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TECHNICAL MEETING OF WORKING GROUP ON GYROTRONS AND WINDOWS

by Dr. T. Nagashima, Division Head, In-Vessel Ancillaries, ITER Garching Joint Work Site

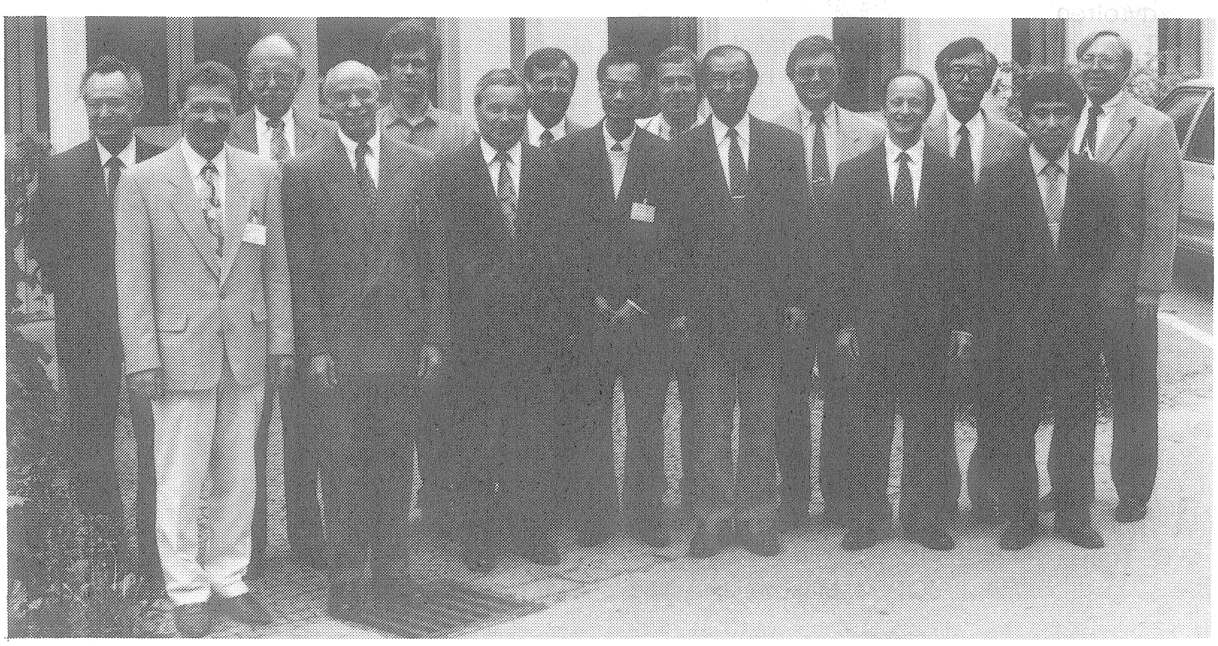
The Technical Meeting of the Working Group on Gyrotrons and Windows was held at the Garching Joint Work Site from 16-18 May 1994.

This meeting had the objective of discussing the results of the feasibility studies on the development of a 170 GHz 1 MW CW gyrotron for use on ITER as a Heating and Current Drive System. An additional purpose was to present new experimental data and the recent results of ongoing development of gyrotrons and windows.

Another most important component of this meeting was to reach agreement among the Home Teams (HTs) and the Joint Central Team (JCT) regarding the R&D effort necessary to develop and validate, as soon as possible, a reliable gyrotron and window for ITER. The following is a summary of the status (1), feasibility studies (2) and proposed direction of the R&D for the gyrotron and window (3).

(1) Status of Gyrotron and Window Development

Recent excellent results were presented by Japan on the high power high efficiency gyrotron with Collector Potential Depression (CPD). Their experiment demonstrated that the overall efficiency was improved from 30% to 50% with the CPD including the internal converter efficiency. The output power was 610 kW, 50 msec at 110 GHz. The CPD concept will be applied to the 170 GHz gyrotron development. They have also demonstrated long pulse operation of 5 sec for 350 kW and also 420 kW for 2.6 sec (tests are ongoing).



Participants in the Meeting

The second significant result reported at this meeting was that the Russian tube demonstrated 500 kW for 3 sec with efficiency of 42% at 140 GHz. For all operating points of a beam voltage of 70 kV and beam currents of 16-23 A, the efficiency was ≈40%. A rectangular rf field distribution was applied to the output window to increase the cooling capability of the single disc BN window with periphery water cooling.

In the United States a prototype distributed window concept (6 m x 6 cm) has been tested at low power and found to have a transmission efficiency for the HE_{11} mode of 96 ± 2%. A better polished taper surface might improve the efficiency even further.

(2) 170 GHz Gyrotron Feasibility Studies

Several independent design approaches for a 1 MW, CW, 170 GHz gyrotron were presented by all the Parties. All have focused on a cylindrical cavity gyrotron. In addition, two novel design concepts were presented. The first was an optimized depressed collector tube, yielding an overall rf efficiency of $\geq$50% based on the recent experimental results of CPD. The second was for a coaxial cavity gyrotron with the potential of generating up to 2 MW at 170 GHz and scalable to 1 MW at 220 GHz. A summary of the tubes characteristics is presented in Table I.

The convergence of the designs for the conventional cylindrical cavity gyrotrons is quite significant. It provides confidence that the design approach is fundamentally correct and that in some sense it is near optimal. Consequently, it allows the program to proceed rapidly to the next phase of development, that of a detailed design for the fabrication of a test vehicle. The other designs presented are also significant for achieving the ITER goals of high efficiency and higher unit power tubes.

(3) ITER Gyrotron and Window R&D

Discussions were held based on the revised JCT proposal of the R&D plan for the gyrotron and window. The main discussions and conclusions are as follows:

- From the experience of the electron tube manufactures a windowless experiment would not be suitable under the limited time frame of the ITER EDA.
- Test facilities would be available under the base programs.
- Operation at 1 MW, CW 170 GHz appears feasible. Efficiency is predicted without CPD to be 35-40% and with CPD $\geq$50%.
- Concerns raised on the cooling of the gyrotron components including cavity as well as the window have led all Parties to agree that a 140 GHz, 0.5 MW long-pulse (CW) test would be an appropriate near-term step before advancing to a CW test of a 170 GHz gyrotron. Experiments at lower frequencies (i.e. at 110 and 118 GHz with gyrotrons at present under development), at 0.5 to 1 MW, CW could also give relevant cooling information for the development of a 1 MW, CW, 170 GHz gyrotron.
- To meet ITER requirements parallel efforts are still necessary in 1994-95 and finally a more focused approach will be undertaken in 1996-97.

Electron Cyclotron Heating (ECH) continues to raise strong interest because of its merits of efficient and localized heating and the possibilities of start-up burn-through and current drive. Because of its quasi-optical properties of launch its antenna components can be relatively easily installed and withdrawn from the plasma and would certainly reduce the engineering problems associated with penetration of the blanket as well as with high delivered power density. With a demonstrated performance of a 170 GHz, 1 MW CW gyrotron and torus window, ECH would be a very viable heating system for ITER.

LIST OF PARTICIPANTS

EC: V. Erckmann (observer), W. Kasparek, M. Thumm, M.Q. Tran

JA: T. Imai, K. Sakamoto, M. Sato (observer)

RF: V.V. Alikaev, G.G. Denisov, A.G. Livak

US: R. Freeman, M. Loring, R. Temkin

JCT: M. Makowski, T. Nagashima, R. Parker, D. Remsen

Table I: 170 GHz Gyrotron Feasibility Studies

Tube Characteristic	EC #1	EC #2	JA	RF	US
Output Power	1.16 MW	2.0 MW	1.0 MW	1.0 MW	1.1 MW
Cavity Mode	$TE_{28,8}$	$TE_{35,11}$	$TE_{22,12}$ or ($TE_{22,6}$)	$TE_{28,7}$	$TE_{30,9}$
Internal Mode Converter	Internal EC Type	Internal EC Type	Internal Denisov Type	Internal Advanced Design	Internal Denisov Type
Output Mode	TEM_{00}	TEM_{00}	TEM_{00}	TEM_{00}	TEM_{00}, elliptical
Pulse/CW	CW	CW	CW	CW	CW
Output Window	Cryogenic: Sapphire LN, LNe, LHe or Alternative	Cryogenic: Sapphire LN, LNe, LHe or Alternative	Double Disk Sapphire or Cryogenic	Cryogenic or Two Windows	Distributed
Depressed Collector	30 kV, 40 A, Single Stage	30 kV, 40 A, Single Stage	50 kV x 45 A Main 80 kV x 0.1 A V_a, Single Stage	N/A	24 kV ,Single Stage
Peak Cavity Wall Loading	2.97 kW/cm^2	2.96 kW/cm^2	1.8 kW/cm^2 or 2.9 kW/cm^2	2.5 kW/cm^2	< 3.0 kW/cm^2
Beam Current	36 A	60 A	40 A	40 A	37 A
Beam Voltage	79 kV	90 kV	75 kV (at cavity)	80 kV	83 kV
RF Efficiency	36% and ≥ 50 %*	37%	≥ 50%*	35% and 50%*	35% and 50 %*
Tube Type	Diode MIG Gun	Inverse Diode MIG Gun	Triode, Develop Diode	Diode	Triode; Develop Diode for Production

*) with Depressed Collector (CPD)

TECHNICAL MEETING ON ITER POWER SUPPLY

by Dr. P.L. Mondino, Division Head, Plasma & Field Control Division, ITER Naka Joint Work Site

The first Technical Meeting on ITER Power Supply was held on May 10-13, 1994 at the Naka Joint Work Site with representatives from the four Home Teams and the JCT. The objectives of the meeting, which were sent to the Home Team Leaders and all participants prior to the meeting, included:

- Verification that the JCT is developing and conducting its Work Plan (Design and R&D Tasks) in the proper direction.
- Presentations by the Home Teams of their work plans and status of their 1994 Design Tasks supporting the JCT.
- Establishment of how Home Team experience and interest in Power Supplies could be incorporated into the project in the future.

Specific technical goals for the meeting included:

- Presentation of the status and preliminary results of the design characteristics of the ITER power supply system.
- Review of the technical features of the JCT Power Supply Work Plan.
- Technical reports from the EC and RF Home Teams for allocated Design Tasks.
- Review of the technical specifications for future Design and R&D Tasks including procedures for industrial involvement.
- Specifications for an updated component cost analysis from data obtained at existing tokamak facilities.

The topics discussed were:

- Power from the HV Grid and Local Energy Storage;
- AC/DC Conversion Scheme;
- Switching Network and Fast Discharge Circuit; and
- Tentative Power Supply Scheme.

The Technical Meeting, chaired by P.L. Mondino, started on Tuesday as a plenary session. Five presentations on the status of the design were provided by JCT members and presentations by the Home Team Members followed. On Wednesday afternoon, after a general discussion, the technical meeting was split in separate groups each chaired by a rapporteur.

The Chairmen were as follows: E. Bertolini for Power from the HV Grid and Local Energy Storage, C. Neumeyer for AC/DC Conversion Scheme, V. Koutchinsky for Switching Network and Fast Discharge Circuit, and M. Huart for Tentative Power Supply Scheme.

A reception offered by JAERI and held on Wednesday evening allowed the participants to enjoy Japanese culinary specialties and to establish a very pleasant and friendly atmosphere that lasted during the whole week.

On Thursday separate meetings continued until late afternoon when the rapporteurs presented their conclusions in a plenary session; discussions followed.

On Friday, after a plenary session dedicated to conclusions and review of homework, the rapporteurs prepared the summaries and the Chairmen prepared the conclusions. Both the draft summaries and draft conclusions were distributed to all participants on Friday evening; a general discussion followed and some modifications were agreed upon.

On Power from the HV Grid and Local Energy Storage, I. Benfatto presented the ITER power pulse described in the paper "Preliminary Description of the ITER Power Supply System". The power pulse was discussed and modified in the separate session. The agreed wave forms (active and reactive power) are part of the Technical Specifications, presented by E. Bertoloni, for the studies to be done by utilities in the framework of Design Task D49.

During the meeting it was assessed that a powerful HV Grid could provide the ITER power pulse. The results of the Design Task D49, which addresses this subject, are expected until the end of July. Given its limited resources, the JCT at Naka will not propose Design Tasks and R&D on Local Energy Storage at this time.

Good work was done by the EC Home Team on Design Task D51 related to the Preliminary Power Supply Scheme. Following the JCT design task specifications, namely the HV Grid, four transformers supply four busbars at intermediate voltage. Each converter supplying the Poloidal Field (PF) coils is divided into four sections, each connected to one of the four busbars. This design scheme is symmetric but three different converter modules are necessary. Their No-load Voltage, in the range 1.5-2.0 kV, is reasonable considering thyristors available on the market today but could be relatively low given the expected trend for thyristors of higher voltage capability by the time ITER is built.

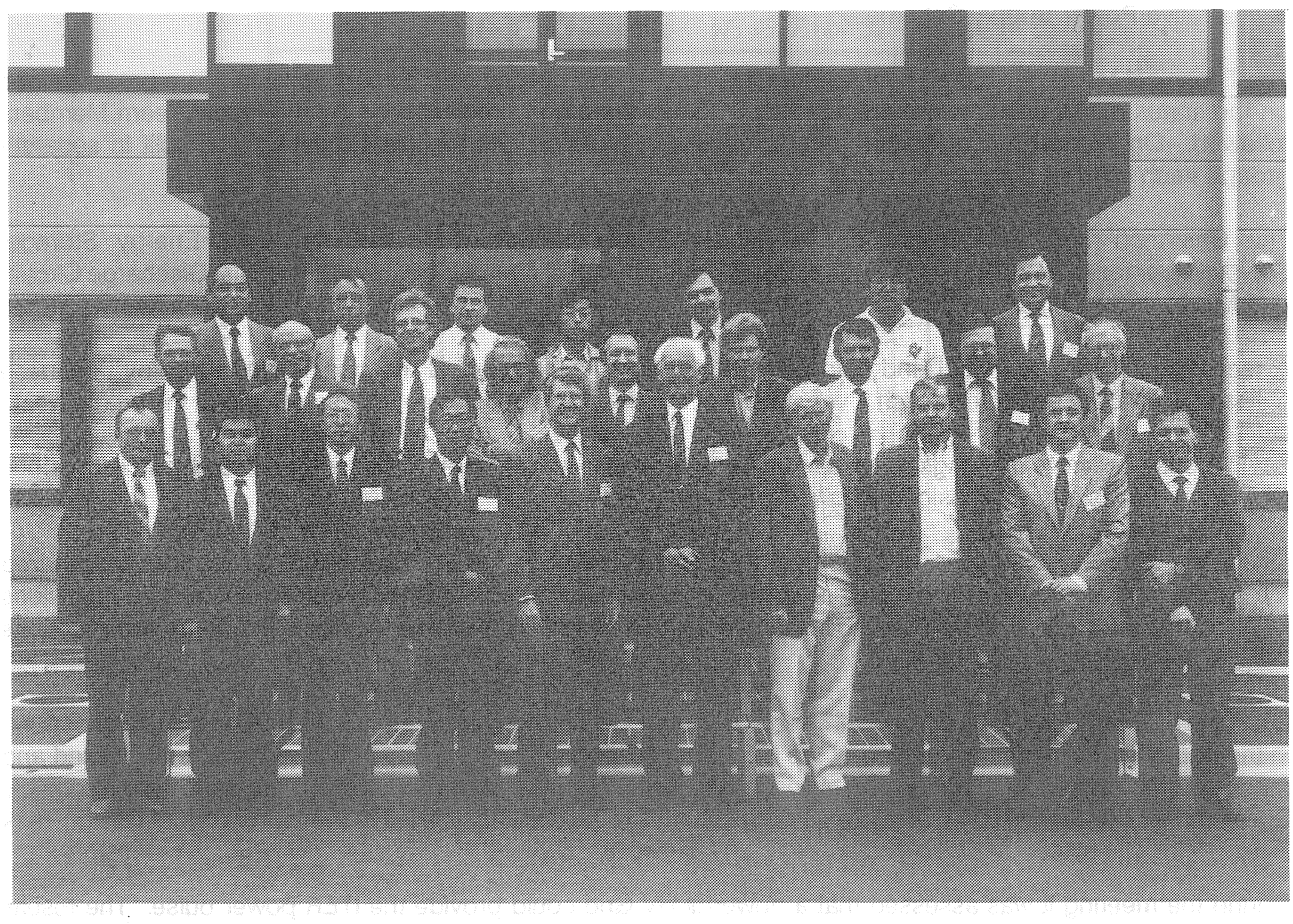
The work done on Design Task D50 related to the AC/DC Conversion Scheme was limited. During the separate session a different approach on "standardization" was followed; the standard module could have 2.0-2.5 kV No-load Voltage and 10 kA Nominal Current.

Good work was done by the RF Home Team on Design Task D48 related to the Switching Network and Fast Discharge Circuit; a new approach to switch design was presented. The analysis of the PF coils fast discharge and the identification of peak voltages, etc., were reported.

B. Bareyt presented the document "Preliminary Design of the Toroidal Field (TF) Coil Circuit of the ITER Machine" that includes the TF fast discharge system. The report was reviewed during the separate session. It was agreed that 20 kV versus earth (ground potential) could be reached in case of two subsequent faults: one circuit breaker failure to interrupt and one earth (ground) fault.

Progress in the PF outer coil circuits can be made if the coil design is made available to Home Teams.

The meeting was mainly focused on design issues since the design, at sketch level, has to be provided for the Interim Design Report (March 1995). The related feasibility study and cost assessment, to be done by industry, will be the basis for the Interim Design. These activities are considered to be of the highest priority.



Participants in the Meeting

The identification of proposals for R&D is included in the scope of the Design Tasks D48 (Switching Network and Fast Discharge Circuit) and D50 (AC/DC conversion Scheme). Available resources should be distributed in favour of the development of components for the Switching Network and Fast Discharge Circuit.

Finally, it would be useful to have key Visiting Home Team Persons at Naka during the autumn to help the JCT in preparing the Interim Design Report.

The members of the Home Teams and the JCT found the meetings fruitful, the atmosphere very constructive, and many informal discussions took place in parallel to the formal sessions. The status of the design tasks already allocated was reviewed and new design tasks were discussed. In the session dedicated to conclusions, the Chairman stressed the need to produce well-prepared technical reports on time at the conclusion of the work on each design task. The quality of these technical reports will be an important element in the allocation of future design tasks.

LIST OF ATTENDEES

EC:
E. Bertolini, JET
J. Bottereau, CEA
A. Coletti, ENEA
M. Huart, JET
A. Maschio, ENEA/CNR
W. Weigand, IPP/Siemens

JA:
K. Ikeda, Mitsubishi
S. Kawashima, Toshiba
Y. Matsuzaki, JAERI
I. Nakazawa, Mitsubishi
R. Shimada
Tokyo Inst.of Techn.
Y. Yasaka, Hitachi

RF:
S. Boulgakov, Efremov
V. Koutchinsky, Efremov
N. Mikhailov, Efremov

US:
A. Nerem, GA
C. Neumeyer, PPPL

JCT: D. Remsen, Garching; B. Bareyt, Naka; I. Benfatto, Naka; A. Kostenko, Naka; N. Mitchell, Naka; P.L. Mondino, Naka; A. Roshal, Naka; M. Matsukawa, Naka; C. Ahlfeld, San Diego.

FORTHCOMING EVENTS *)

- Magnets Technical Meeting, Naka, Japan, 6-7 July
- MAC-6, Garching, Germany, 6-8 July
- TAC-6, St. Petersburg, Russia, 12-14 July
- IC-6, Moscow, Russia, 27-28 July

*) Attendance at all ITER Meetings by invitation only.

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kouvchinnikov, ITER Office, IAEA, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: 43 1 237762 (phone 23606392).

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