GA–C19462

DIII–D EXPERIMENTAL PLAN FOR FY–1989

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by
FUSION DIVISION STAFF
J.L. LUXON, EDITOR

Prepared under
Contract No. DE–AC03–89ER51114
for the San Francisco Operations Office
U.S. Department of Energy

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NOVEMBER 1988

GENERAL ATOMICS

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GENERAL ATOMICS PROJECT 3466
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APPROVALS

Approved: Thomas C. Simonen Dec 2, 1988

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FOREWORD

This document presents the planned experimental activities for the DIII–D tokamak facility for the period FY 1989. This plan is part of a five year contract between General Atomics and the Department of Energy. The plan will be reviewed by both organizations and approved by the DIII–D Program Director, Fusion Division, General Atomics, the Onsite Project Manager, SAN Office, DOE, and the DIII–D Program Manager, Division of Confinement Systems, Washington, D.C.

It is anticipated that this document will be updated yearly, and that the progress of the DIII–D program will be reviewed quarterly against this plan. In the event of major budgetary, technical, or programmatic changes this document will be revised.

LIST OF ACRONYMS

APS	American Physical Society
a	Minor radius of plasma
B	Magnetic field
CIT	Compact Ignition Tokamak
DIII–D	Tokamak Fusion Device located at General Atomics
ECH	Electron Cyclotron Heating
ELM	Edge localized mode that limits energy storage in plasma
FY	Fiscal year
H–mode	A high regime of tokamak confinement
I	Plasma current
IAEA	International Atomic Energy Agency
IBW	Ion Bernstein Wave method of ion cyclotron heating
ITER	International Thermonuclear Experimental Reactor
JET	Joint European Tokamak located in England
L–H Transition	Transition from L–mode to H–mode
L–mode	A low regime of tokamak confinement
NBI	Neutral beam injection
OFE	Office of Fusion Energy

O–mode	A mode of microwave propagation in which the microwave electric field is parallel to the toroidal magnetic field
q	Tokamak safety factor $q = 3$ means that a magnetic field line traverses the toroidal direction three times in one poloidal rotation.
R&D	Research and development
rf	Radio frequency
X–mode	A mode of microwave propagation in which the microwave electric field is perpendicular to the toroidal magnetic field
X–point	The location where the magnetic field is purely toroidal (no poloidal component).
β	The ratio of plasma pressure to magnetic field pressure.
Ω_{H}	Hydrogen ion cyclotron frequency.

CONTENT

1. INTRODUCTION

This document summarizes the Experimental Plan for the DIII–D tokamak facility for the fiscal year 1989. The long-range DIII–D 5 yr plan is directed ultimately at the goal of achieving good confinement at high beta in a plasma with non-inductively driven current. This is important to the design of a steady-state reactor. This program may be thought of as occurring in two phases. In the first phase of the program we are separately investigating high beta plasma confinement in inductively-driven plasmas, and non-inductive current drive. In the second phase we will combine these two elements to investigate high beta plasma confinement with non-inductive current drive.

The FY 89 plan continues the first phase of the DIII–D experimental effort that contains a strong focus on beta and confinement in non-circular plasma configurations and in the divertor configuration in particular. Important work also continues in the development of rf heating systems for heating, profile control, and current drive. This research is coupled to theoretical efforts at General Atomics.

The FY 89 research program outlined herein is diverse and multifaceted. However, it is also characterized by a greater synthesis of techniques toward a common goal. An example is the application of ECH for sawtooth suppression that would improve the low q confinement and allow higher β to be obtained. We believe this research program will provide a solid foundation for the continued development of the tokamak toward high beta steady-state reactor application.

The DIII–D FY 89 research program will provide results that will help resolve many CIT and ITER Physics R&D issues. In addition, DIII–D confinement studies will be an important input to the newly formed National Transport Task Force.

The outline for the remainder of this plan is as follows:

Sec. 2. Summary discussion of the Experimental Plan.

3. A bar chart which summarizes the proposed Experimental Plan.

4. A summary of the research goals for FY 89.

5. A tentative detail breakdown of the research plan.

6. A detail plan for major hardware tasks.

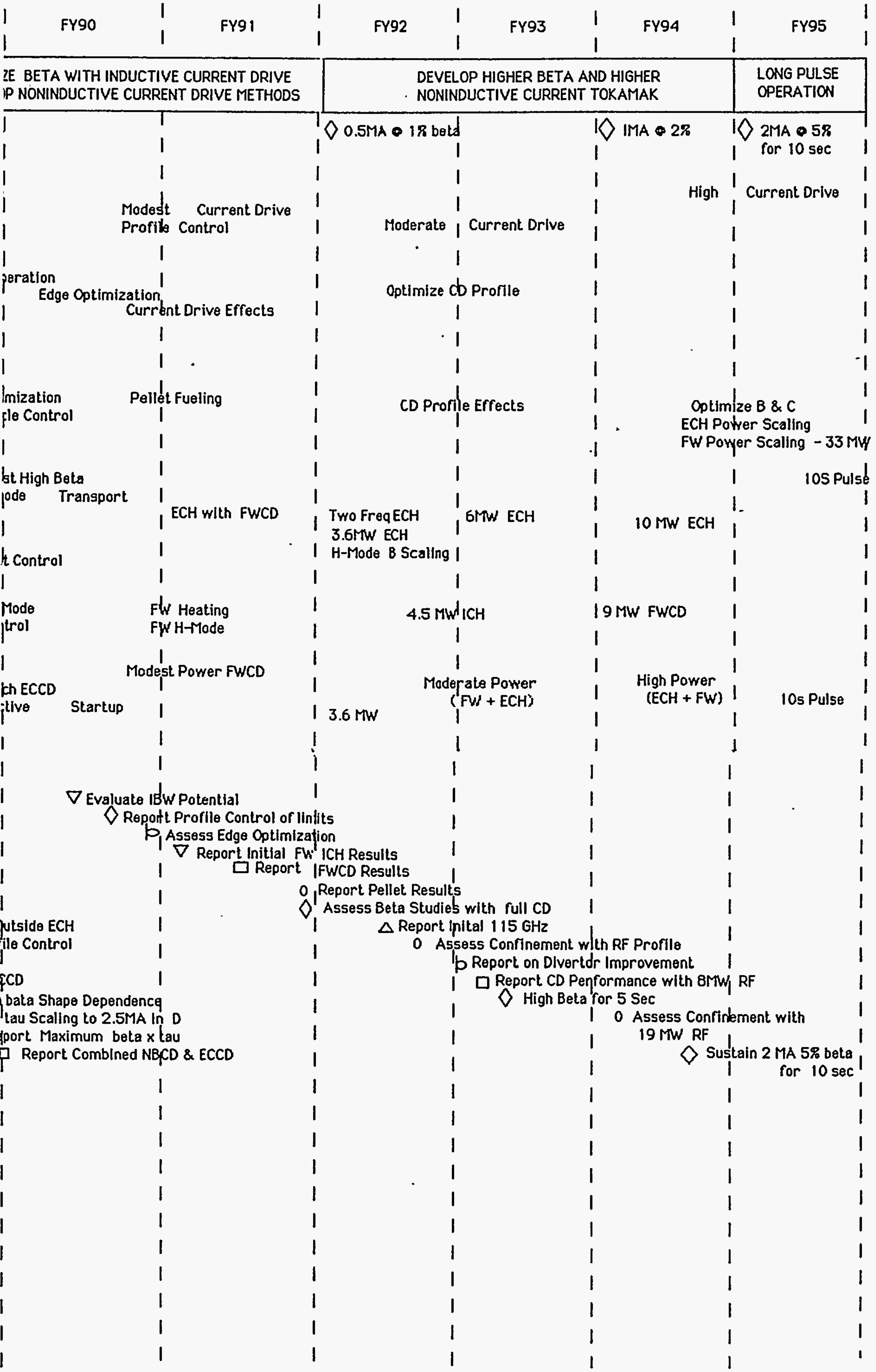
T
LONG-RANGE

CY	FY86	FY87	FY88	FY89
RESEARCH OBJECTIVES	INITIAL OPERATION	DEVELOP HIGH BETA PLASMAS WITH INDUCTIVE CURRENT DRIVE BUILD ECH & ICH SYSTEMS		OPTIMI DEVELO
NON INDUCTIVE CURRENT DRIVE BETA GOALS		◇ 0.3MA	○ 1/2% beta	
PHYSICS				
HIGH BETA (◇)	Plasma Production	High Beta Beta Limit	Double Null Shape Topology	Advanced Shape Profile Control
CONFINEMENT (O)	Achieve H-mode	H-mode scaling Current scaling Elm Physics	Ohmic H-mode Counter Injection Elm/St Suppression Low q	2.5MA Deuterium O With IBW
DIVERTOR/EDGE (⊳)	Heat Loads	Density Feedback Neutral Pressure Lansmuir Probe Strike Point Sweep	Top Divertor Inside Wall Wall Conditioning Tangential H -alpha Heat Loads	Edge Opt Parti
ECH (△)		Outside Launch Heating Elm/St Control H-Mode		Ass Outside Launch O-m Inside Launch H-Mode Profile Control Elm/S
ICH (▽)		FW Coupling to H-Mode Connection to Theory	IBW Heating	H- Profile Co
CURRENT DRIVE (□)			Demonstrate NBCD	NBCD Scaling Inside Lau Non Indu

PHYSICS MILESTONES

● Evaluate Confinement with NBI
▲ Report on Outside Launch ECH
● Report on Divertor studies
◆ Report on Beta Results
● Report on Double Null
◇ Report on beta limit
O Assess Confinement
△ Compare Inside/(
△ Assess ECH Pro
□ Assess NBCD
□ Evaluate E
◇ Report o
O Report
O R

ABLE I
RESEARCH PLAN



1989 will also contain initial efforts at affecting β limits using profile control from ECH or IBW. We also intend to try to reach higher numerical values of β_T by pushing up to the β limit in the regime $q < 3$. At present, the achieved β in this regime has been limited by the energy confinement time becoming independent of I_p for $q < 3$. We feel this loss of current scaling at $q < 3$ is owing to the combined action of sawteeth and ELMs. Consequently, the research topics on sawtooth suppression and ELM suppression appear variously under the beta, confinement, and rf program headings. The effort to attain higher β_T will also be helped by the neutron shielding which will enable deuterium neutral beam injection into deuterium plasmas which yields higher beam power and better plasma confinement. These advantages may be crucial to achieving high beta in some of the more advanced limiter plasma shapes where H–mode is probably not available. In FY 89, we also intend to mount an experiment aimed at pushing into the second stable regime.

Confinement Research

The confinement research program in FY 89 has components that relate to the beta program, to producing scaling information for future machine design, and to providing basic understanding in several areas of plasma transport research. H–mode studies will continue to be emphasized. The neutron shielding will allow us to obtain the clear scaling information with deuterium neutral beam injection into deuterium plasmas, uncomplicated by isotope effects. These data will also be our contribution to a joint effort with JET to extract the size scaling of H–mode from direct comparisons of corresponding discharges in our two machines. Following up our first production of H–mode with ECH alone and even with ohmic power alone, we will continue exploring rf produced H–mode with ECH and IBW.

In more basic studies, we will seek a greater depth of understanding of interior plasma transport coefficients and processes using pulse modulation techniques and the UCLA scattering system. Because of our excellent rotation speed profile measurements derived from the charge exchange recombination diagnostic system, momentum confinement studies will come along as a by-product of scaling studies.

Edge and Divertor Research

Boundary physics studies in FY 89 will concentrate on H–mode topics and other divertor issues relevant to future machine design efforts. We perceive that the demonstration of long pulse, steady H–mode is a critical issue in future machine designs. We have already obtained a 4.4 second steady H–mode with good confinement characterized by grassy ELMs. We have also seen effective prevention of central impurity accumulation by ELMs in high current operation. These lines of research on long-pulse and impurity control will be continued. We will also study particle transport. An effort is underway to form a collaborative arrangement with other edge plasma specialists to provide the necessary studies of erosion/redeposition, main plasma exhaust, pumping and recycling, and helium exhaust. In this area, we note the critical role that the development of helium glow wall conditioning has played in our program this year. Work will continue on defining effective methods of divertor plasma-wall interaction for future machine designs. In FY 87 and early 88, our detailed investigation of ELMs in H–mode led us to propose that ELMs are triggered by edge ballooning instabilities. In FY 89, we will concentrate on the physics of the L–H transition, bringing to bear data from the UCLA scattering system and microwave reflectometer system.

Radiofrequency Heating

The rf heating program will have two operational components in FY 89: electron cyclotron heating (ECH) and ion Bernstein wave heating (IBW). The ECH program in FY 87 and 88 utilized second harmonic outside launch and studied heating, obtained H–mode, suppressed sawteeth, and suppressed ELMs. Because of the low cutoff density for the available outside launch X–mode waves, $\bar{n}_e \lesssim 2 \times 10^{13}$ cm^{-3}, this impressive list of accomplishments was performed in a density regime somewhat disjoint from other experiments, especially the high beta work which is usually done at higher density. Because of our desire to use ECH for sawtooth and ELM suppression to improve confinement at low q in the beta program, we have installed both an X–mode inside launch ECH system for which the cutoff density is about 7×10^{13} cm^{-3} and an O–mode outside launch system for which the cutoff density is $\lesssim 3 \times 10^{13}$ cm^{-3}. Initial experiments with the inside launch system resulted in some damaged waveguides which we plan to repair during a torus vent this winter. The outside launch system is operational. In low density plasmas, ECH will assist NBI current drive by boosting the electron temperature.

The IBW research program will begin in FY 89. The entire antenna and 2 MW generator system is installed and being commissioned. We already know that IBW coupling to H–mode plasmas is less sensitive to edge conditions than fast wave coupling. Initial experiments will concentrate on basic IBW heating mechanisms. Key physics issues are linear versus non-linear absorption mechanisms and majority versus minority heating schemes. By employing the tunability of the system, varying the toroidal field, and using different harmonic resonances, great flexibility in heating location can be obtained. In particular, the IBW should be useful in pressure profile control in low B_T, high beta plasmas. This application takes on added importance since we believe the modes which prevent the attainment of the highest value of β_N are primarily pressure driven.

Current Drive Research

The current drive program in FY 89 will continue to investigate neutral beam (NBI) current drive, make a preliminary assessment of ECH current drive, and study neutral beam current drive combined with ECH. Initial NBI current drive experiments have, in addition to driving substantial currents, shown that the second stability regime can be approached. This occurs by virtue of the relatively high plasma energy developed at modest current resulting in high β_P. Further experiments are planned to explore the second stable regime behavior. The ability of ECH to assist NBI current drive by increasing the electron temperature will be studied. Current drive using ECH alone may require re-orienting either the inside or outside launchers. This change requires hardware modifications and a vent, and it is currently being considered.

3. EXPERIMENTAL PLAN

Table II summarizes the overall program for the next year for the basic program elements. The plan consists of 22 weeks of operation. Two machine vents in December and April are anticipated for ECH waveguide modifications, diagnostic improvements, and general maintenance. At the present time the most variable element is the timing of the ECH waveguide modifications. The key hardware completion dates are given to indicate significant changes in capability. The numbers indicate OFE DOE milestones.

TABLE II
DIII–D FY 1989 RESEARCH PLAN

```
                              ¦ CY 1988                                           ¦ CY 1989
                              ¦     OCT             NOV                DEC        ¦     JAN              FEB               MAR               APR             MAY                JUN              JUL             AUG                SEP               OCT     ¦
                              ¦   7  14  21  28   4  11  18  25   2   9  16  23  30   6  13  20  27   3  10  17  24   3  10  17  24  31   7  14  21  28   5  12  19  26   2   9  16  23  30   7  14  21  28   4  11  18  25   1   8  15  22  29   6  13  20  27
                              ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦   ¦
                              ¦---------------¦---------------¦-------------------¦---------------¦---------------¦-------------------¦---------------¦---------------¦-------------------¦---------------¦---------------¦-------------------¦---------------¦
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
EXPERIMENTS                   .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  RUN DAYS                    .        10     .        10     .         10        .       2       .       10      .         10        .       5       .        10     .         10        .       10      .        12     .         11        .        10     .
                              .   IAEA        APS             .                   .               .               .                   .               .               .                   .               .               .                   .               .
  MEETINGS                    .   I--I        I--I            .                   .               .               .                   .               .     ECH       .                   .               .               .                   .               .
                              .               .               .                   .    ECH        .               .                   .               .    I--I       .                   .               .               .                   .               .
  TORUS VENTS                 .               .               .                   .   I--I        .               .                   .               .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
HARDWARE AVAILABILITY         .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
                              .               .               .    INSTALL        .               .               .                   .               .AVAILABLE      .                   .               .               .                   .               .
  SHIELDING                   .               .               .   I-------------------------------------------------------------------I               I---------------------------------------------------------------------------------------------------------
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  ECH, OUTSIDE LAUNCH O-MODE  --------------------------------I                   .               .               .                   .               .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  ECH, INSIDE LAUNCH X-MODE   .               .               .                   .               .               .                   .               I-------------------------------------------------------------------I                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  IBW SYSTEM                  --------------------------------------------I       .               I-------------------------------------------------------------------I                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
OPERATION ISSUES              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  SHAPE CONTROL               .               I-------------------------------------------------------------------I                   .               .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  HIGH CURRENT DEVELOPMENT    .               .               .                   .               I-------------------------------------------I       .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
  PULSE LENGTH EXTENSION      ----------------I               .                   .               .               .                   .               .               .                   .               .               .                   .               .
                              .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
HIGH BETA STUDIES             .               .               .                   .               .               .                   .               .               .                   .               .               .                   .               .
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   PLASMA SHAPE                    .           .           .              .           .           I-----------------------------------------------------I           I--------------------------------------I
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   TRANSPORT STUDY                 .           .           .              .           .           .              .           .           I--------------I           .           .              I-----------I
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   IBW PROFILE CONTROL             .           .           .              .           .           .              I-----------------------I              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   ECH ELM SUPPRESSION             .           .           .              .           .           .              .           .           .              .           I-----------I              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   SECOND STABILITY                .           .           .              .           .           .              .           .           .              I--------------------------------------I           .

CONFINEMENT STUDIES                .           .           .              .           .           .              .           .           .              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   SCALING STUDIES                 .           .           .              .           .           .              .           I-----------I              .           .           I--------------I           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   SIZE SCALING OF H-MODE (JET)    .           .           .              .           .           .              .           I-----------I              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   H-MODE WITH RF                  .           .           I--------------I           .           .              .           .           .              I-----------I           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   STABILIZATION OF INSTABILITIES  I-----------I           .              .           .           I--------------------------I           .              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   MODULATED TRANSPORT             .           .           .              .           .           .              .           I--------------------------------------------------I              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
BOUNDARY PHYSICS STUDIES           .           .           .              .           .           .              .           .           .              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   LONG PULSE H-MODE               ------------I           .              .           .           .              .           .           I-----------------------------------------------------------------I
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   PARTICLE AND IMPURITY TRANSPORT .           .           .              .           .           .              .           .           I-----------------------------------------------------------------I
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   WALL CONDITIONING ASSESSMENT    .           .           .              I-----------I           .              .           .           .              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
RF HEATING (BASIC)                 .           .           .              .           .           .              .           .           .              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
   ECH, OUTSIDE LAUNCH O-MODE      ------------I           .              .           .           .              .           .           .              .           .           .              .           .
   ECH, INSIDE LAUNCH X-MODE       .           .           .              .           I-----------I              .           .           .              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
IBW STUDIES (BASIC)                ---------------------------------------I           I--------------------------------------------------I              .           .           .              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
CURRENT DRIVE STUDIES              .           .           .              .           .           .              .           I--------------------------------------------------I              .           .
                                   .           .           .              .           .           .              .           .           .              .           .           .              .           .
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4. GOALS FOR EXPERIMENTS IN 1989

This section contains a short summary of the principal goals for the experiments on DIII–D during 1989. The work is broken down into five subject areas: beta studies, confinement investigations, boundary physics, rf heating program, and current drive studies. Each of these areas supports the others; accordingly, in some cases, you will find the same goal listed under two topics. The aim of most DIII–D experiments is to integrate these individual topics. A common example is confinement studies carried out at high beta with divertor discharges.

4.1. BETA STUDIES

The main goals in the high beta area are:

1. Develop effective control methods for more advanced plasma shapes including
   a. Double-null divertors
   b. Plasmas with elongation up to 3
   c. Plasmas with high triangularity and indentation.
2. Extend the beta limit studies to these more advanced plasma shapes.
3. Reach the β limit in the regime $q < 3$.
4. Explore the utility of profile control derived from ECH or IBW.
5. Continue second stability investigations in high poloidal beta plasmas.
6. Study plasma transport, including fast ion transport, at high beta.

4.2. CONFINEMENT INVESTIGATIONS

1. Study confinement with deuterium injection into deuterium plasmas up to plasma currents of at least 2.5 MA.

2. Study H–mode produced with rf power alone (ECH and/or IBW).
3. Improve confinement at low q by stabilizing sawteeth and/or ELMs.
4. Provide information on the size scaling of H–mode (jointly with JET).
5. Perform a detailed transport study using pulse modulation techniques and scattering diagnostics.
6. Study momentum confinement.

4.3. BOUNDARY PHYSICS STUDIES

1. Demonstrate and study long pulse (~5 sec) quasi-stationary H–mode plasmas. Study impurity transport properties.
2. Study particle transport in H–mode to understand the flat to hollow density profiles and steep edge gradients.
3. In general, understand the physics of the L–H transition. Identify the nature of the turbulence and fluctuations that correlate with L– versus H–mode.
4. Document divertor region heat loads, particle loads, and impurity effects as a function of X–point position and for single- and double-null divertors.
5. Continue to develop improved methods of wall conditioning.

4.4. RF HEATING PROGRAM

Both electron cyclotron heating (ECH) and ion Bernstein wave heating (IBW) will be studied.

4.4.1. ECH Program

1. Verify ECH fundamental mode heating physics.
2. Attempt to produce and study H–mode with ECH alone.
3. Enhance H–mode by means of central ECH to peak up profiles or edge ECH for ELM stabilization.
4. Stabilize sawteeth.

5. Assist NBI current drive.

6. Provide a preliminary test of ECH current drive.

4.4.2. IBW Program

1. Explore and document IBW heating efficiency and coupling in various regimes. Key issues are linear versus non-linear heating mechanisms and majority versus minority species heating regimes.

2. Attempt to produce H–mode with IBW alone or in combination with ECH.

3. Utilize IBW for pressure profile control in the high beta studies.

4.5. CURRENT DRIVE STUDIES

1. Assess (preliminary) ECH current drive.

2. Assist NBI current drive with ECH.

3. Investigate second stability behavior in current drive plasmas.

5. DETAIL RESEARCH PLAN

Table III the following page gives the tentative detail Experimental Plan by experimental task. The current operative schedule calls for two weeks of operation followed by two non-operating weeks. The schedule gives the allotted time in days for an experimental as part of the plan for the two weeks in the month noted.

TABLE III
FY 1989 PLANNED EXPERIMENT TASK RUN DAYS

	CY 88			CY 89								
	O	N	D	J	F	M	A	M	J	J	A	S
EXPERIMENTS												
Run days (110)	10	10	10	2	10	10	5	10	10	10	12	11
Meetings*		I, A										A
Torus Vents		ECH										
HARDWARE AVAILABILITY												
SHIELDING												
ECH, outside launch O–mode	■	■										
inside launch X-mode				■	■	■	■	■	■			
IBW System	■	■	■							■	■	■
OPERATIONAL ISSUES (10)												
Vertical Control (b/a<3)		2										
Triangularity Control			1		1							
Indentation Control			1		1							
High Current Development					1		1					
Improved Low I_p Control					1							
Pulse Length Extension	1											
HIGH BETA STUDIES (25)												
Double-Null Divertor		2			2							
High Elongation			2			2					2	
High Triangularity							2					2
Indentation								2				
Transport Study									2			
IBW Profile Control											2	2
ECH ELM Suppression							1					
Second Stability										2		
CONFINEMENT STUDIES (25)												
D into D Scaling Study								4				4
Size Scaling of H–mode (JET)								2				
ECH H–Mode						1						
IBW H–Mode			2							2		
Sawtooth Stabilization	2					2						
Scattering Data						2						1
Modulated Transport						2		1				
BOUNDARY PHYSICS STUDIES (16)												
Long Pulse H–Mode	1								1	2		
Particle Transport											2	
Impurity Transport										2		
Fluctuation Study							1			2		
X–Point Scans						1					2	
Wall Conditioning Assessment				2								
ECH STUDIES (Basic) (6)												
Outside Launch Heating O–Mode	2											
Inside Launch Heating X–Mode					4							
IBW STUDIES (Basic) (18)												
Central Heating (3/2 ΩH)	2	2							1			
Edge Heating (3/2 ΩH)		2	2						1			2
Off-Axis Heating (5/2 ΩH)	2	2									2	
CURRENT DRIVE STUDIES (10)												
ECH Alone									2			
ECH Assisting NBI									1			
NBI Alone								1			1	
Second Stability Attempt			2						2		1	

*Meetings: I = IAEA; A = APS.

TABLE IV

DIII–D FY 1989 MASTER SCHEDULE

```
RCN BROWN
13266
                                                                                                          : 1989
                                                                        OCT         NOV           DEC     :   JAN         FEB           MAR           APR        MAY            JUN          JUL         AUG           SEP
                                                                     7 14 21 28  4 11 18 25  2  9 16 23 30  6 13 20 27  3 10 17 24  3 10 17 24 31  7 14 21 28  5 12 19 26  2  9 16 23 30  7 14 21 28  4 11 18 25  1  8 15 22 29
  ITEM                     DESCRIPTION                   TASK LEADER :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :
-------------------------------------------------------------------¦-----------¦-----------¦--------------¦-----------¦-----------¦--------------¦-----------¦-----------¦--------------¦-----------¦-----------¦-------------¦
                                                                    OPS            OPS         OPS               B/LS  OPS         OPS         OPS        OPS                   OPS         OPS         OPS         OPS
1.0      OPERATIONAL WEEKS (22 WKS)(TENTATIVE)              N/A     IXXXXXI        IXXXXXI  |  I-----I              #  I-----I     I-----I     I-----I     I-----I              I-----I     I-----I     I-----I     I-----I
                                                                            D/V         C/V|                 D/V BAKE/DC               C/V                      D/V BAKE/DC
2.0      VESSEL VENT (TENTATIVE)                            N/A             IXI         IXI|                 I--I-----I(3 DAY D/V)     I-I (1 DAY C/V)          I---I----------I(6 DAY D/V)
                                                                      IAEA  A  APS      A  |                 A                         A                        A
3.0      CONFERENCES                                        N/A       IXXI  :  IXXI     :  |                 :                         :                        :
                                                                            :           :  |                 :                         :                        :
4.0      MILESTONES                                                         :           :  |                 :                         :                        :
         ----------                                                         :           :  |                 :                         :                        :
                                                                  8/88      \           :  |                 :                         :                        :                       ¦----------------------------------------¦
  56.0     BEGIN EXPERIMENTS USING 1.4 MW ECH POWER      PRATER    ▲   COMPLETE         :  |                 :                         :                        :                       ¦               LEDGEND                  ¦
                                                                  9/88                  :  |                 :                         :                        :                       ¦                                        ¦
  51.0     COMPLETE RADIATION SHIELDING ROOF             VENKATESH▲    COMPLETE         :  |                 :                         :                        :                       ¦ CRITICAL PATH =           ==========   ¦
                                                                             10/88      \  |                 :                         :                        :                       ¦ COMPLETED MILESTONES =    ▲            ¦
  50.0     INITIATE ICH IBW EXPERIMENTS                  MAYBERRY     - - -   ▲    COMPLETE|                 :                         :                        :                       ¦ PROGRESS OF ACTIVITY =    IXXI-----I   ¦
                                                                                         11|88               :                         :                        :                       ¦ INSIDE VESSEL HDWR =      (ISVH)       ¦
  53.0     REPT THE PHYSICAL MECHANISM OF THE BETA LIMIT STAMBAUGH - - - - - - - - - - -  ▲   COMPLETE      \                         :                        :                       ¦ DIRTY VENT =              D/V          ¦
                                                                                           |            12/88 (1)                      :                        :                       ¦ CLEAN VENT =              C/V          ¦
  47.0     COMPARE INSIDE & OUTSIDE LAUNCH HEATING       PRATER     - - - - - - - - - - - -| - - - - - - -#                            :                        :                       ¦ POSSIBLE RESCHEDULE REQ'D=(1)          ¦
                                                                                           |                        1/89               :                        :                       ¦ ALL DATES SHOWN REFLECT FRIDAYS        ¦
  57.0     REPT ON PRELIM ASSESSMENT OF ECH PROFILE CONTL PRATER    - - - - - - - - - - - -| - - - - - - - - - - - - -#                :                        :                       ¦ NBI AVAILABLE BY 1/20/89 = #           ¦
                                                                                           |                                           \                        \                       ¦----------------------------------------¦
  54.0     ASSESS CONFINEMENT NBI CURRENT DRIVE DISCHARGES STAMBAUGH - - - - - - - - - - -| - - - - - - - - - - - - - - - - - - - - - - - - - -#
                                                                                           |                                                               4/89
  52.0     COMPLETE RADIATION SHIELDING WALLS            VENKATESH  - - - - - - - - - - - -| - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  -#
                                                                                           |                                                                           5/89 (1)
  48.0     EVALUATE ECH CURRENT DRIVE EFFICIENCY         PRATER     - - - - - - - - - - - -| - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  -#
                                                                                           |                                                                                          6/89
  49.0     REPT DEPENDANCE OF BETA LIMIT ON PLASMA SHAPE STAMBAUGH  - - - - - - - - - - - -| - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  -#
                                                                                           |                                                                                                      7/89
  58.0     EVAL CURRENT & PWR IN D AT HIGH PLASMA CURRENTS STAMBAUGH - - - - - - - - - - -| - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -  -#
                                                                                           |                                                                                                                                 9/89
  55.0     REPT ON THE OPTIMAL PLASMA CONFIGURATION      STAMBAUGH  - - - - - - - - - - - -| - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -#
                                                                            \           \  |                 \                         \                        \
         HARDWARE DEVELOPMENT                               N/A             :           :  |                 :                         :                        :
         --------------------                                               :           :  |                 :                         :                        :
5.0      MECHANICAL ENGINEERING TASKS                    ANDERSON           :           :  |                 :                         :                        :
         ----------------------------                                       \           \  |                 \                         \                        \
  5.1      DEVICE UPGRADES                               CALLIS                            |
           ---------------                                          UPGRADE MOTORS         |
    5.1.1    SHIELDING (ROOF)                            VENKATESH XXXXXXXXXXXXXXXXXXXXX----|--I
                                                                    DESIGN & PERMITS  ORDER|MAT'L INSTL STEEL    FORM PLYWOOD  POUR WALLS         INSTL MISC
    5.1.2    SHIELDING (WALLS)                           VENKATES IXXXXXXXXXXXXXXX-IXXXXXXX|-----I--------------I-----------I--------------------I-----------I
                                                                                       DES |         TEST              FAB
    5.1.3    OUTER WALL TILES (ISVH)                     SMITH                        IXXXX|---------I-----------------I--------------------------------------I
                                                                                           |
    5.1.4    LIMITER HEAD REPAIR (ISVH)                  ANDERSON   SCHEDULE PENDING       |
                                                                    QUOTE             PLACE|P/O   LEAD TIME                                 INSTALL        START UP
    5.1.5    CRYO COMPRESSOR UPGRADE                     LANGHORN   XXXXXXXXXXXXXXXXXXXXXXX|XXX---------------------------------------------I--------------I-----I
                                                                                           |
    5.1.6    PELLET INJECTOR                             TBD        SCHEDULE PENDING       |
                                                                     CONCEPTUAL DESIGN     |               DETAIL DESIGN                          PROCURE & FAB
    5.1.7    BIAS DIVERTOR (ISVH)                        SCHAFFER   IXXXXXXXXXXXXXXXXXXXXXX|---------------I--------------------------------------I-----------------------------------------------------------------------------)
                                                                                           |                                       CONCEPTUAL DES  DETAIL DES              PROCURE FROM ORNL
    5.1.8    IBW ANTENNA UPGRADE (ISVH)                  MAYBERRY/PHELPS                   |                                       I--------------I-----------------------I-----------------------------------------------------)
                                                                                           |DES/ORDER MAT'L   FAB TILE INSP  OVERCOAT TILE
    5.1.9    SANDIA TILE INSTALLATION (ISVH)             SMITH                             |---------------I-----------I--I--------------------I
                                                                            \           \  |                 \                         \                        \
  5.2      DIAGNOSTIC SYSTEMS                            STAMBAUGH          \           \  |                 \                         \                        \
           ------------------                                        PROCURE SPEC          |                      INSTL   SOFTWARE DEVELOPMENT       REMV & CAL
    5.2.1    DUAL RANGE SPRED                            BROOKS      XXXXXXXXXXXXXXXXX-----|---------------------I-----I - - - - - - - - - - - - - - I-----I
                                                                     CONCEPTUAL DESIGN     |                DESIGN                                PROCUREMENT & FAB
    5.2.2    CURRENT PROFILE                             POLITZER    I----------------------|---------------I--------------------------------------I-----------------------------------------------------------------------------)
```

```
                                                                          DESIGN           |                           PROCURE & FAB HDWR        INSTL & TEST
    5.2.3    CENTERPOST IR CAMERA SYSTEM                 PETRIE        IXXXXXXXXXXXXXXXXXXX|---------------------------I-------------------------I----------------------I
                                                                                           |CONCEPTUAL DESIGN                              DESIGN                                                  PROCURE & FAB
    5.2.4    MULTICHANNEL BOLOMETER                      PETRIE                            |-----------------------------------------------I-------------------------------------------------------I-------------------------)
                                                                    COMPLETE PHASE I       |                          PHASE II
    5.2.5    IR CAMERA DIGITIZING SYSTEM                 PETRIE     IXXXXXXXXXXXXXXXXXXXXXX|--------------------------]----------------------------------------------------------I
                                                                    CONCEPTUAL             |               DESIGN                                      PROCURE & FAB
    5.2.6    MULTIPULSE THOMSON                          HSIEH      IXXXXXXXXXXXXXXXXXXXXXX|--------------I-------------------------------------------I----------------------------------------------------------------------)
                                                                                           |
    5.2.7    DIAGNOSTIC SHIELDING                        SNIDER     SCHEDULE PENDING       |
                                                                            T           T  |                 T                         T                       T
  5.3      NEUTRAL BEAMS                                 COLLERAINE         :           :  |                 :                         :                       :
           -------------                                                    :           :  |                 ↓                         :                       :
    5.3.1    B/L INTERNAL INSPECTION                     COLLERAINE         :           :  |              I-----------I                :                       :
                                                                            ↓           ↓  |                                           :                       :
    5.3.2    NEUTRALIZER GAS PUFF SYSTEM                 COLLERAINE XXXXXXXXXXXXXXXXXXXXXXX|--------------------------I                :                       :
                                                                            T           T  |PROCURE MAT'L    T REPAIR DURING VENT      :                       :
    5.3.3    REPAIR LEAKING TIVS (ISVH)                  COLLERAINE         :           :  |-----------------I--I                      :                       :
                                                                            :           :  |                 :                         :                       :
  5.4      ECH INSIDE LAUNCH UPGRADE                     PRATER             :           :  |                 :                         :                       :
           -------------------------                                MOD/ASSY: VENT      :  |                 :                         :                       :
    5.4.1    TC INSTALLATION ON REMAINING WINDOW ASSY    HOFFMANN   XXXXXXXXIXI         :  |                 :                         :                       :
                                                                    FAB            ASSY :C/| C/O             :                         :                       :
    5.4.2    MODE CONVERTER MODIFICATION                 MOELLER    XXXXXXXXXXXXXXIXXXXXXXI|XXI              :                         :                       :
                                                                                           |FAB              :D/V (3 DAYS)             ↓                       :
    5.4.3    THROUGH-PORT INSTALLATION (ISVH)            HOFFMANN                          |XXX----------I -I--I(ASSUMING MOST HDWR AVAIL)                     :
                                                                                           |  FAB MANDRELS         PLT/MACH   ASSY     T C/V                   :
    5.4.4    PRODUCTION  SYSTEM (10EA)                   HOFFMANN                          |  :XXI=================I========I=======\===I=I (1DAY)             :
                                                                                           |   DES   Q  FAB        PLT/MACH                                    D/V
    5.4.5    REORIENT ANTENNAS TO 30° (2EA) (ISVH)       HOFFMANN                          |  I-----I--I-----------I-----------I - - - - - - - - - - - - - - -I--I(6 DAYS)
                                                                                           |
6.0      ELECTRICAL ENGINEERING TASKS                    ROCK                              |
         ----------------------------                                                      |
  6.1      DEVICE UPGRADES                               ROCK                              |
           ---------------                                          DESIGN                 |PROCURE & FAB              INSTALL
    6.1.1    I SQ t DETECTORS                            ARNOLD      IXXXXXXXXXXXXXXXXXXX--|--------------------------I--------------------------I
                                                                                           |               DESIGN                 PROCURE & FAB             INSTALL
    6.1.2    S1/S2 PROTECTION                            ARNOLD                            |              I-----------------------I-------------------------I--------------------------I
                                                                    IDENTIFY EQUIP REQUIRIN| CAL     LOCATE OUTSIDE SOURCE
    6.1.3    ELECTRONIC CALIBRATION LAB                  ARNOLD                   IXXXXXXXX|--------I-----------------I INITIATE PERIODIC CALIRRATION 2/1/89
                                                                                           |
  6.2      ICRH SYSTEMS                                  NEREM                             |
           ------------                                                                    |                                                                 ICRH UPGRADES
    6.2.1    ICRH UPGRADES (FWCD WITH ORNL)              NEREM                             |                                                                I--------------------------------------I
                                                                                           |
  6.3      NEUTRAL BEAM                                  COLLERAINE                        |
           ------------                                             330° SYSTEM            |                          30° SYSTEM  210° & 150° SYSTEMS
    6.3.1    ARC REGULATION                              COLLERAINE XXXXXXXXXXXXXXXXXXXXXXX|XXXXXXXXX-----I          I------------I----------------I
                                                                    REVIEW & PROCURE       |              30° SYSTEM                                30° SYSTEM                   210° SYS               150° SYS
    6.3.2    LOGIC CONTROL UPGRADE                       COLLERAINE XXXXXXXXXXXXXXXXXXXXXXX|--------------I-----------I                            I-----------I                 I-----I                I-----I
                                                                    REVIEW & PROCURE       |                                      IMPLEMENT 1ST SYSTEM (330°)
    6.3.3    SYSTEM AUTOMATION                           COLLERAINE XXXXXXXXXXXXXXXXXXXXXXX|--------------------------------------I----------------------------------------------I
                                                                                           |
    6.3.4    TOTAL BEAM ENERGY (TBE) UPGRADE             COLLERAINE XXXXXXXXXXXXXXXXXXXXXXX|-------------------------------------------------------------------------------------------I
                                                                                           |
  6.4      ECH SYSTEMS                                   NEREM                             |
           -----------                                                          REMV @ LLNL| SHIP   INSTALL OUTDOOR & INDOOR EQUIPMENT.                   POLARITY REVERSAL CONTROLS   INTEGRATION, TEST & COMM
    6.4.1    MFTF POWER SUPPLY INSTALLATION (ONE SYSTEM) SANTAMARIA                  IXXXXX|XXIXXI--------------------------------------------------------I----------------I-----I--------------------------I
                                                                                           |
    6.4.2    GYROTRON TESTS OF SN 105                    NEREM                          I--|
                                                                                           |
    6.4.3    INSIDE LAUNCH COMPONENT TESTS               NEREM     IXXXXXXXXXXXXXXXXXXXXXXX|-----------------------------------------------------I
                                                                                           |
    6.4.4    UPGRADE MAGNET LEAD COOLING SYSTEM          NEREM                             |        I--------------------------------------------I
                                                                                           |
    6.4.5    UPGRADE WATER HOSES                         NEREM                             |        I----------------I
                                                                                           |
7.0      COMPUTER MOVE                                   HENLINE                           |
         -------------                                                                     |
  7.1      MOVE USC FROM BLDG 13 TO BLDG 15              HENLINE                     IXXI  |

                                                                       OCT         NOV     !      DEC    !    JAN         FEB            MAR         APR         MAY            JUN         JUL         AUG            SEP
                                                                  30  7 14 21 28  4 11 18 25  2  9 16 23 30  6 13 14 27  3 10 17 24  3 10 17 24 31  7 14 21 28  5 12 19 26  2  9 16 23 30  7 14 21 28  4 11 18 25  :  8 15 22 29
                                                                   :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :  :
                                                                 --:-----------:-----------:--------------:-----------:-----------:--------------:-----------:-----------:--------------:-----------:-----------:--------------:
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