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Large Scale experimental facility for assessment the performances of the vacuum vessel pressure suppression system of ITER

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Abstract

The nuclear fusion reactor ITER (International Thermonuclear Experimental Reactor) foresees a Pressure Suppression System (PSS) in order to manage a Loss of Coolant Accident (LOCA) or other over pressurization accidents in the Vacuum Vessel (VV) which has a pressure limit fixed at 150 kPa (abs).
This system (VVPSS) has a key safety function because a large internal pressure in the VV could lead to a breach of the primary confinement barrier. The pressure suppression is ensured by discharging the steam, produced by the LOCA, in 4 tanks, 100 m3 of volume partially filled by water, where it condenses (Figure 1).

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Differently by the applications in the nuclear fission reactors, the steam condensation occurs in ITER at sub-atmospheric pressure conditions.
No previous applications of direct steam condensation at sub-atmospheric conditions have been done. Therefore, experimental assessment of VVPSS has been necessary considering the direct condensation of the steam in the ITER thermal-hydraulic conditions.
Under financial support of ITER Organization an extensive experimental program has been performed at the Department of Civil and Industrial Engineering (DICI) of the University of Pisa using a small-scale experimental rig (1/22 scale factor) [ref1]-[ref3]. Figure 2 shows the reduced scale experimental rig.

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The main component is the Reduced Condensation Tank (RCT). It is deeply instrumented with 28 temperature sensors and 8 pressure transducers. An internal vertical sparger with several holes discharges the steam inside the water. The steam mass flow rate, produced by an electric steam generator, is controlled by means of Vortex or Coriolis measurement devices.
Different temperature, pressure and steam mass (flow rate per hole) conditions and sparger patterns have been investigated in about 400 tests. The experimental results demonstrated that there are strong differences between the steam direct condensation at atmospheric and sub-atmospheric pressure.
First of all the condensation regimes (stable, oscillation, chugging and bubbling condensation) occur for different values of unit steam mass flow rate per hole (Kg/sm2). Moreover these condensation regimes depend on the pressure inside of the tanks. Figure 3 illustrates the map of condensation regimes determined by means of the experimental program.

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The experimental results permitted to elaborate a suitable similitude analysis which describes the steam condensation at sub-atmospheric pressure.
ITER Organization launched an international tender in order to perform an experimental activity on a Large Scale facility which the aim was the assessment the scale laws determined in the small scale facility. University of Pisa won this international tender and has built the large scale experimental rig, shown in Figure 4.

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This facility, presently in commissioning phase, is about a full scale from the geometric point the view (1/1.09 scale factor) and it is 1/10 scale factor from the steam mass flow rate point of view. In fact the condensation tank has a volume of 92 m3 and the electric steam generator produces 0.5 Kg/s mass flow rate of steam. The actual tanks of VVPSS have 100 m3 of volume and the maximum steam mass flow rate for each tank in the envisaged accidental scenario (Large LOCA accident) is 5 Kg/s. The built facility has the possibility also to simulate the full scale accidental scenario. By means two 15 m3 high pressure vessels it is possible to produce 5 Kg/s of steam for an interval of time equal to the foreseen accidental scenario.
This paper describes the main results obtained by means of the tests performed on the small scale rig. Moreover the Large Scale experimental rig built at the University of Pisa and the test matrix, which will be performed, are illustrated. These tests will permit to verify the scale laws determined in the previously performed research program on the small scale rig.
The results of this research program are of fundamental importance in order to assess the reliability of VVPSS.

References

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