The JRC Experimental Program

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JRC-ETHEL has chosen as the principle objective of its research program the improvement of protection measures in facilities handling large amounts of tritium. Technically, this involves investigating and assessing tritium propagation modes and transfer pathways in materials, components, equipment, and process plants. The experimental research work to be performed in ETHEL will basically aim at investigating:

- Loss mechanisms by identifying physico-chemical parameters such as adsorption/desorption rates, permeation rates, leakages of materials for fusion reactors and the effects of potential remedies like permeation barriers under process-like conditions.
- Multiple containment systems and fluid clean-up concepts under normal and accidental conditions.
- Methods for solid waste handling, treatment, conditioning, and final disposal.
- Techniques for tritium control, monitoring, and surveillance over the whole concentration range during both normal and accidental conditions and maintenance activities.

With the availability of two "climate chambers," the small and large caissons of 5 and 350 m³ volume respectively, ETHEL is especially suited for benchmark and scale-up tests of many kinds of large gas volumes treatment system. This will help to close the gap between laboratory-scale results and plant-size design specifications and represents an important source of information for designers (NET, ITER) and regulatory authorities.

1. INTRODUCTION

An important issue guiding the evolution of the European Community Fusion Program is the development of tritium technology up to demonstrating the reliable performance of large-scale components, processes, and facilities while simultaneously substantiating the safety and environmental feasibility of fusion power including implicit safety criteria. The handling of large amounts of tritium in a sequence of interrelated complex operations requires the development and application of demanding safety and waste handling measures, as derived from modern legislation and public acceptance considerations.

The European Tritium Handling Experimental Laboratory (JRC/ETHEL) has been constructed to provide the principal missing basic data and technological development for the next generation of fusion research reactors in which tritium will be an obligatory ingredient to guarantee progress toward the final goal, i.e., power generation. The laboratory has been conceived as a multipurpose facility, essentially experiment independent, to allow the incorporation of experiments derived from current conceptual designs and the testing of state of the art technologies.(1)

JRC-ETHEL has chosen as the principal objective of its research program the improvement of protective measured for the public and for the personnel in facilities handling large amounts of tritium. Technically, this involves investigating and assessing tritium propagation modes and transfer pathways in materials, components, equipment, and process plants. The aim is to identify new protective barriers for achieving an improved con-
finement of tritium under normal and accidental conditions and thus, leading to minimization of subsequent tritium dilution and dispersion. This last aspect is also particularly important in attaining a reduction of waste.

2. DESCRIPTION OF EXPERIMENTS

2.1. Tritium Recycling from First Wall Candidate Materials Under Fusion Reactor Conditions

Particles can escape from the imperfect magnetic confinement of D-T fusion reactors and impinge on the first wall. The fraction of implanted particles will be recycled into the plasma. Recycling of hydrogen isotopes from plasma-facing components in a magnetic fusion device is widely accepted as a crucial issue affecting the fuelling and the tritium inventory of the reactor.

The proposed experiment,\(^{(2)}\) presently being undertaken as a NET Task (PPM6-6), uses a plasma simulator with characteristics similar to ITER in order to study the recycling and outgassing of tritium and tritium–deuterium mixtures from first wall materials. The scope is to study hydrogen isotopes implantation, uptake and release of graphite, CFC, doped CFC, and low Z material with the following operating conditions:

- Implantation at low energies (50-500 eV), high flux densities \(10^{16}-10^{17} \text{ atoms.cm}^{-2}\text{s}^{-1}\) and at different temperatures.
- Measurement of hydrogen isotopes (tritium) release rates as a function of time and characteristic recycling times at different ion energies, particle flux densities, and target temperatures.

For the containment of tritium, a multi-barrier containment scheme has been adopted. The first level is made up of the experiment components, e.g., UHV experimental chamber, valves, process piping. The second level is provided by a glove-box suite of around 7 m\(^3\). Finally, the tertiary containment is provided by the ETHEL laboratory itself. One important feature of this installation is a very sensitive quadrupole (QMF) system with additional three-lens optics. This system permits the measurement of the gas composition in the ion source volume. This is accomplished by switching on the crossbeam ion source of the QMF. Furthermore, the plasma and the chemical composition of the target surface composition is needed for the determination of the particle flux on the target and that of the target surface composition is necessary because the recycling flux strongly depends on the conditions of the target surface. The QMF will give information about the chemical specie \(\text{C}_x\text{T}_y\), \(\text{C}_x\text{T}_y\text{D}_z\), etc) under which the recycling flux is being released into the chamber. This is important from the reactor impurity control standpoint.

2.2. Tritium Permeation Barriers

The tritium permeation rate through structures such as the first wall and breeder blanket containment is a critical factor in the determination of fusion reactor viability. It is necessary to investigate the transport of hydrogen isotopes in candidate materials and to develop methods of reducing the permeation rate. One promising technique is to deposit layers of materials with low diffusivity and/or low recombination rate constant for hydrogen isotopes. In addition to reducing permeation, such layers should be adhesive, resistant to attack by breeder materials and other process fluids and should not crack during thermal recycling.

The objectives of the investigation currently underway as a task under the European Fusion Technology Program on Blanket Technology (LMB-BAR-J and LMB-PER-J) are:

- To test the effectiveness of applied surface layers as permeation barriers on steel.
- To investigate the effects of liquid lithium or lithium lead on the applied layers.

More specifically, the program has involved the construction of an apparatus to measure the permeation of hydrogen or deuterium through both disc-shaped and tubular specimens.\(^{(3)}\) This apparatus, the “Hydrogen Prototype” is the forerunner of ETHEL-004, which is the experiment, currently in the detailed design phase, to measure directly the permeation of tritium through various materials. The base materials of most immediate interest are SS 316L austenitic and DIN 1.4914 martensitic steels, which have been chosen as structural materials for NET/ITER. It is proposed, therefore, to concentrate on the investigation of coatings on these two steels although, with the designed equipment, it is possible to study the permeation of hydrogen isotopes through a wide range of materials.

Two basic routes to the formation of permeation barriers have been chosen, namely the growth of oxide layers (\(\text{Cr}_2\text{O}_3\), \(\text{Al}_2\text{O}_3\), etc) and the application of surface coatings. Other non-metals for forming of permeation barriers carbides like SiC and TiC have been proposed. Amongst metals, only W and Au are sufficiently less permeable than steel to warrant investigation as candidate materials for permeation barriers. The application of surface layers, offers a great range of materials for the formation of permeation barriers with a large number