PROGRESS IN TECHNOLOGY
AT JET

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This paper reviews the work of many people from UKAEA, EFDA Close Support Unit and the EFDA Associations.
Contents

1. Results from JET Operations
2. JET Enhancements
3. Tritium Technology
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JET Operations

- Unique ITER relevant capability:
  - Tritium operation / recycling
  - Remote handling
  - Beryllium
  - Size (90m³ plasma, 4 Tesla)
  - NB, RF, LH, pellets, diagnostics….

- ITER-like high triangularity scenarios (>0.47)
  - $H=1, \, n=1.1 \times n_G @ 2.5MA$

- Advanced ITB’s, ‘Steady state’ scenarios…

*cf J Pamela, SOFT*

A Kaye, 16th ANS Topical Meeting on technology of Fusion Energy, Madison, Wisconsin, 14-16 September, 2004
Highly shaped scenarios:
- High vertical forces (x2)
- Management controls

Energy quench:
- Flux to divertor and FW
- Good for ITER divertor!

Fast current quench scaling to ITER:
- c. 40ms independent of thermal stored energy

Diagnostic upgrade in hand:
- More halo probes
- Fast gas valve

cf V Riccardo

Measure v. predicted vertical force (tonnes)
Recent Enhancements - NB Heating Power Upgrade

- New power supplies (2)
  130 kV x 130 A, switched mode

- New PINI accelerators to double current (to 60A)

- New beam scraper to handle increased power

- ...........22.7 MW total NB injection

- Neutraliser modifications (cooled septum) being implemented to reach 25 MW potential

cf. D C Edwards, SOFT
D Ciric, SOFT

A Kaye, 16th ANS Topical Meeting on technology of Fusion Energy, Madison, Wisconsin, 14-16 September, 2004
Conjugate-T Marching of RF Antenna

- Two A2 antenna straps connected with remote conjugate-T

- VSWR remains below c. 1.5 at generator during ELMs

cf. I Monakhov, SOFT
LHCD Matching at ITER Relevant Gaps to the Separatrix

Good coupling /current drive efficiency at 100mm gap to separatrix

Gas puffing adjacent to launcher, effective with D$_2$ and CD$_4$ (cf also Tore Supra)

Sensitive to puffing location/rate ($10^{22}$ elect/s)

Requires further understanding to allow extrapolation to ITER

cf. A Ekdahl, EPS
J Mailloux, IAEA
Extreme Shape Control

Simultaneous control of up to 36 gaps to first wall

Safe operation of highly shaped ITER-like scenarios

Pulse No. 61995 Termination with XSC

Pulse Termination of Highly Shaped Scenario using Extreme Shape Controller
cf. R Albanese, SOFT
The JET ‘EP’ Enhancements: Divertor

- Load bearing divertor septum
- New inner protection tiles
- Refurbished magnetics/Langmuir probes/bolometer
- More halo probes

Allows ITER-like scenarios with increased lower triangularity (0.56) with strong additional heating (40MW for 10sec)
EP Diagnostic Enhancements

• Around 20 new or improved diagnostics - including burning plasma diagnostics (lost alpha and neutron detectors)

• Lost alpha diagnostics include Faraday cup array (from PPPL) and scintillator probe (from IPP)
EP Tritium Retention Diagnostics

- Tritium related diagnostics being installed in the divertor

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EP ICRH Antenna

- New ITER-like ICRF antenna to be installed Nov 2005
- 8 short straps
- Internal conjugate-T matching
- Target: 7.5 MW coupled power, 30-55 MHz
- Matching and capacitors critical!

cf. F Durodie, SOFT
Trace Tritium Campaign

1-3% tritium campaign with tritium NB injection implemented in autumn 2003

• Limits to the Experiment
  – 14 MeV neutron production: $10^{19}$
    (320 $\mu$Sievert/hr 4 months into shutdown)
  – Tritium to torus: 0.5 g
  – Tritium on torus cryopump: 0.7 g

• Tritium Inventory
  – Total of 5 g through machine (of which 4.5 g in NB, 2 ion sources)
  – Negligible additional tritium retained in torus after clean-up

• Safety Issues
  – Nearly equivalent to full tritium campaign
  – Prior review of safety case / approval by Safety Committee
  – Technical review of Key Safety Equipment - some upgrades
  – Extensive training of personnel

  cf T T C Jones, Baden Baden
Alpha particle Localisation during a TTE Pulse

TTE PHYSICS OBJECTIVES

Study of:

- Tritium transport
- Alpha particle dynamics
- Heating and current drive

Using

- 80 ms Tritium gas puffs
- 500 ms NB tritium injection

cf K-D Zastrow, EPS

Gamma emissivity from $^9$Be($\alpha$,n$^\gamma$)$^{12}$C

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Tritium Retention

- Re-deposition on inner strike point/erosion at outer and FW (grad B drift up)
- Co-deposition of tritium at inner strike point; up to 1 TBq/g, surface area 4-7 m²/g
- Some strongly bound in carbon matrix

cf P Coad, Baden Baden

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Tritium Technology

- Detritiation
  - Oxygen-methane flame effective at detritiation of CFC waste
  - Pulsed flash-lamp (300J x 10Hz) detritiation of carbon films on CFC tiles in-vessel being evaluated (including in-vessel demonstration)
  - Pulsed laser system for Carbon films is under development at KFK and PPPL
  - Water detritiation facility being optimised at FZK for use at JET
    Combined Electrolysis and Catalytic Exchange method
    10 tonnes throughput, $10^4$ decontamination factor

- Cryosorption Pumping
  - ITER activated charcoal supercooled LHE panel supplied by FZK
    installed in JET tritium plant for study of tritium characteristics

- Safety Issues
  - Assessment of hazards of highly tritiated dust and flakes.
  - Cumulative experience in management of safety of a tritiated machine over an extended period

  cf BADEN BADEN papers
JET Activation Since 1990

- Dose rate at manned access June, 2004
  260 \(\mu\text{Sievert/hr}\)

of which long lived activation from DTE1
(Co 60, 5 year half life)

100 \(\mu\text{Sievert/hr}\)

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Remote Handling

- **Virtual reality**
  Development of procedures/training implemented largely using virtual reality software

- **Force feedback**
  Force feedback to the operator from strain gauge transducers in the boom - load capability extended to load capacity of boom (400 kg)

Present shutdown has 10 months remote handling, 1 month manned access - 80% reduction in dose to c.40 man.milliSieverts.

*A Kaye, 16th ANS Topical Meeting on technology of Fusion Energy, Madison, Wisconsin, 14-16 September, 2004*
Conclusions

• JET has unique capability and contributes to ITER in many areas, both operations and technology

• Many enhancements have been implemented over the past five years, and continue to be implemented in the present shutdown

• JET contributes especially in Tritium technology, and has recently run a further trace tritium campaign

• JET has a strong remote handling capability which allows major enhancements to be implemented despite machine activation and tritium operations.