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PLASMA PHYSICS NETWORK NEWSLETTER

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA

No. 3 February 1991

WELCOME!

Welcome to the third issue of the Plasma Physics Network Newsletter. We would prefer to get this newletter onto a more regular schedule, but that is turning out to be extraordinarily difficult to do. We hope that the information it contains is of sufficient interest to you to justify its, so far, irregular production and arrival. Once again, we appeal for *your* contributions to this newsletter.
Yours truly,
The Editors

THIRD WORLD PLASMA RESEARCH NETWORK (TWPRN)

In October, five additional people were appointed to the TWPRN Steering Committee:

J. Stöckel	Czechoslovakia
J. Fujita	Japan
T. Todd	UK
S. Luckhardt	USA
D. Banner	IAEA

The addition of members from developed countries and from the IAEA should enhance the ability of the Steering Committee to discuss and adopt practical means for collaboration.

MEETING REPORT

Following is a report by Dr. M. S. Mohamed-Benkadda on the *First South-North International Workshop on Fusion Theory*, that was held in Tipaza, Algeria, September 17-20, 1990.

<u>S N I W F T - 1</u>

First South-North International Workshop on Fusion Theory
Tipaza, 17-20 September, 1990

The first South-North International Workshop on Fusion Theory was held in Tipaza (Algeria) from 17-20 September, 1990. It was organized by the Fusion research group at the Centre de Développement des Technologies Avancées (CDTA), Algiers, and sponsored by the Ministry of Research and Technology, Algeria, the United Nations Educational Scientific and Cultural Organization (UNESCO), the Algerian Touring Club and the Minsitry of Foreign Affairs, France.

Scientists from both the developed and developing countries attended the workshop representing 8 countries - Algeria, Czechoslovakia, France, Iran, India, Portugal, Sweden and Yugoslavia. A number of important research topics were covered, including MHD phenomena in Tokamaks (Sawteeth, Ballooning Instabilities, etc.), Anomalous Transport, Nonlinear Effects related to Transport in Magnetic Chaos and Novel Methods of Analyzing Spatio-temporal Signal Data. The workshop format which included Lectures, Panel Discussions and Free Interaction time, proved very conducive for intensive interaction among the participating scientists. One afternoon was also devoted to a visit to the CDTA institute which gave an opportunity for the participants to look at the laboratory facilities and discuss the ongoing plasma physics research programmes in Algeria.

The workshop also held an important panel discussion to focus attention on the various issues related to South-North and South-South collaboration in the area of plasma physics and fusion. The importance of such collaborative activities and the need to promote it in a meaningful way was emphasized by all participants. A number of interesting suggestions were also made and discussed. These included the setting up of bilateral programmes between laboratories of developing countries (e.g. between Institutes of Plasma Research, India and CDTA, Algeria), sponsoring student training programmes (e.g. with the help of IAEA fellowship), facilitating exchange visits between scientists of laboratories in the North and South (the arrangement between scientists from CDTA and scientists from CEN, Cadarache, France was cited as a successful example of this kind).

The subject of small tokamaks as research devices for developing countries was also discussed. It was pointed out that for carrying out meaningful research in this area the device capability needed to satisfy certain minimum reqquirements (in terms of plasma regimes, independence from all effects, etc.) and the investment needed for this purpose (funding, trained manpower and technology resources) were not insubstantial. The problems inherent in buying a small tokamak or picking up an old machine were discussed in some detail. A suggestion was made to explore the possibility of setting up a research facility around an existing big machine in a developed country after its present planned experiments are completed.

Two other important issues, pertinent to developing countries, are manpower training and establishing efficient communication links with the world scientific community. The role of the Third World Plasma Research Network (TWPRN) which was set up a year and a half ago under the auspices of the IAEA and ICTP, Trieste was discussed in this context. It was recommended that TWPRN should use its resources and facilities to promote communication and training activities and increase the effectiveness of its newsletter. A related issue, that of involving developing countries more directly into the world fusion effort, was discussed in the light of the Buenos Aires Memorandum (composed of Latin American plasma scientists at a workshop meeting in Argentina). While fully agreeing with the objectives set forth in the memorandum, it was felt that the mechanism suggested in the document for fulfilling this goal entailed a duplication of the efforts already invested in setting up the TWPRN. It was suggested that the TWPRN Steering Committee could effectively put up proposals to the International Fusion Research Council (IFRC).

Finally, the panel discussed the question of the effectiveness of the present workshop and its future evolution. It was unanimously decided that the tradition established by the present workshop should be continued and future workshops should be held (preferably in developing countries) in the present format and devoted to fusion theory. A scientific programme committee to plan and assist in the organization of the next workshop was set up.

International Programme Committee

M.S. MOHAMED-BENKADDA, Chairman, CDTA, Algiers
J.L. BOBIN, Univ. Pierre & Marie Curie, France
M. DUBOIS, CEN, Cadarache, France
D. GRESILLON, Ecole Polytechnique, Palaiseau, France
R. LIMA, CNRS, Centre Phys. Théoretique, Marseille, France
A. SEN, Inst. for Plasma Research, BHAT, India
N.M. SKORIC, Inst. of Nucl. Sci., Belgrade, Yugoslavia
H. WILHELMSSON, Chalmers Univ., Göteborg, Sweden

A preliminary proposal (to be confirmed before the end of the year) to hold the next workshop in Lisboa, Portugal was discussed and approved. The workshop will be organized by Dr. T. Mendonca (Centro de Fusao Nuclear, Instituto Superior Tecnico) and will be announced in the IAEA bulletin, TWPRN newsletter and other communications.

Dr. M.S. MOHAMED-BENKADDA
Chairman

BUENOS AIRES MEMORANDUM

A memorandum, referred to as the "Buenos Aires Memorandum," was generated during the IV Latin American Workshop on Plasma Physics, held in Argentina in July, 1990. The memorandum contained a proposal that the IFRC establish a "Steering Committee on North-South Collaboration in Controlled Nuclear Fusion and Plasma Physics Research."

During an IFRC meeting on October 4, 1990, in Washington, D. C., the response of the Council was positive and supportive, even though there are precedural difficulties that proscribe against following the proposals exactly as presented in the memorandum. The Council expressed its historical and continuing support for initiatives to enhance collaboration between scientists in the developing countries and in the developed countries. It noted that the TWPRN Steering Committee, with the recent addition of scientists from developed countries, already provides a framework within which practical schemes for collaboration can be discussed and adopted. Focussing attention on how the Agency might respond to the desire for enhanced collaboration, the Council referred to the existence of the Technical Assistance programme of the Agency and to the availability of Fellowships, Research Contracts, and Coordinated Research Programmes. It was suggested to formally set up a committee to advise the Physics Section on ways that the Agency's currently existing programmes and resources might more effectively be used to promote collaboration on fusion and plasma physics research. Such an advisory committee could also provide a link with the TWPRN Steering Committee and pick up recommendations from that forum as well as, perhaps, from other regional groups or associations of fusion and plasma physics researchers.

The suggestion to set up an advisory committee is under consideration.

FUSION CONFERENCE

The 14th IAEA *International Conference* on Plasma Physics and Controlled Nuclear Fusion Research will be held in Wurzburg, Germany, 30 September through 7 October 1992.

IAEA TECHNICAL COMMITTEE MEETINGS

The following IAEA Technical Committee Meetings are being planned during 1991:

April 8-10:
LIDAR Thomson Scattering, Abingdon, England

April 15-19:
Drivers for Inertial Confinement Fusion, Osaka, Japan

May 27-31:
Stellerator Physics, Kharkov, USSR

June 10-14:
Alpha Particles in Fusion research, Goteborg, Sweden

September 1-3:
Fast Wave Current Drive in Reactor Scale Tokamaks, Cadarache, France

September 10-12:
Instabilities and Disruptions Control, Culham, England

October:
Negative Ion Based Neutral Beam Injection, Naka, Japan

October 3-8:
Research Using Small Tokamaks, Hefei, China

The last TCM on Research Using Small Tokamaks, held in Washington, D. C., September 27-28, 1990, was highly successful. An IAEA TECDOC containing the proceedings of this meeting is in the process of being published. A summary of the meeting was written by A. W. Morris and T. N. Todd of Culham Laboratory, and is scheduled for publication in the March or April issue of *Nuclear Fusion.* Participants at the September meeting recommended that the next meeting be scheduled with an interval of about one year. The Institute of Plasma Physics, Academia Sinica (ASIPP), in Hefei, China, has proposed to host the meeting, and arrangments are being made to accept this proposal.

ITER NEWS

The ITER Conceptual Design Activities (CDA) were successfully concluded by the end of December, 1990. The Agency is proceeding with publication of the final technical reports on the CDA. These reports should all be available by the second quarter of this year. The four ITER Parties (EC, Japan, USSR, USA) have not negotiated a continuation of the ITER project into the Engineering Design Activities (EDA), largely because the U. S. team has not been authorized, yet, to enter negotiations. The U. S. team hopes to have such authorization soon. The negotiations are scheduled to begin in Vienna on February 11, 1991, subject to all Parties being authorized to negotiate. (The other three Parties have already been authorized.)

LONG-TERM PHYSICS R & D PLANNING (FOR ITER)

Following is an article by F. Engelmann on Long-Term Physics R & D Planning. It was originally printed in the October 1990 issue of the *ITER Newsletter.*

REPORTS ON NATIONAL FUSION PROGRAMMES

Two reports follow: One on "Fusion Research in China;" and another, on the Yugoslav Fusion Programme.

OTHER NEWSLETTERS

Here are the titles and contacts for two other newsletters that you may find interesting:

AAAPT Newsletter
(Asian African Association for Plasma Training)
Editor: S. P. Moo
Department of Physics
University of Malaya
59100 Kuala Lumpur
Malaysia

IPG
(International Physics Group--a sub-unit of the American Physical Society)
Secretary-Treasurer:
Jorge José
Physics Department
Northeastern University
Boston, Massachusetts 02115

LONG-TERM PHYSICS R&D PLANNING

by F. Engelmann

Over the last year, a long-term Physics R&D Programme was prepared by the ITER Physics Group. This Programme takes the ITER-related Physics R&D activity ongoing in 1989-1990 as a starting point and is to provide the data base necessary for supporting the decision to start ITER construction. It should be carried out in parallel with the ITER engineering design in the years 1991-1995.

For the full period 1991-1995 a framework programme was established which, in contrast for the 1989-1990 programme, covers <u>all</u> Physics R&D needs. Priority areas are:

- power and particle exhaust physics (i.e., the combined fields of plasma edge physics, plasma-wall interaction and impurity behaviour);
- disruption characterization and control;
- stationary operation in regimes with low energy transport (in particular in the H-mode);
- collective effects caused by a fast ion population.

In fact, the most crucial problems, to validate the ITER design concept and complete the physics data base required for starting ITER construction, in practical terms, are:

- the demonstration, in experiments prototypical for ITER, that operation with a cold divertor plasma (T_e<30eV) is possible, that the peak heat flux onto the divertor plate can be kept below 10 MW/m^2, and that helium exhaust conditions corresponding to a fractional burnup larger than 3% can be ensured;
- a characterization of disruptions which allows specification of the consequences for the plasma facing components, and demonstration that the number of disruptions can be reduced to a level yielding an acceptable lifetime of these components;
- the confirmation that steady operation in a regime with low energy transport (in particular in the H-mode) and satisfactory plasma purity is possible under ITER condition, as well as the capability to predict energy confinement for this mode in ITER with satisfactory accuracy;
- insurance that the presence of an appreciable population of fast ions does not jeopardize plasma performance in ITER.

Further areas covered by the Programme are plasma heating and fuelling, long-pulse operation (including non-inductive current drive) and optimization of discharge startup and shutdown, as well as plasma diagnostics.

An overall assessment of the potential coverage of the R&D needs laid down in the framework programme led to the conclusion that this is satisfactory. There is redundancy in serveral areas, but concentration of efforts on some critical areas will be necessary to obtain all the information needed in time. The R&D work will have to combine experiments, theoretical analysis and modelling; in particular, systematic model development and validation, as a basis for extrapolation to ITER, is required.

An ITER-related R&D programme for the years 1991 and 1992 (but extending beyond as far as possible) is presently being developed from the framework programme 1991-1995. It is based on a detailed description of the R&D needs for ITER and the associated time schedules which were provided to the fusion programmes of the ITER Parties. The programme covers five areas and is subdivided in 22 tasks, supplemented by subtasks where appropriate for a clear definition of the problems (Table I). Ten of these tasks (marked by bold numbers in Table I) address the crucial questions listed above and therefore have been classified as high-priority tasks. The other tasks are concerned with the optimization of ITER operation, including in a few areas (power and particle exhaust; fuelling; non-inductive current drive) alternative and/or innovative schemes, the development of which may extend beyond the end of ITER design.

The coverage of the programme by the contributions which have been offered by the research institutions of the ITER Parties is generally good. However, studies of the edge plasma in ITER-relevant divertor configurations and operating conditions will be intensified only from 1992 on. Further improvement of the diagnostics for the edge plasma is needed. Work on the validation and development of models for the plasma edge as well as the characterization of candidate materials for plasma-facing surfaces (low and high Z) needs to be enhanced. The validation of theoretical predictions on the effects caused by a population of fast ions requires specific attention. The diagnostic means to characterize such a population must be improved. As far as operational issues are concerned, large-scale experiments on non-inductive current drive by fast waves will only be done in 1993 and later, and work on fast (emergency) shutdown is not yet planned.

A special process was adopted for developing an R&D programme for plasma diagnostics. The activity will have to be closely related to ITER design, to a technology oriented R&D activity on nuclear properties of materials and components, as well as to the Physics R&D programme being undertaken at many tokamaks worldwide. It will draw on information arising from these programmes in evolving the R&D requirements.

TABLE I. PHYSICS R&D TASKS DURING 1991-1992 AND BEYOND
(Priority Tasks are referred to in bold)

No.	Task Description, with subcategories where appropriate
1.	POWER AND PARTICLE EXHAUST PHYSICS
1.1	Experimental exploration in hydrogenic background plasmas of the characteristics of the scrape-off layer, divertor plasma and divertor target power load, as well as validation and development of models. a) Poloidal and toroidal dependence of divertor power load and temperature b) Impact of divertor geometry variation c) Hot spots on plasma-facing components

d) Impact of auxiliary heating and current drive on the edge plasma
e) Impact of fuelling
f) Characterization and control of ELMs (and other edge transients)

1.2 Impurity radiation and tansport in the bulk, scrape-off layer and divertor plasma
a) Powerfully radiating plasma edge

1.3 Exhaust of helium and hydrogenic species

1.4 Active control and optimization of divertor and startup limiter conditions

1.5 Characterization and tests of plasma-facing materials
a) Wall conditioning methods
b) Wall conditioning between discharges

1.6 Alternative divertor target concepts

2. DISRUPTION CONTROL AND OPERATIONAL LIMITS

2.1 Characterization and statisctics of disruptions
a) Characterization and minimization of disruption-produced runaway electrons
b) Characterization of disruption with soft current quench

2.2 Characterization of vertical displacement events (VDEs) and plasma motion during disruptions

2.3 Disruption avoidance and control
a) Reliable identification of pre-disruptive state

2.4 Characterization and control of beta-limiting phenomena
a) Impact of profile effects on the beta limit
b) Steady-state pressure and current profiles in inductive operation
c) Impact of the m=1 (sawtooth) and other MHD modes on high beta operation
d) Impact of the presence of fast ion population on high beta operation

2.5 Density limit

3. ENHANCED CONFINEMENT

3.1 Steady-state operation with enhanced confinement
a) Improvement of global energy confinement scalings
b) Plasma particle transport
c) Momentum transport

3.2 Control of MHD activity

3.3 Identification of transport mechanisms relevant in tokamak plasma
a) Identification of plasma turbulence and correlation with transport

4. OPTIMIZATION OF OPERATIONAL SCENARIO AND LONG-PULSE OPERATION

4.1 Long-pulse operational experience
a) Bootstrap current
b) Lower hybrid wave injection and current drive in large tokamaks
c) Fast-wave current drive efficiency
d) Electron cyclotron current drive efficiency
e) Neutral beam current drive
f) Advanced non-inductive current drive techniques

4.2 Optimization of startup
a) Lower hybrid wave current rampup and/or rampup assist

4.3 Optimization of shutdown and development of rapid shutdown techniques, with and without soft disruptions

4.4 Heating physics: heating and control of energetic ions by ion cyclotron waves

4.5 Fuelling physics: pellet ablation model
a) Fuelling by the injection of compact toroids

5. PHYSICS OF A BURNING PLASMA

5.1 Transport of and energy transfer to the plasma from fast ions (single particle effects)
a) Fast ion losses induced by the ripple of the toroidal field

5.2 Collective effects due to a fast ion population

5.3 Properties of DT plasma and of alpha-particle heating

Fusion Research in China

Huo Yu-ping

Institute of Plasma Physics, Academia Sinica, P.R.C.

(I)

China is a big developing country. The National Long-term Plan for Developing Science and Technology started from 1956 has already included the Fusion Research with foresight. The experimental research of high temperatue plasma physics began in 1958 on linear Z-pinch devices by several groups led by Prof. Li Zhen-wu and his wife Prof. Sun Xang in Institute of Atomic Energy (IAE) and Institute of Physics (ASIP) respectively. This work was followed by studies on a pyrotron-type magnetic compression mirror, plasma focus devices and small theta pinches in the early Sixties. A small stellarator began to be built in IAE later. It seems very strange that, the extensive development of Chinese Fusion Research began at the begining of Seventies, the difficult time in China. The Plasma Division in IAE and another small engineering institute all moved to Leshan and formed The South-Western Instituite of Physics (SWIP) supported by the Ministry of Nuclear Industry. Now it has several small Tokamaks, Mirrors and Theta-pinches. A middle size iron core Tokamak HL-1 (see Tab.1 for parameters) with thick copper shell has been operated since 1985. The Chinese Academy of Science decided extensively to study Fusion since 1972 in Hefei. After several years preparation, the Institute of Plasma Physics (IPPAS) was founded at 1978. It has an air core HT-6B Tokamak with different helical windings and 100kW Low Hybrid Wave Current Drive (LHCD), HT-6M Tokamak with 1MW Ion Cyclotron Resonance Heating (ICRH) (Tab.1 for parameters) and a small simple mirror stablized by hot electron ring produced by Electron Cyclotron Resonance Heating (ECRH). Though a big Belt-pinch Project has been cut down, the High Temperature Plasma Physics research in ASIP has not been interrupted, and the first Chinese

Tab.1 Chinese Tokamaks

..Tokamak	....R	....a	....Bt	...Institute	Heating power	Characters
... HL - 1	1.02m	0.2m	3.0T	....SWIP		copper shell
...HT - 6M	0.65m	0.2m	1.5T	...IPPAS	1MW ICRH	air core
...HT-6B	0.45m	0.12m	1.0T	...IPPAS	100KW LHCD	helical fields
...CT - 6	0.5m	0.12m	1.5T	....ASIP	50KW ECRH	iron core,

Tokamak CT-1 has been succesfully operated since 1974. There is a Subdepartment of Plasma Physics in Modern Physics Department of University of Science and Technology of China, which has a theta pinch and a mini-tokamak for education. Two or three graduate students and near ten undergraduate students have been graduated from this subdepartment for each year. There are several groups of Plasma Theory distributed in different universities and institutes.

(II)

Since its begining there have always been serious arguments about the Chinese Fusion Research within and even beyond the scientific community. Fusion is a long term and expensive science, if China really need it or we could just watch the rich countries to develop it at the present time. But the more serious problem, which has been asked by many people including some fusion scientists, is: we have very limited budget (2-3% of the US fusion budget) and there is no industrial support, except to repeat some priliminary experiments which have been done in advanced countries, perhaps, ten or more years ago, could we make some real contributions worthy for the world wide Fusion? Such arguments have had Chinese Fusion scientists much emphasize the deepgoing studies of the physical natures of high temperature plasma, which are valuable for realization of Controlled Nuclear Fusion, on their small or middle size devices. They well know that the tokamak approach is the most difficult to study for them because there are so many world fusion centres working on this way with big machines and very high technolgy, already for a long period , but the main efforts have still been concentrated on tokamak studies. In last decade Chinese Fusion Research became the bigest one within developing countries and got many new experimental results, which are very valuable for understanding the physical picture of the tokamak plasma.

On a small well operated Tokamak HT-6B in IPPAS, Dr. Xie, Dr.Chen and their group very carefully studied how the l=2/n=1 and l=3/n=1 helical fields suppress different MHD modes. Comparing all the experimental results, it could be concluded that all tearing modes m=3, m=2 and even m=1, are coupled very strongly. In small machine, at least, there is only one global mode located near all resonant surfaces with different poloidal components. It could be changed by a local disturbance near resonant surface. This is a new picture of MHD fluctuation compared with previous tearing mode theory, and some theoretical calculations have been developed by considering the ion inertial effect and transport process. The HT-6B people have further discovered that, the weak helical field which can only directly change the magnetic configuration round the corresponding resonant surface near plasma edge, could amplify the Sawtooth oscillation significantly (see Fig. 1). The thermo-conductivity in outer region of the plasma ($1 < q < 3$) measured by the propagation of heat pulses was reduced by these resonant helical fields, and thus, the energy confinement was improved. These phenomena linked with other experimental results, such as profile consistancy clearly show that the energy confinement process, even in the plasma outer region, should be considered as the combination of macroscopic MHD motion and anomalous transport process. Such a new point of view

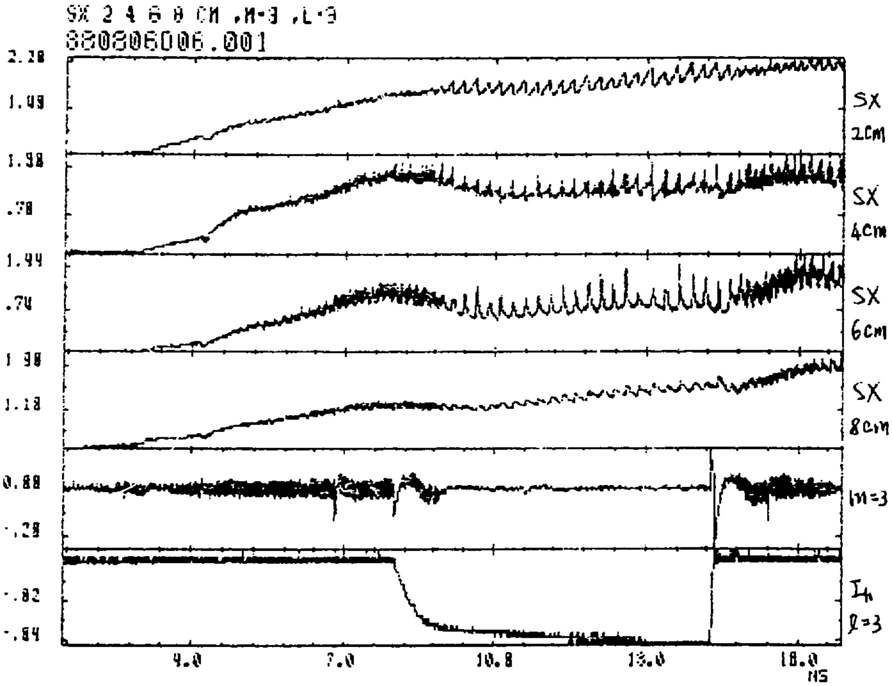

Fig. 1

has been confirmed by a preliminary theoretical calculation based on the coupling of tearing mode equations with the transport equations.

On HL-1 Tokamak in SWIP, people carefully studied the effect of thich copper shell on the plasma behavior. The results could be valuable for further controlling the plasma. The non-resonant absorption of Electron Cyclotron wave has been discovered to be an effetive way on CT-1 in ASIP. The slow minor radius compression experiment has been done on HT-6B. There is a bifurcation followed the compression process. The energy confinement of the plasma of the peak density branch seems to be improved similarly with some improved confinement modes discovered on big devices recently, such as Supershot on TFTR.

According to the cost of the systems and reactor requirments, only high power ICRH has been developed. On HT-6M with plasma volume of

$0.5m^3$, 1 MW ICRH experiment has been going on, and another 2 MW ICRF system could be available at the begining of the 1991. IPPAS has been interested in studying the plasma behavior under high power density heating (2-5 MW/m^3). High power LHCD for moderate density plasma has also been paied attention to. 100kW LHCD experiment on HT-6B has already got many results, and two different 500kW LHCD systems on HL-1 and HT-6M have been in preparation. There are several 30-50kW ECRH systems for controlling the plasma.

Due to the fact that, it is very difficult and rather expensive to get support from Industry, both IPPAS and SWIP have their own big workshops. Nearly all main Instruments and Equipments have to be designed and fabricated within our Institutes. For example, the whole HT-6M device was made in IPPAS (Fig.2), and the power system; the diagonostics system, data system...... all needed to be developed by

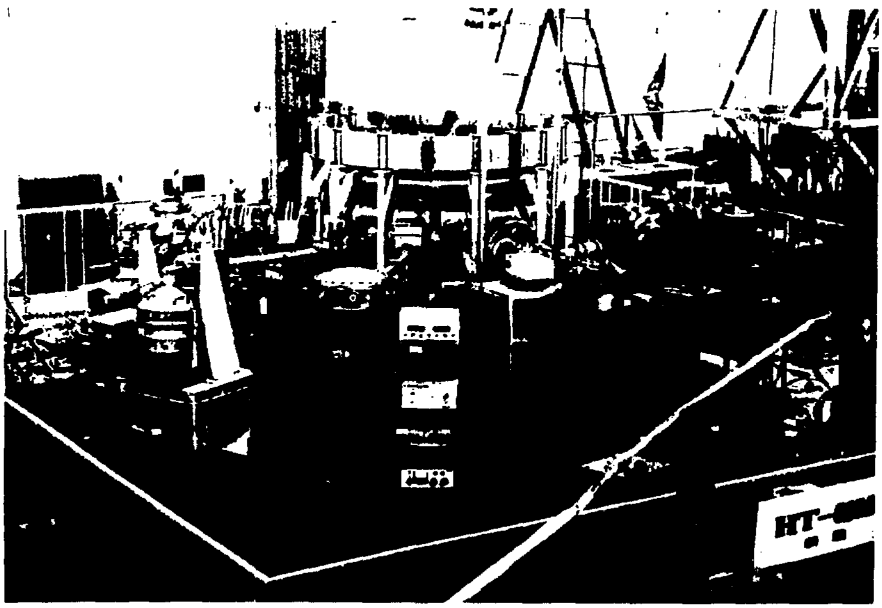

Fig.2

ourselves. IPPAS has the ability and alreay begun to build a middle size Tokamak (Asdex or PDX size) , and has fabricated the vaccum vessel for Text Up-grad. Just due to such wide technical abilities, Chinese Fusion Institutes have developed many tehnologies from Fusion research for Industry or Agricuture. In IPPAS, Neutral Beam Injetion Group has used the ion beam to implante the rice and cotton seeds, and collaborated with some agriculture Institutes to breed them sine 1986. At the present time, Ion Beam Mutation Breeding has already been proved to be more effctive than the neutron mutation or laser mutation, and has begun to be used widely for crops breeding. Both IPPAS and SWIP have also developed the microwave plasma implanting or coating technologies , which could possibly replace the usual vacuum vapor deposition method in many fields due to the high quality of the film and more effective , and began to produce the plasma deposition machines.

(III)

From the point of view of people in developing countries, Controlled Nuclear Fusion is an energy source too far away for surmounting the shortage of energy. This is the reason that China could only support very limited Fusion Research as some basic science and technology. Since the end of seventies, there was a long discussion about how to solve the energy problem in China. Due to the problems of transportation, air pollution and green house effect, the energy consumption could not be met by coal alone in the middle of next century. Hundreds giga-watt nuclear power will be necessary to replenish the billions tons coal. The fission fuel of such big nuclear power could not totally rely on uranium ore, and perhaps, should be mainly produced by Fast Neutron Breeders and Fission-Fusion Hybrid Reactors. In 1986 a Hybrid Reactor Program (HRP) was put into the National High-Tech Program as one part of the Advanced Nuclear Energy Technology. Since then, the Chinese Fusion Research has no longer been aimless, and has a special grant which makes coordination of the efforts of different parts of fusion community possible.

Hbrid Reactor, in our program, is mainly for producing the fission fuel, it is not necessary seriously to consider the energy balance. The only requirement for the plasma core should be enough neutron production rate (10^{19} n/s for experimental reactor and 10^{20} n/s for commercial reactor), it could be burning plasma or sub-breakeven kept by tens MW external heating power. Roughly speaking, the plasma parameters of JET or TFTR are already very near that of experimental Hybrid Reactor. Except the tritium technology, others of the Blancket could be developed from the existing technologies of fission reactor, such as Fast Neutron Breeder and High Temperature Gas Cooled Reactor. Of course, the world wide Fusion Research also could be a very strong support to develop the Hybrid Reactor. Such considerations make us possible to develop Hybrid Reactor even only very few countries to consider it.

Because we have very limited resources, the efforts should be only concentrated to main problems for our goal. For example, the energy confinement problem is not as serious as pure Fusion in our case, but it is necessary to know exactly how to keep the high temperature plasma steadily. ICRF heating is more suitable for reactor, and the high energy ion tail produced in the heating process could enhance the fusion reaction. LHCD is the unique realistic non-inductive way to drive the plasma current, but the plasma density should be kept not higher than 5 $*10^{13}/cm^3$. Comparing with liquid Lithium, the solid tritium breeder and high pressure helium coolant is a more realistic approach, if the heat power density in blancket could be maintained at lower level.

The first five years (1986--1991) is the stage for feassibility study. High power ICRF heating experiment, 500kW--1MW LHCD experiment, Tritium technology, pump-limiter and pellet injection experiment and material testing have been arranged to SWIP, IPPAS and some other nuclear Institutes respectively. Fusion and Fission people have collaborated well in conceptured design of Hybrid Reactor, including Economic analysis. Through HRP, Chinese Fusion Research also became more vivid.

The goal of the coming ten years (1991-2000) is the engineering and technical preparation for designing and building Experimental Hybrid Reactor in the begining of the next century. In this second stage, we are going to build and operate an experimental device for simulating the reactor plasma core (DSRPC). It should have high power ICRF heating for keeping plasma temperature near 10keV, and the ability (high power LHCD, superconductive coils and pump-limiter etc.) of quasi-steady operation. Combining the experiences from DSRPC and world wide fusion studies on burning plasma, we could have real basis to design the plasma core of Experimental Hybrid Reactor. We are also planing to develop the main technologies for the blancket of Hybrid Reactor in the next decade. In all of these fields, except some very special topics, we will actively collaborate with international fusion community, especially the ITER program.

The whole Chinese High-Tech Program has been controlled by Central Government , The National Committee of Science and Technology. But its different parts, including our HRP, have been directed by different committees composed of experts from different fields, Universities or Institutes. The HRP committee has been led by Prof. Qiu, and supported by IPPAS.

(IV)

The Chinese Fusion people have very actively but gradually developed international exchange and collaboration since the end of Seventies. They clearly knew that the lasting collaboration could only be based on mutu-benefit, i.e. Chinese Fusion scientists should convince their foreign colleagues that the Chinese Fusion Research could really be valuable for the world wide Fusion.

It should be pointed out that international support has been one of the main reasons that the Chinese Fusion Research could develop successfully. Since the last decade, there have been more than two hundreds Chinese scientists and engineers who have studied and worked in different foreign Fusion centres for one, two or three years. They have worked abroad very well and have got not only knowledge but also a lot of priceless experiences from different Fusion laboratories. Many of them have already been our scientific leaders, chief scientists and senior engineers. SWIP and IPPAS have contacted with nearly all fusion centres in the world, and could get new main information , scientific results and technical development . Therefore, the Chinese Fusion Research has not been isolated, but part of the world wide Fusion effort. It is also significant for us that, some important euipments which are too expensive for buying but necessary for our next step, have been transfered to IPPAS and SWIP from European Laboratories. The TFR AC fly wheel generator and neutral beam injector from France are the examples. Recently IPPAS and Kurchatov Institute of Atomic Energy, USSR, have collaborated to improve and transfer the superconductive Tokamak T-7 to Hefei. It could make IPPAS to be able, in near future, to do quasi-steady high power ICRF heating experiment, which is very important for HRP.

China has a cooperation agreement with US, according which IPPAS has taken part Text Up-grad construction and experiments, and the bi-sides workshop for concepture design of Fusion and Hybrid Reactor should be held for each year. Except HT-7 (T-7 in Hefei) program, China and USSR agreed to collaborate in Hybrid Reactor design and to conduct an annual workshop. Sao Paulo university collaborate with IPPAS for Brazilian TBR-1 and TBR-2 Tokamak program. IPPAS and SWIP have collaboration relation with National Institute for Fusion Science, Japan and IPP in Julich, FRG. All these and other small scale collaborations have been beneficial for and given an impetus to Chinese Fusion Research.

(V)

Chinese Fusion Research has been developed through a very special way. But it has already begun to show its value for China and for the world wide Fusion Research.

YUGOSLAV FUSION PROGRAMME

M. Skorik
The Boris Kidrik Institute of Nuclear Sciences
Belgrade, Yugoslavia

BACKGROUND

The Yugoslav Fusion Programme came into being through the implementation of the Technological Development Policy of the SFRT in 1988. The initial three year period resulted in the Joint Fusion Research Centre concept (JFRC). The JFRC is seen as the programme principle facility and focal point to be complemented by a network of Associated Laboratories chosen among the leading laboratories in fusion related fields. Though planned as the vehicle of an independent research programme, the Centre and its Associated Laboratories will be instrumental to Yugoslavia's contribution to the global fusion effort. The JFRC and its Associated Laboratories will be critical in channeling expertise and investment towards an internationally competitive programme of the state-of-the-art level around a current generation of toroidal machine to be acquired through international channels.

Insight into the JFRC research and technological goals that encompass the plasma, related nuclear and various fusion relevant fields is best afforded by the Contents (not included in this Newsletter) of the Feasibility Study on the Joint Centre for Controlled Thermonuclear Fusion Research prepared for the Federal Committee on Science, Technology and Informatics, currently the Federal Secretariat for Development. The study is currently being reviewed and awaiting Federal approval.

PLASMA PHYSICS NETWORK NEWSLETTER
Physics Section
International Atomic Energy Agency
Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria

Printed by the IAEA in Austria
February 1991

91-00688