CUMULATIVE REPORT 1978-2014
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PLASMA PHYSICS RESEARCH IN THE GEORGIA INSTITUTE OF TECHNOLOGY FUSION RESEARCH CENTER 1978-2014

Prior to the 1990s, plasma research in the GIT-FRC was in the areas of impurity transport and rotation (refs A), experimental plasma physics (refs B) and a general range of plasma physics such as MHD and burn control (refs C). In the early-1990s the plasma research activities of the GIT-FRC were focused more strongly on the plasma edge and plasma rotation, and new research projects were undertaken on impurity-seeded radiative power exhaust (refs D), neutral atom transport (refs E) and edge radiative instabilities (refs F). Independent calculations by the GIT-FRC group and by a group in Germany led to the radiative edge/radiative divertor power exhaust solution being examined and ultimately adopted for ITER In 1998, Tom Simonen, then Director of the DIII-D Program, invited Prof. Stacey to utilize the modeling and computational resources of the FRC to support the DIII-D Program as part of the DIII-D National Team. The initial DIII-D effort was directed towards the radiative edge impurity "seeding" experiments which DIII-D was undertaking in support of the effort to develop a radiative power exhaust solution for ITER.

GIT work on DIII-D evolved in the early 2000s to encompass radiative instabilities such as MARFEs and disruptions (refs F) and neutral particle recycling (refs E) calculations in the plasma edge. Predictive models for density limits due to MARFEs, disruptions, divertor choking, etc. were developed, incorporated in a GIT plasma edge modeling code for DIII-D (an early version of GTEDGE), and validated by experimental comparison. A new interface current balance methodology for neutral atom transport in the complex edge geometry of DIII-D was developed and Incorporated in the GTEDGE code and in the more geometrically comprehensive GTNEUT code (Refs E13 & 14) which is used for detailed analysis of neutral recycling in DIII-D experiments. GTNEUT was demonstrated to obtain accuracy comparable to Monte Carlo but in a few percent of the MC computing time, and was used for several DIII-D neutral recycling analyses (Ref E17).

Analysis of plasma rotation measurements in DIII-D using an extended neoclassical viscosity theory (developed in large part in the GIT-FRC) has demonstrated that, when poloidal asymmetries in flux surface geometry and plasma variables are taken into account, there is good agreement with experimental measurements, except in the plasma edge. This work established a validated predictive capability for toroidal velocity (Refs A30 & 31).. A different methodology has been developed for calculating the intrinsic rotation due to ion orbit loss which predicts the intrinsic rotation measured in DIII-D quite well (Refs.A32 &34).

For the past decade, the major focus of the GIT analysis and interpretation of DIII-D experiments has been in the area of plasma edge physics (refs G & H). A systematic development (particle, momentum and energy balance) of the equations that should be used to calculate or interpret the measurements of profiles of pressure, density, temperature, rotation, electric field, etc. in the plasma edge identified the importance of non-diffusive transport effects (electromagnetic particle pinch, ion orbit loss) which must be incorporated in the existing equations used for such analyses. A new generalized diffusion theory (Ref H14) was developed and incorporated in the GTEDGE code, which was applied to interpret the diffusive and non-diffusive transport underlying the measured parameter profiles in the DIII-D edge plasma Refs H). New insights have been obtained about the evolution of edge profiles at the L-H transition, between ELMs, etc., and about the differences in edge transport between H-mode and RMP discharges, between L-mode and H-mode discharges, etc. New and extended techniques for data fitting have been developed in collaboration with DIII-D experimentalists.

The work of the GIT-FRC on plasma physics research and the analysis and interpretation of DIII-D experiments from 1978-2014 was performed by Profs. G. Bateman (NRE), J. Mandrekas (NRE), W. M. Stacey (NRE), C. E. Thomas (NRE) and. E. W. Thomas (PHYS), and by a score or more of post-doc and graduate student researchers, working in collaboration with physicists from GA, ORNL, PPPL, LLNL, UCSD and UTEXAS. Numerous papers in leading peer-reviewed journals and presentations at APS-DPP, TTF, H-Mode, PET and other conferences. 17 PhD theses, 5 MS theses and 15 undergraduate research projects have resulted from the GIT-FRC plasma research since the 1980s, many of them associated with the analysis and interpretation of DIII-D experiments.

PLASMA PHYSICS PAPERS BY GIT-FRC RESEARCHERS

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Stacey.

FUSION TECHNOLOGYAND REACTOR DESIGN RESEARCH IN THE GEORGIA INSTITUTE OF TECHNOLOGY FUSION RESEARCH CENTER 1978-2014

The initial work on fusion technology and design at Georgia Tech was associated with the US contribution to the IAEA INTOR Workshop to evaluate the readiness of fusion to move forward to the experimental power reactor stage, during the late 1970s and 1980s. (Refs I) The US effort in INTOR was organized and managed by Prof. Stacey and contributed to by Profs. M. A. Abdou, G. Bateman and C. E. Thomas from the GIT-FRC and hundreds from other organizations. When the ITER project was formed at the end of the INTOR Workshop, Prof. Stacey served as Chairman of the ITER Steering Committee US through the 1990s, and researchers in the GIT-FRC turned their attention to technology investigations of plasma-materials interactions, tritium breeding blankets and low-activation structural materials (refs J). Applications of variational methods to nuclear reactor dynamics and neutral particle transport in plasmas was also examined (Refs. L).

In the 1990s and continuing today, student design projects guided by Profs. Stacey (NRE), Mandrekas (NRE), Lackey (ME), Ghiaasiaan (ME), Tedder (ChE), Van Roojen (NRE) and Erickson (NRE) investigated several fusion-fission transmutation reactor concepts and performed supporting fuel cycle and dynamic safety analyses (refs K). The fuel cycle work led to a collaborative effort with the Karlsruhe Institute of Technology over several years on the evaluation of the GIT SABR concept (a tokamak based on ITER physics and technology surrounded by an annular metal-fueled, sodium-cooled fast reactor of the IFR type—Refs K21 & K32) for the transmutation of spent nuclear fuel.

The FRC being located in a nuclear engineering department provided many opportunities for adapting and extending fission reactor physics and engineering methodologies for application to fusion plasma and reactor analysis. Much of the work on radiative instabilities (Ref F28) was based on the stability analysis methodology of nuclear reactor physics, and the Transmission-Escape Probability method (Refs E) for neutral atom transport was adapted from the neutron transport theory of nuclear reactor physics. The nuclear fuel cycle methodology and the reactor and heat removal systems transient analysis methods of nuclear reactor physics were adapted for the SABR fuel cycle (Refs K9, K15, K24, K30) and dynamic safety (Ref K25) analyses. Variational analysis methods were developed for nuclear reactor dynamics and neutron transport analyses (Refs I1-I3)) and then applied to neutral particle reaction rate calculations (I4).

Several hundred graduate and advanced undergraduate students have been involved in this effort, which has led to 4 PhD theses and 9 MS theses, as well as numerous publications and presentations.

FUSION TECHNOLOGY & REACTOR DESIGN PAPERS & REPORTS BY GIT-FRC RESEARCHERS

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L. VARIATIONAL METHODS

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ONGOING THESIS RESEARCH

PhD

Student: John-Patrick Floyd
Topic Area: Evolution of Edge Profiles and Transport Between ELMs in DIII-D.
Background: Refs.H13
DIII-D Collaborator: R. J. Groebner

Student: Theresa Wilks
Topic Area: Radial Electric Field and Profile Structure in the DIII-D Edge Plasma
Background: Refs. H34, H36
DIII-D Collaborator: T. E. Evans

Student: Jonathan Rovetto
Topic Area: Interpretation of Edge Thermal Transport in DIII-D & Comparison with Theory
Background: Refs. H16, H38
DIII-D Collaborator: TBD

Student: Andrew Bopp
Topic Area: Dynamic Safety Analysis of the SABR Fusion- Fission Hybrid
Background: Refs K25

MSNRE

Student: Timothy Collart
Topic Area: Interpretation of Angular Momentum Transport in DIII-D & Comparison with Theory*
Background: Refs. A31, A34, H15
DIII-D Collaborator: B. A. Grierson

Student: Maxwell Hill
Topic Area: Benchmarking a Burning Plasma Dynamics Model to DIII-D Data*
Background: Refs. I36-I39, J17
DIII-D Collaborator: TBD

Student: Nicholas Piper
Topic Area: Interpretation of Change in Edge Toroidal Rotation Profile Across L-H Transition in DIII-D*
Background: Refs. H31
DIII-D Collaborator: R. J. Groebner

Student:: Matthew Schumann
Topic Area: Poloidal Distribution of Particle, Momentum and Energy Fluxes into the SOL in DIII-D*
DIII-D Collaborator: TBD

- Intend to continue this area of research for a PhD thesis.

PEOPLE IN GIT-FRC

FACULTY

M. A. Abdou (NRE)	Fusion Nuclear Engr*	1978-79
G. Bateman (NRE)	Plasma Theory & Comp*	1980s
A. S. Erickson(NRE)	Heat Removal, Fusion-Fission*	2010s
S. M. Ghiaasiaan(ME)	Heat Removal*	1990s-2000s
N. E. Hertel (NRE)	Waste Management*	1990s
W. J. Lackey (ME)	Materials Fusion-Fission*	1990s-2000s
J. Mandrekas (NRE)	Plasma Phys*.	1987-2004
B. Petrovic (NRE)	Fuel Cycle, Fusion-Fission*	2010s
W. M. Stacey (Dir., NRE)	Plasma Phys., Design*	1970s-2010s
D. W. Tedder (ChE)	Nucl. Chem., Fusion-Fission*	1990s-2000s
C. E. Thomas (NRE)	Exp. Plasma Physics*	1985-1991
E. W. Thomas (PHYS)	Atomic Phys*.	1980s-1990s
W. Van Rooijen (NRE)	Reactor Phys., Fusion-Fission*	2000s

*principal research interest

POST-DOCS

Z. El-Derini		Plasma Phys.	1979
A. W. Bailey		Plasma Phys.	1980s
C. M. Ryu	(NFRI-Kor)	Plasma Phys.	1980s
J. Mandrekas	(OFES-DOE)	Plasma Phys.	1980s
M. Kwon	(NFRI-Kor)	Plasma Phys.	1990s
R. W. Johnson		Plasma Phys	2000s

PhD.s

R. B. Bennett	(Gen Pub Util)	Plasma Impurity Transport	1984
A. B. DeWald	(SRL)	Plasma-Material Interaction	1984
R. N. Norris	(ORNL)	Plasma MHD Instabilities	1984
G. W. Neeley	(B&W)	Plasma Impurity Transport	1987
M. A. Malik	(Pak AEA)	Plasma Impurity Transport	1988
M. Kwon	(KSTAR)	Exp. Plasma Phys, ICRH	1990
G. R. Hanson	(ORNL)	Exp. Plasma Phys, Reflectometry	1991
M. R. Wade	(DIII-D)	Exp. Plasma Phys, Fast Ions	1991
G. Pautasso	(ASDEX-U)	Plasma Rotation	1991
K. Indireshkumar		Plasma Phys.—Transport	1993
R. Logan		Exp. Plasma Phys, Pulsed Electrodes	1994
I. Collazo		Exp. Plasma Phys. Reflectometry	1995
J. A. Favorite	(LANL)	Variational Transport Theory	1997
F. W. Kelly		Plasma Radiative Instabilities	2000
R. Rubilar	(KAPL)	Neutral Atom Transport	2000
E. A. Hoffman	(ANL)	Fusion-Fission Fuel Cycle	2002
D.-K. Zhang	(GIT)	Neutral Atom Transport	2005
Z. W. Friis	(West Consult)	Neutral Atom Transport	2010

C. S. Sommer	(KAPL)	Fusion-Fission Fuei Cycle	2011
C. Bae	(KSTAR)	Plasma Rotation	2012
J-P. Floyd		Edge Plasma Transport Inter-ELM	2014*
T. M. Wilks		Interp DIII-D Edge Plasma Structure	2015*
J. J. Rovetto		Interp DIII-D Edge Transport	2016*
M. D. Hill		Fusion-Fission Plasma Dynamics	2016*
A. T. Bopp		Fusion-Fission Reactor Dynamics	2016*

*anticipated

MSNREs

D.R. Jackson		Plasma Rotation	1993
J. A. Favorite	(LANL)	Variational Reactor Dynamics	1995
E. A. Hoffman	(ANL)	Low Activation Fusion Materials	1995
D. C. Norris	(SAIC)	Plasma Facing Components	1997
A. N. Mauer	(NRC)	Transmutation Reactor	2002
Z. W. Friis	(West Consult)	MARFEs & H-L Transition	2005
J. W. Maddox	(AREVA)	Fusion-Fission Fuel Cycle	2006
C. M. Sommer	(KAPL)	Fusion-Fission Fuel Cycle	2008
T. S. Sumner	(ANL)	Fusion-Fission Dynamics & Safety	2008
J-P. Floyd		Numerics of Generalized Diffusion	2011
M-H. Sayer	(USN)	Interp. L-H Transition Exps.	2012
T. M. Wilks		Interp. RMP Phasing Exps.	2013
C. S. Stewart		Fusion-Fission Fuel Cycle	2013
A.T. Bopp		Fusion-Fission Bowing Coefficient	2013
M. D. Hill		Modeling Diii-D Plasma	2014*
T. G. Collart		Interp DIII-D Rotation Exps.	2014*
M. Schumann		Interpret DIII-D Divertor Exps.	2015*
N. A. Piper		Interpret DIII-D L-H Trans Exps	2015*

*anticipated

UNDERGRAD RESEARCH STUDENTS

C. Hammond (NRE)	1987
M. Carroll(NRE)	1998
Z. Friis(NRE)	2005
S. Jones(NRE)	2005
J-P. Floyd(NRE)	2006
A. Seltzman(PHYS)	2006
S. Pinkerton(PHYS)	2008
L. Zhou(PHYS)	2009
R. Lober(ME)	2009
T. Collart(NRE)	2012-13
S. Tandon(ME)	2012-13
T. Blanton(NRE)	2012
S. Mellard(ME)	2012-14
G. Salkowski(NRE)	2014
D. Carroll(NRE)	2014

COLLABORATORS FROM NON-GIT ORGANIZATIONS*

C. Bae	KSTAR
J. A. Boedo	UCSD
N. Bretz	PPPL
J. D. Callen	U WISC
R. J. Colchin	ORNL
J. Dunlap	ORNL
D. A. Ehst	ANL
P. Edmonds	U. TEXAS
T. E. Evans	GA
J. Galambos	ORNL
R. Gandy	AUBURN
R. Goulding	ORNL
B. A. Grierson	PPPL
R. J. Groebner	GA
J. J. Grudzinksi	ANL
J. Harris	ORNL
E. A. Hoffman	ANL
G. L. Jackson	GA
A. Kritz	LEHIGH U
A. W. Leonard	GA
A. Mahdavi	GA
T. K. Mau	UCSD
D. Meade	PPPL
S. Medley	PPPL
M. Murakami	ORNL
T. H. Osborne	GA
L. W. Owen	ORNLL\
L. J. Perkins	LLNL
C. C. Petty	GA
T. W. Petrie	GA
D. Post	PPPL
J. Rapp	TEXTOR
M. E. Rensink	LLNL
L. Roquemore	PPPL
T. D. Rognlien	LLNL
V. Romanelli	KFK
M. Salvatores	CEA
T. Shepardt	ORNL
D. J. Sigmar	ORNL/MIT
W. M. Solomon	PPPL

M. R. Wade	GA
P. West	GA
J. Wilgen	ORNL
A. Wootton	U. TEXAS

*There was a major collaboration with hundreds of physicists and engineers in the US fusion program during the course of the INTOR and ISCUS work in the 1979-2000 period which is documented elsewhere.

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