THEATRe™ Real-Time Simulation Thermohydraulics Model

THEATRe is an advanced thermal hydraulic code developed for real-time simulation applications, which utilizes licensing grade best-estimate engineering methodology. It is a generic transient analysis code which can be used for simulation of thermal non-equilibrium, non-homogeneous two-phase flow systems involving steam-water mixture, non-condensable species, and non-volatile solute.

The physical principles and numerical methodology of the THEATRe code are adopted from the RELAP5/MOD2 and MOD3 state-of-the-art engineering code. In order to meet the real-time simulation constraints, elements of the RELAP methodology are selectively merged with proven real-time simulation methodology. The fundamental RELAP physical principles are completely maintained with one major improvement, using the drift flux approach for real-time application. The resulting code consists of five basic two-phase and one non-condensable gas field equations, five state equations, a drift flux relationship, a full range of two-dimensional steam tables (based on NIST steam program), a complete set of RELAP flow regime maps and constitutive correlations for interfacial heat transfer, drift flux parameters, wall drag and wall heat transfer.

Components models cover a wide range of specific reactor applications, e.g., critical flow, centrifugal pump, boron tracking, water-metal reaction, activity and temperature transport, asymmetric cooling, and detailed void distribution. These physical equations are solved by using a nodal momentum and nodal pressure type of RELAP two-step implicit numerical scheme.

The development of THEATRe followed a rigorous assessment and verification procedure. Analytical solutions, experimental test data or actual plant data are used for benchmarks. Counterpart RELAP calculation results are used as referenced benchmark data whenever the actual data is not available. Assessment tasks have included:

- Confirmation of the code with idealized problems. These problems have either analytical or conceptualized solutions.
- Verification of the code against separate effect experimental test data.
- Validation of the code against integral system test data or actual plant data.
Features

- Complete thermal non-equilibrium between liquid and gas
- Unequal phasic velocities, including flow in opposite directions (countercurrent flow)
- RELAP5/MOD3: field equations, flow regime maps, constitutive correlations, state equations, and NSSS model input format
- Conservation of Mixture Momentum from RELAP5/MOD3 gas and liquid momentum equations plus drift flux by Ishii & Zuber
- The nodal momentum solution retains mass conservation
- NIST/NRC steam tables: most current thermophysical properties of steam and water for each node based on nodal pressure
- Clad temperature and hydrogen generation
- Critical flow, non-condensable gas, soluble boron, and radioactivity
- Special models provide for momentum loss coefficients, enthalpy transport, fluid stratification, imperfect mixing, and application of experimental correlations
- Modularized, structured programs and subroutines in standard FORTRAN