport resulting from the measured particle flux due to the correlated fluctuations (taking into account the effect of temperature fluctuations) is very similar to the transport calculated under the assumption $\widetilde{T_e}/T_e \simeq 0$.

B. Brañas reported reflectometry results obtained in W7-AS using a combined broadband heterodyne reflectometer with amplitude modulation (AM) and carrier phase detection. Phase, amplitude, and time delay of the reflected microwave beam are measured to obtain information simultaneously on density profile and density turbulence. Results concerning density fluctuation measurements in L and H modes and during ELMs were presented, as well as the results during density and power scan experiments. Density profiles are routinely obtained using the AM reflectometry system, with the advantage of an easier tracking of the phase over a classical swept reflectometer.

The results of a numerical simulation of edge turbulence in the ATF torsatron based on the resistive pressure-gradient-driven-turbulence model were presented by L. García. The comparison of the simulation results about the fluctuation level at the plasma edge with experimental data from reflectometry, HIBP, and Langmuir probes showed a reasonable agreement. The model was also applied to the simulation of the L-to-H transition in stellarators. The main characteristics of H-mode phase are obtained: reduction of the particle flux, decreasing of the rms fluctuation level, improved confinement associated with the building up of an edge pedestal, and strong amplification of the poloidal sheared flow at the transition.

In another paper, L. García presented results of theoretical calculations of the TJ-I U stability. They showed that the configuration is stable to ideal modes and that the resistive modes have the characteristics of resistive ballooning ones.

A review of TJ-I U experiments was reported by E. Ascasíbar. First ECRH plasmas (28–37.5 GHz, X-mode, second harmonic, P = 200–250 kW, pulse length ≃ 25 ms, quasioptical transmission line) were produced in 1994. Electron temperatures up to 200 eV have been achieved in plasmas with line average electron densities up to 0.6×10^{13} cm^{-3}. So far low (≃ 25%) fraction of absorbed power has been observed Because of the high magnetic field gradient in the cross section corresponding to the microwave injection port.

K. Likin presented the conceptual design of transmission lines for ECRH and ECCD experiments in the CIEMAT's next device, TJ-II. Two 53.2-GHz/400-kW gyrotrons are planned. In the initial phase, the parameters of the first launching beam (incident angle and polarization) are fixed; it will be used for plasma startup and ECRH. The parameters of the second beam can be changed with a moveable mirror installed inside the TJ-II vacuum vessel, so that it can be used for ECCD as well as for ECRH. Both quasioptical transmission lines are based on mirrors; the first one (fixed) has 8 mirrors and the second one includes 9 external mirrors and one internal one. Most mirrors are cylindrical (coupled in pairs so that curvature radii of each pair are perpendicular), and some of them focus a wave beam in two planes. Estimated transmission coefficient is about 0.9.

V. Tribaldos presented TRECE, a newly developed ray tracing code, well suited to compute the electron cyclotron emission (ECE) and the electron cyclotron absorption (ECA) for any device. This code includes a promising new method for representing the magnetic flux by means of a neural network. This code was used to look for the best positions for and ECE diagnostic in TJ-II. From its simulations two locations, at toroidal angles 0° and 45°, have been found that reproduce the electron temperature profile regardless of the plasma configuration in a wide range of plasma parameters. It was also shown that the polarization rotation of the received emission due to Faraday rotation and the local magnetic field shear is very small.

J.A. Jiménez reported a method for designing and optimizing magnetic diagnostics based on the combination of plasma equilibrium calculations and multivariate regression techniques. To check the applicability of the method, it was applied to the complex magnetic configuration of a heliac-type stellarator, TJ-II, showing its adequacy. The sketch of the method is as follows: after the generation of an equilibria database, a fast reconstruction technique (function parameterization) is used to determine, for a number of magnetic diagnostic designs, how well the plasma can be recovered. For the limited database used in this work (only β was varied), it was found that a very limited number of properly placed magnetic field coils might already provide sufficient information to recover B. Efforts are in progress to ascertain this result by using a larger database, in which not only β but other parameters as well, are varied.

TJ-II transport studies using the Proctr code were also presented by J. Guasp. Transport coefficients were chosen to fit scaling laws because no experimental data are still available. A plasma discharge with two heating phases is simulated: it starts with 400 kW ECRH (53.2 GHz, 2nd harmonic, X-mode), and after 20 ms NBI is switched on. Stationary conditions are reached in 375 ms, with a saturation central density of 1.3×10^{14} cm^{-3}. The predicted electric potentials are always negative, taking values between 300 and 700 V, not strong enough to affect transport properties. Radiative collapse is avoided in the ECRH-to-NBI transition for $Z_{\mathrm{eff}} < 3.5$, in spite of the fact that CX and shine-through losses are important for density values corresponding to the cutoff (1.7×10^{13} cm^{-3}). At the transition β value falls, but after a short time, the density increases and the discharge parameters are recovered.

The fast ion behavior for NBI scenarios in TJ-II was presented by J. Guasp. This work analyzed the dependence with density and beam energy of the different kinds of fast ion losses during tangential balanced NBI injection in TJ-II. Direct losses are much more important than delayed ones (CO beam direct losses predominate). The total value of fast ion losses is about 15–20% of the power entering the torus. This value is high but tolerable. The absorption is rather independent of energy, with low values at low density because of the high shine-through and CX losses, but increasing quickly as the density builds up. The non-collisional loss cone structure and the distribution of trapping regions have been also analyzed. At energies between 1 and 40 keV, without considering collisions and electric field, all trapped particles escape; in particular, locally trapped particles are lost very quickly along the gaps between adjacent TF coils. The impacts of these fast ions on the vacuum vessel show accumulation of direct losses (mainly for the co beam) on some particular regions of the hard core. The resulting peak load levels (600 W/cm^2) in the most unfavorable case (high density) are similar to those produced by shine-through losses. These values are high but tolerable.

C. Alejaldre presented the status of the construction of TJ-II project. The Flexible Heliac TJ-II is entering into its final stage of construction. The problems encountered during manufacturing so far have been solved satisfactorily, although the narrow tolerances, which result from the compact machine design, have created real challenges for the component manufacturers. The manufacturing of poloidal field coils and support structure was already finished in 1994. Construction of the toroidal field coils was terminated in March 1995. Meanwhile, all of the coils have been successfully tested at full operational current using the power supplies of the Max Planck Institute at Garching. The first octant of the vacuum vessel has been delivered most recently. The last octant is expected to be delivered in September 1995. The hard core has entered the final fabrication stage; delivery is scheduled for June 1995, after full current tests are performed in Garching. The installation of the cooling system has been finished. The manufacturing of the power supply system is on schedule. All of its components will be available by the end of 1995. We are aiming at commissioning TJ-II in 1996. Initial heating will be done with two 400-kW gyrotrons working at 53.2 GHz. Contracting for this system is underway; 2 MW of NBI should follow. Though all the main contracts are placed, the total cost is still within the estimated values.

B. Ph. van Milligen presented a paper on the application of a general method for solving differential equations, based on neural networks, to the fast solution of ideal MHD plasma equilibria. Major advantages of the method are that (1) it does not presuppose any particular topology of the solution, (2) the equations are solved in real space, (3) finite differences are not used, and (4) it is potentially fast, especially for problems that have to be solved repeatedly with similar boundary conditions. In this paper a proof-of-principle of the method was provided and its application to three-dimensional stellarator equilibria was discussed.

One of the main requirements of data acquisition systems in fusion devices is to provide enough storage to manage discharges databases. In next-generation devices, storage needs for databases plus data analysis will be in the range of 100 GB. This huge quantity forces the use of compaction techniques for data collected through diagnostics. J. Vega presented a comparative study of several data compaction techniques and found an optimal one that saves over 80% of storage. In addition to this advantage, computing extra load is negligible.

Design studies for a stellarator reactor based on a heliac configuration to determine the minimum size requirements and operational techniques for plasma startup and rundown were presented by A. P. Navarro. Assuming technological constraints as well as plasma parameter limitations, a device with 15-m major radius and 2-m plasma radius is obtained (same aspect ratio, $A = 7.5$, as TJ-II heliac), for a magnetic field of 5 T and power output of 1 GW(e). With these values the average wall loading would be around 3 MW m^{-2}, and a confinement improvement of about 75% over the LHD scaling is required. It was concluded that dynamical processes during plasma startup, rundown and power stabilization can be controlled by continuous application of auxiliary power, on the order of 30 MW.

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