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KATHY Loop

Critical Heat Flux Tests

Measurement of critical heat flux (CHF) performance under steady-state and transient operation conditions

Challenge

Heat transfer in nuclear fuel assemblies is limited by onset of the boiling crisis, called CHF. CHF is indicated by a sudden rise of surface temperature (for example, of the fuel rod cladding) due to the decrease in heat transfer from the surface to the fluid. CHF can not be predicted by pure analytical modeling. Exact knowledge of CHF initiation for all thermal-hydraulic initial conditions is a mandatory prerequisite for licensing of nuclear fuel assembly designs. Fuel assembly design-specific CHF correlations have to be developed and validated.

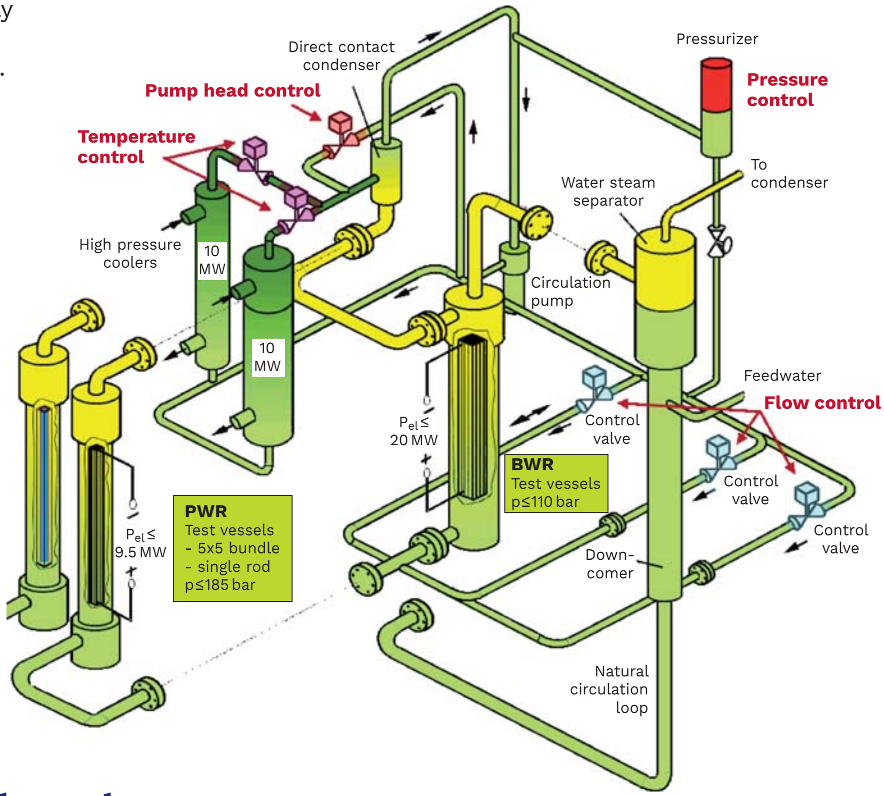
Therefore, CHF tests are performed under realistic boiling water reactor (BWR) or pressurized water reactor (PWR) conditions to generate a CHF database.

Customer benefits

- Full-scale test conditions reduce the need for subsequent modeling
- Precise test performance at high but fine tunable power levels: maximum 20 MW
- Wide range of testable fuel designs due to more than 2,500 heater rods in stock
- Benchmarked against OMEGA Loop (CEA), ATLAS Loop (GE) and HTRF Loop (CU)
- Accredited test and inspection body and accepted by ILAC
- Open to external customers

Solution

The Karlstein Thermal Hydraulic Test Loop (KATHY) is designed for the performance of CHF tests under full-scale conditions to determine the onset of CHF inside electrically heated fuel assemblies which are geometrically identical to real fuel assemblies. This is a challenging task: high electrical power and current levels have to be precisely handled and quickly controlled when sudden CHF occurs. Determining the onset of CHF requires sophisticated and robust instrumentation operating at high pressures and temperatures.



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Technical information

The thermal-hydraulic conditions, such as pressure, temperature and mass flow, are kept constant during the CHF test run while the power is slowly increased until CHF is reached.

The extensive instrumentation with thermocouples inside the heater rods allows local determination of the axial and radial onset of CHF in the test bundle.

Performance of:
- CHF tests on full-scale BWR test bundles (up to 12x12 fuel designs)
- CHF tests on 5x5 PWR test bundles
- Single-phase pressure drop measurements
- Adiabatic two-phase flow pressure drop measurements
- Simulation of reactor transients, for example, pump or turbine trip
- Hydraulic stability investigations on BWR test bundles under natural circulation conditions, also with void fraction modulated neutronic power feedback

KATHY control room

Test bundle installation

Features

- Electrical DC power: 20 MW/85 kA
- Design pressure: 185 bar
- Design temperature: 360°C
- Maximum flow rate 250 m³/h
- Test bundle geometries: 5x5, 9x9, 10x10, 11x11, 12x12
- Rod axial power profiles: cosine, uniform, top-peak, bottom-peak
- Data channels: 620 (easily extendable)
- Number of inlet flow lines: 3 (from very small to large size with independent mass flow measurement to reduce uncertainties)
- Number of test vessels: 3 (PWR and BWR vessels and downcomer with steam-water separator for natural circulation CHF and rewetting tests)
- Precise, automated power control system
- Broad range of instrumentation systems with redundancy for key variables
- High- and low-pressure heat removal system

Test bundle for full-scale test

Key figures

1986 startup testing; since then the KATHY test loop has been continuously used and upgraded

35,000 CHF test runs in database

140 BWR and **90** PWR fuel assemblies tested

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