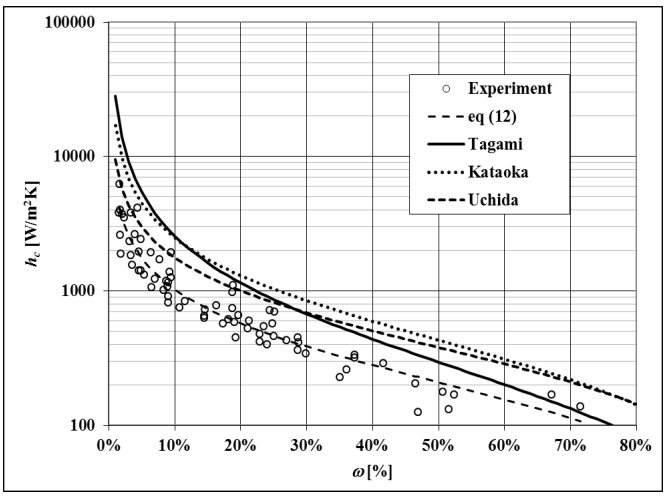

Figure 11 - Comparison of average HTC correlations in the presence of non-condensable gases

CONCLUSIONS

Pure steam and steam-air mixture condensation experiments were carried out in gravity controlled stratified flow regime inside an horizontal and inclined tube (22 mm inside diameter) and the average heat transfer coefficient was evaluated. For pure steam condensation, data was compared with literature correlation predictions (Chato and modified Nusselt correlations) and their agreement was verified, suggesting some minor modifications. An influence of tube inclination on heat transfer was observed. Inclination of the tube seems to have no influence on condensation in the presence of non-condensable gases, especially at high gas concentrations. Two simple empirical correlations have been obtained and could be used in preliminary design or system simulation in transient conditions of a condenser in a passive containment cooling system.

NOMENCLATURE

C_p specific heat at constant pressure	[J/(kg K)]
D, D_h diameter, hydraulic	[m]
h heat transfer coefficient	[W/(m^2 K)]
k thermal conductivity	[W/(m K)]
L length	[m]
q'' heat flux	[W/m^2]
R universal gas constant	[J/(mol·K)]
T temperature	[K]

Greek letters

Θ tube inclination with respect to horizontal	
λ latent heat	[J/kg]
λ' mod. latent heat $\lambda' = \lambda\left[1+0.68\left(\frac{c_{p,f}\left(T_{vi}-T_{wi}\right)}{\lambda}\right)\right]$	[J/kg]
μ dynamic viscosity	[kg/(m s)]
ρ density	[kg/m^3]
ϕ angle of the liquid region at the bottom of the tube	
ψ function of density	
ω mass fraction	

Subscripts

0	reference state
c	condensation
e	external
exp	experimental
g	gas phase; gas mixture
i	internal
in	inlet
ms, sub	subcooled; sensible heat transfer
w	tube wall; water
v	vapour, steam

REFERENCES

[1] Caruso G., Cumo F., De Santoli L., Moncada Lo Giudice G., Naviglio A. *Experimental campaign for the study of the steam condensation inside tubes in presence of high percentage of non condensable*. 11th Intern. Heat Transfer Conferernce, Taylor & Francis Levittown (PA) pp. 361 365 v. 6, 23-28/08/1998 Kyongju, Korea

[2] Caruso G., Cumo F., Iorizzo A., Naviglio A. *Experimental study of in-tube steam condensation in presence of high percentage of noncondensables, aimed at the design of an inherently safe heat transfer emergency system*. 2nd Int. Symp. On Two-phase Flow Modelling and Experimentation. EDIZIONI ETS - Pisa pp. 359 366 v. 1, 23-26/05/1999

[3] G. Breber, J.Palen, J. Taborek, Prediction of horizontal tubeside condensation of pure components using flow regime criteria. J. Heat Transfer, 1980, 102, 471-476

[4] J. C. Chato, "Laminar Condensation Inside Horizontal and Inclined Tubes," ASHRAE J., 4, pp. 52-60, 1962

[5] D. Butterworth and G.F. Hewitt "Two-Phase Flow and Heat Transfer", Oxford University Press, 1977.

[6] J.G. Collier "Convective Boiling and Condensation", McGraw -Hill Book Co., 1972.

[7] H. Uchida, A. Oyama, Y. Togo, 1965, *Evaluation of Post-Incident Cooling Systems of Light-Water Power Reactor,* Proceedings of the third International Conference on the Peaceful Uses of Atomic Energy, Geneva. Vol 13, pp. 93-104. United Nations, New York.

[8] T. Tagami, *Interim Report on Safety Assessment and Facilities, Establishment Project for June 1965* No 1, Japanese Atomic Energy Research Agency, unpublished work, 1965 (see Corradini 1984) .

[9] Y. Kataoka, T. Fukui, S. Hatamiya, T. Nakao, M. Naitoh, I. Sumida, *Experimental study on convection heat transfer along a vertical flat plate between different temperature pools,* National Heat Transfer Conference, Minneapolis, MN, ANS Proceedings, Vol. 5, 1991, pp. 99-106.