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** See annex of J. Pamela et al, "Overview of JET Results ",*
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INTRODUCTION

Erosion and deposition processes have a critical impact on material lifetime and fuel inventory. The assessment of such effects is therefore of primary importance for the steadystate operation of a reactor-class device fuelled with a deuterium-tritium mixture. The experimental approach to studies of material transport involves spectroscopic methods, surface probes and tracer techniques. The term “tracer” denotes an agent not usually present in the system introduced deliberately in minute quantities. In controlled fusion devices, material migration studies by means of tracer techniques are essential to the assessment of erosion, re-deposition and tritium retention. An important issue at JET is to understand the transport of carbon and its co-deposition with fuel species in shadowed areas of the inner divertor where the massive fuel accumulation has been observed in the past [1]. One way in which this is being done is via injection of $^{13}CH_4$ and other species at the end of campaigns preceding major shut-downs, followed by detailed *ex-situ* surface studies of plasma facing components (PFC) retrieved from the torus.

The aim of this paper is to provide: (i) an overview of the latest tracer injection experiment performed at JET in 2004 on the last operation day with the Mk-IISRP divertor and (ii) a comparison with results of the previous experiment of this kind performed at the conclusion of the operation with Mk-IIGB divertor in 2001 [2,3].

1. EXPERIMENTAL

Figure 1 (a)-(c) show the experimental details. Two tracers were introduced by toroidally symmetric gas injection during 32 ELMy H-mode Pulses (Nos: 63405-63445, I_p = 1.2MA B_t = 1.2T and line averaged density = 7.8×10^{19} m^{-3}) with strike points on the vertical targets: 4.29×10^{23} $^{13}CH_4$ molecules (9.26g ^{13}C atoms) from the outer vertical target and 4.25×10^{21} *tri*-methyl borine (TBM) molecules from the outer divertor base (private flux region); TMB was diluted in hydrogen (0.5% TBM in H_2). In addition, hafnium was laser ablated from a single location on the outer midplane. A specially designed fast reciprocating collector probe (with a BN body and equipped with dedicated Si samples) was introduced in each discharge from the top, low-field side of the poloidal cross-section.

During the shutdown directly following this experiment a number of PFC were retrieved by remote handling for *ex-situ* examination: two complete poloidal sets of tiles from the divertor, several components of the main chamber inner and outer poloidal limiters and the collector probe. Surface analyses have been carried out by means of accelerator-based ion beam analysis (IBA) methods and secondary ion mass spectrometry (SIMS) to quantify and obtain the surface and depth distributions of D, Be, B, ^{12}C, ^{13}C and other elements. Details regarding procedures of several IBA techniques in studies of PFC from JET can be found in [4]. The analyses are ongoing so that this paper reports on results available until now for divertor Tiles 1, 3, 4, 7, 8, several outer limiter tiles and the collector probe.

2. RESULTS AND DISCUSSION

Figure 2(a) and (b) show the deposition profiles of C-13 on Tiles 7 and 8, i.e. near the injection point at the outer target. Toroidally integrated amount of the tracer is 7% on Tile 7 and 6% on Tile 8 of the total gas input. No tracer has been found on the rear surfaces of the tiles. This indicates that only a limited amount of carbon sticks to surfaces in the gas inlet vicinity. Analysis of the collector probe (see Fig.3) shows conclusively that C-13 is found predominantly on the side connected to the outer divertor, indicating that the material can be transported by the flows in the scrape-off layer (SOL) from the injection point in the divertor towards the top of the torus. Plots in Fig.3(c) summarise the measurements carried out by various techniques. The distribution of species in the inner divertor is shown in Fig.4(a), (b) for Tiles 1 and 4, respectively. On Tile 3 the amount of detected ^{13}C was 0.7% of the gas input.

The essential results from the examination of the inner divertor tiles are: (i) the tracer is found on the vertical targets (Tiles 1 and 3); (ii) significant ^{13}C deposition has occurred on the plasma facing-surface of the base tile; (iii) no ablated Hf and injected boron has been identified on the analysed surfaces; (iv) no tracer has been detected in the shadowed region of Tile 4. The latter result is the same as obtained in the previous tracer experiment, but there are also differences between the two experiments. They are summarised in Table 1.

CONCLUSION

The results indicate that material can indeed be transported from the outer to inner divertor following a pathway through the SOL plasma. The lack of observed tracer migration to the inner divertor shadowed region, supports the current idea that carbon transport to that area is a multi-step process and is a function also of magnetic geometry.If only vertical target configurations are used the carbon which migrates to the base plates is not further disturbed by subsequent direct plasma impact. There is no immediate C-D film formation in the shadow during operation with strike points on the vertical targets. The presence of C-13 on the base Tile 4 also suggests a significant role of ELMs in re-erosion and re-distribution of carbon from vertical tiles of the inner divertor. This issue will be addressed when the analyses of all tiles from the full poloidal cross section of divertor have been completed.

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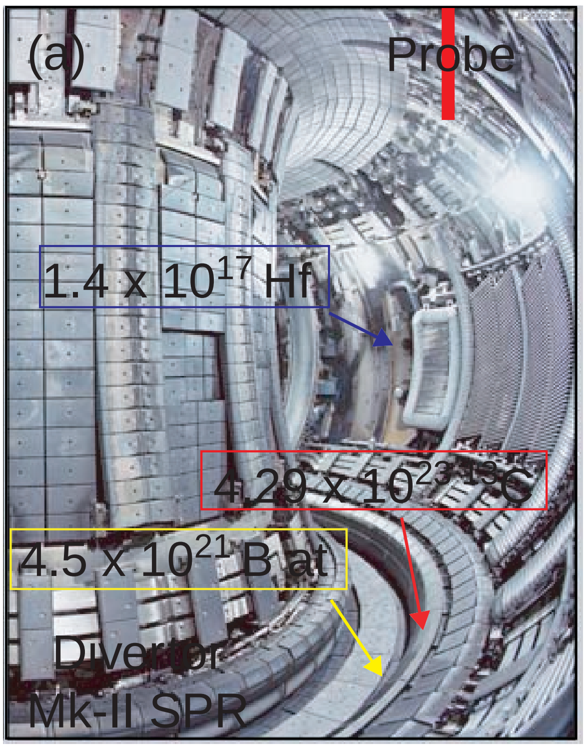
REFERENCES

[1]. J.P. Coad et al., J. Nucl. Mater. 290-293 (2001) 224.
[2]. J. Likonen et al., Fusion Eng. Des. 66-68 (2003) 219.
[3]. M. Rubel et al., J. Nucl. Mater. 329-333 (2004) 795.
[4]. M. Rubel et al., Vacuum 78 (2005) 255.

End of C-4 campaign: Mk-IIGB	**End of C-14 campaign: Mk-IISRP**
Localised $^{13}CH_4$ source from top: $1.3\times10^{23}C$	Toroidally symmetric $^{13}CH_4$ injection from the outer divertor: $4.3\times10^{23}C$
L-mode	ELMy H-mode
^{13}C integrated amount on Tile 4: $1.1\text{x}10^{21}$, i.e. 0.8% of the input (SIMS)	^{13}C integrated amount on Tile 4: 2.8×10^{22}, i.e. 6.5% of the input.
Total amount detected in the divertor: 45% in the inner (Tiles 1 & 3) and < 0.5% in the outer.	Total amount found on the divertor tiles analysed until now: 9.7% on the inner Tiles 1,3,4 and 13.0% on the outer Tiles 7 and 8.

Table 1: Comparison of two C-13 tracer experiments at JET.



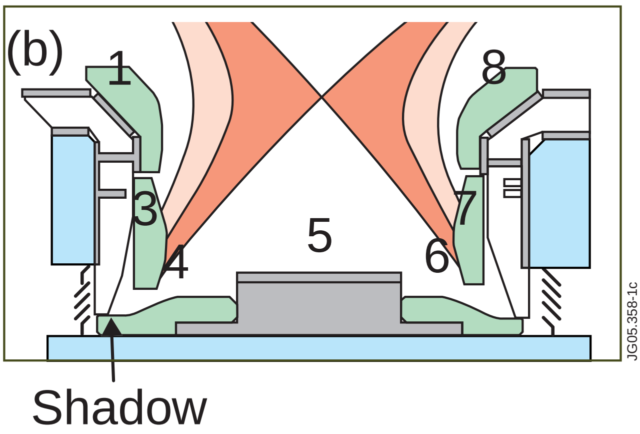


***Figure 1**: (a) JET with the Mk-IISRP divertor. Injection points of tracers are indicated: $^{13}CH_4$ from the outer divetror ring, TMB from the outer divertor base; Hf from the outer midplane;*

***Figure 1**: (b) divertor cross-section with indicated strike point position during the experiment.*

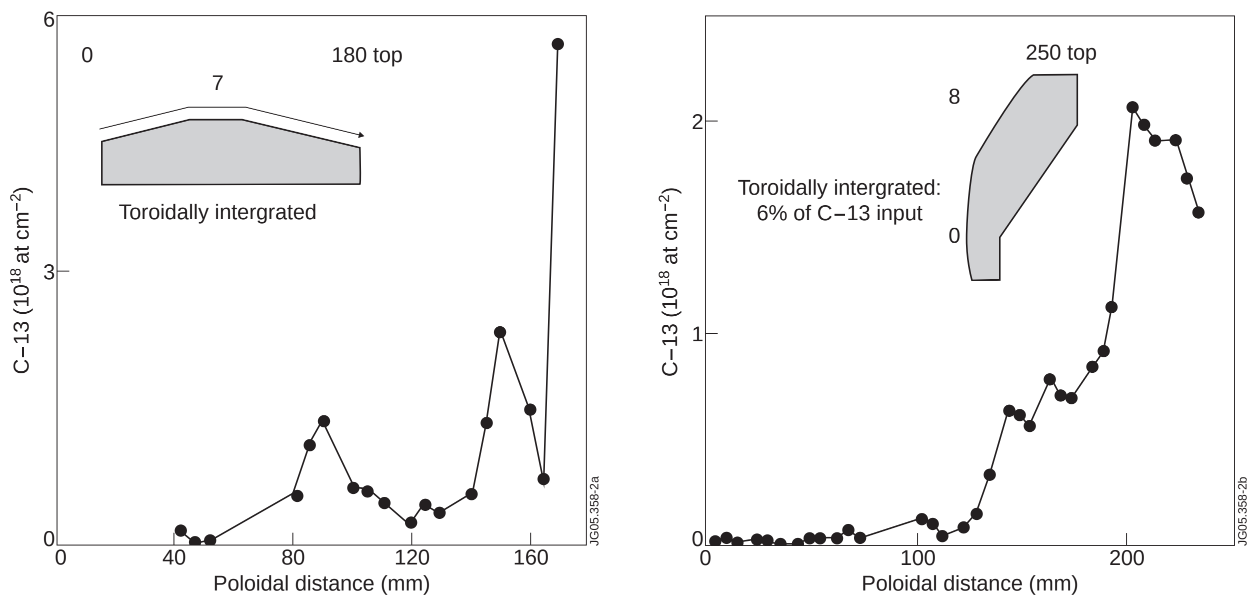


Figure 2: Poloidal distribution and amount of C-13 on vertical plates in the outer divertor near the gas injection point: (a) on Tile 7; (b) on Tile 8.

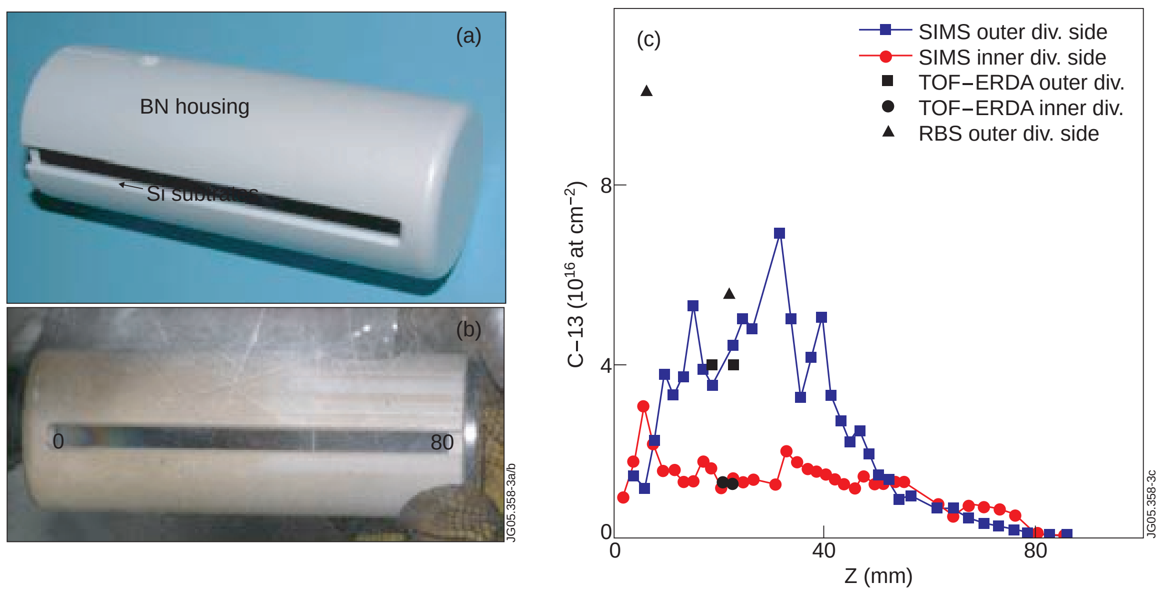


Figure 3: The collector probe head before (a) and after the exposure (b) and the distribution of C-13 on both sides of the probe (c).

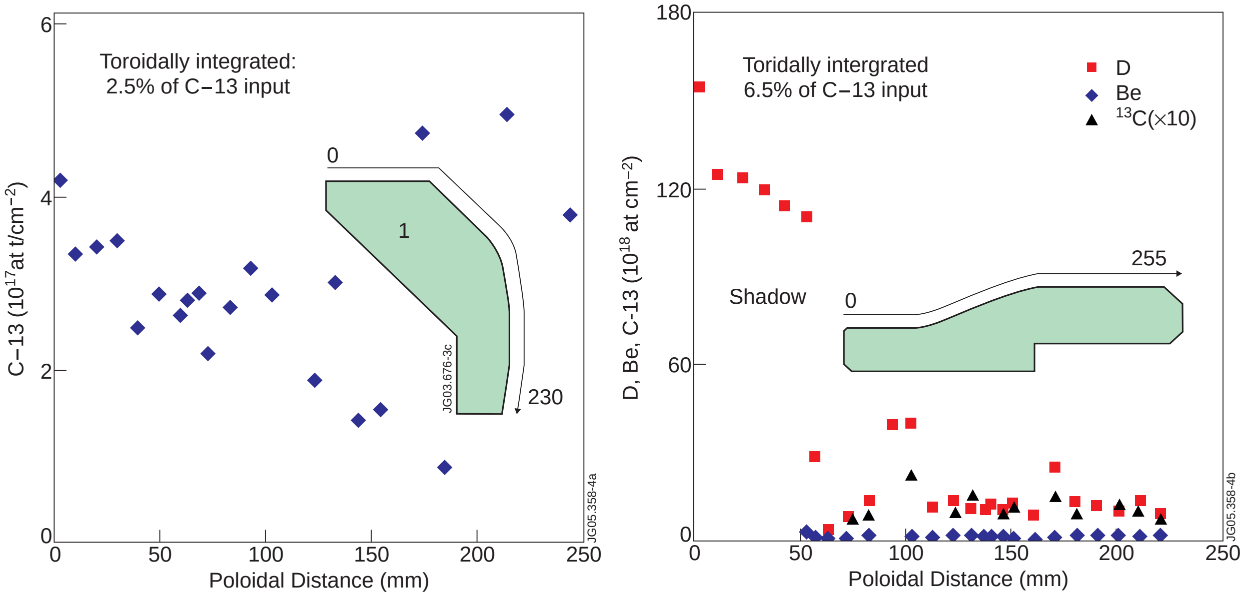


Figure 4: Poloidal *distribution and amount of species found on the inner divertor tiles:*
(a) C-13 on the vertical Tile 1 and (b) D, Be and C-13 on the horizontal base Tile 4.