PPPL-2378

UC20-C

163
12-10-86

ST

5-25
N-10
71-35

PPPL-2378

LONG- AND SHORT-TERM TRENDS
IN VESSEL CONDITIONING OF TFTR

By

P.H. LaMarche et al.

OCTOBER 1986

PLASMA
PHYSICS
LABORATORY PRINCETON UNIVERSITY
PRINCETON, NEW JERSEYPREPARED FOR THE U.S. DEPARTMENT OF ENERGY,
UNDER CONTRACT DE-AC02-76-CHO-3073.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Printed in the United States of America

Available from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price Printed Copy \$ * ; Microfiche \$4.50

<u>*Pages</u>	<u>NTIS Selling Price</u>	
1-25	\$7.00	For documents over 600 pages, add \$1.50 for each additional 25-page increment.
25-50	\$8.50	
51-75	\$10.00	
76-100	\$11.50	
101-125	\$13.00	
126-150	\$14.50	
151-175	\$16.00	
176-200	\$17.50	
201-225	\$19.00	
226-250	\$20.50	
251-275	\$22.00	
276-300	\$23.50	
301-325	\$25.00	
326-350	\$26.50	
351-375	\$28.00	
376-400	\$29.50	
401-425	\$31.00	
426-450	\$32.50	
451-475	\$34.00	
476-500	\$35.50	
500-525	\$37.00	
526-550	\$38.50	
551-575	\$40.00	
567-600	\$41.50	

**LONG- AND SHORT-TERM TRENDS
IN VESSEL CONDITIONING OF TFTR**

P.H. La Marche, H.F. Dylla, M.G. Bell, F.P. Boody, C.E. Bush,⁺ R.J. Groebner,[§] R.J.
Hawryluk, K.W. Hill, D. Mueller, D.K. Owens, A.T. Ramsey, J.F. Schivell, S. Sesnic,
B.C. Stratton, M. Ulrickson

Plasma Physics Laboratory

Princeton University

Princeton, NJ 08544

PPPL--2378

DE87 003067

ABSTRACT

We have investigated trends in the conditioning of the Tokamak Fusion Test Reactor (TFTR) vacuum vessel during the May 1984 to April 1985 run period. The initial conditioning of the vessel, consisting of glow discharge cleaning (GDC) and pulse discharge cleaning (PDC) in concert with a 150°C vessel bakeout, is necessary to assure plasma operation after atmospheric venting. A long-term conditioning process, ascribed to limiter conditioning, effectively improves operational conditions during the course of the run. Over several thousand high power plasma discharges, the improvement was documented by using standard parameter (fiducial) plasma discharges. Several techniques demonstrated short-term improvements in vessel conditioning during this time period, including: Cr gettering and programming the plasma position relative to the limiter contact area.

* Permanent Address: Oak Ridge National Laboratory, Oak Ridge, TN 37830
USA.

§ Permanent Address: G A Technologies, Inc., San Diego, CA 92138 USA.

MASTER

EBB

REPRODUCTION OF THIS DOCUMENT IS UNLIMITED

1. INTRODUCTION

Magnetic fusion devices experience initial operating periods in which the amount of impurity influx from the walls of the device is generally high. As time progresses the amount of impurity influx decreases, a process known as conditioning [1,2]. Historically, glow discharge cleaning (GDC) and pulse discharge cleaning (PDC) have been used to achieve vacuum vessel conditions necessary for successful operation of fusion devices and have been found effective in decreasing the initial conditioning time [3,4]. Furthermore, in situ evaporative gettering has been found effective in the reduction of plasma impurity influx in conditioned devices [1,5].

Conditioning experiences for the Tokamak Fusion Test Reactor (TFTR) have been described for the initial, low ohmic-power-heated, plasma run periods [2,3]. This work reviews the machine conditioning for plasma operations in TFTR during the May 1984 to April 1985 run period when initial neutral beam heating experiments were begun.

2. EXPERIMENTAL ARRANGEMENT

The TFTR machine and facility have been discussed elsewhere [6]. The plasma discharges produced in TFTR range in size from 0.4 to 0.85 m in minor radius and from 2.15 to 3.05 m in major radius. Plasma currents up to 2.5 MA have been run with toroidal magnetic fields up to 5.2 T. Feedback loops provide control of plasma discharge position, density, and current. The maximum neutral beam power injected into the machine during the 1984/85 operating

period was ≈ 6 MW. During this time period nearly 3,000 high power plasma discharges were performed.

The TFTR vacuum vessel [7] is manufactured from 304 LN stainless steel, is approximately 86 m^3 in volume, and has a geometrical surface area of approximately 200 m^2 . Typical base pressures in the well-conditioned torus several hours after plasma operations (i.e., overnight) are in the low 10^{-9} torr (10^{-7} Pa) range. This ultra-high vacuum condition is achieved with two large turbo-pumped (20 m long by 1 m diameter) ducts, which provide 10 kl/s pumping speed (of H_2) to the torus. An additional 100 kl/s torus hydrogenic pumping speed is provided by the prototype ZrAl bulk gettering system [8].

For the work described in this paper, the plasma is run on a movable outer limiter (≈ 15 cm from the outer wall) surfaced with bare graphite (POCO AXF-5Q) tiles [9]. Plasma discharges were occasionally run on an inner-wall limiter made of Inconel X750. In the summer of 1985 this Inconel limiter was replaced by an inner-wall axisymmetric bumper limiter, surfaced with graphite tiles [10]. Carbon tiles, nominally coated with $20 \text{ }\mu\text{m}$ of titanium carbide, protect the outer walls from neutral beam injection (NBI) shine-through and inadvertent direct NBI strikes. These armor tiles cover about 10% of the torus surface area.

Of the numerous plasma diagnostics in use at TFTR, we make specific use of several for this work: wide angle bolometers [11] for total radiated power measurements, a soft X-ray spectrometer (SOXMOS [12]) and a multichannel monochromator (SPRED [13]) for detecting and identifying plasma impurities,

an X-ray pulse height spectrometer (PHA [14]) used to measure metal and low-Z impurity concentrations and to calculate the effective ionic charge (Z_{eff}), and residual gas analyzers (RGA [15]) for measuring impurity components in the neutral gas used during GDC and PDC.

Glow discharge cleaning and pulse discharge cleaning are used on TFTR after a vacuum vessel opening together with a bakeout of the vacuum vessel to 150 °C. We typically run GDC with 15 A current ($\approx 10 \mu\text{A cm}^{-2}$) at ≈ 400 V probe potential for several tens of hours. PDC is usually run in one of several modes; starting with Taylor type PDC (TDC) followed by "aggressive" PDC (APDC). The relevant operating parameters for all types of TFTR plasma discharges are shown in Table 1.

Throughout the course of the 1984/85 run period, we instituted the running of baseline or fiducial plasma discharges, with nominally fixed plasma parameters, to make long-term comparisons of machine conditions. The fiducial plasma discharge (or fiducials) have an average density of $2.4 \times 10^{19} \text{ m}^{-3}$, a plasma current of 1.4 MA, and toroidal magnetic field of 4.0 T. These plasma discharges were relatively easy to produce in TFTR and it was felt that they could be produced under most machine conditions (clean or dirty). Approximately 200 plasma discharges during this run were fiducials.

Gettering of the TFTR vacuum vessel was provided by a prototype ZrAl nonevaporative getter system [8], and by a temporary Cr evaporative getter system [16]. The effects of both systems have been published elsewhere [16], but we will discuss the results of these techniques in so far as how they

affected the machine conditioning. The full ZrAl getter system (8% torus area coverage) was installed in the summer of 1985, but has yet to be put to a definitive test of its effect upon plasma discharges. Future Cr gettering has been deemed to be too difficult to implement due to the large inner wall carbon limiter (which should be kept clean of metals) greatly reducing the surface area available for Cr deposition.

3. RESULTS AND DISCUSSION

3.1 Initial Conditioning

A summary of the conditioning history for TFTR for the 1984/85 run period is shown in Table 2. Over the course of several operating periods, we have observed that it takes about a month or so to initially condition the machine after a major vacuum vessel opening (i.e., after several months have elapsed to change major components inside TFTR). After the short (one week) vacuum vessel openings for minor maintenance activities, only two weeks are needed, subsequently, for the conditioning process. As one might expect, when few changes are made to the interior of the machine and personnel are present for a much shorter time, there are less impurities (i.e., water and hydrocarbons) to remove. The 150°C bakeout of the vacuum vessel is important to increase the water outgassing rate, decrease the readsorption rate, and to increase the impurity production rates during GDC and PDC.

As has been observed in the past [1-4], i.e., impurity production rate falls inversely with time during GDC, and is particularly effective in removing the gross surface contamination such as hydrocarbons. GDC has been well documented in the literature and represents no new work here; the inverse

relationship with time is explained as a multicomponent diffusion process [3,4,17].

After GDC, conditioning of the machine is performed using PDC. The rate of impurity production is dependent upon the operating parameters of the plasma cleaning technique, especially in the case of PDC. Taylor discharge cleaning (TDC) uses low current (~ 50 kA) plasma discharges performed at high fueling pressure (see Table 1) with a resulting low electron temperature. The fueling pressure is adjusted to maximize the production of water and methane as measured in the RGA.

A good representation of the impurity production during TDC and subsequent outgassing of water (D_2O) can be seen in Fig. 1. After an initial start-up transient, an inverse square root time dependence is seen during TDC followed by an outgassing phase, which varies inversely with time.

Aggressive pulse discharge cleaning is performed at a lower pressure and higher current than for TDC (see Table 1). The maximum current for APDC is controlled by the maximum toroidal magnetic field that can be run continuously. These discharges are an attempt to maximize the number of the modest power discharges. The rate of impurity production is dependent upon fueling pressure, repetition rate, plasma current, and outgassing rates of the wall and limiter. Usually the impurity production rate is about an order of magnitude less than that for TDC (see Fig. 2). With higher electron temperature than for TDC [1], APDC increases the impurity ionization and the wall pumping. However, more power is delivered to the limiter in APDC, and it

is a technique for heating the limiters to higher temperatures, which are not cooled during PDC, thereby increasing the outgassing rate. The repetition rate is limited by eddy current heating of certain temperature sensitive parts of TFTR, as in the case of TDC.

TDC is performed exclusively until such time as APDC can be successfully started. From that point on it has been the practice to alternate TDC and APDC, temporarily stopping APDC when the movable limiter reaches a bulk temperature of 250°C, the thermal stress limit.

3.2 GDC and PDC Documentation

Due to the very slow time dependence of the impurity production during PDC, it is very difficult to make an end point determination based upon objective criteria. In order to provide more information for determining an end point criterion, a week of TFTR operations was devoted to documenting the effects of discharge cleaning using high power plasma (HPP) discharges, with the full complement of plasma diagnostics.

GDC was found to do little in an already conditioned vessel apart from temporarily increasing the observed radiated power, which recovered after several HPP discharges. PDC lowered the oxygen and carbon radiation by 30 to 40% and the total Z_{eff} dropped from 5.2 to about 4 for plasma densities of $2 \times 10^{19} \text{ m}^{-3}$. The metal (stainless steel) VUV radiation, however, increased by 50%, and the radiated fraction increased. The metals are probably placed on the limiter by the sputtering of the wall material and subsequent deposition on the limiter.

Also, during this period of time, we saw little effect on impurities, the radiated power, or fueling performance after activating the prototype ZrAl getter system, apart from a transient of poor performance for several discharges (presumably from the impurities outgassed from the getter structures during the getter activation). These results will be more fully discussed in Sec. 3.4.

3.3 Fiducial Plasma Documentation of Machine Conditioning

The most impressive changes in machine conditioning came from running several thousand HPP discharges. As can be seen in Fig. 3, there is a reduction of the radiated fraction (from 100% to 50%), the Z_{eff} is reduced from 5 to 1.5, the radiation from the hydrogen-like state of oxygen (O VIII) was reduced by a factor of ten, and the radiation from the hydrogen-like state of carbon (C VI) was reduced over the course of the 1984/85 run period for the fiducial plasma discharges as defined in the previous section. Little differences were observed for the metal concentration, except for a transient increase of a factor ≈ 5 immediately after PDC as measured by PHA. Metals constitute very low levels, $\approx 0.02\%$ for typical TFTR fiducial HPP discharges versus $\approx 1\%$ for oxygen and 5% to 8% for carbon. This long-term conditioning trend persisted across several events, including several vacuum vessel ventings (with subsequent initial conditioning followed by a small number of HPP discharges to achieve the previous level). Table 3 lists the date and closest shot number for various events during the 1984/85 run period.

This result graphically illustrates the experience for most tokamaks

(especially with carbon limiters): running a machine under HPP conditions renders the machine in a better operating state. The mechanism by which this slow, but effective conditioning takes place is not very well understood. One remarkable trait of this form of conditioning is its ability to transcend vacuum venting. This implies a "deep" or permanent change to the character of the limiter and/or wall. This phenomenon is poorly understood from a materials standpoint. Extensive ex situ analysis of limiter and wall material [17,18], in search of physical changes to the limiter, have not provided any clear indication. Metal impurities are found on virtually all limiters, and TFTR is no exception [18]. This metallic layer may be playing a role in the reduction of chemical erosion of the carbon limiter, thereby reducing the carbon influx to the plasma. Pontau et al. have found that samples of the TFTR movable carbon limiter tiles, after being conditioned during the 1984/85 run period, produce from 4 to 10 times less methane when bombarded with 6 keV D_3^+ compared to the behavior of virgin POCO graphite [19].

3.4 Gettering

We compared the relative performance of a low surface area, high pumping speed getter system (ZrAl) versus a large area, low pumping speed system (Cr). We found little or no effect on plasma performance using the prototype ZrAl gettering system, in spite of the factor of ten increase in hydrogenic pumping speed that it afforded to the torus. Evaporation of a thin Cr film over 70% of the torus area, however, in spite of a relatively small increase in oxygen pumping speed (factor of 2), decreased the oxygen radiation by a factor of two in HPP discharges and extended the density limit by 20%. Dylla et al. [17] attributed the improvement in plasma operation to a change in the sourcing of

oxygen from the wall. The higher binding energy for oxygen to the surface of Cr over the mixed Fe, Ni, and Cr surface found in stainless steel, together with the clean surface of a freshly deposited metal, which can act as a diffusion barrier to the relatively dirty surface beneath, are possible reasons for reduced availability of oxygen to the plasma discharge. The prototype ZrAl bulk gettering system cannot control the influx of oxygen from the wall apparently because of its low projected area and the relatively large separation of the getter surfaces from the plasma edge (~ 15 cm). On the other hand, Cr layer deposition is not seen as a viable solution to the current needs of modern, large magnetic fusion devices. Problems with large surface areas of carbon inside these machines and tritium inventory difficulties preempt the use of Cr evaporation.

3.5 Plasma Motion

Another activity which increased the quality of the HPP discharge operation was the programming of the plasma position feedback control to grow the plasma on the outer limiter inward toward the center of the vessel. This had the result of reducing large bursts in the radiated power during the start-up phase of the discharge [6]. This method of plasma start-up significantly reduced the number of disruptions that occurred under normal operating conditions. This technique keeps the plasma further away from the wall during a time when the scrape-off lengths are quite long compared to steady-state plasma operation.

Another plasma position programming technique which affected the impurity content was the formation of detached plasma discharges. The detachment from the limiter was performed by ramping the plasma current down while

employing a strong gas feed [20]. The plasma radiated fraction increases to 100% and the minor radius shrinks. Once the plasma loses contact with the limiter, the metal impurity lines on the PHA X-ray spectrum are significantly reduced (below background). These plasma discharges are stable, and have existed for several hundred milliseconds. This phenomenon supports the inference that most of the metal impurities seen in the plasma are coming from the metals coating the limiters.

4. SUMMARY

As we have seen in past operating periods for TFTR, it was necessary to perform GDC and PDC after venting and entering the vacuum vessel during the 1984/85 run period. The amount of time devoted to this initial conditioning process is related to the level of activity in the vacuum vessel. By using a series of fiducial plasma discharges, we have documented the slow but inexorable improvements in vessel conditioning over several thousand HPP discharges for the 1984/85 run period. These improvements transcended venting of the tokamak, and minimal conditioning time was necessary to regain the previous conditioning level. There were several techniques that produced nearly immediate improvements in HPP discharge performance: Cr gettering, plasma growing, and detached plasma discharges. Areas of further study with regard to TFTR conditioning include: reliable end point determination for PDC and the root cause of the observed long-term conditioning.

ACKNOWLEDGMENT

This work supported by the United States Department of Energy, Contract Number DE-ACO2-76CHO3073.

REFERENCES

- [1] H.F. Dylla, J. Nuc. Mater. **93&94** (1980) 61.
- [2] J. Winter et al., J. Nuc. Mater. **128&129** (1984) 841.
- [3] H.F. Dylla et al., J. Vac. Sci. Technol. A **2** (1984) 1188.
- [4] H.F. Dylla et al., J. Nucl. Mater. **128&129** (1984) 861.
- [5] J.L. Cecchi and R.J. Knize, J. Vac. Sci. Technol. A **2** (1984) 1214.
- [6] D. Mueller et al., in the Proceedings of the Workshop on Tokamak Start-up and Scenarios Related to Transient Phases of Ignited Tokamaks, Enrice, Italy, July 1985.
- [7] W.G. Reddan, J. Vac. Sci. Technol. **20** (1982) 1173.
- [8] J.L. Cecchi et al., J. Nucl. Mater. **128&129** (1984) 1.
- [9] M.A. Ulrickson et al., J. Nucl. Mater. **133&134** (1985) 235.
- [10] L. Sevier et al., in the Proceedings of the Tenth Symposium on Engineering Problems in Fusion Research, (IEEE, New York, 1981).
- [11] J. Schivell, Rev. Sci. Instrum. **56** (1985) 972.
- [12] A.W. Wouters et al., Rev. Sci. Instrum. **56** (1985) 849.
- [13] R.J. Fonck, A.T. Ramsey, and R.V. Yelle, Appl. Optics **21** (1982) 2115.
- [14] K.W. Hill et al., Rev. Sci. Instrum. **56** (1985) 840.
- [15] W.R. Blanchard et al., J. Vac. Sci. Technol. A **4** (1986) 1715.
- [16] H.F. Dylla et al., J. Vac. Sci. Technol. A **4** (1986) 1753.

- [17] B.B. Dayton in Vacuum Symposium Transactions (Pergamon, New York, 1961), p. 42.
- [18] A.E. Pontau et al., J. Vac. Sci. Technol. A **4** (1986) 1193.
- [19] A.E. Pontau and R.A. Causey, J. Nucl. Mater. (in press).
- [20] J.D. Strachan et al., J. Nucl. Mater. (in press).

TABLE 1

Glow Discharge Cleaning (GDC):

DC glow in 5 mtorr of hydrogen or deuterium at 390 V at 15 A ($\approx 10 \mu\text{A cm}^{-2}$).

Pulse Discharge Cleaning (PDC):

Prefill

Type	I_p	B_T	T_{disch}	Pressure	(rep. rate) $^{-1}$
Taylor (TDC)	50 kA	0.15 T	0.05 s	10^{-4} torr	5-10 s
Aggressive (APDC)	300	0.6	0.2	10^{-5}	5-10
Full HPP plasma	0.3- 2.5 MA	1- 5	4 - 8	10^{-5}	5-8 min.
Fiducial	1.4 MA	4.0	4	10^{-5}	5-8 min.

Summary of the various types of plasma discharges run in TFTR. Glow Discharge Cleaning (GDC) is used to clean the surface layers of hydrocarbons and oxides accumulated during a vacuum opening. Pulse discharge cleaning (PDC) is used for similar reasons, especially Taylor PDC (TDC). Aggressive PDC (APDC) is used, in addition, for heating the limiters. Fiducial plasma discharges are standard discharges used for measuring long- and short-term trends in machine conditioning.

TABLE 2

TFTR VESSEL CONDITIONING
FOR THE 1984/85 RUN PERIOD

	May	August	November	December
Time vented	4 months	1 week	1 week	1 hour
Bakeout (150 °C)	350 hours	130 hours	75 hours	75 hours
GDC	50 hours	30 hours	25 hours	20 hours
PDC	70 hours	36 hours	50 hours	55 hours
(PDC pulses)	42,000	36,000	54,000	27,000

Summary of the time and number of TDC and APDC pulses needed to precondition the TFTR vacuum vessel after vessel venting (in 1984).

TABLE 3

SHOT	DATE	COMMENTS
9475	06/05/84	First plasma of the 1984/85 run period (ZrAl active).
10043	08/02/84	First plasma after venting vessel (ZrAl inert).
10476	08/28/84	Machine vented to 1 torr of nitrogen (No GDC or PDC).
10520	08/29/84	First NBI (hydrogen beams).
11263	11/14/84	First plasma after venting vessel (ZrAl inert).
11340	11/17/84	ZrAl active.
11835	12/19/84	First plasma after machine venting (ZrAl inert).
12573	01/23/85	Limiter tile breaks. (see ref. [9])
12589	01/24/85	First plasma after first Cr evaporation.
12916	02/13/85	First NBI with deuterium beams.
13634	03/15/85	First pellet injection.
14846	04/13/85	Last shot of the run period.

Summary of the important events during the 1984/85 TFTR operating period.

FIGURE CAPTIONS

- Figure 1. Partial pressure of D_2O as a function of time during and after Taylor discharge cleaning (in deuterium). The partial pressure is proportional to the rate of evolution of a particular gas species. During TDC the rate of impurity production varies inversely with the square root of time, and the outgassing rate after TDC is inversely proportional to time.
- Figure 2. Partial pressure of D_2O as a function of time during Taylor discharge cleaning followed by aggressive pulse discharge cleaning and reverting back to TDC.
- Figure 3. Plots of parameters relevant to machine conditioning for fiducial plasma discharges (discharges with similar operating parameters, e.g., plasma current, magnetic field, density, etc.). See text for details.

Figure 1

Figure 2

Figure 3

EXTERNAL DISTRIBUTION IN ADDITION TO UC-20

Plasma Res Lab, Austra Nat'l Univ, AUSTRALIA
 Dr. Frank J. Paoloni, Univ of Wollongong, AUSTRALIA
 Prof. I.R. Jones, Flinders Univ., AUSTRALIA
 Prof. M.H. Brennan, Univ Sydney, AUSTRALIA
 Prof. F. Cap, Inst Theo Phys, AUSTRIA
 M. Goossens, Astronomisch Instituut, BELGIUM
 Prof. R. Bouclique, Laboratorium voor Natuurkunde, BELGIUM
 Dr. D. Pelumbo, Dg XII Fusion Prog, BELGIUM
 Ecole Royale Militaire, Lab de Phys Plasmas, BELGIUM
 Dr. P.H. Sakanaka, Univ Estadual, BRAZIL
 Lib. & Doc. Div., Instituto de Pesquisas Espaciais, BRAZIL
 Dr. C.R. James, Univ of Alberta, CANADA
 Prof. J. Telchmann, Univ of Montreal, CANADA
 Dr. H.M. Skarsgard, Univ of Saskatchewan, CANADA
 Prof. S.R. Sreenivasan, University of Calgary, CANADA
 Prof. Tudor W. Johnston, INRS-Energie, CANADA
 Dr. Hannes Bernard, Univ British Columbia, CANADA
 Dr. M.P. Bachynski, MPB Technologies, Inc., CANADA
 Chalk River, Nucl Lab, CANADA
 Zhengwu Li, Sw Inst Physics, CHINA
 Library, Tsing Hua University, CHINA
 Librarian, Institute of Physics, CHINA
 Inst Plasma Phys, Academia Sinica, CHINA
 Dr. Peter Lukac, Komenského Univ, CZECHOSLOVAKIA
 The Librarian, Culham Laboratory, ENGLAND
 Prof. Schatzman, Observatoire de Nice, FRANCE
 J. Radet, CEN-BP6, FRANCE
 JET Reading Room, JET Joint Undertaking, ENGLAND
 AM Dupas Library, AM Dupas Library, FRANCE
 Dr. Tom Muai, Academy Bibliographic, HONG KONG
 Preprint Library, Cent Res Inst Phys, HUNGARY
 Dr. R.K. Chhajlani, Vikram Univ, INDIA
 Dr. B. Dasgupta, Saha Inst, INDIA
 Dr. P. Kew, Physical Research Lab, INDIA
 Dr. Philip Rosenau, Israel Inst Tech, ISRAEL
 Prof. S. Cuperman, Tel Aviv University, ISRAEL
 Prof. G. Rostagni, Univ DI Padova, ITALY
 Librarian, Int'l Ctr Theo Phys, ITALY
 Miss Ciella De Polo, Assoc EURATOM-ENEA, ITALY
 Biblioteca, del CNR EURATOM, ITALY
 Dr. M. Yamato, Toshiba Res & Dev, JAPAN
 Direc. Dept. Lg. Tokamak Dev. JAERI, JAPAN
 Prof. Nobuyuki Inoue, University of Tokyo, JAPAN
 Research Info Center, Nagoya University, JAPAN
 Prof. Kyoji Nishikawa, Univ of Hiroshima, JAPAN
 Prof. Sigeru Mori, JAERI, JAPAN
 Prof. S. Tanaka, Kyoto University, JAPAN
 Library, Kyoto University, JAPAN
 Prof. Ichiro Kawakami, Nihon Univ, JAPAN
 Prof. Satoshi Itoh, Kyushu University, JAPAN
 Dr. D.I. Choi, Adv. Inst Sci & Tech, KOREA
 Tech Info Division, KAERI, KOREA
 Bibliotheek, Fon-inst voor Plasma, NETHERLANDS
 Prof. B.S. Lilley, University of Waikato, NEW ZEALAND
 Prof. J.A.C. Cabral, Inst Superior Tecn, PORTUGAL
 Dr. Octavian Petrus, ALI CUZA University, ROMANIA
 Prof. M.A. Hellberg, University of Natal, SO AFRICA
 Dr. Johan de Villiers, Plasma Physics, Nucor, SO AFRICA
 Fusion Div. Library, JEN. SPAIN
 Prof. Hans Wilhelmson, Chalmers Univ Tech, SWEDEN
 Dr. Lennart Stenflo, University of JMEA, SWEDEN
 Library, Royal Inst Tech, SWEDEN
 Centre de Recherches, Ecole Polytech Fed, SWITZERLAND
 Dr. V.T. Tolok, Kharkov Phys Tech Ins, USSR
 Dr. D.D. Ryutov, Siberian Acad Sci, USSR
 Dr. G.A. Efiseev, Kurchatov Institute, USSR
 Dr. V.A. Glukhikh, Inst Electro-Physic, USSR
 Institute Gen. Physics, USSR
 Prof. T.J.M. Boyd, Univ College H Wales, WALES
 Dr. K. Schindler, Ruhr Universität, W. GERMANY
 ASDEX Reading Rm, IPP/Max-Planck-Institut für
 Plasmaphysik, F.R.G.
 Nuclear Res Estab, Jülich Ltd, W. GERMANY
 Librarian, Max-Planck Institut, W. GERMANY
 Bibliothek, Inst Plasmaforschung, W. GERMANY
 Prof. R.K. Janew, Inst Phys, YUGOSLAVIA