INTRODUCTION

The European Tritium Handling Experimental Laboratory (ETHEL) is a new tritium research facility situated at the Commission of the European Community's Joint Research Centre, Ispra Establishment, Italy. The laboratory will investigate tritium related safety aspects associated with the development of commercial fusion power reactors. Ultimately, the research may involve the handling of relatively large tritium inventories and, for this purpose, a laboratory license to operate with up to 100 g (37 PBq) of tritium has been requested from the Regulatory Authority.

When handling macro quantities of tritium, regulations are needed for three distinct reasons: safety, security and cost. The radiotoxic nature of tritium coupled with its extreme mobility necessitates that a comprehensive radiological protection monitoring system for safety purposes [1]. Concerning security, although tritium alone is not a usable material for weapons, it is employed at gramme levels in nuclear bombs to boost energy yields [2]. The strategic significance of this weapon enhancement capability is that, even though not classified as a special nuclear material, tritium is increasingly coming under the focus of the safeguards community. Finally, tritium can represent a prominent fraction of a laboratory's operating costs especially as the bench-mark price has more than doubled in the last few years. Apart from good operational practice, eg tritium is a finite resource, it is apparent from the above discussion that tritium control within a facility such as ETHEL is mandatory.

LABORATORY OPERATIONS

ETHEL will receive tritium from external suppliers on portable getters in the solid form of uranium titride, UT₃, a getter may be considered as a metallic sponge which, in this instance, can reversibly bind and release tritium. Following assay, the tritium will be transferred to permanently fixed getters which form an integral part of the laboratory's Tritium Receipt & Storage System (TRSS) [3]. This system is contained in a glove-box located in the Tritium Magazine. Subsequent distribution of tritium to the laboratory's various experiments will also be performed using portable getters.

When conceived, tritium accountancy in the TRSS using the classical pressure, volume, temperature and composition approach was adopted. As a consequence, the TRSS is provided with two assay tanks for quantifying transfers between the Tritium Magazine and research areas in the laboratory. However, the ideal gas technique requires a knowledge of the tritium gas purity and this must be physically measured to determine the presence, if any, of likely contaminants such as other hydrogen isotopes, helium and argon. To overcome this weakness, other accountancy methods are being considered in ETHEL. Calorimetry is a non-intrusive technique for measuring the thermal power of heat producing samples and is widely used nuclear materials accounting. As such, it appears a suitable method for quantifying the tritium in getters and offers two advantages: a potential for reducing staff requirements and avoiding unnecessary waste production.
CALORIMETER DESIGN

As the available space in the TRSS glove-box is limited, the whole calorimeter system, *ie* measurement chamber and electronic instrumentation rack, will be located outside of the TRSS glove-box. Operational requirements, however, necessitate that a portable getter can only be passed out of the glove-box when it is contained in its secondary, gas-tight pot. Therefore, the chamber has been designed to directly receive the portable getter/containment pot assembly.

Getters are an extremely compact way of storing tritium. Initially, the portable getters employed in ETHHEL will be supplied by AMERSHAM, model 0035 Mk IV, and each will contain about 320 g of depleted uranium. This equates to an effective getter operational capacity of 5 g of tritium assuming a maximum uranium saturation of ~ 50 %. The required total system accuracy of the calorimeter system, expressed as a percentage error of the absolute tritium quantity, depends on the quantity of tritium to be assayed. The target accuracies are errors of less than 0.5 %, 2.0 % and 10.0 % for tritium quantities of 5 g, 1 g and 0.1 g respectively. The decay of tritium evolves the production of β-particles with a mean energy 5.65 keV. Based on a half-life of 12.33 years, the resulting specific thermal energy release is 324 mW g⁻¹ [4]. Hence, the nominal operating range of the calorimeter has been established from a few mW to about 1.5 W.

Two types of containment pot are foreseen having a similar external dimension of \( \Phi_{ext} \), 101 x 165 mm. For tritium arriving from external suppliers, the pot will be composed of stainless steel as provided by AMERSHAM. In contrast, an aluminium pot will be employed for the distribution of tritium inside of the laboratory. Compared with stainless steel, the latter material offers two advantages, namely a reduction in both weight and thermal inertia. On this basis, calorimetric measurements are envisaged to take \( \leq 4 \) h with the stainless steel pot and about half this time with the aluminium container.

The design of the ETHHEL tritium calorimeter is based on the power replacement or power difference method isothermal mode of calorimeter which has been successfully employed in plutonium calorimeters [5]. The thermal element, which encompasses the measurement chamber, consists of three concentric regions separated by a heat transfer medium. The inner cylinder temperature is selected to match that of the getter containment pot while the middle cylinder's temperature is optimised to provide an adequate energy flow for differential heat balance purposes. Both of these temperature set-points can be modified to suit various operating conditions. Finally, the periphery of the outer cylinder is cooled by a Peltier air-to-air heat exchanger.

The cylinder heating coils form part of a closed loop control system with integral resistance thermometers constituting arms of sensitive bridge circuits. The output signal from each circuit indicates the temperature off-set of the related cylinder and this is employed to control the individual cylinder temperatures to better than 1 mK. A measurement is made by inserting the containerised getter into the chamber which is then closed with an insulating plug. The difference in applied energy for isothermal conditions before and after insertion of the heat source is quantified and defined in terms of appropriate units, *eg* g of tritium.

The calorimeter system is driven by a software programme operating on a personal computer in a "Windows" environment although, for safety reasons, suitable hard-wired circuits and "watch-dogs" prevent the getter being heated to an unacceptable elevated temperature. During operation, the software furnishes the state of the measurement and calorimeter conditions as well as providing the usual print-outs and disk archiving capabilities. Of particular interest is the use of equilibrium power prediction algorithm. This expert system software module controls the end point prediction routine and indicates to the operator when a satisfactory result has been obtained, providing both a measurement result and its uncertainty. Finally, the software includes diagnostic tools which, with a sample facility, tests both the system hardware and software.
At-works tests, envisaged for mid-1992, will make use of the automatic electrical calibration procedure which is provided as a routine technique in tuning the calorimeter although the application of heat sources located in the measurement chamber is being considered.

Unfortunately, ETHEL will not have been licensed when the calorimeter is ready for on-site commissioning. Tests will therefore be performed using the PERLA plutonium and mixed oxide calibrated standards [6]. In particular, use will be made of the samples contained in the model N° 5 container, four of which can be placed in a slightly modified getter containment pot. The decay energy of the standards are generally known to about ± 0.5 % which means that known sources having thermal outputs from 5 - 500 mW are readily available. Even though the temperature profile will not be identical to a portable getter, the use of the standards will help in assessing the overall performance of the calorimeter especially at the low end of the operating range.

References


