## Wet-Steam Turbines (Non-Equilibrium CFD Methods, Wetness Losses, etc)

The prediction of water formation and movement in steam turbines and the effects of departures from thermodynamic equilibrium on the turbine performance provide some very difficult problems in turbomachinery. The subject is important because so much of the world's electricity is generated by steam turbines in power stations. It has been known since the 1920s that the water (mainly submicron-sized fog droplets) causes a large loss of turbine efficiency and research over the years has produced a good understanding of the phenomena involved. Rather less progress has been made in terms of useful design information but modern computational ability holds the promise of major advances. There are publications on the following topics and more details are provided in the review *Wet-Steam Research at Cambridge, 1980–1995*:

- CFD for steady and unsteady non-equilibrium flows [1982, 1984a-c, 1985, 1992, 1993, 2011].
- Designer equations of state for CFD calculations [1988a].
- Wake-blade interactions and their effect on nucleation in turbines [1994].
- A transonic wet-steam cascade experiment [1996].
- Interpretation of pitot measurements in wet-steam flows [1997].
- Liquid transport in turbines – establishing the link between fog droplet and coarse water measurements via theories of droplet deposition [1988b].


Yeoh CC, Young JB. 1984a. Non-equilibrium throughflow analyses of low-pressure, wet steam turbines. *ASME J. Eng. for Gas Turbines & Power*. 106: 716-724.

Yeoh CC, Young JB. 1984b. The effect of droplet size on the flow in the last stage of a one-third scale model low-pressure turbine. *Proc. Instn. Mech. Engnrs*. 198A: 309-316.

Moheban M, Young JB. 1984c. A time-marching method for the calculation of blade-to-blade non-equilibrium wet steam flows in turbine cascades. *Instn Mech. Engnrs. Conf. on Computational Methods in Turbomachinery*. Paper C76/84, 89-99.

Moheban M, Young JB. 1985. A study of thermal non-equilibrium effects in LP wet steam turbines using a blade-to-blade time-marching technique. *Int. J. Heat & Fluid Flow*. 6: 269-278.

Young JB. 1988a. An equation of state for steam for turbomachinery and other flow calculations. *ASME. J. Eng. for Gas Turbines & Power*. 110: 1-7.

Young JB, Yau KK, Walters PT. 1988b. Fog droplet deposition and coarse water formation in low-pressure steam turbines: A combined experimental and theoretical analysis. *ASME. J. Turbomachinery*. 110: 163-172.

Young JB. 1992. Two-dimensional, non-equilibrium, wet-steam calculations for nozzles and turbine cascades. *ASME J. Turbomachinery*. 114: 569-579.

White AJ, Young JB. 1993. A time-marching method for the prediction of two-dimensional unsteady flows of condensing steam. *AIAA J. Propulsion & Power*. 9: 579-587.

Guha A, Young JB. 1994. The effect of flow unsteadiness on the homogeneous nucleation of water droplets in steam turbines. *Phil. Trans. Roy. Soc.* A349: 445-472.

White AJ, Young JB, Walters PT. 1996. Experimental validation of condensing flow theory for a stationary cascade of steam turbine blades. *Phil. Trans. Roy. Soc.* A354: 59-88.

White AJ, Young JB. 1997. Loss measurements and interpretation of Pitot pressures in two-phase vapour-droplet flow. *Experimental Thermal & Fluid Science*. 15: 279-287.

Chandler KD, White AJ, Young JB. 2011. Unsteady wetness effects in LP steam turbines. *ASME Turbo-Expo 2011*, Vancouver, Paper GT2011-45320.