DEVELOPMENT OF A NOVEL CONTAMINATION RESISTANT ION CHAMBER FOR PROCESS TRITIUM MEASUREMENT AND USE IN THE JET FIRST TRACE TRITIUM EXPERIMENT

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The accuracy of process measurements of tritium with conventional ion chambers is often affected by surface tritium contamination. The measurement of tritium in the exhaust of the JET torus is particularly difficult due to surface contamination with highly tritiated hydrocarbons. JET's first unsuccessful attempt to overcome the contamination problem was to use an ion chamber, with a heating element as the chamber wall so that it could be periodically decontaminated by baking. The newly developed ion chamber works on the principle of minimising the surface area within the boundary of the anode and cathode.

This paper details the design of the ion chamber, which utilises a grid of 50-micron tungsten wire to define the ion chamber wall and the collector electrode. The effective surface area which, by contamination, is able to effect the measurement of tritium within the process gas has been reduced by a factor of ~200 over a conventional ion chamber. It is concluded that the new process ion chamber enables sensitive accurate tritium measurements free from contamination issues. It will be a powerful new tool for future tritium experiments both to improve tritium tracking and to help in the understanding of tritium retention issues.

I. INTRODUCTION

The Joint European Torus (JET) is the largest magnetic confinement fusion experiment and the only operational tokamak to operate with tritium. Tritium measurements are important for accounting, safety, and experimental understanding. A variety of measurement techniques are used on JET for the measurement of tritium. Ion chambers provide the simplest form of online tritium measurement.

II. EXPERIENCE WITH ION CHAMBERS

Several designs of ion chamber have been designed and tested for use in the JET Active Gas Handling System (AGHS)[1,2]. These include a conventional ion chamber, Fig 1a, and one incorporating a heater element[3] Fig.1b.

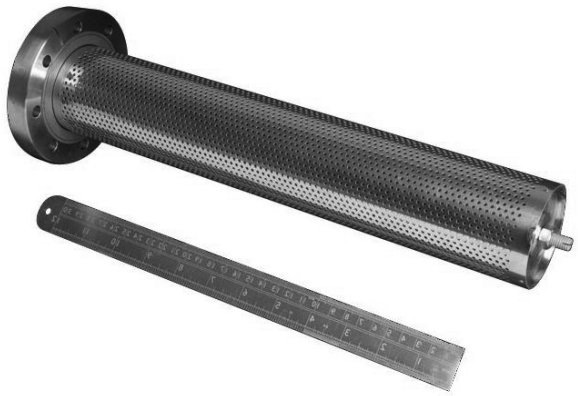

Fig. 1a. Mesh type ionisation chamber; Volume 699713 mm^3. Surface Area 516798 mm^2

These ionisation chambers have been used mainly for the detection of tritium in the secondary containment of AGHS components, in tritium process control applications and for accountancy measurements. These ionisation chambers have been effective in the measurement of tritium with concentrations greater than 1 $MBqm^{-3}$, but due to the memory[4] effects, can be subject to offsets and large errors.

Fig. 1b. Ionisation chamber (heater type). Volume 570000 mm^3. Surface Area ~450000 mm^2

The background ion current from the ionisation chamber tends to rise as the internal surfaces become contaminated with tritium oxide, tritiated hydrocarbons, or tritium which permeates into the surface structure.
Heating up to 200°C has limited success for water vapour de-contamination as tritium permeates into the electrodes and then migrates back to the surface of the ion chamber.

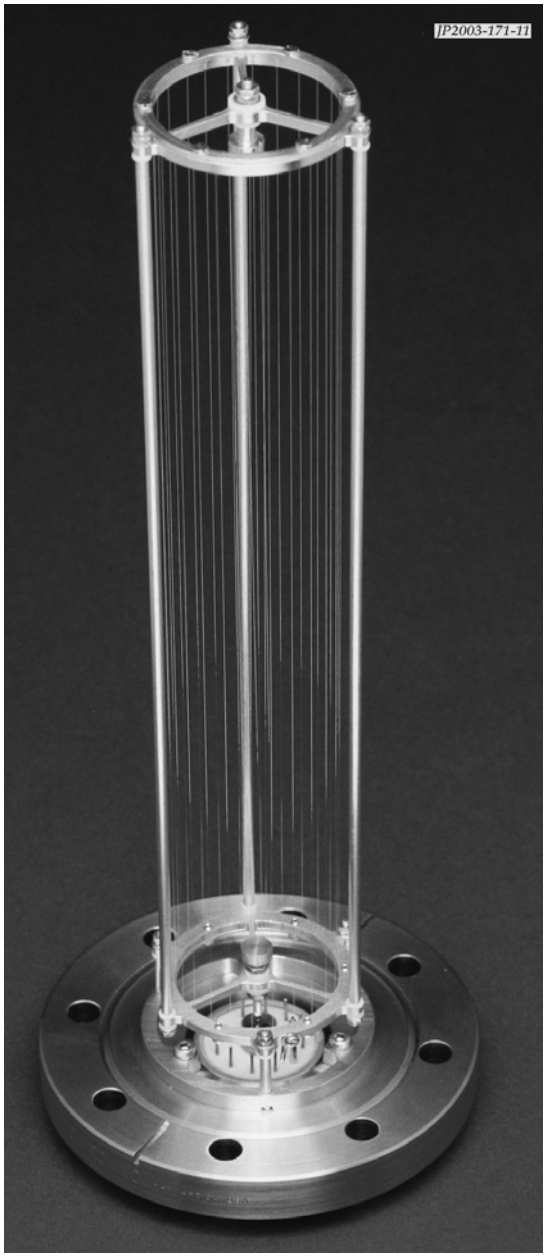

Fig. 1c. New wire grid type ionisation chamber; Volume 401282 mm^3. Surface Area 2857 mm^2

III. NEW DESIGN PRINCIPLES

The standard ion chamber for tritium measurement works on the principle of measuring the ion current between two electrodes. The current being as result of the ionisation of the carrier gas by the beta decay of tritium. The current is driven by a bias on one electrode. The larger the volume between the two electrodes the higher the sensitivity of the instrument .The path length of the mean energy (5.7keV) decay beta in atmospheric air is[5] ~0.36mm. Hence if the volume between electrodes can be kept high, the material surfaces kept away from this volume and the surface area of the electrodes minimised, then a sensitive ion chamber, which is insensitive to contamination effects, can be produced. This principle was first used by Overhoff[4] in commercially available stack and area tritium monitors. The aim of the new JET design was to go significantly further in the reduction of surfaces within the electrode envelope for a process ion chamber. The design was also to take into account the longer path lengths of the highest energy betas (18.5keV) and longer path lengths expected from working at reduced pressure.

IV. MECHANICAL DESIGN

A fine wire mesh has replaced the solid electrode surfaces of the conventional ionisation chamber. The outer electrode mesh forms the chamber wall. For compatibility the design of the new ion chamber uses the same de-mountable Conflat flange fitted with a multi-pin feed through, as on the previous ion chambers installed at JET. The new design (Fig 1c) utilises a fine (50 μm) array of gold-coated tungsten wires for both the bias grid and collector array. The structure supporting the wire grid array was machined from MONEL 400 and gold plated. Gold plating was used to further reduce contamination effects. The seven tungsten wires that form the collector array are tensioned and spot welded to the support structure at both ends, as are the 24 wires that make up the bias electrode. The entire arrangement has a surface area some 180 times smaller than the previous designs (~2857 mm^2 compared to ~516798 mm^2).
The effective volume of the chamber was 401282 mm^3 giving a theoretical sensitivity of ~8.5 $x10^{-19}$ A/Bq. Electrical connections to the 100 V outer bias grid are made through a multi-pin ceramic feed through. The collector connects a gold coated BNC connector situated at the centre of the feed through. The electrical signal was first amplified through an electrometer which was mounted directly onto the detector via the feed-through and carried to the readout through doubly screened cable. The electrometer and amplifier were supplied by The Overhoff Technology Corporation[4].

V. BASIC TESTS & MODE OF OPERATION

An investigation into the variation of detector output current versus bias voltage was performed. The detector was filled with air at atmospheric pressure and stimulated using a Co^{60} gamma source. The bias voltage was varied between 0 and 150 V. At each bias voltage the measured current from the detector is shown in figure 2.

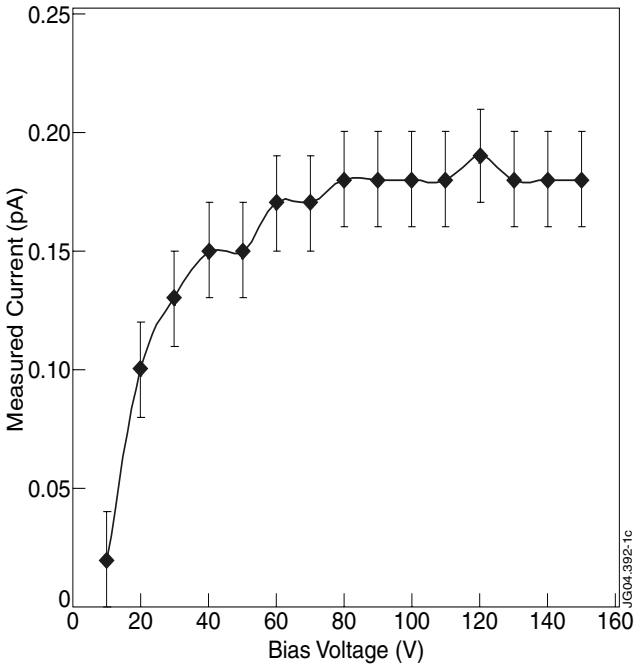

Fig. 2. Ion chamber output current as a function of bias voltage

To characterise the chamber in gas with a known concentration of tritium the wire grid ionisation chamber was installed in the JET facility helium gas-baking loop[6] in series with a tritium monitor, which is used as part of the Radiation Protection Instrumentation (RPI) at JET. This monitor had previously been calibrated with known concentrations of tritium and showed the activity of tritium in the helium loop to be 48.5 $MBqm^{-3}$.

Prior to exposure to the helium loop a background reading of 0.6 $x10^{-14}$ A was recorded from the ionisation chamber. The ionisation chamber was exposed to the helium in the loop and an output current of 6 $x10^{-13}$ A was recorded corresponding to a tritium activity of ~51 $MBqm^{-3}$. The ionisation chamber was left continuously sampling the baking plant gas for 72 hours. A steady output current of 6 $x10^{-13}$ A was recorded for the duration. On completion of the test, purging the detector with nitrogen caused a reduction in ion current to the original amplifier offset thus showing no memory effect at this level of tritium concentration.

VI. INSTALLATION TO MONITOR THE JET EXHAUST

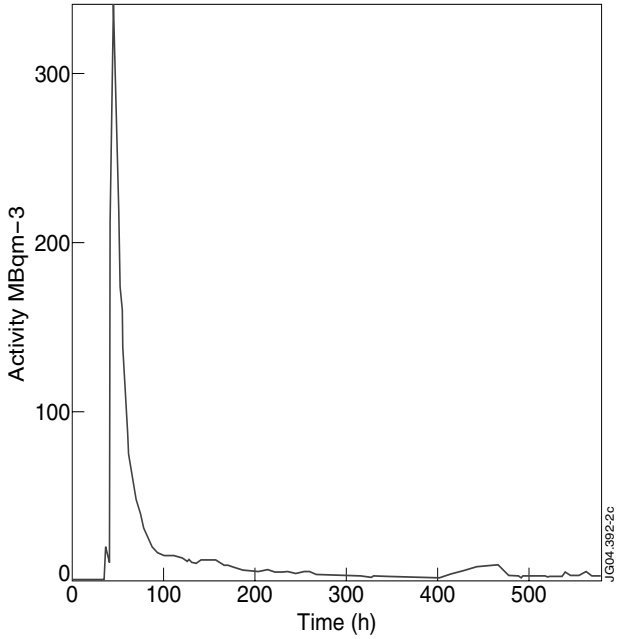

Fig. 3. Activity of torus exhaust Vs time during vent and subsequent air purge.

An ion chamber of new design was installed on the JET machine in the torus exhaust line (ML1) in parallel to an existing ion chamber (of mesh variety), and was operated using a semi-automated sequence sampling the exhaust gas. The sequence consisted of several sequential steps. Collection of the exhaust gas from ML1 followed by the introduction of a carrier gas to raise the pressure in the sample chamber to ~0.5 bar. A measurement of the ion current was made and sample gas was then pumped away by ML1. Neon was chosen as the carrier gas for compatibility with the tritium re-processing plant. Using the ion chamber in this mode allows the sample gas to be exhausted from the ionisation chamber after each measurement, thus minimising the contamination caused by the build up of tritiated hydrocarbons on the ionisation chamber surfaces.

During the clean up phase of the Trace Tritium Experiment[7] (TTE) the wire grid ionisation chamber in ML1 was exposed to tritium in the exhaust gas for long periods, both during pulsing and after operations where the exhaust gas was held in the ionisation chamber overnight. Prior to exposure to the exhaust gas the measured current from the chamber was 3 $x10^{-14}$ A. The ion chamber exhaust gas sequence was operated over 60 times during the clean up phase and the final ion current measured, after single purge with neon, was 4 $x10^{-14}$ A.

The ion chamber was opened to the torus exhaust during the vessels first purge with air following TTE.

The signal from the wire grid ionisation chamber was continuously monitored and is shown in figure 3. The rapid nature of the decay has not previously been observed using other ion chambers which were affected by contamination.

Figure 4 shows the tritium concentration as measured by the mesh type ionisation chamber compared to that measured by the wire grid ionisation chamber after some period of air purging. (Both installed in the same position).

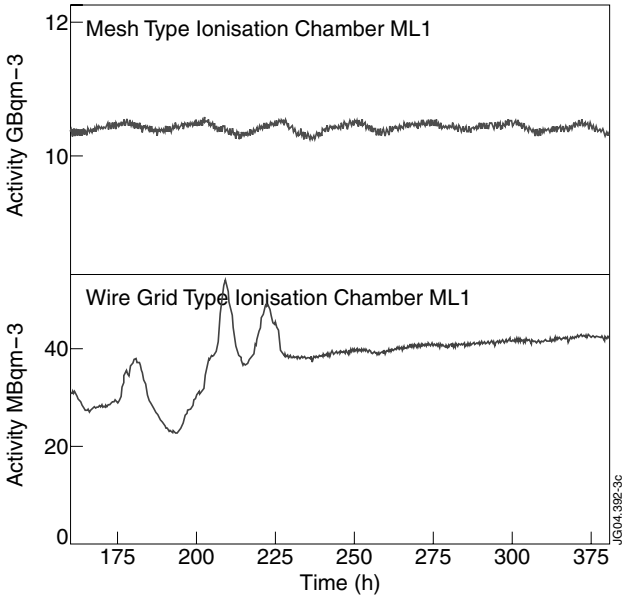

Fig. 4. Comparison of signals from ionisation chambers in ML1

Note the mesh type ionisation chamber records a tritium concentration 300 times higher than the wire grid ionisation chamber due to contamination. The variation in the signal from the wire grid ionisation chamber is attributed to differing rates of air purge through the torus.

VII. FURTHER INVESTIGATION

It is planned to fully automate the torus exhaust sampling system, timed to the end of a JET pulse with a measurement made directly after each pulse, allowing a detailed measurement of the tritium gas balance on JET during future operations. It is also planned to extend the operation to the pumping line from the Neutral beam injection[8] (NI) to AGHS, thus enabling the inventory of tritium on the cryogenic panels in the NI to be ascertained prior to reprocessing of the gas by AGHS after regeneration.

Two further ion chambers of the wire grid design are to be installed in glove-boxes on the AGHS plant and will be used to measure tritium concentrations in atmospheric air of ~ 1MBqm^{-3}. It is also planned that an ion chamber will be installed in the tritium re-processing loop in AGHS. This ion chamber will be exposed to tritium gas with well known concentrations from 25 % to 100 % to further test the resistance of the chamber to contamination.

VIII. CONCLUSIONS

We have demonstrated a new design of ion chamber utilising ultra fine wire electrodes. The ion chamber can measure tritium down to 1 MBqm^{-3} . We have shown that, at the concentrations of tritium in the exhaust gas from TTE, the wire grid ionisation chamber does not show any of the memory effects associated with contamination seen in other ion chambers. The ion chamber is a demonstrably significant improvement over previous JET designs and a very useful tool in monitoring the torus exhaust. Its use at JET will be expanded and its resistance to surface contamination after exposure to much higher concentrations of tritium tested.

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