41
11/14/96 JS①

DIII-D RESEARCH OPERATIONS

ANNUAL REPORT

**OCTOBER 1, 1994
THROUGH
SEPTEMBER 30, 1995**

MASTER

ng

**GA-A22308
UC-420**

**DIII-D RESEARCH OPERATIONS
ANNUAL REPORT TO THE
U.S. DEPARTMENT OF ENERGY**

OCTOBER 1, 1994 THROUGH SEPTEMBER 30, 1995

**by
PROJECT STAFF**

**Work prepared under
Department of Energy
Contract No. DE-AC03-89ER51114
W-7405-ENG-48 and DE-AC05-96OR22464**

**GENERAL ATOMICS PROJECTS 3466, 3467, 3470, 3473
DATE PUBLISHED: SEPTEMBER 1996**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed 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. Referenced herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced
directly from the best available copy.

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
Prices available from (615) 576-8401,
FTS 626-8401.

Available to the public from the
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.
Springfield, VA 22161

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

CONTENTS

1. DIII-D PROGRAM OVERVIEW	1-1
2. DIVERTOR AND BOUNDARY RESEARCH PROGRAM.....	2-1
2.1. Divertor Characterization Experiments.....	2-1
2.2. Divertor Impurity Enrichment	2-2
2.3. Divertor Modeling	2-4
3. ADVANCED TOKAMAK RESEARCH	3-1
3.1. Beta Limit and Performance with Negative Central Magnetic Shear	3-1
3.2. Fast Wave Current Drive	3-4
4. TOKAMAK PHYSICS	4-1
4.1. Disruptions.....	4-1
4.2. Nondimensional ρ_* Scaling Experiments	4-1
4.3. β -Limit in Experiment ITER Shape	4-2
5. OPERATIONS.....	5-1
5.1. Tokamak Operations	5-1
5.2. Neutral Beam Operations	5-2
5.3. RF Operations	5-3
5.3.1. ICRF.....	5-3
5.3.2. ECH Operations.....	5-4
5.4. Computer Systems.....	5-4
5.5. Mechanical Engineering	5-5
5.6. Electrical Engineering.....	5-5
5.7. Integrated Preventive Maintenance Program (IPMP).....	5-6
5.8. Diagnostics	5-6
6. PROGRAM DEVELOPMENT	6-1
6.1. ECH Upgrade Project	6-1
6.2. 4 MW Fast Wave Upgrade Project.....	6-1
6.3. Radiative Divertor Upgrade Project	6-3
6.4. Vanadium Divertor Structure	6-5
7. SUPPORT SERVICES	7-1
7.1. Quality Assurance	7-1
7.1.1. Design Support	7-1
7.1.2. Inspection Support.....	7-1
7.1.3. Tooling/Layout/Alignment Support	7-2
7.1.4. QA System Improvements	7-2
7.1.5. Other Support	7-2
7.2. Planning and Control	7-2
7.3. Environment Safety and Health.....	7-3
7.3.1. Fusion and DIII-D Safety	7-3
7.3.2. FY95 Safety	7-4
7.4. Visitor and Public Information Program	7-5

8. TPX PHYSICS SUPPORT	8-1
9. COLLABORATIVE EFFORTS	9-1
9.1. DIII-D Collaborative Programs Overview	9-1
9.2. Lawrence Livermore National Laboratory	9-1
9.3. Oak Ridge National Laboratory	9-1
9.4. International Cooperation	9-3
9.4.1. JET (England)	9-3
9.4.2. ASDEX-Upgrade (Germany)	9-3
9.4.3. TEXTOR (Germany)	9-3
9.4.4. Tore Supra (France)	9-4
9.4.5. JT60-U (Japan)	9-4
9.4.6. Italy	9-4
9.4.7. Russia	9-4
9.4.8. Netherlands	9-5
9.4.9. China	9-5
10. FY95 PUBLICATIONS	10-1

TABLES

1-1.	DIII-D program collaborators	1-2
1-2.	DIII-D capabilities.....	1-3
1-3.	DIII-D achieved parameters.....	1-4
1-4.	DIII-D program 1995 accomplishments	1-5
5.8-1.	Plasma diagnostics	5-8

FIGURES

1-1.	Measured profiles in L-mode	1-6
1-2.	UEDGE simulation matches many features observed with divertor Thomson scattering.....	1-6
2.1-1.	2D Poloidal distribution of divertor electron temperature	2-2
2.1-2.	Measured electron pressure along the poloidal length of a flux tube	2-3
2.2-1.	Divertor neon retention experiment.....	2-4
2.3-1.	A 2D map of divertor electron temperature during a radiative divertor discharge	2-5
3.1-1.	(a) Radial profiles of measured ion thermal diffusivity; (b) Measured safety factor profile.....	3-1
3.1-2.	Particle diffusivity in high power (9.3 MW) NCS discharge showing strong reduction of particle transport.....	3-2
3.1-3.	Maximum stable beta versus peaking of the pressure profile	3-3
3.1-4.	D-D fusion neutron rate versus density peaking factor	3-4
3.2-1.	The noninductive current density driven by fast waves can exceed the local density by a factor of three.....	3-5
4.2-1.	Dimensionally similar paths for the loss power of DIII-D H-mode discharges	4-3
4.3-1.	$m/n = 2/1$ rotating mode limit on β_N versus density	4-4
5.1-1.	DIII-D FY95 weekly operations schedule	5-2
5.2-1.	Neutral beam availability by month	5-3
5.2-2.	Causes of downtime by category	5-3
5.8-1.	Real-time computation of q_0	5-11
6.2-1.	Schematic for one of the 2 MW 30-120 MHz fast wave current drive systems	6-2
6.3-1.	The DIII-D radiative divertor is a flexible slot design	6-3
6.3-2.	Modeling by DEGAS and UEDGE show an optimum inner baffle penetrates past the 2 cm midplane flux line	6-4
8-1.	Net change in wall loading during discharge sequence without HeGDC	8-2
9.2-1.	LLNL installed two important divertor diagnostics on DIII-D in 1995	9-2

1. DIII-D PROGRAM OVERVIEW

The DIII-D research program funded by the U.S. Department of Energy (DOE) is aimed at developing the knowledge base for an economically and environmentally attractive energy source for the nation and the world. The DIII-D program mission is to advance fusion energy science understanding and predictive capability and improve the tokamak concept.

The DIII-D scientific objectives are:

- Advance understanding of fusion plasma physics and contribute to the physics base of ITER through extensive experiment and theory iteration in the following areas of fusion science
 - Magnetohydrodynamic (MHD) stability
 - Plasma turbulence and transport
 - Wave-particle interactions
 - Boundary physics plasma neutral interaction
- Utilize scientific understanding in an integrated manner to show the tokamak potential to be
 - More compact by increasing plasma stability and confinement to increase the fusion power density ($\beta\tau$)
 - Steady-state through disruption control, handling of divertor heat and particle loads and current drive
- Acquire understanding and experience with environmentally attractive low activation material in an operating tokamak

The DIII-D program strives to be a world leader in tokamak concept improvement and, through coordination with international tokamaks, to be a major contributor to ITER Physics R&D as a U.S. center for National collaboration.

Over the past three decades, the General Atomics' fusion program has been a major contributor to the significant progress in developing innovative fusion concepts, increasing understanding and predictability of fusion plasma regimes, extending plasma parameters to fusion conditions, advancing fusion technology, and refining magnetic fusion power plant concepts. Today, DIII-D continues to develop advanced tokamak concepts such as improved confinement regimes (VH-mode, high-inductance H-mode, negative central shear second stable core, and high poloidal beta) with high percentage bootstrap current, steady-state operation and innovative divertor concepts.

The DIII-D program is able to contribute to the understanding of many of the major tokamak issues confronting fusion research. In addition, contributions are being made in areas which are not addressed here. This vigorous and versatile science program in DIII-D allows much of this research to be carried on synergistically, allowing DIII-D

to provide fusion science research in support of the U.S. magnetic fusion energy science program goals and to guide and support the design of future devices such as ITER while contributing to the U.S. Transport Task Force.

The DIII-D program has had a strong role in determining the evolution of the ITER design. Consequently, DIII-D scientists and engineers are active participants and contributors to ITER R&D. The DIII-D program addresses many issues relevant to ITER and this results in a strong interactive relationship. In particular, the divertor development program on DIII-D has as its goal demonstrating an ITER-relevant divertor operation.

The DIII-D tokamak is operated by General Atomics (GA) for the U.S. Department of Energy (DOE). Major program research participants include GA, Lawrence Livermore National Laboratory (LLNL), Oak Ridge National Laboratory (ORNL), and the University of California together with several other national laboratories and universities listed in Table 1-1. The DIII-D is a moderate sized tokamak with great flexibility and extremely capable subsystems. The primary goal of the DIII-D tokamak research program is to provide the scientific database for a commercially attractive fusion power plant. In so doing, the DIII-D program provides physics and technology R&D output to aid the International Thermonuclear Experimental Reactor (ITER). Specific DIII-D objectives include the achievement of steady-state plasma current as well as the demonstration of techniques for radio frequency heating and current drive, divertor heat removal, particle exhaust and tokamak plasma control. The DIII-D program is addressing these objectives in an integrated fashion in plasmas with high beta and with high confinement.

TABLE 1-1
DIII-D PROGRAM COLLABORATORS

National Laboratories	Universities	International Laboratories
ANL	Cal Tech	Cadarache (France)
INEL	Columbia U.	CCFM (Canada)
LANL	Hampton U.	Culham (England)
LLNL	Johns Hopkins U.	FOM (Netherlands)
ORNL	MIT	Fracati (Italy)
PNL	Moscow State U.	Ioffe (Russia)
PPPL	New York U.	IPP (Germany)
SNLA	RPI	JAERI (Japan)
SNLL	U. Maryland	JET (EC)
	U. Paris	Keldysh Inst. (Russia)
	U. Texas	KFA (Germany)
<u>Industry Collabs</u>	U. Washington	Kurchatov (Russia)
CompX	U. Wisconsin	Lausanne (Switzerland)
CPI (Varian)	UCB	NIFS (Japan)
GA	UCI	Troitsk (Russia)
Gycom	UCLA	SINICA (China)
Orincon	UCSD	Southwestern Inst. (China)
		Tsukuba U. (Japan)

The FY95 DIII-D program concentrated on three major areas: Divertor and Boundary Physics, Advanced Tokamak Studies, and Tokamak Physics. Each of these areas by itself constitutes an ambitious program of research. The major goals of the Divertor and Boundary Physics studies are the control of impurities, efficient heat removal and understanding the strong role that the edge plasma plays in the global energy confinement of the plasma. Advanced Tokamak studies include investigations of new techniques for improving energy confinement, controlling particle fueling and increasing plasma beta. These techniques include control of the current density profile by various techniques, development of advanced plasma shapes with improved stability and confinement and fueling in part with solid pellets. Tokamak Physics goals include studies of the understanding of energy and particle transport in a power plant relevant plasma, the study of heating by radio frequency techniques and non-inductive current generation. The DIII-D tokamak characteristics, maximum plasma parameters and experimental results are summarized in Tables 1-2 and 1-3.

Highlights of the FY95 DIII-D Research Program are summarized in Table 1-4. An important focus of the program was experiments on measurement and control of the plasma current profile. Using techniques developed previously, in FY95 we carried out systematic experiments with plasmas with negative central magnetic shear. These plasmas, with hollow current profiles, have improved stability and confinement which were the subject of an article reporting this breakthrough in Science Magazine. Figure 1-1 shows results of such experiments. Much higher ion temperatures are obtained due to the transport barriers associated with the central regions of negative shear.

A second major breakthrough occurred in the area of divertor physics. Employing an array of new diagnostics an extensive series of divertor characterization experiments were carried out. In these experiments it was discovered that very low plasma electron temperatures (down to 2 eV) were able to be produced in the plasma which is near the divertor vacuum vessel walls. That such low temperatures can be maintained near the walls (while the central temperatures are thousands of times higher) is good news. The low temperatures mean that wall erosion and heat loads will be much easier to manage. Results of these measurements are shown in Fig. 1-2.

**TABLE 1-2
DIII-D CAPABILITIES**

	Present
Vacuum vessel volume	37 m ³
Major radius	1.67 m
Minor radius	0.67 m
Maximum toroidal field	2.2 T
Vertical elongation ratio	2.6
Maximum plasma current	3.0 MA
Neutral beam power	20 MW
RF power (ECH)	Upgrade to 3 MW at 110 GHz in progress
RF power (ICRF)	6 MW
Current flattop (divertor at 2 MA)	5 s

TABLE 1-3
DIII-D ACHIEVED PARAMETERS
(NOT SIMULTANEOUS, τ_E IS GLOBAL)

I/aB	3.3 MA/m/T
$\beta_T(0)$	44% (second stable core)
$\langle\beta_T\rangle$	12.5%
H factor	4
β_N	6
β_P	5.2
$\epsilon\beta_P$	1.8
$\bar{n}_e$	$1.4 \times 10^{20} \text{ m}^{-3}$
$T_e(0)$	8 keV
$T_i(0)$	22 keV
W	3.7 MJ
τ_E	0.4 s, ($P_{\text{HEAT}} = 4\text{MW}$)
$\bar{n}_e(0) \tau_E$	$0.39 \times 10^{20} \text{ m}^{-3} \text{ s}$
$n_D(0) T_i \tau_E$	$7 \times 10^{20} \text{ m}^{-3} \text{ keV s}$
H-mode duration	10.3 s

To carry out the DIII-D program, GA provides a combination of extensive institutional experience in the field, a skilled and internationally recognized staff and a unique experimental facility — the DIII-D tokamak. GA has had an active fusion research program for more than three decades. It is the only industrial participant in the U.S. program with a major, integrated effort in all aspects of plasma physics and fusion research, from basic plasma theory, diagnostics, magnetic fusion device design, engineering, construction, and operation, to fusion reactor technology.

DIII-D will be the largest operating U.S. tokamak after the Princeton Tokamak Fusion Test Reactor (TFTR) completes its research program. The DIII-D divertor and advanced tokamak upgrades together with the strong national collaborative program will continue to provide the U.S. with an internationally competitive magnetic fusion tokamak facility connecting with and supporting the design and initial operation of ITER.

TABLE 1-4
DIII-D PROGRAM 1995 ACCOMPLISHMENTS

- **Provided key new experimental results for ITER, TPX, TTF R&D**
 - Stability: stability limits of negative central shear plasmas, ITER demonstration discharges, and disruption characterization
 - Advanced Tokamak: negative central shear high β regimes, VH-mode extension, and on-axis FWCD
 - Confinement: dimensionally similar ρ_* scaling, L-H transition physics and power scaling, and turbulence studies
 - Divertor: radiative and detached divertor, particle exhaust, diagnostic measurements, modeling, and database
- **Commissioned new facility capabilities**
 - C-coil to control error fields for rotation and transport studies (GA)
 - Beam line helium pumping for centrally injected alpha ash transport studies (GA)
 - Pellet injector for particle transport studies: hydrogen (ORNL) and lithium (GA/MIT)
 - Improved digital plasma control (GA)
 - New diagnostics
 - ★ Thomson scattering (LLNL, GA) for divertor studies
 - ★ Spectroscopic diagnostics (GA, LLNL, ORNL) for divertor studies
 - ★ X-point probe (SNL, UCSD) for divertor studies
 - ★ Edge MSE instrument (LLNL) and real time q profile measurement
 - ★ Core BES (U. Wisconsin, GA) for fluctuation measurements
- **Reconfigured ohmic heating solenoid successfully**
 - Following fatigue crack in one lead
- **Carried out upgrade projects**
 - FWCD project (GA, ORNL, LLNL)
 - ★ Three transmitters and antennae now operational
 - ★ Delivered 4.4 MW during plasma operation
 - ECH project
 - ★ Gycom gyrotrons operational
 - ★ Varian gyrotron tested and awaiting high power window
 - RDP project
 - ★ Completed preliminary design and initiated construction
 - ★ Identified fabrication cost savings
 - ★ Initiated vanadium procurements
- **Expanded DIII-D National Program**
 - Initiated PPPL, Columbia U., U. of Wisconsin collaborations
 - Initiated international collaborations with China, Italy, Netherlands
 - Participated actively in ITER Experts Group
 - Participated in experiments at JET, TFTR, Tore Supra

Fig. 1-1. Measured profiles in L-mode with negative magnetic shear (dashed curves and open circles, discharge 83721 at $t = 1.55$ s); H-mode with negative magnetic shear (solid curves and solid circles, same discharge at $t = 1.66$ s); and VH-mode with normal magnetic shear (dotted curves, discharge 783132 at $t = 2.66$ s). Profiles include (a) ion temperature, (b) ion toroidal rotation frequency, and (c) safety factor. A broken vertical line indicates the maximum radius of negative shear for the first two cases. For all cases: $B = 2.1$ T, $I = 1.6$ MA, and $P_{NB} = 7.7$ – 8.7 MW.

Fig. 1-2. UEDGE simulation matches many features observed with divertor Thomson scattering.

2. DIVERTOR AND BOUNDARY RESEARCH PROGRAM

2.1. DIVERTOR CHARACTERIZATION EXPERIMENTS

There were important results obtained in many divertor areas, but the dominant focus of our effort was divertor characterization experiments. The addition of many new divertor diagnostics during FY95 provided the tools necessary for a detailed characterization of the divertor plasma during normal and detached operation. The primary diagnostics related to this work are the new divertor Thomson scattering system, the new divertor SPRED VUV spectrometer, the new X-point fast scanning Langmuir probe, the bolometer arrays, visible spectroscopy and filtered cameras, fixed Langmuir probes in the divertor floor, fast pressure measurements using ASDEX style ionization gauges, and pumping plenum partial pressure measurements using a modified Penning gauge. Tomographic analysis of the bolometric data and the visible camera data yields a true 2D poloidal distribution of total radiation and visible impurity line emissivity. The divertor Thomson scattering system, the fast scanning probe, and the divertor SPRED each obtain data along vertical chords centered at a major radius of 148.5 cm. In order to get a 2D poloidal distribution of the plasma electron temperature and density, and the "radial" distribution of the chord integrated VUV impurity line emission, the divertor configuration is swept in time past this viewing chord. Using the EFIT program to provide a mapping of the magnetic configuration at multiple times during the sweep, a map of the poloidal distribution of electron density and temperature can be produced. Such data has been obtained in a variety of operating modes, including L-mode, ELMing H-mode, and Partially Detached Divertor (PDD) operation.

Although analysis of the data is an on-going process, some notable results are quickly obtained from the divertor Thomson data. During PDD operation most of the divertor, from the strike point up to near the X-point, is quite cold, with electron temperatures (T_e) well below 5 eV. Shown using a false color image in Fig. 2.1-1 (lower) is the remapped Thomson T_e data during PDD operation, and in Fig 2.1-1 (upper) during ELMing H-mode operation. This display technique makes it quite clear that during PDD, the entire outer leg of the divertor has reached a very cold state. This 2D mapping of the Thomson data can also be used to investigate the electron pressure balance along a flux tube, from the midplane to just above the divertor floor. In Fig. 2.1-2 are shown two cases, one in normal ELMing H-mode operation, where the electron pressure is seen to be nearly constant along a flux tube just outside the separatrix, and in PDD, where pressure is seen to drop significantly as the tube approaches the floor. Analysis of the divertor SPRED data, coupled with the divertor Thomson and the visible spectroscopic video data, is providing information on the primary radiating species in the divertor during PDD operation, where bolometry indicates that 70% to 90% of the input power to the plasma is dissipated by radiation. The analysis indicates that both carbon and deuterium are playing significant roles in the radiation, with CIII and CIV being the most important carbon ionization states for radiation.

Fig. 2.1-1. 2D Poloidal distribution of divertor electron temperature (T_e) measured with divertor Thomson scattering and mapped onto an EFIT flux plot for a standard ELMing H-mode plasma (upper) and a PDD plasma (lower).

The new divertor data provides a very detailed benchmark for the modeling of the divertor and scrape-off layer using the UEDGE 2D fluid code, the Monte Carlo 2D impurity transport model MCI, and the 1D multifluid plasma with impurities model NEWT1D. The analysis and modeling to date have provided guidance for important experiments to carry out during the upcoming year. Detailed plasma data along the inner leg of the divertor would provide guidance for modeling the detachment process, since detachment always occurs first at the inner strike point. A divertor sweep at low X-point height has been developed which allows the inner strike point to be swept outward well beyond the divertor Thomson chord. The analysis of spectroscopic data indicates that direct measurement of the dominant radiating lines of D and CIV is needed. We will pursue a modification of the divertor SPRED to allow measurement of the spectral region from 120 to 165 nm, which includes these lines.

2.2. DIVERTOR IMPURITY ENRICHMENT

We obtained the first *direct* measurements of exhaust impurity enrichment in a diverted tokamak and investigated its dependence on D_2 puffing and divertor pumping. Enrichment, the ratio of divertor to core impurity concentrations, is important because a high concentration of radiating impurities is desired in the divertor plasma to disperse power from the scrape-off plasma before it strikes the target, but only limited impurities can be tolerated in the core plasma. Previously, a large reduction of core argon was observed in DIII-D during "puff and pump", but divertor Ar concentration could not be measured. Recently, neon enrichment in the ASDEX-U exhaust was deduced from experimental data using a simple divertor chamber model; however, such models require many assumptions. In our new experiment neon and deuterium were measured quantitatively in both the core and exhaust.

The density of Ne^{+10} ions in the core was measured directly as full radial profiles by absolutely calibrated charge exchange recombination (CER) spectroscopy, while less-ionized neon near the plasma edge was obtained by UV spectroscopy and MIST code modeling. Neon and D_2 pressures in the divertor exhaust gas were measured directly by visible line intensities in a calibrated modified Penning gauge.

Fig. 2.1-2. Measured electron pressure along the poloidal length of a flux tube just outside the separatrix is shown for two cases, (upper) a standard ELMing H-mode and (lower) a standard PDD H-mode. The poloidal length extends from the X-point down to the target, and the electron pressure is normalized to its upstream midplane value.

Figure 2.2-1 illustrates the divertor neon retention experiment. Wherein two cases were studied and compared. One case was a conventional unpumped ELMing H-mode plasma. In the other, D_2 was puffed near the top of the plasma and pumped from the divertor at the bottom of the vessel, both at 6×10^{21} D atom/s. Both plasmas had the virtually the same macroscopic parameters, including density and temperature profiles, ELM frequency (55-60 Hz), and exhaust plenum gas pressure (2.2-2.5 mTorr). It is thought that the divertor density and temperature must then also be nearly identical. Neon was puffed into the private flux via a calibrated valve — a single short puff in the unpumped case and a 2 s steady puff in the pumped one. The resulting neon exhaust enrichments were 0.8 in

Fig. 2.2-1. Divertor neon retention experiment. Core and divertor neon concentrations were measured quantitatively and compared in various cases — here unpumped versus top deuterium puff with equal divertor pumpout.

the unpumped case vs. 2.1 for puff and pump. Two other puff and pump cases were also tested at the same 6×10^{21} D atom/s rate: deuterium puffing from 16 outlets distributed around the equatorial midplane, and deuterium puffing into the private flux region. They yielded enrichments of 1.7 and 0.7, respectively, but some of the loss of enrichment might be due to reduced ELMing frequency caused by the puffing in these plasmas. However, the association of increased divertor neon retention with deuterium injection into the scrape-off layer seems clear. In future experiments the neon concentration will be raised to try to produce increased divertor radiation.

Quite unexpectedly, the detailed temporal neon particle balance indicated a reservoir of up to $\sim 4 \times 10^{19}$ having ~ 10 ms exchange time with the divertor plasma. This neon is not in any open vessel volume, and we hypothesize a temporary neon storage in near-surface layers of the target, from which it recycles mainly to the divertor plasma. Such neon holdup significantly affects the calculation of enrichment from simple models and highlights the need for direct measurements, as in our recent experiments.

2.3. DIVERTOR MODELING

The UEDGE code, which is a collaboration between LLNL and several other institutions, is a 2D fluid code for tokamak edge plasma simulation. Continuing progress was made in reproducing the observed boundary plasma parameters and profiles using the UEDGE code, and in coupling UEDGE to DEGAS2 and EIRENE for neutral transport. The physics in the UEDGE code has been benchmarked by simulating the divertor plasma for a real discharge that had been thoroughly diagnosed using the divertor Thomson scattering system. From Thomson scattering, we obtained 2D poloidal profiles of the electron temperature and density near the outer leg of a single null configuration. The temperature comparison is shown in Fig. 2.3-1.

Fig. 2.3-1. A 2D map of divertor electron temperature during a radiative divertor discharge. Temperatures at the plate are less than 2 eV after gas puffing.

In both cases, the electron temperature near the plate ($L_{pol}=0$) is less than 10 eV in the private flux region. The peak temperature near the plate is ~ 25 eV in the simulation compared to ~ 17 eV in the measurement. This case corresponds to a plasma that is attached at the outer strike point (L-mode, reversed $\mathbf{B}$, *i.e.*, $-\mathbf{B}$ drift downward). Both the measurement and simulation show $T_e \sim 50-70$ eV at a distance $L_{pol}=20$ cm from the plate, *i.e.*, near the X-point. Under other conditions, both UEDGE simulation and Thomson scattering measurements have shown temperatures less than 2 eV near the plate for detached plasmas.

During 1995, the LLNL scrape-off layer (SOL) and divertor modeling group completed work on physics analysis and support of the engineering design activity for the DIII-D Radiative Divertor Upgrade. This involved a coordinated effort in SOL/divertor plasma modeling (using the UEDGE code) and neutral hydrogen modeling using DEGAS. As in previous years, calculations were done in an open-loop mode in which the plasma solution was obtained using UEDGE with a simplified neutrals model, and the detailed behavior of the neutrals penetrating back into the core plasma from the divertor was evaluated with DEGAS.

3. ADVANCED TOKAMAK RESEARCH

3.1. BETA LIMIT AND PERFORMANCE WITH NEGATIVE CENTRAL MAGNETIC SHEAR

Discharges with negative central magnetic shear (NCS) have yielded significant improvements in fusion performance in DIII-D during the past year. NCS discharges are attractive for high fusion performance because of their potential for superior confinement and stability. Enhanced central confinement has been observed in neutral beam heated DIII-D discharges with L-mode and H-mode edges, as well as in RF heated discharges, showing that this operating regime is not dependent on a particular edge condition or heating method. Furthermore, the possibility of good bootstrap current alignment makes NCS discharges attractive for steady-state scenarios. Bootstrap current fractions greater than 50% have been observed in NCS discharges in DIII-D.

Increased understanding of the physics of the transport barrier in NCS discharges has been gained in the past year. Negative central shear discharges in DIII-D are characterized by steep gradients associated with a transport barrier in the vicinity of $r/a = 0.3$ to 0.5 . Reduced transport is observed in all channels, ion and electron temperatures, density, and angular momentum, with central ion temperatures as high as 22 keV. In fact, the measured ion thermal diffusivity is often below the standard neoclassical value (Fig. 3.1-1), but may be consistent with modifications to neoclassical theory which take into account the large ion orbits in the central region. Far infrared scattering data shows strong suppression of turbulence in the plasma core, consistent with observed reduction in core transport. The predicted stabilization of trapped electron modes in the negative shear region is not sufficient to explain the core transport barrier formation, and it seems clear that $\mathbf{E} \times \mathbf{B}$ flow shear, driven in part by the steep pressure gradient, also plays an important role.

Fig. 3.1-1. (a) Radial profiles of measured ion thermal diffusivity before ($t=1.0$ s) and after ($t=1.1$ s) the transition to enhanced core confinement, with calculated neoclassical value. (b) Measured safety factor profile, from equilibrium fit with motional Stark effect data. (Discharge 84736).

Density peaking and ion temperature peaking were observed at input power levels above a threshold. Fig. 3.1-2 shows a transport result for a 1.6 MA L-mode discharge. The density peaking shows up as reduced particle diffusivity. Within experimental uncertainty, the rate of rise of electron density is determined by the particle source which is dominated by neutral beams in the core. There are large uncertainties in the electron particle diffusivity D_e near the magnetic axis because of the lack of central density measurements. Ion transport decreased and electron transport was little affected.

Our participation in these experiments and their analysis will be valuable for our on-going work in time-dependent modeling of NCS discharges. For this work transport models will be required for predictive modeling of temperature and density profiles and their effect on plasma current profiles, *e.g.*, bootstrap, rf, and neutral beam current drive.

Fig. 3.1-2. Particle diffusivity in high power (9.3 MW) NCS discharge showing strong reduction of particle transport. Uncertainty in D_e in the core results from lack of on-axis core Thomson scattering measurements.

Stability to low- n MHD modes presents a challenge for NCS discharges, and the form of the pressure profile is found to be crucial. Ideal stability calculations for NCS discharges in DIII-D show that most of the plasma volume has direct access to the second stable regime for high- n ballooning modes, as expected. Plasma rotation and rotational shear are expected to stabilize external kink modes and double tearing modes. However, NCS discharges with an L-mode edge typically disrupt with a relatively low beta limit, $\beta_N = \beta / (I/aB) \leq 2.4$. These discharges develop strongly peaked pressure profiles, $p_0 / \langle p \rangle \geq 4$, and their disruption threshold (Fig. 3.1-3) and characteristics of the observed precursors are consistent with calculations of a resistive interchange mode driven by a large central pressure gradient in the presence of negative shear. In contrast, NCS discharges with an H-mode edge have broader pressure profiles, $p_0 / \langle p \rangle \leq 3$, and do not disrupt. They reach higher normalized beta, $\beta_N \approx 4$, and the enhanced confinement phase is typically ended by a low- n edge-localized kink mode at the onset of ELM's. This observed dependence on the pressure profile is also consistent with ideal stability calculations for a highly triangular plasma (shown in Fig. 3.1-3), and the ideal stability limit is predicted to occur at beta values slightly above the resistive threshold.

Fig. 3.1-3. Maximum stable beta versus peaking of the pressure profile, showing the ideal limit calculated with GATO (dashed curve) and resistive interchange limit calculated with MARS (solid curve), for NCS q-profiles and a conducting wall at $r/a=1.5$. Also shown are the trajectories of two experimental NCS discharges (with arrowheads).

Our new understanding of the importance of the pressure profile has led to significant increases in fusion performance. L-mode NCS discharges typically disrupt, as described above, but the broader pressure profile of H-mode NCS discharges leads to off-axis deposition of the neutral beam power and eventually to loss of the central heating which appears to be necessary to sustain the NCS configuration. The best fusion performance so far has been obtained by leaving the discharge in L-mode as the central temperature and density build up. Just before the central pressure gradient reaches the critical value, a controlled L-H transition is used to broaden the pressure profile and avoid the instability. With this technique, D-D fusion neutron rates up to $1.2 \times 10^{16} \text{ s}^{-1}$ were achieved (Fig. 3.1-4), nearly double the previous DIII-D record obtained in VH-mode discharges.

A promising operating regime has recently been identified with a region of weakly negative shear. Such discharges exhibit an internal transport barrier containing a larger volume than in strongly negative shear discharges. The combination of weakly negative shear and a naturally broadened pressure profile appears to provide good low- n stability properties, and also has the potential for good bootstrap current alignment. Values of β_N up to 5 with good global energy confinement ($H > 4$) have been achieved in these discharges.

Future work will focus on avoiding instabilities and prolonging the duration of the enhanced performance phase. The disruption mechanism in L-mode discharges will be identified clearly, and means sought to avoid it through profile modification. The high performance phase of H-mode discharge will be extended by prolonging the ELM-free period through edge modification, or by maintaining the NCS configuration after the onset of ELMs. The

divertor cryopump will be an important tool in sustaining near-steady NCS discharges, as will off-axis ECH current drive as it becomes available. The role of discharge shape will be studied experimentally, with low triangularity single null NCS discharges which are relevant to JET and JT-60U as well as ITER. We will also investigate transport and stability physics in the newly discovered regime of weakly negative shear.

Fig. 3.1-4. D-D fusion neutron rate versus density peaking factor. Disruptions (crosses) prevent discharges with strongly peaked pressure and density profiles from reaching high fusion performance.

3.2. FAST WAVE CURRENT DRIVE

The Fast Wave Current Drive (FWCD) program on the DIII-D tokamak is a collaborative effort between General Atomics (GA) and the Oak Ridge National Laboratory (ORNL), with ORNL providing the design and fabrication of the FWCD antennas and GA providing the technology to generate, transmit, and couple the high power rf to the antenna. Both parties participate in the experimental program.

The newly completed fast wave current drive system on DIII-D consists of three antennas, one of which can be operated from 30 to 60 MHz, and the other two of which can be operated from 30 to 120 MHz. Each antenna is comprised of four radiating elements which launch traveling waves that Landau damp on electrons, heating and driving current in the central region of the plasma.

This system has provided us with a useful tool for studying two aspects of advanced tokamak discharges. First, separate systems for heating the ions and electrons allows the sources in the energy transport equations to be more accurately evaluated than with only neutral beam injection. In hot, DIII-D discharges, the electrons are heated predominantly by the fast waves in the central region of the plasma (peaked inside ($\rho = 0.2$)). With this additional electron heating (up to a 5 keV increase in some cases), the neutral beams are more efficiently absorbed by ions, thus fast waves and neutral beams can be used separately to heat the electrons and ions respectively. Second, the central current drive allows us to change the evolution of the current profile. By changing the antenna phasing between shots, discharges with fast wave driven current in the same (co) direction as the inductive current and the opposite (counter) direction can be compared to determine the effect of the rf driven current. In NCS plasmas, this has been used to increase the negative shear with counter current drive and to flatten the central current profile with co current drive.

In 1995, experiments were carried out to measure the profile of fast wave driven current in plasmas with negative shear. The current drive and electron heating was measured under a variety of conditions, providing useful data on current drive efficiency in the presence of neutral beams. This has lead to a scientific understanding which allows the fast wave driven current to be optimized for further experiments, and allowed sophisticated theories of current drive to be tested. Under some conditions, the fast wave driven current density can exceed the local current density by a factor of three (as shown in Fig. 3.2-1). This is precisely the configuration in which fast wave current drive might be used in advanced tokamak operations on ITER. A record current of 250 kA was driven by 2.1 MW of coupled rf power in this configuration, in good agreement with theory, thus providing the scientific basis for extrapolating to ITER.

The FWCD was used as a tool to study the physics of the NCS transition. With counter current drive, a NCS transition was observed in which the electron thermal diffusivity dropped by a factor of two and the ion thermal diffusivity dropped by a factor of three. This new result complements previous studies in which only the particle diffusivity or ion thermal diffusivity exhibited this behavior. The measured rotation profile was consistent with the working hypothesis that the change in confinement is due to a change of the $\bar{E} \times \bar{B}$ shear. The use of counter current drive allowed this transition to occur at peak current densities than previously observed, providing additional information on the role of the current profile on the transition.

Fig. 3.2-1. The noninductive current density driven by fast waves can exceed the local density by a factor of three.

Experimental analysis of the electron power deposition profiles for the FWCD experiments was carried out using the ORNL ECE radiometer signals in response to rf power modulation. The derived electron power deposition profiles are peaked near the center with the volume integrated power of about 90% of the predicted direct electron heating with the PICES full-wave code. In addition, theoretical calculations of the electric field profiles using PICES agree well with measurements with the UCLA's reflectometer, in particular showing the correct directionality of the launched waves when the antenna straps are phased to drive current.

Mode conversion current drive on DIII-D is being studied. The ORNL FAST1D predicts that the drive current is about 150 kA with 3 MW rf coupled power. A new ray tracing code, MORAYS, has been developed to study propagation, absorption, and current drive of mode converted ion Bernstein waves.

4. TOKAMAK PHYSICS

4.1. DISRUPTIONS

In FY95, the disruption research program expanded and made significant progress in a number of different areas including disruption characterization, diagnostic upgrades, database analysis, improved modeling capability and disruption avoidance.

In the area of disruption characterization, simultaneous measurements of density, temperature, and current profiles were made during both high beta and impurity induced disruptions. During the thermal quench phase of the disruption, both density and temperature in the plasma core drop while in the scrapeoff layer (SOL), both n_e and T_e rise from their pre-disruptive values and often the density is peaked at the edge of the plasma. The broader SOL implies that the heat flux pattern to the divertor will be broader thus lowering disruption induced erosion. Current profile measurements using the upgraded MSE diagnostic evolution clearly show that the profile flattens rapidly from $\ell_i \sim 1.5$ to 0.5 in approximately 1 ms. The process occurs only at the final stage of the thermal quench and occurs more rapidly than can be explained with either classical or neoclassical diffusion.

Characterization of both the disruptive heat pulse and of disruption induced poloidal halo currents have also been obtained. Measurements of the heat flux to the divertor region during impurity induced and high beta disruptions indicate that between 70%–90% of the thermal energy lost is incident on the divertor region. The main observations are that the peak heat flux is often far from the divertor strikepoints and can move considerably during a disruption. Peak widths (full width at half maximum) at the divertor plate ranged from as narrow as 3 cm to as wide as 10 cm. Following the upgrade of the multi-element toroidal and poloidal tile current array in the fall, measurements of the halo currents have improved significantly. Initial data has clearly shown the existence of toroidal asymmetries in the halo current with a peak-to-average value of 1.7.

As part of a collaboration with ORINCON Corp. disruption avoidance in high beta discharges is being pursued on DIII-D. A high beta disruption alarm has been developed using a neural network based on a multi-layer perceptron. The system uses 33 plasma diagnostic signals including magnetics, H_α , soft X-ray, visible bremsstrahlung, neutron emission, and line integrated density. The results indicate the neural network provides a better description of the disruption boundary than the simple Tryon limit ($\sim I/aB$) or a current profile corrected Tryon limit ($\sim \ell_i I/aB$) and can predict the boundary a few hundred milliseconds before the disruption occurs. The technique is now being implemented in the real time plasma control system on DIII-D.

4.2. NONDIMENSIONAL ρ_* SCALING EXPERIMENTS

The confinement properties of future magnetic fusion devices can be extrapolated from existing experiments using the scaling of heat transport with nondimensional parameters such as the relative gyroradius ρ_* , the gyroradius normalized to the plasma minor radius. A series of experiments have been performed on DIII-D to both test the validity of the nondimensional scaling approach to confinement physics and to measure the ρ_* scaling of ion and electron heat transport. The assumption that heat transport is a function of local nondimensional parameters has been

tested globally by comparing dimensionally identical discharges on DIII-D with Alcator C-mod for L-mode and JET for H-mode plasmas. Dimensionally identical discharges have all the nondimensional parameters the same, including ρ_* ; therefore, the energy confinement time (normalized to the cyclotron frequency) should be the same. This has been verified experimentally, since the normalized confinement times between DIII-D and Alcator C-mod and DIII-D and JET differed by less than the experimental errors.

The dependence of the gyroradius scaling of heat transport on the shear scale length has also been investigated. Previous experiments on DIII-D found that the ρ_* scaling of the ions varied from gyro-Bohm-like (the theoretically expected value) for plasmas with broad density and current profiles to worse than Bohm-like for peaked density and current profiles; the ρ_* scaling for electrons was always found to be gyro-Bohm-like. In order to determine separately the effects of the density and current profiles on the ρ_* scaling for the ions, experiments were done with a broad density profile (H-mode) and a peaked current profile (high safety factor). The result was that the ion ρ_* scaling was Bohm-like globally whereas the electrons scaled gyro-Bohm-like as always. These detailed sets of experiments show that the ion fluid deviates from the expected gyro-Bohm-like scaling when either the density or shear scale lengths become small compared to the plasma minor radius.

The ρ_* scaling of dimensionally similar discharges have been compared between DIII-D and JET for H-mode plasmas in order to test the extrapolation of heat transport between different sized machines. This extrapolation from DIII-D to smaller ρ_* on JET is complicated by the requirement that the loss power from core transport remain above the H-mode threshold power along the dimensionally similar path. Experimentally the core transport power scales gyro-Bohm-like in H-mode plasmas with low safety factor, whereas the H-mode threshold power scales worse than Bohm-like. Choosing a scaling path at high beta (and low collisionality), along which the loss power remains above the H-mode threshold to the point of ignition, allows one to take full advantage of the gyro-Bohm-like scaling of heat transport in H-mode plasmas in the design of an ignition tokamak. This is shown by the open square in Fig. 4.2-1, where the extrapolated ignition point along the higher beta curve occurs at 4 m major radius for $B_T=5.7$ T.

4.3. β -LIMIT IN EXPERIMENT ITER SHAPE

Successful steady-state tokamak operation requires operating at the highest possible β while avoiding both ideal and resistive MHD instabilities which reduce confinement and induce disruption. The maximum operational β in single-null divertor (SND) long-pulse discharges in DIII-D with a cross-sectional shape similar to the proposed ITER tokamak is found to be limited not by ideal modes but by the onset of resistive MHD instabilities. While discharges with $\beta_N=3.5$ in this shape were operated for one second in DIII-D without instabilities in the late 1980s, those plasmas had low toroidal field and high recycling mostly metal walls so that the density and collisionality were high. Recent work with high toroidal field and low recycling freshly boronized all carbon walls is much lower collisionality more typical of what ITER will experience. There is a "soft" β limit due to the onset of an $m/n=3/2$ rotating tearing mode which saturates at an amplitude that decreases the energy confinement by about 20% and a "hard" β limit at slightly higher beta due to an $m/n=2/1$ rotating tearing mode which grows to an amplitude that reduces the confinement and usually induces a disruption. These experiments are done with plasmas which are neutral beam heated ELMing H-mode that have sawteeth. The safety factor q_{95} is just above 3.

Fig. 4.2-1. Dimensionally similar paths for the loss power of DIII-D H-mode discharges (filled squares), the projected loss power for gyro-Bohm-like scaling at two values of beta (dashed lines), the H-mode threshold power (solid line), and the alpha loss power for the high-beta path (dotted line). ITER-EDA is represented by a filled circle and the open square represents an ignition point.

Higher stable β in these long-pulse discharges is successfully run by operating at higher density and higher collisionality which suppresses both the 3/2 and 2/1 mode onsets. Density is the control parameter varied by gas puffing. The stable boundary for the hard 2/1 mode versus density is shown in Fig. 4.3-1 where the density is normalized to the Greenwald parameter for convenience. Some of these discharges while 2/1 stable have a saturated 3/2 mode and degraded confinement. The 2/1 limit approaches the expected ideal limit of about $4 \ell_i \sim 3.8$ at high density. Note that while ITER anticipates operation at $G \sim 1.5$, the relative collisionality will be lower than in DIII-D.

Two possible means have been identified as the cause of the onset of these instabilities. Resistive modes can be destabilized either from free energy from an unstable current J_ϕ profile or to a helical bootstrap current which amplifies a seed island such as periodically occurs from sawteeth and/or elms. Active multi-laboratory collaboration is underway to do ideal and resistive stability analysis of sample DIII-D ITER shaped discharges so as to better understand and predict the physics of β limiting instabilities in ITER.

Fig. 4.3-1. $m/n = 2/1$ rotating mode limit on β_N versus density.

5. OPERATIONS

5.1. TOKAMAK OPERATIONS

The principal functions of the DIII-D Operations group are to ensure reliable tokamak operations, develop new capabilities, and refurbish existing systems. During the year there were 73 days of machine operations for experimental research and a similar number of days for preparation, calibration and testing of tokamak and diagnostic systems. The availability of the tokamak during scheduled research operations was 74%. The main program elements are shown in Fig. 5.1-1.

There was one major vent in February-March, during which time two new diagnostics were installed; the divertor Thomson system, and the beam emission spectroscopy. Two hardware failures, in the current limiting line inductors and in one of the two central solenoids making up the ohmic heating coil, caused the operational schedule to be changed. Operations weeks were moved from the third quarter into the fourth, during which the tokamak was operated intensely to complete the scheduled experiments.

In January a fault occurred on the electrical bus between the DIII-D motor generator and the dc power supply input breakers during power supply testing last week. The fault caused minor damage to the mechanical structure, whereas the surfaces on several of the protecting line inductors were charred. Three of the inductors were sent back to the manufacture to be rewound. The three other ones were cleaned and were used for the next run period to operate two of the four modules in the ohmic heating power supply. All but one of the physics experiments scheduled could be completed with the new configuration. The cause of the fault was never definitively established. It was surmised that it could have been caused by a bird, since a bird's nest was found in the area. The insulation on the line inductors was improved and the full set was operational later in the year.

In late April, a water leak was discovered in the lead to the B solenoid of the ohmic heating coil. The area around the leak and the corresponding area on the A solenoid was inspected with a borescope to get an understanding of what had caused the failure. The conclusions of the inspection were that the B solenoid had been incompletely impregnated, yet had served for 17 years before failing, whereas the A solenoid had been well impregnated. It was then decided to reconfigure the ohmic heating coil in such a way that all the coil sections except for the failed B solenoid would be used. The new configuration, while limiting the error field in the plasma region, was only capable of supplying half the original volt-seconds. The machine was started up in July with the new configuration. After one week of studying the new plasma initiation phase physics, experiments began. By using neutral beam injection early in the plasma ramp up phase, it has been possible to run plasmas with currents up to 2.5 MA.

Radiation management tasks include monitoring the site boundary radiation, monitoring the dose exposures of individuals from pit runs and vessel entries, ensuring compliance with legal limits, DOE guidelines and DIII-D procedures, monitoring material for activation, maintenance and operation of the radiation monitoring detectors (neutron and gamma), and maintaining a database of radiation measurements and of personnel dose exposures.

Fig. 5.1-1. DIII-D FY95 weekly operations schedule.

The total neutron radiation at the site boundary for FY95 was 5.1 millirem, the total gamma radiation was 1.5 millirem, giving a total site dose for the year of 6.6 millirem. This is well below the SAN DOE annual guideline limit of 40 millirem and the California annual limit of 100 millirem. The total dose exposure personnel received was kept below the DIII-D procedural limits. Three DIII-D radiation training classes were given as part of the radiation training for new personnel and for refresher training. A total of 197 people received training.

5.2. NEUTRAL BEAM OPERATIONS

Fifteen weeks of plasma heating experiments were supported by neutral beams in FY95. There were 29 days of plasma experiments in the first quarter of FY95. Beam systems performed beam shine-through calibrations and beam physics study in January 1995, and supported 8 days experiments in February. Six weeks of plasma experiments were supported by neutral beams in the fourth quarter of FY95.

The 30° left ion source developed leaks on two bellows of one plasma grid module at the end of the October run period. This is the failure that two other ion sources experienced in April and September 1994. In the efforts of finding the cause of this failure, it was found that plasma grid has significant vibration at frequency around 7.7 and 30 kHz when cooling water flow was greater than 8 GPM. No more such plasma grid failure has occurred since we lowered the cooling water for the plasma grid to 7 GPM, which is still sufficient for active cooling of the grid.

Four ion sources of 150° and 210° beamlines were operated with helium beams to support helium transport and helium exhaust experiments in October. Beamline argon frosting system, installed in FY94 on these two beamlines to pump helium gas, worked extremely well so that not only helium beams with 2 s pulse length were achieved, as compared to 0.5 s beams in the past with argon frosting system, but the cold helium gas diffusing into the tokamak was also greatly reduced. With this helium gas pumping capability, we were able to develop a more stable helium beam operation for the ion source, resulting in quick source recovery for deuterium beam operation without any damage to the arc chamber, which had been the problem in operating helium beams in the past.

Availability of the neutral beam system by month is shown in Fig. 5.2-1. The "Available" category is based on the beam system requirement requested by the physics experiments. The difference between the "Available" and "Injecting" categories represents beam systems which were available but were not used for injection during physics experiments. The various causes for downtime are shown in Fig. 5.2-2. Power supply and computer problems are the two highest downtime categories.

Fig. 5.2-1. Neutral beam availability by month.

Fig. 5.2-2. Causes of downtime by category (percent of total operating time).

5.3. RF OPERATIONS

5.3.1. ICRF

Throughout the year, the focus of the ICRF Operation efforts was to commission the new fast wave current drive (FWCD) hardware, with the anticipation that full current drive experiments could be conducted on DIII-D by years end. At the beginning of the year, only one of the new systems was operational and it was used to power the 0° FWCD antenna. The system was tested at half power (≈ 1 MW) over several frequencies ranging from 60 to 90 MHz. As the power was raised to the full power level of 2 MW, breakdown in the transmission line system, both coaxial components and phase shifters, was encountered. This led to the need to rework all the transmission line

hardware to increase its standoff capability and improve its long pulse reliability. Since this repair, the hardware has performed at full power without failure.

By February, all three transmitters were operational; however, parasitic oscillations in the two new ABB transmitters prevented them from operating above the 1 MW level. The onset of these oscillations were caused by the overheating and ultimate degrading of ferrite material installed in the final power amplifier cavity to prevent such oscillations. With the replacement of this ferrite material, the transmitters were able to operate at full power with limited pulse length to prevent overheating the ferrite. In July, both ABB units were operating at the 1.5 MW level into a plasma load. And in August, a new maximum combined transmitter output power of 4.6 MW (total all three transmitters) was demonstrated.

Transmission line and antenna arcs cause high reflected power conditions that could damage the final power tube. To avoid damage, each transmitter is equipped with a reflected power detector to look for high reflections and, when detected, shut down the transmitter. Unfortunately, ELMs also have a high reflected power and can occur at a high rate (ten to hundreds per pulse). In order to prevent continuous shut down of the transmitters during an ELMing plasma, an ARC/ELM discriminator needs to be developed.

A detection system looking at low frequency noise, in the 8 to 20 MHz range, seems to hold promise of such a discriminator. A second harmonic detector proposed by Jim Rogers (PPPL) detected arcs but also was sensitive to ELMs. If the low frequency detector pass band was raised above 20 MHz, it became sensitive to ion cyclotron emission from the plasma, and if the pass band was lowered below 8 MHz, the broad band noise from the plasma swamped out the arc signal. Work is continuing in this area in conjunction with work performed by the ORNL collaborators.

Throughout FY95, the antenna at 285° had limited performance due to arcing between the antenna and its Faraday shield. Earlier in FY94, this antenna had the coating of the Faraday shield removed because it was flaking off during plasma shots. When the flakes entered the plasma volume, a shot ending disruption would usually occur. However, without the high temperature coating, the Inconel rods of the shield would over heat and either cause nickel impurities to enter the plasma or the outgassing of the rods would lead to an arc within the antenna structure. Either way, the effective power limit of the antenna was about 1 MW. In FY95, a new shield was built and coated and was ready for installation in the January 1996 vent.

5.3.2. ECH OPERATIONS

In preparation for the new 1 MW 110 GHz gyrotron to be purchased from Russia, the only ECH operation activity this year was the operation of the 500 kW 110 GHz Varian gyrotron. This operation was performed to validate the transmission line hardware. Pulses up to 400 ms were successful without any breakdown detected in the transmission line. This gyrotron was then removed to make room for the new 1 MW gyrotron arriving in FY96.

5.4. COMPUTER SYSTEMS

During FY95 3957 shots of data were acquired. The largest shot was 157.6 Mbytes and over 261 Gbytes of data was collected.

All hardware and software associated with the data acquisition system is now located on the motorola 88K UNIX cpu. The system runs reliably and allows for much more data to be collected. The generation of shot files by individual diagnostics has also speeded up data access and made it possible to collect more data.

Programs with more modern and useful x window interfaces were installed for the user – these include the master timing system program, a new shot logger program and a more stable plotting/calculation program.

Using existing mechanisms, software was developed so that asynchronous data not associated with a plasma shot can be collected, archived and easily retrieved and analyzed. This includes data such as thermocouple readings and RGA data from long bakes.

Installation of the new network in building 34 was completed and operating well. Fiber optic and category 5 cable (capable of 10 Megabits/s) was installed in 24 ethernet segments which provides capacity for the future, speeds up transfers, reduces error rates, and makes the diagnosis of any network problems much easier. The new network includes a FDDI link to the USC. The old network is still in place and will be used for desktop video conferencing. Greater use of the internet and world wide web has been implemented to provide better communication with collaborators.

A workstation was installed in the USC for use in system development and network monitoring. C and FORTRAN were installed and the HP-UX operating system upgraded to 10.01. This workstation is for testing all production codes on the new version of the operating system as well as for non-production software development and testing.

5.5. MECHANICAL ENGINEERING

Engineering, design and fabrication of the beam emission spectroscopy, X-point probe and the redesigned charge exchange at 105° were completed and the diagnostics installed in the vessel. Modifications were completed on the divertor Thomson scattering diagnostic for reducing stray light. The lithium pellet injector was installed on the vessel and successfully tested. The Radiative Divertor Project, feedthrough flow test assembly was modified and successfully tested to verify cryogenic vertical flow stability.

In late April, engineering attention was focused on a water leak in the lead that supplies power to half of the E-coil solenoid. Manufacturing and operational records were reviewed followed by appropriate analysis. Electrical bus modifications were implemented to disconnect the leaky half of the solenoid from the circuit. The modifications were completed and the machine returned to operation in June. Repair options to restore the lead are being evaluated.

5.6. ELECTRICAL ENGINEERING

Electrical Engineering support of DIII-D operations continued routinely during the two first quarters. A ground fault in the power distribution system to the ohmic heating power supply occurred during operations during second quarter with resulting damage to three power line inductors. Operations were restored using two of the four power supply modules in this system after making repair and modifications to this circuit.

Electrical Engineering support was also provided to restore operations following the failure of a lead in one of the ohmic heating solenoids on the DIII-D tokamak during the third quarter operations. A new E-coil circuit configuration was implemented using the undamaged solenoid. Operations resumed and required lower currents in the

outer field coils during plasma initiation with the new E-coil configuration than previous operations. Modifications were successfully made to the HX chopper controllers to achieve this lower current operation and have proved to enhance the flexibility of operation of the tokamak.

Sources of a delay in switching the polarity of the ohmic heating power supply during the ramp up of the plasma current were investigated and identified. A plan was developed to reduce the crossover delay time, and work has started according with this plan. Software engineering of the version 10.0 of the Plasma Control System were completed and the new software was implemented. Control system algorithm software and hardware upgrades were subsequently completed and implemented in support of the Advanced Tokamak program. A new plasma vertical position control algorithm based on the old analog version was successfully tested on the digital control platform. The first of four CER CCD systems were also installed and is being evaluated. Approximately 4815 man hours were used by the electrical engineering group to complete 1605 preventive maintenance tasks this fiscal year.

5.7. INTEGRATED PREVENTIVE MAINTENANCE PROGRAM (IPMP)

There were 2953 maintenance tasks identified for all of FY95. Of this number, 2599 preventive maintenance (PM) and 342 corrective maintenance (CM) tasks were completed. The outstanding 12 PM and CM tasks will be completed on a priority basis in FY96. For the year, the average turn-around time was 16 days for PMs and 28 days CMs.

At the end of FY95, there were 1481 pieces of equipment being tracked by the IPMP. This is a 13% increase over FY94.

Safety training and related safety issues added to the IPMP in FY94 for tracking proved advantageous and are being updated as required.

Nineteen new turbomolecular vacuum pumps were ordered in the first part of a multi-year program to replace aging pumps. A new 8 MW cooling tower for motor generator #2 and a 4 MW heat exchanger for vessel cooling water were procured to replace severely worn units.

5.8. DIAGNOSTICS

The DIII-D diagnostic effort in FY95 concentrated on completing the divertor diagnostics started in FY94 and using the large complement of divertor diagnostic to characterize attached and detached divertor plasmas over a wide range of parameter space. The emphasis on the divertor diagnostics was aimed at exploiting the pumped divertor and the relatively good diagnostic access available with the existing divertor configuration while preparing for the radiative divertor installation now planned for FY97. The critically important detailed 2-D measurements of the density and temperature in the divertor can now be routinely made with the installation of three new divertor diagnostics, a divertor Thomas scattering diagnostic, a fast stroke Langmuir probe in the X-point region and a divertor reflectometer. Further, our measurement capability of impurities in the divertor was significantly improved with the installation of spatially overlapping visible and EUV spectrometers in the divertor. While the emphasis in FY95 was on the divertor, there were some improvements and additions to the core diagnostics. Of particular note is the installation and operation of the BES diagnostic that will greatly enhance our ability to measure the density fluctuation in the core of the plasma. There are more than 50 major diagnostic systems now operating on DIII-D. Table 5.8-1 lists the major diagnostic systems along with the quantities measured. In addition to the development of new diagnostic systems, we continue to refurbish diagnostics that are known to be operating with critical

components near or beyond their life expectancies. Many of the diagnostics systems on DIII-D have been operating for many years (some were initially built for Doublet III) and we expect the refurbishment effort to continue throughout the life of DIII-D.

In FY95, the DIII-D resources for new diagnostics were concentrated on completing the divertor diagnostics that were started in FY94. The completion of these diagnostics gives DIII-D the best diagnosed divertor plasma in the world and will allow us to continue to make significant progress in divertor physics understanding.

The completion of a Thomson scattering diagnostic in the divertor represents a major milestone in the understanding of divertor plasmas. This diagnostic provides a very detailed 2-D map of density and temperature of the divertor (made possible by scanning the location of the X-point). A fast stroke Langmuir probe that plunges from the bottom of the tokamak into the divertor and an upward looking reflectometer were also installed and commissioned in FY95 and complete the divertor density diagnostic suite. The fast stroke probe also has mach probes installed on the tip and will provide a flow measurements in the divertor.

The divertor Thomson scattering system, designed and installed by LLNL and the GA Thomson Scattering group, was brought on line and used extensively in the divertor characterization experiments. By sweeping the discharge across the Thomson beam, we were able to obtain for the first time on any tokamak, 2-D maps of electron temperature, density, and pressure in the outer leg of the divertor (and some data for the inner leg) in lower single-null discharges. Several discharge conditions were characterized, including L-mode, H-mode, and detached H-mode. Electron temperatures near the plate were reliably measured at less than 2 eV in detached plasmas. This measurement by the LLNL divertor Thomson system shows that the DIII-D divertor is in an entirely different physics regime during detached operation than previously predicted.

Impurity concentration measurements in the divertor are needed to validate divertor models and to understand radiative divertors (both attached and detached). Toward that end we have installed spatially overlapping visible and absolutely calibrated EUV spectrometers in the divertor to complement the 2-D images from a tangentially viewing filtered camera.

Improvements to the core diagnostic set included the installation and commissioning of a beam emission spectroscopy diagnostic aimed at improving our ability to diagnosis density fluctuations in the core of the plasma. Also a vertical array of particle analyzers is being installed to provide information on the profile of fast ion distributions.

The LLNL MSE diagnostic was used to measure the current profile, and we have provided real-time q_0 measurements, which will be used in future experiments for feedback control of the current profile using rf current drive. Figure 5.8-1 shows q_0 from the real-time calculation compared with q_0 calculated after the discharge using a full EFIT. The real time calculations of q_0 agree quite well with the EFIT values.

The refurbishment of aging diagnostic components continues on DIII-D. The development of a detector system using a fast readout CCD to replace obsolete image intensifiers on the entire CER diagnostic continues. Two spectrometers with detectors have been installed on DIII-D. Early testing indicated that additional neutron shielding would be required. Additional neutron shielding is now being installed and will be tested in FY96. The tile current monitor array was refurbished during a vent in FY95.

**TABLE 5.8-1
PLASMA DIAGNOSTICS**

Diagnostic	Quantity Measured	Comments
<u>Operations-Related Diagnostics</u>		
Magnetics	$\dot{B}$, Magnetic flux I_p	2 poloidal (58), 1 toroidal (8) mag. Probe arrays with 50 kHz response; 41 flux loops, 9 diamagnetic loops, 30 saddle loops, 3 I_p Rogowskis
Hard X-rays		2 toroidal locations, 4 detectors, 1 kHz response
Plasma TV	Visible light	Radial view, divertor, rf antennas
IR cameras	Heat load to armored surfaces	Upper divertor; inside wall, 2 toroidal locations, lower divertor
H_α monitors	H_α radiation, recycling	H_α filtered, 16 locations, 10 kHz response
Neutron detectors	Fusion and photo-neutrons	3 toroidal locations, 200 Hz response
Soft X-ray arrays	Internal fluctuations	1 vertical, 1 horizontal, 32 ch. ea. ~4 cm resolution, 4 toroidal locations, 12 ch. ea. >250 kHz response
<u>Electron Profiles</u>		
Multipulse Thomson profile	$T_e(r,t)$, $n_e(r,t)$	7 lasers, 6 ms, vertical profile, 40 pts., <1 cm in edge resolution, 20 keV > T_e > 10 eV
CO ₂ interferometers	$\bar{n}_e(t)$	Vertical: 3 chords; radial: 1 chord
ECE Michelson	$T_e(r,t)$	Radial profile, each 25 ms
Microwave radiometer	$T_e(r,t)$	32 ch. (ORNL), 0.2 ms, 2 cm resolution
<u>Fluctuations</u>		
Microwave reflectometer	$n_e(r,t)$, $\tilde{n}_e(r,t)$	UCLA collaboration — broadband; system gives profile in 5 ms, narrowband system, 400 kHz bandwidth
Correlation reflectometer	Radial correlation lengths in $\tilde{n}$	UCLA
FIR scattering	$\tilde{n}_e(r,t)$	UCLA collaboration — 4 MHz bandwidth
CO ₂ scattering	$\tilde{n}_e(r,t)$	MIT collaboration - phase contrast 1 kHz, 100 MHz bandwidth
Fast magnetic probes	$\tilde{B}_\theta$	1 MHz resolution, 2 arrays totaling 7 probes
Beam emission spectroscopy	$\tilde{n}_e(r)$ in the core	U. Wisconsin collaboration
Li beam	Edge $\tilde{n}_e(r,t)$	Turbulence measurement near the edge

TABLE 5.8-1
PLASMA DIAGNOSTICS (Continued)

Diagnostic	Quantity Measured	Comments
<u>Ion Temperature and Rotation</u>		
Charge exchange recombination	$T_i(r, t)$, $v_\phi(r, t)$, $v_\theta(r, t)$	16 channels bulk plasma; 16 channels edge plasma; 3 mm Ti edge resolution; 6 mm v_ϕ , v_θ , edge resolution
<u>Impurities and Boundary Parameters</u>		
Visible bremsstrahlung	$Z_{\text{eff}}(r, t)$	Radial profile, 16 chords, 1 kHz
Bolometer arrays	Radiated power	Tomographic reconstructions, 3 arrays, 60 ch., 1 kHz
Graphite foil bolometers	Heat load to the wall	7 on the outer wall, 2 inside wall, 2 lower divertor, 1 upper divertor
SPRED (dual range)	Impurity concentrations	280–1200 Å; 100–290 Å, spectrum every 1 ms; edge profiles with scanning capability
H $_{\alpha}$ TV	Divertor H $_{\alpha}$	LLNL
Divertor IR Cameras	Heat load to divertors	LLNL, GA, 125 ms for a profile, upper, 2 lower
Langmuir probes	Edge $T_e(t)$, $n_e(t)$	On divertor tiles
Fast stroke Langmuir probe	Edge $T_e(t)$, $n_e(t)$	SNL, UCLA
DIMES calorimetry	Surface erosion	Divertor Material Exposure System
Penning gauges	He pressure	ORNL — He pressure under the divertor baffle
Divertor microwave interferometer	$\bar{n}_e$ in divertor legs	2 chords (LLNL)
Divertor reflectometer	Peak n_e in divertor	12 ch. in lower divertor (LLNL)
Divertor Thomson scattering	$n_e(r)$, $T_e(r)$ in divertor	1 laser, 50 ms, 8 pts., <1 eV temperature sensitivity (LLNL, GA)
Divertor SPRED	Impurity concentrations in divertor	LLNL
Visible SPRED	Impurity concentrations in divertor	Many chords
X-point fast stroke probe	$T_e(r)$, $n_e(r)$ in divertor	UCSD, SNL
Fast pressure gauges	Neutral pressure	Near divertor region (ASDEX, LLNL), toroidal array, 2–3 ms response
Tile current monitors	Poloidal tile currents	Includes tile currents in the ADP, toroidal array
Multichannel divertor visible spectrometer (MDS)	Divertor impurity concentrations	ORNL — 7 channels
Divertor Baratron gauge	Neutral pressure	ORNL — verified ASDEX gauge measurements

TABLE 5.8-1
PLASMA DIAGNOSTICS (Continued)

Diagnostic	Quantity Measured	Comments
<u>Fast Ion Diagnostics</u>		
Scintillator	Neutron fluctuations	50 kHz response time
EII B charge exchange	Beam-ion density profile	Conventional charge exchange analyzer coupled with H_{α} detectors used to measure beam neutral density profile, scannable, spectrum in 1 ms
Fusion products	Fast neutrons, tritons He^3 , other fast ions	UCI collaboration; movable probe assembly
<u>Current Drive Diagnostics</u>		
Motional stark effect (MSE)	$B_p(r)$	16 radial channels; 2 cm resolution, 5 ms response
ECE Michelson	Microwave emission	Detects tail population in the electron distribution function, profile in 25 ms (LLNL and Maryland)
SXR pulse height	High energy X-ray spectrum	Russian collaboration; detects tail population in electron distribution; spectrum every 100 ms
RF probes	RF radiation	Phase and amplitude of ICH rf on inside wall

Our major diagnostic effort in FY96 will be to prepare for the installation of the high-triangularity advanced tokamak RDP divertor pump in October 1996. Due to budget constraints only those modifications necessary to maintain existing diagnostic capabilities will be undertaken in FY96. The installation of the upper outer baffle limits the view from R+2 ports and, Consequently, the wide-angle bolometric and soft X-ray arrays must be relocated to R+1 ports. As part of this move, both bolometer arrays used for tomographic reconstruction will be moved to a new toroidal angle where poloidally localized radiation from beam injection is absent. New magnetic probes will be installed on the plasma facing side of the new divertor baffle to improve X-point position control.

Fig. 5.8-1. Real-time computation of q_0 . The solid line in the top plot is the real-time calculation of q_0 and the dotted line is the post-shot calculation by EFIT. The center plot shows the assumed value of k_0 for the real-time calculation, and the dotted line is the value arrived at by EFIT. The bottom trace shows the major radius of the magnetic axis.

6. PROGRAM DEVELOPMENT

6.1. ECH UPGRADE PROJECT

The CPI (formerly Varian) MW level internal mode converter gyrotron performed very well. Peak power of 1 MW were reached for 2 ms 6% duty, and 106 kW cw operation for several hours were obtained. Using an infrared camera to monitor the output window temperature high power pulses of 680 kW, 530 kW and 350 kW for 0.5, 2 and 10 s respectively have been obtained. Significant is the 350 kW for 10 s, which is a new world record for energy throughput for the 100+ GHz gyrotron class above the 200 kW level. In all the pulsed high power tests, the window temperature is the limiting factor on gyrotron performance. To improve the performance of this tube, a General Atomics (GA) distributed window is being developed.

The initial testing at GYCOM of the MW level 2 s gyrotron achieved over 800 kW, however, the efficiency dropped above this level such that 1 MW was not achievable. Therefore, the gyrotron was rebuilt with corrections made to the cavity and electron gun. The new tube went into test the middle of April and by the middle of May had reached 890–920 kW 2 s at an efficiency of 39%. At the end of May we visited the Kurchatov Institute to witness tests of the 1 MW, 110 GHz gyrotron. Measurements of rf power in long pulse regime was performed by “window calorimetry” method. RF losses in the output window were calibrated by means of calorimetric load at pulse lengths of 0.1 s. The mode pattern measurements were performed with the matching optics in short pulse operations of ≤ 2 ms. The gyrotron performance during the long pulse tests was 900 ± 30 kW for 2 s 38% efficient. For these tests the frequency stabilized after 300 ms. and was constant until the end of the pulse, the frequency shift during the first 300 ms. was 350 MHz. A test for injection of the rf beam into a corrugated waveguide was performed using two curved mirrors to direct and focus the beam from the 100 mm output diameter into a 33 mm diameter waveguide. The power out of the gyrotron was 960 kW and the power through the waveguide was 860 kW for a transmission efficiency coefficient of 88%–89%.

The GYCOM gyrotron and magnet were shipped from Russia and arrived at GA in August. A magnet expert from Russia came and the magnet was successfully cooled down with liquid helium and energized to nominal operating current levels. The gyrotron was installed into the magnet and fit-up to the connections of the water cooling and cryogenics systems. A short pulse load for initial testing of the gyrotron was fabricated. An expert from GYCOM of arrived at GA in October to start up the gyrotron.

6.2. 4 MW FAST WAVE UPGRADE PROJECT

The FWCD program on the DIII-D tokamak is a collaborative effort between GA and the Oak Ridge National Laboratory (ORNL), with ORNL providing the design and fabrication of the FWCD antennas and GA providing the technology to generate, transmit, and couple the high power rf to the antenna. Both parties participate in the experimental activities.

The 4 MW upgrade consists of two systems each having its own 2 MW transmitter connected to a four strap antenna by an all ceramic insulated coaxial transmission line, as shown in Fig. 6.2–1. The transmission line is

configured to provide the flexibility of adjusting the phasing of the straps for electron heating ($0, \pi, 0, \pi$) or for current drive ($0, \pi/2, \pi, 3\pi/2$), while providing matching between the antenna-plasma impedance ($\approx 1-4 \Omega$) and the 50Ω impedance that the transmitter requires for optimum power delivery. The transmission system must also compensate for the mutual inductance between the straps. This has been achieved by using a decoupler developed earlier on DIII-D.

At the beginning of the fiscal year both transmitters were installed and progressing through their installation and checkout procedures. In parallel the transmission lines between the transmitters and the two antennas at 0° and 180° were being installed. During the checkout of the transmitters three of the final power amplifier tubes were damaged and a spurious oscillation inside the final power amplifier cavity limited the pulse length and power level the transmitters could be operated. It took the transmitter manufacturer almost the full year to correct the design so that the systems could be operated at their full rated parameters.

Fig. 6.2-1. Schematic for one of the 2 MW 30-120 MHz fast wave current drive systems.

When the 0° transmission system was operated at high power levels for the first time arcing in one of the stub tuners was observed. Arcing was also detected on the insulators of the 25 ohm coaxial transmission line sections. Since the arcing repeated itself after initial repairs, it was determined that the design and material selected for these parts by our supplier was insufficient to meet our needs. Therefore all the phaseshifters and the 25 ohm coaxial components were reworked to provide higher voltage stand-off capability. Since these changes these components have not suffered arcing failures even though the power levels have been increased to the full design value of 2 MW.

The project has met its milestone objectives and is now used in physics experiments. The project is completed.

6.3. RADIATIVE DIVERTOR UPGRADE PROJECT

In the Radiative Divertor Modification Project (RDP), we are designing a new divertor for DIII-D. This is a joint GA-LLNL activity with key contributions from ORNL and other collaborators. We have used input from tokamak experiments with the present Advanced Divertor and modeling to guide the design. The RDP is designed to provide particle control and pumping for high triangularity Advanced Tokamak shaped plasmas. The RDP is also designed to reduce heat flux on the divertor plates by dispersing the power with radiation in the scrape-off-layer. As shown in Fig. 6.3-1, the baseline design includes slots and pumping at the four strikepoints of a double-null plasma. Either single- or double-null configurations can be run.

Fig. 6.3-1. The DIII-D radiative divertor is a flexible slot design.

Preliminary design of the design of the RDP was completed in FY95 and final design work started.

Due to funding limitations, a phased implementation plan was developed for the installation of the RDP. The first phase includes the upper outer baffle along with the outer cryopump and the necessary ex-vessel cryo system to support the operation. This initial phase (1a) provides pumping and particle control for the Advanced Tokamak program, while divertor characterization experiments can continue in the open low triangularity lower divertor with its excellent diagnostic set, including divertor Thomson and an absolutely calibrated EUV spectrograph. The second phase (1b) will complete the baseline installation of the double-null structure as shown in Fig. 6.3-1. Phase 1a installation is scheduled to start in October 1996 with Phase 1b slated for 1998.

This year, LLNL completed studies to optimize the performance of the design. This produced a new maximum in the reduction of core ionization current in the RDP design compared with the present open divertor. Two outstanding physics issues were addressed: (1) the effect of small changes in the shape of the tile on the outer baffle closest to the separatrix, and (2) optimization of the inner baffle tiles shape. Simulations of the modified outer baffle

tiles, which have engineering advantages compared with the reference design, showed no degradation in physics performance. Results of the inner baffle shape optimization study are shown in Fig. 6.3-2.

Fig. 6.3-2. Modeling by DEGAS and UEDGE show an optimum inner baffle penetrates past the 2 cm midplane flux line.

The preliminary design on the baffle structure was completed this year and final design started. A full size model of a portion of the lower structure was made. This model was valuable in visualizing the components and diagnostic views through the structure. The Inconel 625 material for the full structure was procured. Orders for two 90 degree prototype sectors were placed and fabrication was started. Two separate vendors were downselected after competitive quotes were obtained. Weld schedules were developed by the suppliers. Completion of the prototypes will be in FY96.

Computer models have guided the design of the tiles, particularly the slot width and length. The UEDGE fluid plasma model calculates the plasma conditions in the scrape-off-layer after comparison of data at the plasma midplane and divertor plate. The DEGAS Monte-Carlo neutrals model then calculates the neutral distribution of this (fixed) plasma solution. Results have determined the shape for the outer baffle tiles, reducing core ionization by a factor of about seven compared to an open divertor. The shape and positions of the inner baffle was optimized, further reducing the total core ionization to a factor of nine. The designs for standard tiles were developed on the CAD system. The graphite for the RDP was ordered and delivered. In addition, the hold-down hardware for the tiles was ordered and delivered.

To confirm the flow stability for the proposed vertical feedlines for the cryo pumps, a test was designed and performed. The test results confirmed that there was no effect on flow stability for the vertical feed with the two phase flow liquid helium. After completion of the test, Inconel tubing for all the pumps was ordered and received. Preliminary design of the pumps was completed and final design started. Rolling of the tubing for the helium, nitrogen, and radiation shells of the pumps was completed.

System design of the cryo system was completed and a review was held. The system supports the three new cryo pumps with two new cryostats and flexible transfer lines. This was a reduction from the original plan of three cryostats and transfer lines. This cost cutting plan allows operation of three of the four pumps with only one of the upper pumps capable of being run at a time. Switching of the upper pumps can be accomplished on an overnight basis. Components for the cryostats were ordered to allow early assembly of the pumps. Mock-ups of the cryostats and transfer lines were installed in the machine pit.

The allocation of ports for diagnostic and RDP water and cryo feeds was determined. The relocation of diagnostics was minimized in the plan. Design of some diagnostic relocations was initiated. Interfaces for diagnostic views through the structure were defined and modifications made to the design of the structure for both planned and possible future diagnostics.

6.4. VANADIUM DIVERTOR STRUCTURE

A plan for utilizing low activation vanadium alloy in DIII-D was developed in collaboration with Argonne National Laboratory (ANL) and ORNL. The goal of the plan was to demonstrate the design, fabrication, and operation of a vanadium alloy structure in the DIII-D tokamak. The plan has three phases culminating with the installation of a portion of the water-cooled RDP structure manufactured from vanadium alloy.

A review of the proposed plan was held and was endorsed by a panel of experts. The material requirements were defined and a specification for a 1200 kg ingot of V-4-Cr-4-Ti vanadium alloy ingot was written. An order was placed and melting commenced. Exposure of vanadium alloy specimens started in DIII-D to verify the compatibility of the material with the tokamak environment. Two types of exposures were made, long term (79 months) and short term (<1 week). Analysis of the specimens is being performed by ANL. Research and development of welding methods was initiated. Initial results on resistance and inertial welding were positive.

7. SUPPORT SERVICES

7.1. QUALITY ASSURANCE

Fusion Quality Assurance (QA) engineers, inspectors, and support personnel maintained a high level of activity during 1995. Significant projects supported were the E-coil solenoid buswork failure evaluation, the GYCOM (Russian) gyrotron installation, Advanced Divertor Program (ADP), the Fast Wave Current Drive (FWCD) antenna, and the Ion Cyclotron Resonant Heating System (ICRH).

7.1.1. DESIGN SUPPORT

The QA group performed the following specific jobs:

1. Provided as-built elevations of support structures and work platforms adjacent to the DIII-D device to the DIII-D design group.
2. Provided as-built measurements of Fast Wave Current Drive components to the task engineer to assist in the redesign of the components.
3. Accurately defined the centerline of the future location of the pellet injector at 60 degrees and provide relative elevation to the task engineer and technician to support the design effort.
4. Provided as-built measurements of the 60 degree and 105 degree R-O ports to the task engineer to assist in the design of the Charge Exchange Diagnostic Device.
5. Reviewed and approved all DIII-D design drawings, specifications, procedures, and procurement requisitions. Participated in design reviews and chaired the Material Review Board (MRB).

7.1.2. INSPECTION SUPPORT

1. The majority of QA activities during the year involved receiving and source inspections of purchased and fabricated material, parts, subassemblies and assemblies. Inspection activity was particularly heavy for the E-coil solenoid buswork evaluation, the DiMES project, and the FWCD antenna project.
2. QA performed hardness tests, ultrasonic NDE tests, characterized weld distortions, witnessed hydro and air pressure tests, performed borescope inspections, and verified machine setups prior to machining operations. QA also provided measurements and adjustments to various machine features, performed tubing straightness evaluations, monitored repairs and provided realignments of removed and replaced components, performed dye penetrant evaluations on the ICRH tubing, performed bench and field accuracy tests on alignment scopes for the Thompson tower, characterized Neutral Beam Injector sources grids on the Coordinate Measuring Machine (CMM), and numerous other varied inspection tasks.
3. Coordinated the visual/video inspections of the E-coil solenoid lead failure, contacted outside (contract) video inspection services, invited video equipment distributors to demonstrate various remote visual inspection equipment and arranged for the procurement of two video probes.

7.1.3. TOOLING/LAYOUT/ALIGNMENT SUPPORT

The QA group provided the following support activities for layout verification in the vicinity of DIII-D:

1. Completed the quarterly column and footing subsidence tasks, and the semi-annual pit wall crack inspections.
2. Measured the attitude and relative elevations of many DIII-D components using optical instrumentation.
3. Performed many as-built measurements of ports and port boxes to assure adequate clearances for new equipment, and verified location and orientation of equipment during and after welding.
4. Developed special tooling and optical alignment techniques to position the mirror optics unit (MOU) and waveguide run on the beam centerline of the Gycon Gyrotron.
5. Assisted GA and ORNL personnel in layout and alignment of the Oak Ridge National Lab Pettet Injector.
6. Penetrant inspected welds on special lifting equipment and monitored proof (load) test

7.1.4. QA SYSTEM IMPROVEMENTS

1. Issued Quality Assurance Program Document (QAPD) 3466. The QAPD implements the Fusion Group QA Manual, Fusion Group Procedures, and DIII-D Work Procedures on the DIII-D Program.
2. Issued the Fusion Group Procedures. The Fusion Group Procedures implement the requirements specified in the Fusion Group QA Manual.

7.1.5. OTHER SUPPORT

Additional support was provided by QA in the following areas:

1. Fusion QA personnel conducted hoisting and rigging equipment inspections, and monitored a large number of high consequence lifts.
2. QA staff also reviewed drawings, procedures, technical specifications, procurement requisitions, supplier disposition requests, material certifications, attended various design and operations meetings, expedited inspection efforts, tracked and processed incoming procurements.
3. Researched historical data on numerous occasions. Provided interested project personnel with design and as-built data on the DIII-D vessel, coils, and support structures.
4. Assisted in trouble shooting problems with the FWCD Phase Shifter Recirculating Ball Drive.

7.2. PLANNING AND CONTROL

The Planning and Control group supported operation and maintenance of the DIII-D facility. Planning and Control provided long-term program planning, as well as day-to-day scheduling (cost control, preparation of Field Work Proposals and Cost and Fee Proposals), processing of purchase requests, expediting and reporting of status. These support activities are essential to constraining the program within prescribed budgets and schedules. Our planning activities (budget, schedule, resource) enabled us to maximize the utilization of available resources for

accomplishment of program goals and were important in planning and replanning of scope, budget, and schedule with fluctuating funding levels.

Major planning activities during FY95 included work on the 4 MW ICH and radiative divertor upgrades, installation of the ORNL pellet injector, C-coil installation, diagnostic upgrades, machine operations and maintenance, and a major six-month vent.

7.3. ENVIRONMENT SAFETY AND HEALTH

7.3.1. FUSION AND DIII-D SAFETY

The fusion safety program provides for the safe operation of the DIII-D facility and for a safe working environment for employees and visitors. Special programs address high voltage and high current, high vacuum systems, ionizing radiation, microwave radiation, cryogenics and the use of power equipment and machine tools. The publication "DIII-D Safety Procedures for Facility and Equipment Operation" contains policies and procedures that must be adhered to at the DIII-D site. Fusion works closely with GA's Licensing, Safety and Nuclear Compliance organization in areas such as health physics, industrial hygiene, environmental permitting hazard communication and hazardous waste and industrial safety.

The Fusion Safety Committee provides a means of focusing on and addressing both the numerous safety issues faced daily and longer range safety needs and goals. The Fusion Safety Committee is comprised of representatives from various departments within the Fusion Group, including management, supervisors, operators, and technicians. The Safety Committee meets twice a month to address safety activities and concerns of the Fusion Group such as hazardous work requests, radiation work authorizations, accident/incident reports, near misses, equipment malfunctions, accident avoidance programs, supervisor involvement, training, inspections, access control procedures and high voltage hazards. The Safety Committee also solicits specialized help from any of the five fusion safety subcommittees during reviews of lasers, electrical systems, vacuum systems, the use of cryogenics or chemicals.

In addition to the Fusion Safety Committee's oversight of activities at DIII-D, two individuals are dedicated full-time to onsite "preventive" safety involvement. Their activities include writing and reviewing procedures, developing and conducting special training classes, conducting inspections and follow-up, maintaining chemical inventories, MSOSs and hazardous waste collection sites, interfacing and coordinating with GA's Licensing, Safety and Nuclear Compliance organization and providing continuous oversight to assure compliance with established safety policies, procedures, and regulations.

The DIII-D Emergency Response Team consists of individuals involved directly with maintenance and operation of the DIII-D equipment. They are trained in cardio-pulmonary resuscitation (CPR), first aid, use of self-contained breathing apparatus (SCBA) and the use of fire extinguishers, evacuation and crowd control and facility familiarization. The team can respond within seconds to provide immediate assistance until the company Emergency Medical Technicians (EMTs) arrive.

Safety inspections are conducted throughout the year to promote an active hazard prevention program. The inspections are conducted by a combination of Fusion, GA Licensing Safety and Nuclear Compliance personnel and outside consultants.

A report is provided to the Fusion Safety Committee where corrective action assignments are made. DIII-D inspections include:

Inspection	Frequency
Site Inspection (GA Personnel)	Monthly
Electrical Consultant	Yearly
CAL/OSHA Consulting Service	Yearly
Insurance Carrier Inspection	Yearly (Multiple)
S.D. City Fire Department CEDMAT	Yearly
GA Safety Committee Hazards Survey	Yearly
DOE-SF Safety Review Inspection	Every 2 years

The Senior Fusion Safety Officer is responsible for tracking the progress of all discrepancies and ensuring resolution.

All new employees and collaborators must go through a thorough and comprehensive safety indoctrination by the Senior Fusion Safety Officer and Pit Coordinator. They are informed of the specific potential hazards that are present daily at DIII-D and the special safety precautions and rules that apply, with specific emphasis on the areas where they will be working. Subcontractors also receive a similar indoctrination.

7.3.2. FY95 SAFETY

7.3.2.1. Training

Training is all-important to the safety of both personnel and equipment. Due to the complexity of the DIII-D site and its potential hazards, numerous safety training classes are conducted. Subjects of the classes include, but are not limited to: confined space entry, back injury prevention, radiological safety, laser safety, electrical and high voltage safety, hazard communication and hazardous waste disposal, cryogenic safety, crane and forklift operation, lockout/tagout, machine shop tool usage and basic industrial safety requirements.

7.3.2.2. Inspections/Reviews

Seven internal safety inspections of the DIII-D site were conducted by representatives from GA Safety, Fusion Safety, Fusion Management and Fusion Facilities Engineering with a total of 2782 discrepancies noted. At the close of FY95, there were zero items remaining on the discrepancy list.

The San Diego Fire Department's Combustible, Explosive and Dangerous Materials (CEDMAT) team inspected the DIII-D facility.

An outside electrical inspector was contracted to inspect the DIII-D facility for electrical discrepancies. There were 24 items that were found to need modification or improvement and at the close of FY95 all items had been corrected.

7.3.2.3. Other Activities

The Fusion Safety Committee met 10 times this fiscal year to discuss various safety issues. The Committee:

1. Reviewed and approved 24 Hazardous Work Authorizations (HWA) after appropriate recommendations and changes by the Safety Committee and select safety subcommittees and;
2. Reviewed two incidents that involved no injury, two minor first aid incidents, four accidents that required minor off-site medical treatment and one back injury. There were no lost time accidents.

A noise monitoring and hearing conservation survey was conducted at Building 34. Noise amplitude readings were also made in the noisy areas of the facility and the findings were well below the current CAL/OSHA and DOE limits.

The following DIII-D safety procedures were reviewed and updated.

1. DIII-D emergency response procedures.
2. DIII-D confined space procedure.

7.4. VISITOR AND PUBLIC INFORMATION PROGRAM

Tours of the DIII-D facilities are open to organizations and institutions interested in fusion development (colleges, schools, government agencies, manufacturers, and miscellaneous organizations). These tours are conducted on a noninterference basis and are arranged through the DIII-D tour coordinator whose responsibilities include security, arranging tour guides, and scheduling tours. During 1995 1,669 people toured DIII-D for a total of 14,621 during the last ten years.

DIII-D personnel have also taken an active role in supporting science education within the community. The partnership between the fusion group and Kearny High School included student and teacher internships, donation of surplus equipment, school visits and lectures by staff members and participation by students and teachers in GA sponsored projects. These activities, primarily undertaken by volunteers, have enriched the educational program at Kearny and in the community at large and resulted in the naming of the GA-Kearny High School partnership as the outstanding partnership in San Diego in 1995.

8. TPX PHYSICS SUPPORT

The activities of the DIII-D program in support of TPX physics development during FY95 included tasks directly associated with the TPX project, undertaken at the request of the project, as well as DIII-D experimental studies that were directly relevant to the R&D needs of TPX. Furthermore, part of the direct support comprised a scenario modeling task initiated under a new program to provide long-term physics support for TPX.

The TPX Experimental Plan for the first ten years of operation was completed. The plan included an integrated schedule of experimental campaigns, physics goals, and hardware upgrades. The key physics goals were a demonstration of a 1000 second pulse with controlled current profile at the end of the second year; demonstration of a stable, well controlled, high-performance, advanced tokamak plasma, also for 1000 s at the end of the fifth year; and demonstration of coupled AT and high power divertor operation in a configuration and with a plasma directly relevant to ITER and DEMO in the tenth year. By the end of the tenth year, TPX would have been up to the full power capability of 45 MW.

The development of a negative central shear scenario for TPX using 110 GHz ECH to maintain the off-axis peaking of the current profile was completed. The final scenario was a 1.6 MA discharge, at 3.5 T, with a normalized beta of $\beta_N = 4.8$ and 70% bootstrap current. The off-axis current peak at $r/a = 0.65$ was to be provided by 7.5 MW of ECH, driving 0.26 MA. In addition, we varied the injection angles of the EC launcher in order to illustrate the capability of such a system for easily controlling the location of the current peak, and the minimum in the q profile. Both the poloidal and toroidal angles of launch must be adjusted in order to obtain the optimum current drive efficiency.

The major effort during the second half of FY95 was the TPX Scenario Modeling task. This was part of an effort initiated by the TPX Program Advisory Committee to provide for long-term physics support by the fusion community. The focus of TPX Scenario Modeling task was on bringing DIII-D experimental data to bear on the development of operating scenarios for TPX.

In this task, we modeled four plasma scenarios. The first two were as close as possible to scenarios previously studied by the TPX group, one with normal plasma profiles (the ARIES-I scenario), and one with reversed central shear. The intent was to make contact with previous work, and to demonstrate the capabilities of the GA codes. For both cases we obtained a good match with previous work, and where differences occurred, the sources of the discrepancies are understood. We found that ray tracing is an adequate substitute for full-wave calculations in FWCD modeling. We identified a few problems with the original TPX work in this area, in particular high harmonic ion absorption should be included in the calculations — we found that third harmonic absorption negated the effectiveness of the FWCD under the original conditions. Also, from examination of the inferred thermal conductivity profiles, we note that radiation losses should be included in the modeling in order to maintain plausible conductivity profiles.

We looked in detail at two cases based on experimental DIII-D profiles. The modeled VH-mode scenario is marginally stable to kink and ballooning modes at $\beta = 2.7\%$ ($\beta_N = 3.25$), but resistive stability at $\beta = 2.2\%$ requires a rotation speed near the edge much higher than seen in the experiment. The performance is better than the ARIES-I

case, but is limited by the large edge bootstrap current. We did not complete the negative central shear case based on DIII-D profiles, because of the problem of using transient experimental data to model a steady-state, fully noninductive equilibrium. We found that attempting to maintain these profiles leads to unrealistic current drive requirements. The issue is the evolution of the negative central shear plasma toward a steady-state. Clearly further experiments are needed.

In addition to the R&D tasks outlined above, GA hosted several TPX meetings, including a regular TPX Physics meeting, a TPX PAC meeting, and a meeting on divertor diagnostics.

In relation to TPX Physics R&D, the ORNL group studied particle balance during a discharge sequence in the absence of HeGDC. Analysis indicated that the wall inventory was increased during the phase with the cryopump off by 1250 Torr-l (9×10^{22} atoms), and then reduced back down to the reference level with an active cryopump (Fig. 8-1). In the second area, the edge recycling source and global particle confinement time, τ_p , were computed for an L-mode discharge (result: $\tau_p/\tau_E \sim 2$) and compared with a previous calculation for an ELM-free H-mode discharge ($\tau_p/\tau_E \sim 4$). In addition, a new technique to compute the global particle confinement time during ELMy discharges was tested for recent DIII-D discharges; below an ELM frequency of 25 Hz, the product of ELM frequency and core particle outflux per ELM seems to be roughly constant.

Fig. 8-1. Net change in wall loading during discharge sequence without HeGDC. I.G. represents the particle balance computed using an ASDEX-type fast ionization gauge, and C.M. utilized a slower time response capacitance manometer.

9. COLLABORATIVE EFFORTS

9.1. DIII-D COLLABORATIVE PROGRAMS OVERVIEW

Although the major part of the fusion research which is carried out on DIII-D is performed by General Atomics (GA) scientists, in the last few years DIII-D has become a true national fusion research users facility. The total number of national and international collaborators on DIII-D in FY95 was over 200 including both full and part time collaborators. Through our national and international collaboration programs, DIII-D is playing a major role in the worldwide advancement of fusion research towards the goal of fusion science and energy. Our collaboration with universities and DOE national laboratories has brought new recognition to our program and broadened its scope. DIII-D international collaborations have helped the U.S. to maintain its international role as a strong contributor to ITER.

Our collaboration with Russian fusion research institutes and scientists has helped maintain an active Russian fusion program as well as providing GA and the U.S. fusion program with additional DIII-D relevant research.

The DIII-D collaborative programs have contributed to the results presented in the previous sections of this report and are discussed in more detail in the following.

9.2. LAWRENCE LIVERMORE NATIONAL LABORATORY

During 1995, LLNL participated in both the divertor and tokamak improvement parts of the DIII-D program. Significant progress was made in both areas.

LLNL occupies important roles in the design of the radiative divertor project (RDP). Several new or upgraded divertor diagnostics were installed during the year, maintaining the DIII-D status of arguably having the best-diagnosed divertor. Many of these are LLNL diagnostics (Divertor Thomson, Divertor SPRED, Tangential TV, Divertor Interferometer, and IRTV), as shown in Fig. 9.2-1. In addition, we helped with several of the other diagnostics, providing technical support and maintenance.

During 1995, the LLNL Advanced Tokamak group participated in DIII-D experiments in negative central shear (NCS) discharges with L-mode edges, and discharges with weakly negative shear (WNS). Optimization of the initial NCS discharges later yielded record neutron rates for DIII-D and very good core confinement. The LLNL motional stark effect (MSE) was key to these studies. LLNL also participated in core transport measurements and modeling, current profile measurements, and edge plasma measurements to characterize the scrape-off layer. The analysis of this data resulted in several LLNL publications.

9.3. OAK RIDGE NATIONAL LABORATORY

The ORNL collaboration during the past year included work in the Particle Control Program, the Advanced Tokamak Research Program, and the Tokamak Physics Program.

Fig. 9.2-1. LLNL installed two important divertor diagnostics on DIII-D in 1995: (1) the world's first divertor Thomson scattering system, and (2) a divertor EUV SPRED diagnostic. LLNL engineering and technicians played a key role in upgrading several others (tangential TV, bolometers and the divertor interferometer).

The ORNL main ion particle control program was focused in three main areas: (1) demonstration of the use of continuous divertor cryopump exhaust to maintain a steady "pumping" wall and good performance in the absence of Helium Glow Discharge Cleaning (HeGDC); (2) determination of the global particle confinement time for L-mode and ELMy H-mode discharges through edge plasma and neutrals modeling; and (3) hardware upgrades. In addition, collaborative analysis of late FY94 experiments demonstrated the compatibility of active fueling (by gas injectors) and active exhaust (by divertor cryopump) with high density, partially detached divertor (PDD) operation. This analysis includes divertor impurities.

Analysis of the DIII-D helium exhaust experiments in the presence of a central source of helium during ELMing H-mode plasmas gives a value of $\tau_{\text{He}}^* / \tau_E \sim 8$. This result is consistent with previous experiments in which the helium was introduced via gas puffing. These observations, coupled with other direct measurements of helium transport rates in DIII-D, suggests that the helium core transport rates will not be the limiting factor for ITER.

The ORNL repeating pellet injector was fully commissioned during FY95. All three barrels are operational. The 1.8 mm barrel can operate at 10 Hz with 2×10^{20} atoms per pellet (3 Torr-l gas equivalent); the 2.7 mm barrel at 5 Hz with 7×10^{20} atoms per pellet (9 Torr-l gas equivalent); and the 4 mm barrel at 2.5 Hz with 2×10^{21} atoms per pellet (33 Torr-l gas equivalent). Initial experiments were conducted.

The ORNL Advanced Tokamak (AT) Research activity this year has concentrated in: (1) effects of plasma shaping with VH-mode, (2) plasma startup with the re-configured E-coils, and (3) application of ICRF in fast wave and mode conversion current drive.

Experiments to study the effect of plasma shape on performance showed that the high performance levels characteristic of VH-mode plasmas are only obtained for high triangularity (δ). A characteristic difference in central

heating efficiency was observed when high and low δ plasmas are compared. This difference was found to correlate well with the attainment of Mercier stability. The core plasma for the high δ cases achieved Mercier stability when q_0 rose above a critical value, which depends on δ , providing direct access to the second-stable regime. Other attributes of the VH-mode commenced after a delay. The rise in q_0 was attributed to the radial gradients in the neutral beam and bootstrap current sources. Simulation indicated that such plasmas would persist for many seconds if the rise in density could be controlled, maintaining a centrally peaked neutral beam deposition profile.

A record rf power of 4.4 MW was injected into DIII-D in August using all three ORNL FWCD antennas. The new long-pulse FWCD antennas accounted for 75% of the record rf power, culminating several months of improvements to the transmission line components and transmitters. A new Faraday shield for the 285°/300° antenna was fabricated, sputter coated, and installed on DIII-D.

9.4. INTERNATIONAL COOPERATION

The DIII-D international collaboration program continues to provide a broad source of innovative ideas and opportunities which support the DIII-D research program. Collaborations were carried out with JET in England, ASDEX-Upgrade in Germany, Tore Supra in France and T-10 in Moscow. In addition to the benefits gained from DIII-D staff assignments in these and other laboratories, foreign scientists visiting DIII-D have made significant contributions to DIII-D program goals. A summary of the progress made by DIII-D staff members in support of the international collaboration program is given below.

9.4.1. JET (ENGLAND)

JET is a large European tokamak approximately twice the size and magnetic field strength of DIII-D. Our collaboration with JET remains the largest of our international collaborations. The main topics for this years collaborations were Fast Wave Current Drive, p_* (or size) scaling and studies of magnetic perturbations, error fields, and divertor studies. One exchange involved the participation in fast wave current drive (FWCD) experiments and the installation at JET of the method for analyzing the loop voltage that was first developed at DIII-D. Discussions were also held with JET scientists concerning the p_* scaling on JET versus DIII-D. In conjunction with GA, LLNL participated in an exchange to model divertor and edge plasmas with UEDGE and to compare the results with JET code results.

9.4.2. ASDEX-UPGRADE (GERMANY)

Three major exchanges were completed with ASDEX-U: modeling of impurity transport in the plasma edge; investigation of the effect of ELMs on the divertor plasma; and participation in the initial plasma experiments with electron cyclotron heating (ECH) on ASDEX. The NEWT1D code was used to model the boron transport with plasma conditions similar to the ASDEX Upgrade discharges during the boron spectroscopy campaign.

9.4.3. TEXTOR (GERMANY)

In collaboration with KFA, Jülich, Germany, a new colorimetry diagnostic was installed and operated on DIII-D. Colorimetry measures changes in thickness of *in-situ* films, and hence erosion and deposition of plasma facing surfaces. Two types of experiments were performed. First, film thickness was determined as a function of time

for two boronizations by exposing a silicon sample on the face of a DiMES probe. Deposition rates determined by these measurements were used to improve the boronization process. The second set of experiments used carbon films deposited on two DIMES probes by KFA Jülich.

9.4.4. TORE SUPRA (FRANCE)

Dr. Xavier Garbet and Dr. Pascale Monier-Garbet completed a one year exchange at DIII-D. Dr. Xavier Garbet worked on transport issues and Dr. Pascale Monier-Garbet worked on Charge Exchange Recombination Spectroscopy.

Two exchanges were held this year at Tore Supra. The main topic for both was study of the control of current density profiles, utilizing Lower Hybrid Current Drive and dynamic plasma shape control.

9.4.5. JT60-U (JAPAN)

The DIII-D U.S./Japan Steering Committee exchange was held at General Atomics. Tokamak physics of interest to both sides was discussed with regard to the DIII-D/JAERI exchange program. The main topics of interest were, high triangularity, Negative Central Shear and High Beta Poloidal. Plans are under way for using the GA designed combine ICRF antenna on JFT-2M. This year high triangularity experiments were performed on JT60-U. The plasma shaping scenario for these experiments was proposed two years ago at JT60-U by Tony Taylor as part of a JT-60U exchange. The experiments showed an increase in achievable normalized beta as the triangularity was increased.

Dr. Kawano from JT60-U completed his six month stay at DIII-D. He analyzed results from negative central shear plasmas. Dr. N. Isei, who is at DIII-D for one year working in the area of disruptions, is presently investigating the possibility of using ECE diagnostics for analyzing disruptions.

9.4.6. ITALY

Dr. Paolo Micozzi from the ENEA fusion lab at Frascati, Italy, completed a two month exchange working on the effect of geodesic curvature on plasma stability and the attainment of high performance.

9.4.7. RUSSIA

Four Russian scientists from the Kurchatov Institute T-10 group visited DIII-D. The primary areas of exchange were ECH and ECCD experiments on T-10 and X-ray spectroscopy on DIII-D. Our contract with Kurchatov Institute to perform gyrotron based ECH and ECCD experiments on T-10 was extended into next year.

DIII-D has an exchange program with the TRINITI lab at Troitsk, near Moscow. The main topics are: materials for plasma facing components such as graphite with boron and silicon carbide coatings; plasma and divertor spectroscopy; and the use of the Russian developed DINA code for modeling dynamic plasma behavior.

GA is contracting with Moscow State University to support more than ten Russian theorists to perform theoretical analyses of plasma physics problems of relevance to understanding the performance of DIII-D. Included among these are transport and MHD stability modeling of DIII-D, modeling of current drive techniques, L- H-mode

theories and studies of divertor transport. Several of these theorists visited GA in 1995 for discussions with their GA colleagues.

9.4.8. NETHERLANDS

Dr. Joop Konings from F.O.M. in the Netherlands is on a one year exchange working with DIII-D. His primary interest is performing transport modeling of DIII-D plasmas.

9.4.9. CHINA

This year we had four scientists from Southwestern Institute of Physics and the Institute of Plasma Physics, SINICA for six month exchanges and a few others for shorter exchanges. These exchanges have concentrated in the area of the Thomson scattering diagnostic with other work in reactor studies and ECH.

10. FY95 PUBLICATIONS

- Allen, J.C., R.W. Callis, W.P. Cary, R. O'Neill, "Russian 110 GHz Gyrotron Control System," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 167.
- Allen, S.L., A.S. Bozek, N.H. Brooks, D.A. Buchenauer, K.H. Burrell, T.N. Carlstrom, J.W. Cuthbertson, J.C. DeBoo, R. Ellis, J.C. Evans, T.E. Evans, "Recent DIII-D Divertor Research," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, July 3–7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22091 (1995).
- Allen, S.L., N.H. Brooks, R.B. Campbell, M.E. Fenstermacher, D.N. Hill, A.W. Hyatt, D. Knoll, C.J. Lasnier, E.A. Lazarus, A.W. Leonard, S.I. Lippmann, M.A. Mahdavi, R. Maingi, W. Meyer, R.A. Moyer, T.W. Petrie, G.D. Porter, M.E. Rensink, T. Rognlien, M.J. Schaffer, J.P. Smith, G.M. Staebler, R.D. Stambaugh, W.P. West, and R.D. Wood, "Development of a Radiative Divertor for DIII-D," Proc. 11th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 23–27, 1994, Mito, Japan [J. Nucl. Mater. **220–222**, 336 (1995)]; and General Atomics Report GA-A21714 (1994).
- Allen, S.L., M.E. Fenstermacher, D.N. Hill, A.W. Hyatt, B. Johnson, D.J. Lasnier, A.W. Leonard, R. Maingi, M.A. Mahdavi, T.W. Petrie, G.D. Porter, M.E. Rensink, T. Rognlien, M.J. Schaffer, J.P. Smith, R.D. Stambaugh, T.S. Taylor, W.P. West, R.D. Wood, "Progress in Radiative Divertor Design for DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1832 (1995) (Abstract).
- Anderson, P.M., "TPX Divertor Design," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 120.
- Anderson, P.M., "Tokamak Physics Experiment Divertor Design," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22170 (1996).
- Austin, M.E., R.F. Ellis, R.A. James, T.C. Luce, "Wall Reflectivity for Electron Cyclotron Frequencies in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1789 (1995) (Abstract).
- Baggest, D., S. Pang, D. Rothweil, M. Walker, and A. Nerem, "Improving Plasma Shaping Accuracy Through Consolidation of Control Model Maintenance, Diagnostic Calibration, and Hardware Change Control," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 209.
- Baggest, D.S., D.A. Rothweil, S. Pang, M.L. Walker, A. Nerem, "Improving Plasma Shaping Accuracy Through Consolidation of Control Model Maintenance, Diagnostic Calibration, and Hardware Change Control," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22199 (1996).
- Baker, D.R., and G.L. Jackson, "Analysis of Particle Transport Barrier in DIII-D Elm Free H-mode Plasmas," Bull. Am. Phys. Soc. **40** (No. 11), 1790 (1995) (Abstract).

- Baxi, C.B., "Comparison of Swirl Tube and Hypervapotron for Cooling of ITER High Heat Flux Components," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 94.
- Baxi, C.B., "Comparison of Swirl Tube and Hypervapotron for Cooling of ITER," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22175 (1996).
- Baxi, C.B., E.E. Reis, K. Redler, E. Chin, R. Boonstra, K.M. Schaubel, P.A. Anderson, E. Hoffmann, "Thermal Hydraulic Analysis of the TPX Plasma Facing Components," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 150.
- Baxi, C.B., E.E. Reis, K.M. Redler, E.E. Chin, R.H. Boonstra, K.M. Schaubel, P.M. Anderson, E.H. Hoffmann, "Thermal Hydraulic Analysis of the TPX Plasma Facing Components," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22168 (1996).
- Bozek, A.S., C.B. Baxi, J.V. DelBene, G.J. Laughon, E.E. Reis, H.D. Shatoff, and J.P. Smith, "Engineering Design of Cryocondensation Pumps for the DIII-D Radiative Divertor Program," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 213.
- Bozek, A.S., C.B. Baxi, J.V. DelBene, G.J. Laughon, E.E. Reis, H.D. Shatoff, and J.P. Smith, "Engineering Design of Cryocondensation Pumps for the DIII-D Radiative Divertor Program," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22151 (1996).
- Broesch, J.D., "A Digital Long-Pulse Integrator," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 114.
- Broesch, J.D., E.J. Strait, R.T. Snider, M.L. Walker, "A Digital Long Pulse Integrator," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22218 (1996).
- Brooks, N.H. and S.N. Tugarinov, A.A. Oleinikov, "Ion Temperature Measurements in the DIII-D Divertor During Experiments with Strong Gas Puffing," Bull. Am. Phys. Soc. 40 (No. 11), 1832 (1995) (Abstract).
- Brown, L.C., K.K. Boline, C.R. Gibson, M.J. Hansink, and G.J. Laughon, "Moving Cryostat Target Insertion System for the OMEGA Upgrade ICF Laser," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 67.
- Buchenauer, D., T.W. Petrie, C.J. Lasnier, D.N. Hill, S.L. Allen, A.W. Leonard, J.W. Cuthbertson, and R. Maingi, "Characterization of Divertor Plasma Detachment in DIII-D," Bull. Am. Phys. Soc. 40 (No. 11), 1832 (1995) (Abstract).
- Burrell, K.H., M.E. Austin, T.N. Carlstrom, S. Coda, E.J. Doyle, P. Gohil, R.J. Groebner, J. Kim, R.J. La Haye, L.L. Lao, J. Lohr, R.A. Moyer, T.H. Osborne, W.A. Peebles, C.L. Rettig, T.L. Rhodes, D.M. Thomas, "H-Mode and VH-Mode Confinement Improvement in DIII-D: Investigations of Turbulence, Local Transport, and Active Control of the Shear in the E×B Flow," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 1, 221 (1995)]; and General Atomics Report GA-A21833 (1994).

- Burrell, K.H., E.J. Strait, L.L. Lao, M.E. Mauel, B.W. Rice, T.S. Taylor, T.A. Casper, B.W. Stallard, E.A. Lazarus, T.H. Osborne, "Core Transport Barrier Development in Reversed Magnetic Shear Discharges in DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1786 (1995) (Abstract).
- Callis, R.W., W.P. Cary, R. O'Neill, J.C. Allen, T.E. Harris, J.S. deGrassie, S.W. Ferguson, F.W. Baity, G. Barber, J. Tooker, D.A. Phelps, "Upgrade of the DIII-D RF System," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 174.
- Callis, R.W., W.P. Cary, R.C. O'Neill, J.C. Allen, T.E. Harris, J.S. deGrassie, S.W. Ferguson, F.W. Baity, G.C. Barber, J.F. Tooker, D.A. Phelps, "Upgrade of the DIII-D RF Systems," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22145 (1996).
- Carlstrom, T.N., "Study of the Conditions for Spontaneous H-mode Transitions in DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1804 (1995) (Invited Abstract).
- Carlstrom, T.N., D.J. Campbell, J.G. Cordey, J.C. DeBoo, R.J. Groebner, E. Righi, G. Sailbene, D.P. Schissel, D. Start, K. Thomsen, "JET/DIII-D Size Scaling of the H-Mode Power Threshold," to be published in *Proc. International Atomic Energy Agency Meeting on H-Mode Physics*, September 18–20, 1995, Princeton, New Jersey; and General Atomics Report GA-A22205 (1995).
- Cary, W.P., F.W. Baity, G. Barber, R.W. Callis, J.S. deGrassie, S.W. Ferguson, T.E. Harris, R. O'Neill, R.I. Pinsker, "4 MW Upgrade to DIII-D FWCD System: System Commissioning and Initial Operation," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 207.
- Cary, W.P., F.W. Baity, G.C. Barber, R.W. Callis, J.S. deGrassie, S.W. Ferguson, T.E. Harris, R.C. O'Neill, R.I. Pinsker, "4 MW Upgrade to DIII-D FWCD System: System Commissioning and Initial Operation," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22161 (1996).
- Casper, T.A., M.S. Chu, P. Gohil, W.W. Heidbrink, A.W. Hyatt, R.A. James, R. Jong, L.L. Lao, M. Makowski, W. Meyer, P.A. Politzer, G.D. Porter, B.W. Rice, H. St. John, B.W. Stallard, E.J. Strait, S.J. Thompson, A.D. Turnbull and D. Wroblewski, "Fluctuations in High β_p Plasmas in DIII-D," *Proc. 21st European Conference on Controlled Fusion and Plasma Physics*, June 27–July 1, 1994, Montpellier, France [European Physical Society, Petit-Lancy, Switzerland **18B** (Part I) 190 (1994)]; and General Atomics Report GA-A21750 (1994).
- Casper, T.A., J.A. Crotinger, S.W. Haney, J.M. Moller, L.D. Pearlstein, B.W. Rice, B.W. Stallard, and T.S. Taylor, "Time Dependent Modeling of Reversed Central Shear Experiments on DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1787 (1995) (Abstract).
- Chan, V.S., R.L. Miller, S.C. Chiu, and A.D. Turnbull, "Radiofrequency Wave Heating and Current Drive in Low Aspect Ratio Tokamaks," *Bull. Am. Phys. Soc.* **40** (No. 11), 1788 (1995) (Abstract).
- Chin, E., and E.E. Reis, "Elastic-Plastic-Creep Analyses of Brazed Carbon-Carbon/OFHC Divertor Tile Concepts for TPX," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 150.
- Chin, E., and E.E. Reis, "Elastic-Plastic-Creep Analyses of Brazed Carbon-Carbon/OFHC Divertor Tile Concepts for TPX," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22180 (1996).

- Chiu, S.C., J.S. deGrassie, R.W. Harvey, V.S. Chan, Y.R. Lin-Liu, R.D. Stambaugh, H. Ikezi, T.K. Mau, W.W. Heidbrink, "Interaction of Fast Waves with Ions," to be published in Proc. 11th Topical Conference on Radio Frequency Power in Plasmas, May 17-19, 1995, Palm Springs, California; and General Atomics Report GA-A22062 (1995).
- Chiu, S.C., R.W. Harvey, J.S. deGrassie, V.S. Chan, Y.R. Lin-Liu, R.D. Stambaugh, T.K. Mau, "Interaction Between Energetic Ions and Fast Waves," Bull. Am. Phys. Soc. **40** (No. 11), 1838 (1995) (Abstract).
- Chiu, S.C., C.F.F. Karney, T.K. Mau, and Y.R. Lin-Liu, "Theory of Current Drive by Parallel Acceleration of Electrons in a Weakly Relativistic Plasma," Phys. Plasma **2** (2) 450 (1995); and General Atomics Report GA-A21599 (1994).
- Chu, M.S., J.M. Greene, L.L. Lao, R.L. Miller, A. Bondeson, "Rotation Stabilization of Advanced Tokamaks," Bull. Am. Phys. Soc. **40** (No. 11), 1645 (1995) (Abstract).
- Coda, S., M. Porkolab, K.H. Burrell, "Edge Turbulence Measurements During the L- to H-Mode Transition by Phase Contrast Imaging on DIII-D," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, July 3-7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22086 (1995).
- Coda, S., M. Porkolab, and K.H. Burrell, "A Study of Edge Turbulence by Phase Contrast Imaging on DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1836 (1995) (Abstract).
- Cummings, J.W., and P.A. Thurgood, "A UNIX Based SCADA Software Package for the Machine Control and Neutral Beam Computers at DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 212.
- DIII-D Education Team, "Advancing Precollege Science and Mathematics Education in San Diego County," Bull. Am. Phys. Soc. **40** (No. 11), 1690 (1995) (Abstract).
- deGrassie, J.S., F.W. Baity, S.W. Ferguson, C.B. Forest, R.H. Goulding, H. Ikezi, R.I. Pinsker, "ELM Driven Variation in the Fast Wave Antenna Loading on DIII-D and Techniques for Transmitter Protection," Bull. Am. Phys. Soc. **40** (No. 11), 1837 (1995) (Abstract).
- deGrassie, J.S., C.C. Petty, R.I. Pinsker, C.B. Forest, H. Ikezi, R. Prater, F.W. Baity, R.W. Callis, W.P. Cary, S.C. Chiu, E.J. Doyle, "Fast Wave Current Drive on DIII-D," to be published in Proc. 11th Topical Conference on Radio Frequency Power in Plasmas, May 17-19, 1995, Palm Springs, California; and General Atomics Report GA-A22039 (1995).
- Doyle, E.J., K.H. Burrell, W.A. Peebles, C.L. Rettig, and T.L. Rhodes, "Investigation of Turbulence Asymmetries Across the L to H Transition on DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1836 (1995) (Abstract).
- Duong, H.H., R.V. Budney, R.K. Fisher, N.N. Gorelenkov, J.M. McChesney, S.S. Medley, P.B. Parks, M.P. Petrov, "The Effect of Toroidal Field Ripple on Confined Alphas in TFTR," Bull. Am. Phys. Soc. **40** (No. 11), 1672 (1995) (Abstract).
- Evans, T.E., M.E. Fenstermacher, M.A. Mahdavi, W.H. Meyer, G.D. Porter, G.T. Sager, W.P. West, "Monte-Carlo Impurity Transport Simulations in the Edge of the DIII-D Tokamak Using the MCI Code," to be published in Proc. 10th International Conference on Stellarators, May 22-26, 1995, Madrid, Spain; and General Atomics Report GA-A22064 (1995).

- Evans, T.E., C.J. Lasnier, D.N. Hill, A.W. Leonard, M.E. Fenstermacher, T.W. Petrie, and M.J. Schaffer, "Measurements of Non-Axisymmetric Effects in the DIII-D Divertor," Proc. 11th International Conference on Plasma Surface Interactions in Fusion Devices, May 23-27, 1994, Mito, Japan [J. Nucl. Mater. **220-222**, 235 (1995)]; and General Atomics Report GA-A21707 (1994).
- Evans, T.E., G.T. Sager, M.E. Fenstermacher, D.G. Whyte, M.A. Mahdavi, G.D. Porter, W.P. West, "Intrinsic Carbon Transport Studies in DIII-D Plasmas Using the Monte-Carlo Impurity (MCI) Code," Bull. Am. Phys. Soc. **40** (No. 11), 1834 (1995) (Abstract).
- Fagaly, R.L., L.C. Brown, R.B. Stephens and M. Wittman, "Inertial Confinement Fusion Target Insertion via Augmented Mass Free Fall," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 67.
- Fagaly, R.L., L.C. Brown, R.B. Stephens and M.D. Wittman, "Inertial Confinement Fusion Target Insertion Via Augmented Mass Free Fall," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22182 (1996).
- Ferguson, S.W., R.W. Callis, W.P. Cary, T.E. Harris, and J.C. Allen, "RF Power Diagnostics and Controls on the DIII-D, 4 MW, 30-120 MHz Fast Wave Current Drive System," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 210.
- Ferguson, S.W., R.W. Callis, W.P. Cary, T.E. Harris, and J.C. Allen, "RF Power Diagnostics and Control on the DIII-D, 4 MW 30-120 MHz Fast Wave Current Drive System (FWCD)," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22172 (1996).
- Ferguson, S.W., R.W. Callis, W.P. Cary, D.A. Phelps, and D. Ponce, "High Voltage Performance of RF Transmission Line Components on the DIII-D Fast Wave Current Drive System," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 207.
- Ferguson, S.W., R.W. Callis, W.P. Cary, D.A. Phelps, D. Ponce, F.W. Baity, and G. Barber, "RF High Voltage Performance of RF Transmission Line Components on the DIII-D Fast Wave Current Drive (FWCD) System," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22188 (1996).
- Ferron, J.R., L.L. Lao, T.H. Osborne, O. Sauter, E.J. Strait, T.S. Taylor, S.J. Thompson, and A.D. Turnbull, "The Effect of the Edge Current Density on Confinement and Kink Mode Stability in H-Mode and VH-Mode Discharges," Proc. 21st European Conference on Controlled Fusion and Plasma Heating, June 27-July 1, 1994, Montpellier, France [European Physical Society, Petit-Lancy, Switzerland **18B** (Part I) 86 (1994)]; and General Atomics Report GA-A21737 (1994).
- Ferron, J.R., B. Penaflor, M. Walker, J. Moller, D. Butner, "A Flexible Software Architecture for Tokamak Discharge Control Systems," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 210.
- Ferron, J.R., B. Penaflor, M.L. Walker, J. Moller, D. Butner, "A Flexible Software Architecture for Tokamak Discharge Control Systems," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22160 (1996).

- Ferron, J.R., M.L. Walker, J. Broesch, C.B. Forest, D.A. Humphreys, A.W. Hyatt, J. Leuer, B. Penaflor, J.T. Scoville, T.S. Taylor, M. Brown, D. Butner, J. Moller, B.W. Rice, "Improved Shape and Position Control for DIII-D Using Real Time Digital Analysis," *Bull. Am. Phys. Soc.* **40** (No. 11), 1791 (1995) (Abstract).
- Fisher, R.K., R.V. Budney, H.H. Duong, N.N. Gorenlenkov, J.M. McChesney, D.K. Mansfield, S.S. Medley, P.B. Parks, M.P. Petrov, M.H. Redi, A.L. Roquemore, "Alpha Particle Studies in TFTR Using the Pellet Charge Exchange Diagnostic," *Bull. Am. Phys. Soc.* **40** (No. 11), 1671 (1995) (Abstract).
- Forest, C.B., K. Kupfer, T.C. Luce, P.A. Politzer, L.L. Lao, and D. Wroblewski, "A Method for Measuring the Inductive Electric Field Profile and Noninductive Current Profiles on DIII-D," *Proc. 21st European Conference on Controlled Fusion and Plasma Heating*, June 27–July 1, 1994, Montpellier, France [European Physical Society, Petit-Lancy, Switzerland **18B** (Part III) 1146 (1994)]; and General Atomics Report GA-A21747 (1994).
- Forest, C.B., C.C. Petty, B.W. Rice, R. Prater, R.I. Pinsker, F.W. Baity, S.C. Chiu, J.S. deGrassie, K. Kupfer, "Experimentally Determined Profiles of Fast Wave Current Drive on DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1646 (1995) (Abstract).
- Forest, C.B., C.C. Petty, F.W. Baity, S.C. Chiu, J.S. deGrassie, R.J. Groebner, H. Ikezi, E.F. Jaeger, K. Kupfer, M. Murakami, R.I. Pinsker, "Experimentally Determined Profiles of Fast Wave Current Drive on DIII-D," to be published in *Proc. 11th Topical Conference on Radio Frequency Power in Plasmas*, May 17–19, 1995, Palm Springs, California; and General Atomics Report GA-A22048 (1995).
- Gohil, P., K.H. Burrell, A.B. Hassam, T.H. Osborne, "Energy and Angular Momentum Transport During On- and Off-Axis NBI in the DIII-D Tokamak," *Bull. Am. Phys. Soc.* **40** (No. 11), 1790 (1995) (Abstract).
- Gootgeld, A.M., "Cooling Water Conditioning and Quality Control for Tokamak," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 206.
- Gootgeld, A.M., "Cooling Water Conditioning & Quality Control For Tokamak," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22152 (1996).
- Greenfield, C.M., J.C. DeBoo, K.H. Burrell, P. Gohil, "Modification of the Toroidal Rotation Profile by Plasma Shaping in DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1789 (1995) (Abstract).
- Groebner, R.J., M.E. Austin, K.H. Burrell, T.C. Carlstrom, S. Coda, E.J. Doyle, P. Gohil, J. Kim, R.J. La Haye, C.L. Hsieh, L.L. Lao, J. Lohr, R.A. Moyer, C.L. Rettig, T.H. Rhodes, G.M. Staebler, R.E. Stockdale, D.M. Thomas, and J.G. Watkins, "Evidence for Modified Transport Due to Sheared $E \times B$ Flows in High-Temperature Plasmas," *Proc. International Conference on Plasma Physics*, October 31–November 4, 1994, Foz do Iguacu, Brazil, (1994) p. 74; and General Atomics Report GA-A21872 (1994).
- Groebner, R.J., T.N. Carlstrom, K.H. Burrell, P. Gohil, and J. Kim, "Correlation of H-mode Transition with Local Edge Parameters in DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1646 (1995) (Abstract).
- Harris, J.J., J.D. Broesch, R.M. Coon, "A Combined PLC and CPU Approach to a Multiprocessor Control," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 210.
- Harris, J.J., J.D. Broesch, R.M. Coon, "A Combined PLC and CPU Approach to Multiprocessor Control," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22196 (1996).

- Harris, T.E., J.C. Allen, W.P. Cary, S.W. Ferguson, C.C. Petty, and R.I. Pinsker, "System Control and Data Acquisition of the Two New FWCD RF Systems at DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 210.
- Harris, T.E., J.C. Allen, W.P. Cary, S.W. Ferguson, C.C. Petty, and R.I. Pinsker, "System Control and Data Acquisition of the Two New FWCD RF Systems at DIII-D," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22212 (1996).
- Harvey, R.W., O. Sauter, K. Kupfer, "Parallelization of the FPET Fokker-Planck Edge Transport Code; Coupled Electron-Ion Distributions," Bull. Am. Phys. Soc. **40** (No. 11), 1835 (1995) (Abstract).
- Heidbrink, W.W., "Beam-Driven Chirping Instability in DIII-D," to be published in Plasma Physics and Controlled Fusion; and General Atomics Report GA-A21988 (1995).
- Heidbrink, W.W., "Experimental Aspects of Effects of High-Energy Particles on Alfvén Modes," Proc. European Theory of Fusion Plasmas Conference, August 22–26, 1994, Varenna, Italy, (1994) p. 49; and General Atomics Report GA-A21811 (1994).
- Heidbrink, W.W., E.M. Carolipio, R.A. James, E.J. Strait, "Summary of Recent Studies of Beam-Driven BAE and Chirping Modes in DIII-D," Nucl. Fusion **35** (12) 1481 (1995); and General Atomics Report GA-A22040 (1995).
- Henline, P.A., "Improved Operating Scenarios of the DIII-D Tokamak as a Result of the Addition of UNIX Computer Systems," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 212.
- Henline, P.A., "Improved Operating Scenarios of the DIII-D Tokamak as a Result of the Addition of UNIX Computer Systems," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22146 (1996).
- Hill, D.N., S.L. Allen, N.H. Brooks, D. Buchenauer, J.W. Cuthbertson, T.E. Evans, M.E. Fenstermacher, Ph. Ghendrih, D.L. Hillis, J.T. Hogan, A.W. Hyatt, G.L. Jackson, R.A. James, R. Jong, C.J. Lasnier, A.W. Leonard, M.A. Mahdavi, R. Maingi, M.M. Menon, P.K. Mioduszewski, R.A. Moyer, T.W. Petrie, G.D. Porter, M.E. Rensink, M.J. Schaffer, G.M. Staebler, D.M. Thomas, M.R. Wade, J.G. Watkins, F. Weschenfelder, W.P. West, D. Whyte, R. Wood, "Divertor Research on the DIII-D Tokamak," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 1, 499 (1995)]; and General Atomics Report GA-A21851 (1994).
- Hillis, D.L., M.R. Wade, D.G. Whyte, W.P. West, R.J. Groebner, "Low-Z Impurity Transport and Accumulation in Enhanced Confinement Regimes in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1790 (1995) (Abstract).
- Hinton, F.L., and Y.B. Kim, "The Ion Temperature Pedestal in H-mode Plasmas," Bull. Am. Phys. Soc. **40** (No. 11), 1652 (1995) (Abstract).
- Hinton, F.L., M.N. Rosenbluth, "The Mechanism for Toroidal Momentum Input to Tokamak Plasmas from Neutral Beams," to be published in Nucl. Fusion; and General Atomics Report GA-A22075 (1995).
- Hodapp, T.R., J.D. Broesch, J.A. Leuer, R.T. Snider, E.J. Strait, "Magnetic Diagnostics for Future Tokamaks," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 116.

- Hodapp, T.R., J.D. Broesch, J.A. Leuer, R.T. Snider, E.J. Strait, "Magnetic Diagnostics for Future Tokamaks," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22195 (1996).
- Hoffmann, E., C.B. Baxi, J. Bialek, E. Chin, K. Redler, and E.E. Reis, "Design of the Inboard Passive Stabilizer for TPX," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 151.
- Hoffmann, E., R. Boonstra, C.B. Baxi, J. Bialek, E. Chin, L. Drees, W. Lee, K.L. Redler, and E.E. Reis, "Design of the Inboard Passive Stabilizer for TPX," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22148 (1996).
- Hollerbach, M.A., J.P. Smith, E. Chin, and H. Shatoff, "Design and Analysis of a Radiative Divertor for Use in DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 205.
- Hollerbach, M.A., J.P. Smith, C.B. Baxi, A.S. Bozek, E. Chin, R.D. Phelps, K.M. Redler, and E.E. Reis, "Design and Analysis of the DIII-D Radiative Divertor Water-Cooled Structures," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22208 (1996).
- Howald, A.M., J.M. McChesney, and W.P. West, "The TEXT Neutral Lithium Beam Edge Density Diagnostic," Proc. 10th Topical Conference on High-Temperature Plasma Diagnostics, May 8–12, 1994, Rochester, New York; Rev. Sci. Instrum. **66** (1), 312 (1995); and General Atomics Report GA-A21711 (1994).
- Hsieh, C., J.C. DeBoo, C.M. Greenfield, R.J. LaHaye, J.R. Luo, T.H. Osborne, D.P. Schissel, H.E. St. John, R.E. Stockdale, T.S. Taylor, "A Heat Transport Model Based on Experimental Observations for Tokamak Plasmas with Auxiliary Heating," Bull. Am. Phys. Soc. **40** (No. 11), 1790 (1995) (Abstract).
- Humphreys, D.A., J.A. Crotinger, S.W. Haney, A.G. Kellman, R.R. Khayrutdinov, V.E. Lukash, L.D. Pearlstein, and M.L. Walker, "Time-Dependent Simulation of DIII-D Plasma Evolution and Control Scenarios," Bull. Am. Phys. Soc. **40** (No. 11), 1791 (1995) (Abstract).
- Hyatt, A.W., R.L. Lee, P.L. Taylor, J.W. Cuthbertson, D.A. Humphreys, A.G. Kellman, C.J. Lasneir, "Magnetic and Thermal Flow During Disruptions in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1792 (1995) (Abstract).
- Ikezi, H., J.S. deGrassie, D.A. Phelps, "Designs for the Conversion of an ICH Antenna to a Traveling Wave Antenna on the DIII-D Tokamak," Bull. Am. Phys. Soc. **40** (No. 11), 1838 (1995) (Abstract).
- Ikezi, H., D.A. Phelps, "Traveling Wave Antenna for Fast Wave Heating and Current Drive in Tokamaks," to be published in Fusion Tech.; and General Atomics Report GA-A21993 (1995).
- Ikezi, H., R.I. Pinsker, S.C. Chiu, J.S. deGrassie, "Experimental Studies of Fast Wave Propagation in DIII-D," to be published in Proc. 11th Topical Conference on Radio Frequency Power in Plasmas, May 17–19, 1995, Palm Springs, California; and General Atomics Report GA-A22057 (1995).
- Ikezi, H., R.I. Pinsker, S.C. Chiu, J.S. deGrassie, "Fast Wave Propagation Studies in the DIII-D Tokamak," to be published in Phys. Plasmas; and General Atomics Report GA-A22017 (1995).

- Jackson, G.L., D.R. Baker, K.L. Holtrop, S. Konoshima, R. Maingi, G.M. Staebler, W.P. West, "Effects of Particle Fueling and Plasma Wall Interactions on DIII-D Discharges," Proc. 11th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 23-27, 1994, Ibaraki-Ken, Japan; and General Atomics Report GA-A21716 (1994).
- Jackson, G.L., F. Weschenfelder, N.H. Brooks, W.P. West, D.G. Whyte, and J. Winter, "Erosion in the DIII-D Divertor Measured by Colorimetry," Bull. Am. Phys. Soc. **40** (No. 11), 1834 (1995) (Abstract).
- James, R.A., C.C. Petty, R.W. Harvey, "A Comparison of Fundamental and Second Harmonic Inside Launch ECCD in the Presence of a dc Electric Field," to be published in Proc. 9th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Heating Conference, January 23-26, 1995, Borrego Springs, California; and General Atomics Report GA-A21994 (1995).
- Jensen, T.H., R.J. La Haye, A.W. Hyatt, "A Nonlinear Model for the Singular Surface Response," to be published in Phys. Plasmas; and General Atomics Report GA-A21996 (1995).
- Jensen, T.H., R.L. Miller, Y.R. Lin-Liu, "Pressure Driven Tokamaks," Bull. Am. Phys. Soc. **40** (No. 11), 1787 (1995) (Abstract).
- Jong, R.A., G.D. Porter, R.J. Groebner, C.J. Lasnier, D.M. Thomas, GA Thomson Team, "Evolution of Scrape-Off-Layer Plasmas in VH-mode Plasmas in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1833 (1995) (Abstract).
- Junge, R.N., C. Dahms, and G.W. Silke, "Remotely-Operated Tube Cutters for TPX," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 158.
- Kellman, A., for the DIII-D Team, "Recent Results from the DIII-D Tokamak," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 173.
- Kellman, A.G., for the DIII-D Team, "Recent Results From the DIII-D Tokamak," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22207 (1996).
- Kessler, D.N., R. Hong, and S.P. Riggs, "A New Technique to Measure the Neutralizer Cell Gas Line Density Applied to a DIII-D Neutral Beamline," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 208.
- Kessler, D.N., R.-M. Hong, S.P. Riggs, "A New Technique to Measure the Neutralizer Cell Gas Line Density Applied to a DIII-D Neutral Beamline," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22149 (1996).
- Kim, J., K.H. Burrell, R.J. Groebner, G.M. Staebler, P. Gohil, R.P. Seraydarian, "Evolution of Main Ion Pressure Gradient and Poloidal Rotation Across L-H Transition in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1836 (1995) (Abstract).
- Kim, J.S., J.M. Greene, and M.S. Chance, "Proper Treatment of Tokamak Data by Singular Value Decomposition," Bull. Am. Phys. Soc. **40** (No. 11), 1653 (1995) (Abstract).
- Kim, Y.-B., R.E. Waltz, "General Gyrokinetic Stability in Solov'ev Equilibria," Bull. Am. Phys. Soc. **40** (No. 11), 1652 (1995) (Abstract).

- Knighton, K.E., "Distributed Timing System Control for DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 211.
- La Haye, R.J., "Calculation of the Impact of $n=1$ Error Fields on the Divertor Heat Loading of the Tokamak Physics Experiment," Fusion Technology **29**, 126 (1996); and General Atomics Report GA-A21341 (1993).
- La Haye, R.J., L.L. Lao, E.J. Strait, and T.S. Taylor, " $m/n=2/1$ Rotating Mode Limit on Steady High Beta Tokamak Operation," Bull. Am. Phys. Soc. **40** (No. 11), 1788 (1995) (Abstract).
- La Haye, R.J., T.H. Osborne, C.L. Rettig, C.M. Greenfield, A.W. Hyatt, and J.T. Scoville, "Core Flow Shear as the Cause of Very High Confinement in the DIII-D Tokamak," Nucl. Fusion **35**, 988 (1995); and General Atomics Report GA-A21544 (1994).
- La Haye, R.J., J.T. Scoville, "Use of an $M=2$, $N=1$ Static Error Field Correction Coil, 'The C-Coil,' on DIII-D to Avoid Disruptive Locked Modes," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, June 3–7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22033 (1995).
- Lao, L.L., "Rotational and Magnetic Shear Stabilization of MHD Modes and Turbulence in DIII-D High Performance Discharges," Bull. Am. Phys. Soc. **40** (No. 11), 1829 (1995) (Invited Abstract).
- Laughon, G.J., "Inertial Confinement Fusion Target Insertion Concepts for the National Ignition Facility," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 69.
- Lazarus, E.A., and A.W. Hyatt, "Plasma Startup in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1791 (1995) (Abstract).
- Lazarus, E.A., A.W. Hyatt, T.H. Osborne, S.E. Attenberger, M.E. Austin, K.H. Burrell, T.A. Casper, M.S. Chu, J.W. Cuthbertson, E.J. Doyle, P. Gohil, "The Role of Shaping in Achieving High Performance in DIII-D," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 1, 609 (1995)]; and General Atomics Report GA-A21807 (1994).
- Lee, R.L., C. Lasnier, A.W. Hyatt, A.G. Kellman, and P.L. Taylor, "Thermal Deposition Analysis During Disruptions on DIII-D Using Infrared Scanners," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 213.
- Lee, R.L., C.J. Lasnier, A.W. Hyatt, A.G. Kellman, P.L. Taylor, "Thermal Deposition Analysis During Disruptions on DIII-D Using Infrared Scanners," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22217 (1996).
- Leonard, A.W., S.L. Allen, M.E. Fenstermacher, D.N. Hill, C.J. Lasnier, W.M. Meyer, T.W. Petrie, J.G. Watkins, R.D. Wood, DIII-D Team, "Radiation Distributions in Detached Divertor Operation on DIII-D," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, June 3–7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22068 (1995).
- Leonard, A.W., J. Goetz, C. Fuchs, M. Marashek, F. Mast, R. Reichle, "Bolometry for Divertor Characterization and Control," to be published in Proc. The Diagnostics for ITER International Workshop, August 28–September 1, 1995, Varenna, Italy; and General Atomics Report GA-A22138 (1995).

- Leonard, A.W., C.J. Lasnier, C.W. Cuthbertson, T.E. Evans, M.E. Fenstermacher, D.N. Hill, R.A. Jong, W.H. Myer, T.W. Petrie, and G.D. Porter, "Power Balance in DIII-D During Single-Null ELMing H-Mode Plasmas," Proc. 11th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 23-27, 1994, Mito, Japan [J. Nucl. Mater. **220-222**, 325 (1995)]; and General Atomics Report GA-A21693 (1994).
- Leonard, A.W., C.J. Lasnier, M.E. Fenstermacher, D.N. Hill, C.C. Klepper, W.H. Meyer, T.W. Petrie, W.P. West, D.G. Whyte, R.D. Wood, "Power Flow in the Divertor of DIII-D During Radiative Divertor Experiments on DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1646 (1995) (Abstract).
- Leuer, J.A., and J.L. Luxon, "Impact of PF and TF Coil Misalignment on $m=2$, $n=1$ Plasma Error Fields in TPX," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 155.
- Leuer, J.A., J.L. Luxon, M.-F. Xu, T.A. Antaya, "Impact of PF and TF Coil Misalignment on Toroidally Asymmetric Plasma Error Fields in TPX," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22187 (1996).
- Lin-Liu, Y.R., V.S. Chan, S.C. Chiu, "Plasma Rotation in the Presence of Radio Frequency Fields," to be published in Proc. 11th Topical Conference on Radio Frequency Power in Plasmas, May 17-19, 1995, Palm Springs, California; and General Atomics Report GA-A22070 (1995).
- Lin-Liu, Y.R., R.L. Miller, "Upper and Lower Bounds of the Effective Trapped Particle Fraction in General Tokamak Equilibria," Phys. Plasmas **2** (5), 1666 (1995); and General Atomics Reports GA-A21820 (1994).
- Lin-Liu, Y.R., R.L. Miller, T.S. Taylor, V.S. Chan, A.D. Turnbull, "Self-Consistent High- ℓ_i , High- β Advanced Tokamak Operational Modes," Bull. Am. Phys. Soc. **40** (No. 11), 1788 (1995) (Abstract).
- Luce, T.C., C.C. Petty, "Experimental Determination of the Dimensionless Scaling Parameter of Energy Transport in Tokamaks," to be published in Proc. 22nd EPS Conference on Controlled Fusion and Plasma Physics, July 3-7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22096 (1995).
- Luce, T.C., C.C. Petty, "Gyroradius Scaling of Energy Transport and Predictions of Fusion Device Performance," Bull. Am. Phys. Soc. **40** (No. 11), 1791 (1995) (Abstract).
- Luce, T.C., C.C. Petty, "Two-Fluid Analysis of Dimensionally Similar Discharges," Proc. Workshop on Correlation Between Experiment and Theory in Magnetic Confinement Systems, June 13-16, 1994, Goteborg, Sweden; and General Atomics Report GA-A21733 (1994).
- Luce, T.C., C.C. Petty, K.H. Burrell, C.B. Forest, P. Gohil, R.J. Groebner, J.C.M. deHaas, R.A. James, M. Makowski, "Experimental Constraints on Transport," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26-October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 1, 319 (1995)]; and General Atomics Report GA-A21834 (1994).
- Luxon, J.L., for the DIII-D Team, "Recent Results from the DIII-D Tokamak and Implications for Future Devices," Proc. 18th Symposium on Fusion Technology, August 22-26, 1994, Karlsruhe, Germany **1**, 39 (1995); and General Atomics Report GA-A21814 (1995).

- Mahdavi, M.A., S.L. Allen, D.R. Baker, B. Bastasz, N.H. Brooks, D. Buchenauer, R.B. Campbell, J.W. Cuthbertson, T.E. Evans, M.E. Fenstermacher, D.F. Finkenthal, J. Foote, D.N. Hill, D.L. Hillis, F.L. Hinton, J. Hogan, A.W. Howald, A.W. Hyatt, G.L. Jackson, R. Jong, S. Konoshima, C. Lasnier, A.W. Leonard, S.I. Lippmann, R. Maingi, M.M. Menon, P.K. Mioduszewski, R.A. Moyer, H. Ogawa, T.W. Petrie, G.D. Porter, M.E. Rensink, T.D. Rognlien, M.J. Schaffer, K.M. Schaubel, D.L. Sevier, J.P. Smith, G.M. Staebler, G.T. Sager, R.D. Stambaugh, D.M. Thomas, M.R. Wade, J.G. Watkins, F. Weschenfelder, W.P. West, D.G. Whyte, J. Winter, C.P.C. Wong, and R.D. Wood, "Divertor Heat and Particle Control Experiments on the DIII-D Tokamak," Proc. 11th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 23-27, 1994, Mito, Japan [J. Nucl. Mater. **220-222**, 13 (1995)]; and General Atomics Report GA-A21706 (1994).
- Mahdavi, M.A., and G.M. Staebler, "Radiative Cooling Scenarios for ITER," Bull. Am. Phys. Soc. **40** (No. 11), 1834 (1995) (Abstract).
- Maingi, R., G.L. Jackson, M.R. Wade, M.A. Mahdavi, P.K. Mioduszewski, G. Haas, M.J. Schaffer, J.T. Hogan, C.C. Klepper, "Control of Wall Particle Inventory with Divertor Particle Exhaust on DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1647 (1995) (Abstract).
- Maingi, R., G.L. Jackson, M.R. Wade, M.A. Mahdavi, P.K. Mioduszewski, G. Haas, M.J. Schaffer, J.T. Hogan, "Divertor Particle Exhaust and Wall Inventory on DIII-D," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, June 3-7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22065 (1995).
- Maingi, R., G.L. Jackson, M.R. Wade, M.A. Mahdavi, P.K. Mioduszewski, M.J. Schaffer, J.T. Hogan, C.C. Klepper, G. Haas, "Control of Wall Particle Inventory with Divertor Pumping on DIII-D," to be published in Nucl. Fusion; and General Atomics Report GA-A22014 (1995).
- Maingi, R., P.K. Mioduszewski, D.N. Hill, M.A. Mahdavi, J.W. Cuthbertson, D.N. Hill, D.L. Hillis, J.T. Hogan, C.C. Klepper, C.J. Lasnier, D.K. Lee, A.W. Leonard, M.A. Mahdavi, R.A. Moyer, L.W. Owen, M.J. Schaffer, R.D. Stambaugh, M.R. Wade, and J.G. Watkins, "Effect of Low Density H-Mode Operation on Edge and Divertor Plasma Parameters," Proc. 11th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 23-27, 1994, Mito, Japan [J. Nucl. Mater. **220-222**, 320 (1995)]; and General Atomics Report GA-A21705 (1994).
- Makariou, C.C., R.E. Stockdale, T.N. Carlstrom, C.-L. Hsieh, "Data Acquisition Extensions for DIII-D Thomson Scattering," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 213.
- Mandl, W., K.H. Burrell, R.J. Groebner, J. Kim, R.P. Seraydarian, M.R. Wade, J.T. Scoville, "Investigation into Ion Edge Temperature Behaviour Using CER Spectroscopy at DIII-D," Nucl. Fusion **35**, 3 (1995) 347; and General Atomics Report GA-A21685 (1994).
- Mangano, R.A., N.B. Alexander, R.L. Fagaly, and J. Learning, "High Pressure Cryogenic Valve for Tritium Use," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 66.
- Mauel, M.E., B.W. Rice, E.J. Strait, L.L. Lao, T.S. Taylor, K.H. Burrell, M.S. Chu, Y.B. Kim, R.J. La Haye, E.A. Lazarus, Y.R. Lin-Liu, "Production and Stability of High-Beta DIII-D Discharges with Reversed Magnetic Shear," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, July 3-7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22101 (1995).
- McCheseny, J.M., W.H. Goldstein, K.B. Fournier, J.F. Hansen, S.J. Sanders, "A Laser-Induced Fluorescence Diagnostic for Divertors," Bull. Am. Phys. Soc. **40** (No. 11), 1793 (1995) (Abstract).

- McHarg, Jr., B.B., "Conversion of the Central DIII-D Data Acquisition System to a UNIX Based Platform," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 211.
- McHarg, Jr., B.B., "Conversion of the Central DIII-D Data Acquisition System to a UNIX Based Platform," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22153 (1996).
- Menon, M.M., C.B. Baxi, G.L. Campbell, J.T. Hogan, G.J. Laughon, *et al.*, "Particle Exhaust Characteristics of an In-Vessel Cryopump Used in DIII-D Diverted Plasmas," Fusion Technology 27 (4), 355 (1995); and General Atomics Report GA-A21659 (1994).
- Miller, R.L., "MHD Stability and Current Drive in Low Aspect Ratio Tokamaks," Bull. Am. Phys. Soc. 40 (No. 11), 1788 (1995) (Invited Abstract).
- Miller, R.L., F.L. Waelbroeck, A.B. Hassam, and R.E. Waltz, "Stabilization of Ballooning Modes with Sheared Toroidal Rotation," Phys. Plasmas 2 (10), 3676 (1995); and General Atomics Report GA-A21751 (1994).
- Miller, R.L., F.W. Waelbroeck, L.L. Lao, and T.S. Taylor, "Stabilization of Ballooning Modes with Sheared Toroidal Rotation," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 3, 231 (1995)]; and General Atomics Report GA-A21793 (1994).
- Miller, R.L., and R.E. Waltz, "On the Nature of Rotational Shear Stabilization in Toroidal Geometry and Its Numerical Representation," Phys. Plasmas 1, 2835 (1994); and General Atomics Report GA-A21438 (1994).
- Murakami, M., E.F. Jaeger, F.W. Baity, S.C. Chiu, J.S. deGrassie, C.B. Forest, J.D. Galamob, G.R. Hanson, D.W. Kim, J.M. Lohr, C.C. Petty, R.I. Pinsker, R. Prater, D.C. Stallings, J.B. Wilgen, "Measurements of Fast Wave Direct Electron Heating Profiles and Comparison with RF Modeling on DIII-D," Bull. Am. Phys. Soc. 40 (No. 11), 1646 (1995) (Abstract).
- Nilson, D.G., N.H. Brooks, J.P. Smith, R.T. Snider, "Diagnostics for the DIII-D Radiative Divertor," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 174.
- Nilson, D.G., N.H. Brooks, J.P. Smith, R.T. Snider, "Diagnostics for the DIII-D Radiative Divertor," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22189 (1996).
- O'Neill, R.C., R.W. Callis, W.P. Cary, J.L. Doane, R. Gallix, T.R. Hodapp, and C.P. Moeller, "ECH Mirror Interface Tank for 110 GHz, 1 MW Gyrotron," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 208.
- O'Neill, R.C., R.W. Callis, W.P. Cary, J.L. Doane, R. Gallix, T.R. Hodapp, J.M. Lohr, T.C. Luce, and C.P. Moeller, "ECH Mirror Interface Tank for 110 GHz, 1 MW Gyrotron," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22216 (1996).
- Osborne, T.H., K.H. Burrell, M.S. Chu, E.J. Doyle, J.R. Ferron, P. Gohil, R.J. Groebner, D.N. Hill, G.L. Jackson, L.L. Lao, E.A. Lazarus, A.W. Leonard, C.J. Lasnier, M.A. Mahdavi, T.W. Petrie, G.D. Porter, C.L. Rettig, R.D. Stambaugh, G.M. Staebler, E.J. Strait, A.D. Turnbull, M.R. Wade, W.P. West, "ELMs on DIII-D," Bull. Am. Phys. Soc. 40 (No. 11), 1833 (1995) (Abstract).

- Owen, L.W., R. Maingi, M.A. Mahdvi, J.T. Hogan, T.W. Petrie, J.W. Cuthbertson, D.A. Buchenauer, "Neutral Pressure Dependence on Divertor Plasma Parameters and Geometry on DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1834 (1995) (Abstract).
- Parks, P.B., "Energy Transport by Plasma Particles to Vaporizing Divertor Plates During Disruptions," *Bull. Am. Phys. Soc.* **40** (No. 11), 1792 (1995) (Abstract).
- Parks, P.B., R.K. Fisher, and J.M. McChesney, "Effect of Stochastic Ripple Diffusion on the Detection of Fusion Product Ions by Charge-Exchange Pellet Diagnostics," *Nucl. Fusion* **35**, 1297 (1995); and General Atomics Report GA-A21689 (1994).
- Parks, P.B., D. Whyte, R. Bastasz, N.H. Brooks, W.R. Wampler, W.P. West, and C.P.C. Wong, "First Measurements of the Ion Energy Distribution at the Divertor Strike Point During DIII-D Disruptions," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22237 (1996).
- Petrie, T.W., D. Buchenauer, J.W. Cuthbertson, R.A. Jong, J. Kim, R. Maingi, S.L. Allen, T.E. Evans, M.E. Fenstermacher, D.N. Hill, C.J. Lasnier, A.W. Leonard, G.D. Porter, W.P. West, D.G. Whyte, R.D. Wood, "Plasma Pressure Balance in the Scrape-off Layer of Radiative Divertor Discharges in DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1832 (1995) (Abstract).
- Petrie, T.W., D.N. Hill, S.L. Allen, N.H. Brooks, D. Buchenauer, J.W. Cuthbertson, T.E. Evans, P.H. Ghendrih, C. Lasner, A.W. Leonard, R. Maingi, "Radiative Divertor Experiments in DIII-D with D₂ Injection," to be published in *Nucl. Fusion*; and General Atomics Report GA-A21879 (1995).
- Petty, C.C., M.E. Austin, F.W. Baity, R.W. Callis, C.S. Chiu, J.S. deGrassie, C.B. Forest, R.L. Freeman, P. Gohil, R.H. Goulding, R.W. Harvey, "Fast Wave Current Drive in DIII-D," *Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research*, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 2, 211 (1995)]; and General Atomics Report GA-A21826 (1995).
- Petty, C.C., C.B. Forest, F.W. Baity, S.C. Chiu, J.S. deGrassie, R.J. Groebner, Y.R. Lin-Liu, T.C. Luce, R.I. Pinsker, M. Porkolab, R. Prater, "Current Profile Evolution During Fast Wave Current Drive on the DIII-D Tokamak," to be published in *Proc. 11th Topical Conference on Radio Frequency Power in Plasmas*, May 17–19, 1995, Palm Springs, California; and General Atomics Report GA-A22063 (1995).
- Petty, C.C., C.B. Forest, F.W. Baity, S.C. Chiu, J.S. deGrassie, H. Ikezi, Y.-R. Lin-Liu, M. Murakami, R.I. Pinsker, R. Prater, "Measurements of Fast Wave Current Drive During VH-Mode in DIII-D," *Bull. Am. Phys. Soc.* **40** (No. 11), 1646 (1995) (Abstract).
- Petty, C.C., T.C. Luce, K.H. Burrell, S.C. Chiu, J.S. deGrassie, C.B. Forest, P. Gohil, C.M. Greenfield, R.J. Groebner, R.W. Harvey, R.I. Pinsker, R. Prater, R.E. Waltz, R.A. James, and D. Wroblewski, "Nondimensional Transport Scaling in DIII-D: Bohm Versus Gyro-Bohm Resolved," *Proc. 1994 American Physical Society Division of Plasma Physics Meeting*, November 7–11, 1994, Minneapolis [Phys. Plasmas **2** (6), 2342 (1995)]; and General Atomics Report GA-A21904 (1995).
- Petty, C.C., T.C. Luce, R.I. Pinsker, K.H. Burrell, S.C. Chiu, P. Gohil, R.A. James, and D. Wroblewski, "Gyroradius Scaling of Electron and Ion Transport," *Phys. Rev. Lett.* **74**, 1763 (1995); General Atomics Report GA-A21632 (1994).
- Petty, C.C., R.I. Pinsker, M.E. Austin, F.W. Baity, S.C. Chiu, J.S. deGrassie, C.B. Forest, R.H. Goulding, R.W. Harvey, D.J. Hoffmann, R.A. James, "Fast Wave and Electron Cyclotron Current Drive in the DIII-D Tokamak," *Nucl. Fusion* **35**, 773 (1995); and General Atomics Report GA-A21690 (1994).

- Phelps, D.A., H. Ikezi, and C.P. Moeller, "A High Power Experimental Traveling Wave Antenna for Fast Wave Heating and Current Drive in DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 208.
- Phelps, D.A., H. Ikezi and C.P. Moeller, "A High Power Experimental Traveling Wave Antenna for Fast Wave Heating and Current Drive in DIII-D and Relevance to ITER," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22159 (1996).
- Phelps, D.A., C.P. Moeller, "A High RF Power Density Comblane for JFT-2M and Relevance to ITER," Bull. Am. Phys. Soc. **40** (No. 11), 1838 (1995) (Abstract).
- Phelps, D.A., C.P. Moeller, H. Ikezi, S.C. Chiu, "First Demonstration of a Traveling Wave Antenna in a Tokamak and Relevance to the JFT-2M Comblane," to be published in Proc. 11th Topical Conference on Radio Frequency Power in Plasmas, May 17–19, 1995, Palm Springs, California; and General Atomics Report GA-A22051 (1995).
- Phelps, R.D., S. Coda, "Engineering and Design of a CO₂ Phase Contrast Interferometer System for DIII-D," General Atomics Report GA-A21839 (1994).
- Phillips, J., D.H. Kellman, R. Hong, J. Kim, G.J. Laughon, "Five Second Helium Neutral Beam Injection Using Argon-Frost Cryopumping Techniques," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 208.
- Phillips, J.C., D.H. Kellman, R. Hong, J. Kim, G.M. Laughon, "Five Second Helium Neutral Beam Injection Using Argon-Frost Cryopumping Techniques," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22197 (1996).
- Pinsker, R.I., F.W. Baity, S.C. Chiu, J.S. deGrassie, C.B. Forest, R.H. Goulding, D.J. Hoffmann, H. Ikezi, Y.-R. Lin-Liu, T.C. Luce, C.C. Petty, M. Porkolab, R. Prater, J.P. Squire, D.W. Swain, and the DIII-D Group, "Recent Results from Fast Wave Current Drive Experiments on DIII-D," Proc. 21st European Conference on Controlled Fusion and Plasma Heating, June 27–July 1, 1994, Montpellier, France [European Physical Society, Petit-Lancy, Switzerland **18B** (Part III) 1118 (1994)]; and General Atomics Report GA-A21759 (1994).
- Pinsker, R.I., F.W. Baity, S.C. Chiu, J.S. deGrassie, C.B. Forest, H. Ikezi, M. Murakami, C.C. Petty, R. Prater, and the DIII-D Group, "Direct Electron Heating with Directional Fast Wave Launch on DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1837 (1995) (Abstract).
- Pinsker, R.I., F.W. Baity, S.C. Chiu, J.S. deGrassie, C.B. Forest, H. Ikezi, M. Murakami, C.C. Petty, R. Prater, D.W. Swain, DIII-D Group, "Direct Electron Heating with Directional Fast Wave Launch on DIII-D," to be published in Proc. 11th Topical Conference on Radio Frequency Power in Plasmas, May 17–19, 1995, Palm Springs, California; and General Atomics Report GA-A22081 (1995).
- Politzer, P.A., "Ion Orbits Near the Plasma Axis and Implications for Reversed Shear Operation," Bull. Am. Phys. Soc. **40** (No. 11), 1787 (1995) (Abstract).
- Politzer, P.A., for the DIII-D Team, "Development of a Tokamak Plasma Optimized for Stability and Confinement," Proc. 6th International Toki Conference on Plasma Physics and Controlled Nuclear Fusion, November 29–December 2, 1994, Toki, Japan; and General Atomics Report GA-A21926 (1995).

- Prater, R., F.W. Baity, W.P. Cary, S.C. Chiu, J.S. deGrassie, C.B. Forest, R.W. Harvey, H. Ikezi, E.F. Jaeger, K. Kupfer, Y.R. Lin-Liu, "First Results on Fast Wave Current Drive in Advanced Tokamak Discharges in DIII-D," to be published in Proc. 22nd EPS Conference on Controlled Fusion and Plasma Physics, July 3-7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22088 (1995).
- Project Staff, "DIII-D Research Operations Annual Report to the U.S. Department of Energy, October 1, 1993 through September 30, 1993," General Atomics Report GA-A21935 (1994).
- Redler, K.M., C.B. Baxi, E. Chin, E.H. Hoffmann, E.E. Reis, and K.M. Schaubel, "Use of a Thermal Analogy to Find Electrical Resistances of the Electrical Breaks in the TPX Passive Stabilization Systems," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 151.
- Redler, K.M., C.B. Baxi, E.H. Hoffmann, and K.M. Schaubel, "Use of a Thermal Analogy to Find Electrical Resistances of the Electrical Breaks in the TPX Passive Stabilization Systems," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22147 (1996).
- Reis, E.E., C.B. Baxi, E. Chin, and K.M. Redler, "Thermal and Structural Analysis of the TPX Divertor," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 150.
- Reis, E.E., C.B. Baxi, E. Chin, K.M. Redler, "Thermal and Structural Analysis of the TPX Divertor," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22164 (1996).
- Rice, B.W., "Demonstration of High Performance Reverse Shear Discharges in the DIII-D Tokamak," Bull. Am. Phys. Soc. **40** (No. 11), 1747 (1995) (Invited Abstract).
- Riggs, S.P., R. Hong, and D.N. Kessler, "Neutral Beam Shintthrough Power and It's Dependence on the Line Density of the DIII-D Plasma," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 209.
- Riggs, S., R. Hong, and D. Kessler, "Neutral Beam Shine-Through Power and It's Dependence On The Line Density Of The DIII-D Plasma," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22150 (1996).
- Robinson, J.I., and J.T. Scoville, "Development of a New Error Field Correction Coil (C-Coil) for DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 206.
- Robinson, J.I., and J.T. Scoville, "Development of a New Error Field Correction Coil (C-coil) for DIII-D," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22223 (1996).
- Rothweil, D.A., D.A. Phelps, R. Doerner, and A. Nerem, "Interpretation of PISCES-A RF Antenna System Experimental Results with Circuit Simulation," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 168.
- Rothweil, D.A., D.A. Phelps, and R. Doerner, "Interpretation of PISCES-A RF Antenna System Experimental Results," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22209 (1996).

- Sager, G.T., T.E. Evans, M.E Fenstermacher, D.G. Whyte, M.A. Mahdavi, G.D. Porter, G.M. Staebler, W.P. West, and A.W. Leonard, "Development and Benchmarking of the MCI Code," *Bull. Am. Phys. Soc.* **40** (No. 11), 1835 (1995) (Abstract).
- Sager, G.T., C.P.C. Wong, and ARIES Design Team, "Characteristics of the U.S. Demo-1 Divertor," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 135.
- St. John, H.E., Y.R. Lin-Liu, S.C. Chiu, M.S. Chu, R.L. Miller, P.A. Politzer, A.D. Turnbull, "Optimization of Advanced Tokamak Discharges in TPX," *Bull. Am. Phys. Soc.* **40** (No. 11), 1787 (1995) (Abstract).
- St. John, H.E., T.S. Taylor, Y.R. Lin-Liu, "Transport Simulation of Negative Magnetic Shear Discharges," *Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research*, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 3, 603 (1995)]; and General Atomics Report GA-A21847 (1994).
- Schaffer, M.J., A.V. Chankin, R.D. Monk, "MHD Equilibrium, Pfirsch-Schlüter Currents and Tokamak Divertor Detachment," *Bull. Am. Phys. Soc.* **40** (No. 11), 1832 (1995) (Abstract).
- Schaffer, M.J., R. Maingi, A.W. Hyatt, M.A. Mahdavi, "Increased Divertor Exhaust by Electrical Bias in DIII-D," to be published in *Nucl. Fusion Lett.*; and General Atomics Report GA-A21878 (1995).
- Schaffer, M.J., D.G. Whyte, N.H. Brooks, J.W. Cuthbertson, J. Kim, S.I. Lippmann, M.A. Mahdavi, R. Maingi, R.D. Wood, "Impurity Reduction During 'Puff and Pump' Experiments on DIII-D," *Nucl. Fusion Lett.* **35**, 1000 (1995); and General Atomics Report GA-A21687 (1995).
- Schaubel, K.M., P.M. Anderson, C.B. Baxi, R.H. Boonstra, B.E. Eklund, R. Pearsons, J.L. Pickering, K.M. Redler, E.E. Reis, D.L. Sevier, "Design of the TPX Outboard Toroidal Limiters," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 151.
- Schaubel, K.M., P.M. Anderson, C.B. Baxi, R.H. Boonstra, B.E. Eklund, E.H. Hoffmann, R.L. Pearsons, Jr., J.L. Pickering, K.M. Redler, E.E. Reis, D.L. Sevier, "Design of the TPX Outboard Toroidal Limiters," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22177 (1996).
- Schaubel, K.M., J.P. Smith, G.J. Laughon, C.B. Baxi, G.L. Campbell, M.A. Mahdavi, R. Maingi, M.M. Menon, M.J. Schaffer, R.D. Stambaugh, "The DIII-D Divertor Cryopump System Design and Operational Experience," *Proc. 18th Symposium on Fusion Technology*, August 22–26, 1994, Karlsruhe, Germany, **1**, 347 (1995); and General Atomics Report GA-A21787 (1994).
- Schissel, D.P., K.H. Burrell, T.A. Casper, J.C. DeBoo, L.L. Lao, E.A. Lazarus, M.E. Mael, T.H. Osborne, B.W. Rice, B.W. Stallard, H.E. St. John, E.J. Strait, T.S. Taylor, "A Comparison Between Reversed Magnetic Shear Discharges in DIII-D and Theoretical Transport Models," *Bull. Am. Phys. Soc.* **40** (No. 11), 1786 (1995) (Abstract).
- Schultz, K.R., "Inertial Fusion Target Development," *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 198.
- Schultz, K.R., "Inertial Fusion Target Development," to be published in *Proc. 16th IEEE/NPS Symposium on Fusion Engineering*, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22219 (1996).

- Schultz, K.R., T. Bernat, R.L. Fagaly, L. Foreman, W. Meier, R. Petzoldt, "Development of IFE Target Systems on the NIF," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22225 (1996).
- Scoville, J.T., and R.J. La Haye, "Plasma Response in DIII-D to an Externally-Applied Low m , $n=1$ Error Field," General Atomics Report GA-A20968 (1994).
- Scoville, J.T., and R.J. La Haye, "Use of the C-coil on DIII-D to Correct $m=2$, $n=1$ Error Fields and Prevent Locked Modes," Bull. Am. Phys. Soc. **40** (No. 11), 1788 (1995) (Abstract).
- Seraydarian, R.P., K.H. Burrell, R.J. Groebner, P. Gohil, and G. Phelps, "A Fast CCD Detector for Charge Exchange Recombination Spectroscopy on the DIII-D Tokamak," Bull. Am. Phys. Soc. **40** (No. 11), 1836 (1995) (Abstract).
- Silke, G.W., and R.N. Junge, "Remote Welding Equipment for TPX," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 159.
- Silke, G.W., and R. Junge, "Remote Welding Equipment for TPX," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22174 (1996).
- Simonen, T.C., G.L. Jackson, E.A. Lazarus, M.A. Mahdavi, T.W. Petrie, P.A. Politzer, and T.S. Taylor, "Recent DIII-D High Power Heating and Current Drive Experiments," Proc. 5th International Conference on Plasma Physics and Controlled Nuclear Fusion, November 16–19, 1993, Tokai, Japan; and General Atomics Report GA-A21603 (1994).
- Smirnov, A.P., R.W. Harvey, "Calculations of the Current Drive in DIII-D with the GENRAY Ray Tracing Code," Bull. Am. Phys. Soc. **40** (No. 11), 1837 (1995) (Abstract).
- Smith, J.P., S.L. Allen, P.M. Anderson, C.B. Baxi, E. Chin, M.E. Fenstermacher, D.N. Hill, M.A. Hollerbach, A.W. Hyatt, R. Junge, M.A. Mahdavi, "Engineering Design of a Radiative Divertor for DIII-D," Proc. 18th Symposium on Fusion Technology, August 22–26, 1994, Karlsruhe, Germany, **1**, 327, (1995); and General Atomics Report GA-A21788 (1994).
- Smith, J.P., C.B. Baxi, E. Chin, M.E. Hollerbach, R.N. Junge, E.E. Reis, D.L. Sevier, "Engineering Design of a Radiative Divertor for DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 174.
- Smith, J.P., C.B. Baxi, A.S. Bozek, E. Chin, M.A. Hollerbach, W.R. Johnson, G.J. Laughon, R.D. Phelps, K.M. Redler, E.E. Reis, and D.L. Sevier, "Engineering Design of a Radiative Divertor for DIII-D," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22157 (1996).
- Smith, J.P., W.R. Johnson, R.D. Stambaugh, P.W. Trester, D. Smith, and E. Bloom "Vanadium Alloys for the Radiative Divertor Program of DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 209.
- Smith, J.P., W.R. Johnson, R.D. Stambaugh, P.W. Trester, D. Smith, and E. Bloom "Vanadium Alloys For The Radiative Divertor Program of DIII-D," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22165 (1996).

- Snider, R.T., R.J. La Haye, A. Turnbull, and D. Wroblewski, "Modification of the Sawtooth Crash Behavior During Large Error Field Experiments on the DIII-D Tokamak," Nucl. Fusion **34** (4), 483 (1994); and General Atomics Report GA-A21276 (1993).
- Staebler, G.M., "The Critical Point for the Onset of Divertor Energy Flux Asymmetry in Tokamaks," to be published in Nucl. Fusion; and General Atomics Report GA-A22053 (1995).
- Staebler, G.M., K.H. Burrell, R.J. Groebner, F.L. Hinton, J. Kim, and C. Wiley, "Towards a Complete Theory of the H-mode," Bull. Am. Phys. Soc. **40** (No. 11), 1835 (1995) (Abstract).
- Stallard, B.W., T.A. Casper, M.E. Fenstermacher, C.B. Forest, P. Gohil, W.W. Heidbrink, A.W. Hyatt, R.A. James, R.A. Jong, L.L. Lao, M.A. Makowski, "q Profile Evolution and Enhanced Core Confinement of High β_p Plasmas in DIII-D," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 2, 251 (1995)]; and General Atomics Report GA-A21799 (1994).
- Stallard, B.W., Y.K. Kawano, Y.R. Lin-Liu, T.A. Casper, L.L. Lao, B.W. Rice, D.P. Schissel, H.E. St. John, and T.S. Taylor, "Transport and Current Profile Evolution in Reverse Central Shear Discharges in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1787 (1995) (Abstract).
- Stambaugh, R.D., for the DIII-D Team, "DIII-D Program Overview," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 1, 83 (1995)]; and General Atomics Report GA-A21840 (1994).
- Strait, E.J., L.L. Lao, M.E. Mauel, B.W. Rice, T.S. Taylor, K.H. Burrell, M.S. Chu, E.A. Lazarus, Y. Kawano, T.A. Casper, T.H. Osborne, B.W. Stallard, H.E. St. John, S.J. Thompson, and A.D. Turnbull, "Enhanced Confinement and Stability in DIII-D Discharges with Reversed Magnetic Shear," Bull. Am. Phys. Soc. **40** (No. 11), 1645 (1995) (Abstract).
- Strait, E.J., L.L. Lao, M.E. Mauel, B.W. Rice, T.S. Taylor, K.H. Burrell, M.S. Chu, E.A. Lazarus, T.H. Osborne, S.J. Thompson, A.D. Turnbull, "Enhanced Core Confinement in DIII-D Discharges with Reversed Magnetic Shear," to be published in Phys. Rev. Lett.; and General Atomics Report GA-A22041 (1995).
- Strait, E.J., T.S. Taylor, A.D. Turnbull, J.R. Ferron, L.L. Lao, B. Rice, O. Sauter, S.J. Thompson, and D. Wroblewski, "Wall Stabilization of High Beta Tokamak Discharges in DIII-D," Phys. Rev. Letts. **74** (13) 2483 (1995); and General Atomics Report GA-A21797 (1994).
- Taylor, P.L., A.G. Kellman, R. Bastasz, N.H. Brooks, T.E. Evans, D.A. Humphreys, A.W. Hyatt, R.L. Lee, B.W. Rice, D.G. Whyte, "Experimental Disruption Studies in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1647 (1995) (Abstract).
- Taylor, P.L., A.G. Kellman, B.W. Rice, R. Bastasz, N.H. Brooks, T.E. Evans, K.L. Holtrop, D.A. Humphreys, A.W. Hyatt, R.L. Lee, D.G. Whyte, "DIII-D Disruption Experiment Results," to be published in Proc. 22nd European Conference on Controlled Fusion and Plasma Physics, July 3–7, 1995, Bournemouth, United Kingdom; and General Atomics Report GA-A22082 (1995).
- Taylor, P.L., A.G. Kellman, B.W. Rice, D.A. Humphreys, "Experimental Measurements of the Current, Temperature, and Density Profile Changes during a Disruption in the DIII-D Tokamak," to be published in Phys. Rev. Lett.; and General Atomics Report GA-A22076 (1995).

- Taylor, T.S., H. St. John, A.D. Turnbull, Y.R. Lin-Liu, K.H. Burrell, V. Chan, M.S. Chu, J.R. Ferron, L.L. Lao, R.J. La Haye, E.A. Lazarus, "Optimized Profiles for Improved Confinement and Stability in the DIII-D Tokamak," Proc. 21st European Conference on Controlled Fusion and Plasma Heating, June 27–July 1, 1994, Montpellier, France [European Physical Society, Petit-Lancy, Switzerland **36** Suppl. (12)B, B229 (1994)]; and General Atomics Report GA-A21757 (1995).
- Taylor, T.S., E.J. Strait, L.L. Lao, M. Mauel, A.D. Turnbull, K.H. Burrell, M.S. Chu, J.R. Ferron, R.J. Groebner, R.J. La Haye, B.W. Rice, "Wall Stabilization of High β Plasmas in DIII-D," Helium Transport and Exhaust Studies in Enhanced Confinement Regimes in DIII-D," Proc. 36th Annual Meeting of the Division of Plasma Physics, November 7–11, 1994, Minneapolis [Phys. Plasmas **2** (6), 2390 (1995)]; and General Atomics Report GA-A21914 (1995).
- Taylor, T.S., A.D. Turnbull, L.L. Lao, "Dependence of the Stability Limit on Discharge Shape for Negative Central Shear Discharges," Bull. Am. Phys. Soc. **40** (No. 11), 1786 (1995) (Abstract).
- Thomas, D.M., "Visualization of Density Structures in Tokamak Edge Plasmas Using Lithium Beam Fluorescence," to be published in Proc. IEEE Transactions on Plasma Science; and General Atomics Report GA-A22098 (1995).
- Thomas, D.M., and D.M. Blackford, "Characterization of ELM Effects on DIII-D Edge Plasma Via Lithium Beam Diagnostic," Bull. Am. Phys. Soc. **40** (No. 11), 1833 (1995) (Abstract).
- Trester, P.W., K.M. Schaubel, E.H. Hoffmann, P.M. Anderson, and E.E. Reis, "Copper Alloy Candidates and Design Considerations for the Heat Sink Structure of Plasma Facing Components in TPX," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 159.
- Turnbull, A.D., B.J. Lee, T.S. Taylor, "Optimum Wall Position for the Negative Central Shear Advanced Tokamak," Bull. Am. Phys. Soc. **40** (No. 11), 1787 (1995) (Abstract).
- Turnbull, A.D., T.S. Taylor, E.J. Strait, S.J. Thompson, M.S. Chu, J.R. Ferron, R.J. La Haye, L.L. Lao, R.T. Snider, B.W. Rice, D. Wroblewski, "Wall Stabilization of Rotating High β Discharges in DIII-D," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 1, 705 (1995)]; and General Atomics Report GA-A21819 (1994).
- Valentine, P.G., P.W. Trestor, J. Winter, J. Linke, J.L. Kaae, A. Schuster, H. Bolt, R. Duwe, E. Wallura, and V. Phillips, "B₄C-SiC Reaction-Sintered Coatings on Graphite for Plasma Facing Components," Proc. 11th International Conference on Plasma Surface Interactions on Controlled Fusion Devices, Mito, Japan, 1994 [J. Nucl. Mater. **220-222**, 756 (1995)]; and General Atomics Report GA-A21719 (1994).
- VanderLaan, J.F., and S. Miller, "Handling and Archiving of Magnetic Fusion Data at DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 211.
- VanderLaan, J.F., S. Miller, B.B. McHarg, Jr., P.A. Henline, "Handling and Archiving of Magnetic Fusion Data at DIII-D," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22167 (1996).
- Wade, M.R., D.L. Hillis, J.T. Hogan, M.A. Mahdavi, R. Maingi, W.P. West, N.H. Brooks, K.H. Burrell, R.J. Groebner, G.L. Jackson, C.C. Klepper, G. Laughon, M.M. Menon, P.K. Mioduszewski, and DIII-D Team, "Helium Exhaust Studies in H-Mode Discharges in the DIII-D Tokamak Using an Argon-Frosted Divertor Cryopump," Phys. Rev. Letts. **74** (14) 2702 (1995); and General Atomics Report GA-A21652 (1994).

- Wade, M.R., D.L. Hillis, J.T. Hogan, R. Maingi, M.M. Menon, M.A. Mahdavi, W.P. West, K.H. Burrell, P. Gohil, R.J. Groebner, R.-M. Hong, D.H. Kellman, J.C. Phillips, R.P. Seraydarian, and the DIII-D Team, D.F. Finkenthal, "Helium Transport and Exhaust Studies in Enhanced Confinement Regimes in DIII-D," Proc. 36th Annual Meeting of the Division of Plasma Physics, November 7-11, 1994, Minneapolis [Phys. Plasmas **2** (6) 2357 (1995)]; and General Atomics Report GA-A21905 (1995).
- Wade, M.R., D.L. Hillis, R. Maingi, J.H. Hogan, R. Hong, J.C. Phillips, "Helium Transport and Exhaust Studies in the Presence of a Central Source of Helium in DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1646 (1995) (Abstract).
- Wade, M.R., J.T. Hogan, D.L. Hillis, M.A. Mahdavi, R. Maingi, *et al.*, "Helium Exhaust Studies in the DIII-D Tokamak," Proc. 11th International Conference on Plasma Surface Interactions in Controlled Fusion Devices, May 23-27, 1994, Mito, Japan [J. Nucl. Mater. **220-222**, 178 (1995)]; and General Atomics Report GA-A21702 (1994).
- Walker, M., J.R. Ferron, B. Penaflor, D.A. Humphreys, J.A. Leuer, A.W. Hyatt, C.B. Forest, J.T. Scoville, B.W. Rice, "Status of DIII-D Plasma Control," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 211.
- Walker, M., J.R. Ferron, B. Penaflor, D.A. Humphreys, J.A. Leuer, A.W. Hyatt, C.B. Forest, J.T. Scoville, B.W. Rice, E.A. Lazarus, T.W. Petrie, S.L. Allen, G.L. Jackson, and R. Maingi, "Status of DIII-D Plasma Control," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30-October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22176 (1996).
- Walker, M.L., T.A. Casper, J.R. Ferron, C.B. Forest, D.A. Humphreys, J. Leuer, V. Lukash, P.A. Politzer, "Developing Next Generation Tokamak Control Design Techniques Using Existing Devices," Bull. Am. Phys. Soc. **40** (No. 11), 1791 (1995) (Abstract).
- Waltz, R.E., "Advances in the Simulation of Toroidal Gyro-Landau Fluid Model Turbulence," Phys. Plasmas **2** (6) 2408 (1995); and General Atomics Report GA-A21871 (1994).
- Waltz, R.E., W. Dorland, G. Hammett, M. Kotschenreuther, "Fast Transport Code with Gyrokinetic Quasilinear Models," Bull. Am. Phys. Soc. **40** (No. 11), 1733 (1995) (Abstract).
- Wang, Z., J. Lohr, G.L. Bell, C. Hsieh, J. Luo, R.E. Stockdale, J.B. Wilgen, J. Zhang, "Study of Electron Temperature Profile Evolution During L-H Transition with Measurement of Electron Cyclotron Emission on DIII-D," to be published in Proc. 9th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Resonance Heating, January 22-26, 1995, Borrego Springs, California; and General Atomics Report GA-A22038 (1995).
- Watkins, J.G., R.A. Moyer, G. Gunner, D.N. Hill, J. Hunter, R. Lehmer, P. Luong, M. Mascaro, J. Robinson, R.T. Snider, M. Ulrickson, "A New X-Point Probe Diagnostic for the DIII-D Divertor," Bull. Am. Phys. Soc. **40** (No. 11), 1835 (1995) (Abstract).
- Weschenfelder, F., G.L. Jackson, N.H. Brooks, R.L. Lee, W.P. West, P. Wienhold, J. Winter, "Three-Filter Colorimetry in DIII-D to Measure In-Situ Erosion and Deposition of Plasma Facing Surfaces," to be published in Rev. Sci. Instrum.; and General Atomics Report GA-A21917 (1995).
- West, W.P., C.C. Klepper, N.H. Brooks, S. Hirshman, D.G. Whyte, R. Campbell, A. Kallenbach, T. Field, K. Krieger, "Multifluid 1D Modeling of the Low Z Impurity Distributions in ASDEX-Upgrade and DIII-D Scrape-off-layer and Divertor Plasmas," Bull. Am. Phys. Soc. **40** (No. 11), 1833 (1995) (Abstract).

- Whyte, D., R. Bastasz, P.B. Parks, N.H. Brooks, W.R. Wampler, W.P. West, and C.P.C. Wong, "First Measurements of the Ion Energy Distribution at the Divertor Strike Point During DIII-D Disruptions," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 206.
- Whyte, D.G., P. Monier-Garbet, M.R. Wade, B.W. Rice, D.K. Finkenthal, R.D. Wood, W.P. West, "Steady State Low-Z Impurity Density Profiles of L-, H- and VH-mode Plasmas on DIII-D," Bull. Am. Phys. Soc. **40** (No. 11), 1647 (1995) (Abstract).
- Wong, C.P.C., C.B. Baxi, C.J. Hamilton, R.W. Schleicher, H. Streckert, "Helium Cooling in Fusion Power Plants," Proc. 15th International Conference on Plasma Physics and Controlled Nuclear Fusion Research, September 26–October 1, 1994, Seville, Spain [International Atomic Energy Agency, Vienna, Vol. 2, 757 (1995)]; and General Atomics Report GA-A21804 (1994).
- Wong, C.P.C., B.W. McQuillan, R.W. Schleicher, E.T. Cheng, and the Demo Team, "Evaluation of U.S. Demo-1 Helium-Cooled Blanket Options," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 145.
- Wong, C.P.C., B.W. McQuillan, R.W. Schleicher, E.T. Cheng, and the ARIES Team, "Evaluation of U.S. Demo Helium-Cooled Blanket Options," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22214 (1996).
- Wong, C.P.C., D.G. Whyte, W.P. West, R. Bastasz, W.R. Wampler, J.N. Brooks, P.B. Parks, "Material Erosion Measurements and Disruption Studies on DIII-D Using DiMES," Bull. Am. Phys. Soc. **40** (No. 11), 1792 (1995) (Abstract).
- Wood, R.D., S.L. Allen, M.E. Fenstermacher, D.N. Hill, C.J. Lasnier, A.W. Leonard, T.W. Petrie, M.R. Wade, W.P. West, D.G. Whyte, "Neon Impurity Profiles During Radiative Divertor Experiments," Bull. Am. Phys. Soc. **40** (No. 11), 1832 (1995) (Abstract).
- Wright, A.L., J. Tooker, J.C. Allen, W.P. Cary, and T.E. Harris, "ECH Control System for New 1 MW 110 GHz Gyrotrons at DIII-D," Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois (Abstract) (1995) p. 212.
- Wright, A.L., J. Tooker, J.C. Allen, W.P. Cary, and T.E. Harris, "ECH Control System for New 1 MW 110 GHz Gyrotrons at DIII-D," to be published in Proc. 16th IEEE/NPS Symposium on Fusion Engineering, September 30–October 5, 1995, Champagne, Illinois; and General Atomics Report GA-A22169 (1996).