LARGE SCALE EXPERIMENTAL FACILITY FOR ASSESSMENT THE PERFORMANCES OF THE VACUUM VESSEL PRESSURE SUPPRESSION SYSTEM OF ITER

ID: 687

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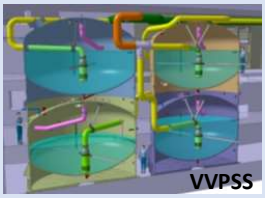
ABSTRACT

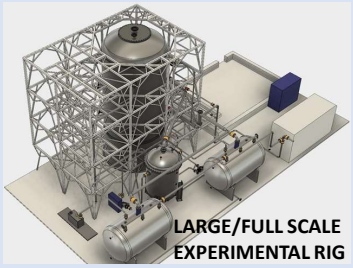
- An extensive experimental research program performed in a Small-Scale Facility at University of Pisa has analysed the steam direct condensation at sub-atmospheric pressure for ITER LOCA or LOVA postulated event.
- A similitude analysis has been elaborated for extrapolating the results to the full-scale safety system of ITER: Vacuum Vessel Pressure Suppression System (VVPSS). Composed of four Vapor Suppression Tanks, 100 m^3 each
- Experimental tests were carried out in a Large-Scale Facility, simulating the first part of Large LOCA, to assess the scale laws,

BACKGROUND

- ITER foresees a Pressure Suppression System (PSS) in order to manage a LOCA and/or LOVA over pressurization accidents in the Vacuum Vessel (VV) for limiting pressure to 150 kPa (abs).
- Steam Direct Contact Condensation in water pool at sub-atmospheric pressure is realized in the VVPSS. It needs to be characterized and verified.



SMALL SCALE Rig	
Tests	400
Condensation tank (m^3)	4.5
Steam mass flow rate (g/s)	45
Scale factor	1/22



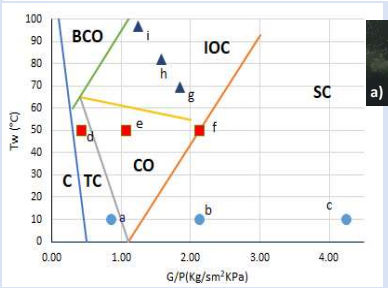
LARGE SCALE Rig	
Tests	70
Condensation tank (m^3)	92
Steam mass flow rate (g/s)	50-520
Scale factor	1/1.09
FULL SCALE Rig	
Steam mass flow rate (g/s)	500-5000

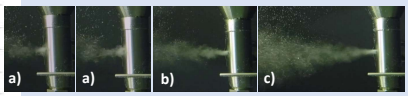
MAIN RESULTS IN SMALL SCALE FACILITY

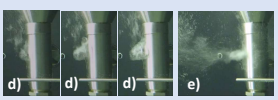
Four video cameras identified 6 condensation regimes, depending on water temperature (T_W), steam mass flow rate per unit of area (G_S) and downstream pressure (P_S).

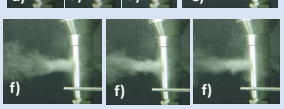
The condensation regimes are similar to those obtained at atmospheric pressure, but they occur at a lower order of magnitude of G_S.

The main experimental outcome, that is, an increase of the downstream pressure, P_S, produces more unstable condensation regimes, has permitted to substitute the 3-D condensation regime distribution with a 2D map using the coordinates T_W and G_S/P_S

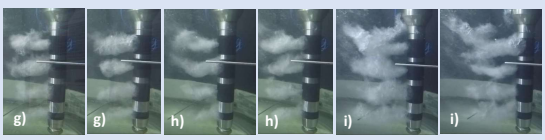








- **Chugging (C)**
- **Transitional Chugging (TC)**
- **Bubbling Condensation Oscillation (BCO)**
- **Condensation Oscillation (CO)**
- **Stable Condensation (SC)**
- **Interfacial Oscillation Condensation (IOC)**



SIMILITUDE ANALYSIS

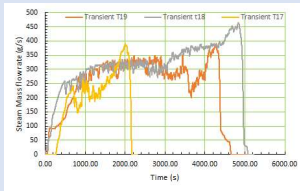
Geometric scale factor S=Vactual/Vscaled (condensation tanks volumes)
Cover gas to pool volume ratio is equal in actual and scaled configuration
Water temperature increase ΔT_W depends on water mass MW and injected MS. In order to have an equivalent energy balance:

- Steam mass is scaled MS(Nscaled/Nactual); N is the hole number;
- Steam mass flow per hole qS is conserved;
- Transient time is amplified by K=(Nactual/Nscaled)/S;
- Water head HW is conserved.

At scaled time (t and Kt), the average water temperature T_W, and the pressure, P_S, are equal in the full-scale and reduced scale system.

EXTRAPOLATION OF LARGE SCLAE TEST TO FULL SCALE

The scale laws have been applied for extrapolating experimental results obtained in the Large Scale Facility (100 holes) to the Full Scale (1000 holes) pressure suppression system (VVPSS).



- Experimental transient in the Large Scale Facility
- Three subsequent tests
- 10960 s in total
- T_{W_IN} = 10 ° C
- T_{W_FIN} = 50 ° C

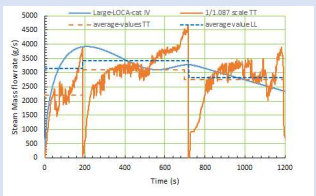
Scaling factors: K=9.2 and S=1.09

t=141 s - q=107 g/s - T_W=11.7 °C

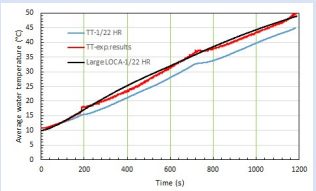
t=190 s - q=140 g/s - T_W=11.8 °C

t=4869 s - q=449 g/s - T_W=36.4 °C

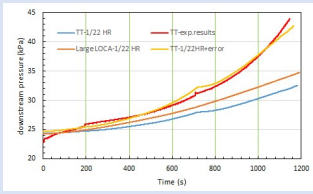
t=4177 s - q=359 g/s - T_W=49.2 °C



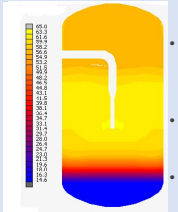
Three tests performed in the Large Scale Facility extrapolated to the full scale system by means of the scale laws



Average water temperature versus time as obtained by the experimental tests applying the scale laws

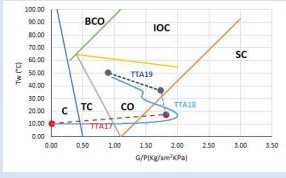


Downstream pressure versus time as obtained by the experimental tests and applying the scale laws



Distribution of temperature inside the condensation tank (t=1168s)

- *the axial temperature stratification reaches the maximum value in correspondence of the water free surface (65°C while the average temperature is about 50°C) .*
- *the saturation pressure and the pressure in the void space depends on this temperature value (65°C)*
- *-the water mass near the bottom (about the 10-15%) partecipates very little to the steam condensation.*



Comparison of the condensation regimes: three tests performed in LSF and Large LOCA scenario

CONCLUSION

- Based on Small Scale Facility results a similitude analysis was developed.
- The first part of a LOCA event in ITER VVPSS was carried out in the Large-Scale Facility, obtained results were extrapolated by scaling laws to VVPSS.
- Small discrepancies due to thermal stratification were reduced/cancelled by a correction factor