Westinghouse's main thermal-hydraulic facilities and testing

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Westinghouse TH facilities for PWR conditions

	Facility	Mission	Transient ?	P (MPa)	T_{max} (°C)	Flow rate or velocity	Power and profile	Steam quality	Chemistry	Instr.	Test section size
Mainly heat transfer-related	ODEN (Västerås, Sweden)	DNB; Δp; TDC	N	20	366	0.7-22 kg/s	12 MW	0-55%	Deionized water	T, p, Δp, $\dot{m}$, v, power	5x5 and 6x6, full-length
	WALT (Churchill, PA)	CRUD; DNB; LOCA (soon)	Y	15.5	345	0-2 kg/s	100 kW, variable profile	Low	Controlled	Rod T, rod int. p, $\dot{m}$	Single rod up to 1 m, or 3x3 for ATR mode
Mainly flow-induced vibration-related	VIPER (Columbia, SC)	Δp; FIV; fretting	N	2.5	200	~260 kg/s (ax); ~13 kg/s (cross)	-	-	-	T, p, Δp, $\dot{m}$, rod and bundle vibration	Single or dual full-scale assembly
	FACTS (Columbia, SC)	Δp; FIV; debris mitigation (modified)	N	1.65	120	~140 kg/s	-	-	-	T, p, Δp, $\dot{m}$, rod and bundle vibration	Full-scale assembly
	VISTA (Columbia, SC)	Δp; FIV	N	Atm	Room	Up to 7 m/s	-	-	-	Laser vibrometer	5x5, full-length

Westinghouse TH facilities for BWR conditions

	Facility	Mission	Transient?	P (MPa)	T_{max} (°C)	Flow rate	Power and profile	Steam quality	Chemistry	Instr.	Test section size
Mainly heat transfer-related	FRIGG (Västerås, Sweden)	Dryout (incl. transient); Δp; hyd. stability	Y	10	311	0.5-25 kg/s	15 MW (variable axial and radial power prof)	0-100%	Deionized water	T (800 TC's); p, Δp, m, v (pitot tubes), power, void fraction (optical probes)	Full-scale (8x8 to 11x11) and ¼ bundle; full-length
	WATCH (Churchill, PA)	CRUD; Dryout; LOCA	Y	12	345	0-1.5 kg/s	90 kW	0-40% void fraction	Controlled	T, p, Δp, rod T, $\dot{m}$	Single rod, 1 meter
Mostly flow-induced vibration and debris	BURE (Västerås, Sweden)	FIV; fretting	N	8	300	22 kg/s	-	0-15%	Deionized water	T, p, Δp, m, v	Full bundle, with pellets.
	FRODE (Västerås, Sweden)	Debris catching test; filter evaluation; Δp; flow distribution; lift forces	N	0.1	20-80	30 kg/s	-	-	Deionized water with various types of debris	T, p, Δp, m, v (pitot tubes)	Actual fuel components, up to 2 m bundles

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Westinghouse facilities are accessible through, typically, purchase orders

EnCore™: the Westinghouse Accident Tolerant Fuel product

- Westinghouse EnCore Fuel is an ATF product that capitalizes enhanced safety to reduce plant capital and operation costs
  - Fuel: U_3Si_2 – fuel temperature and FCC benefits
  - Cladding: coated-Zr (Stage 1) and SiC/SiC (Stage 2) – delayed/reduced H_2 generation and core heatup; retention of coolable geometry by SiC at very high temperature
- Lead Test Assemblies in a commercial reactor in 2021/2022, with expedited schedule of Lead Test Rods in 2018/2019
- Comprehensive testing ongoing and planned, at Westinghouse and through partners:
  - Manufacture
  - Fuel rod performance
  - DNB
  - Corrosion and CRUD
  - LOCA and severe accident conditions

  } **Thermal-hydraulic testing**

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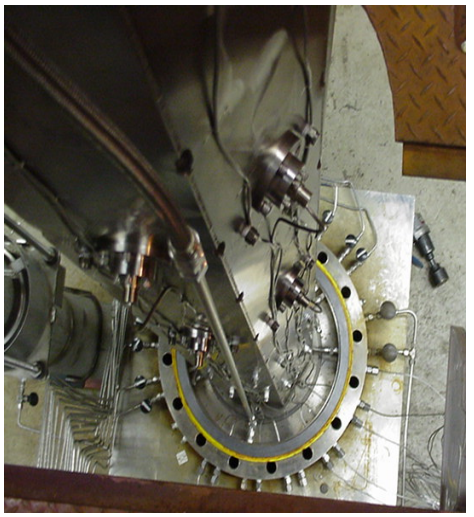
Some of the ongoing TH-related testing at Westinghouse

- Effect of ATF surface roughness on (WALT):
  - Pressure drop
  - Heat transfer
- Crud deposition experiments: comparison ATF-Zircaloy (WALT-WATCH)
- Effect of chemistry conditions change on ATF surface (WALT-WATCH)
- CHF testing, w/ and w/o prior CRUD deposition (WALT)
- CHF testing of different fuel designs for safety analyses (ODEN)
- Fuel assembly flowing water damping tests to address NRC concern on fuel assembly EOL seismic/LOCA performance (VIPER)
- Vibration tests and pressure drop tests for fuel product modification (FACTS)

WALT loop



FACTS loop

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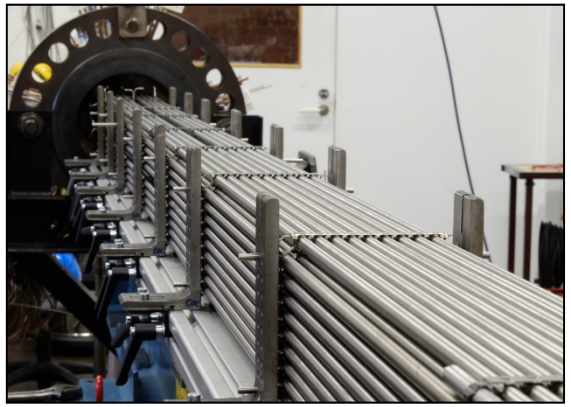
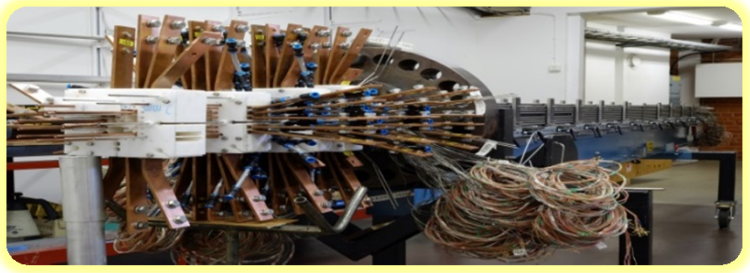
Planned TH-related testing, and key needs

- Some planned testing:
  - LOCA and severe accident testing (WALT)
    - w/ and w/o prior CRUD deposition
    - High and low pressure
    - Various severity of loss of coolant
- TH testing needs:
  - Transient DNB, with high-resolution instrumentation
  - High-resolution multi-phase flow rod bundle data for CFD V&V



Assembling of test bundle (FRIGG)



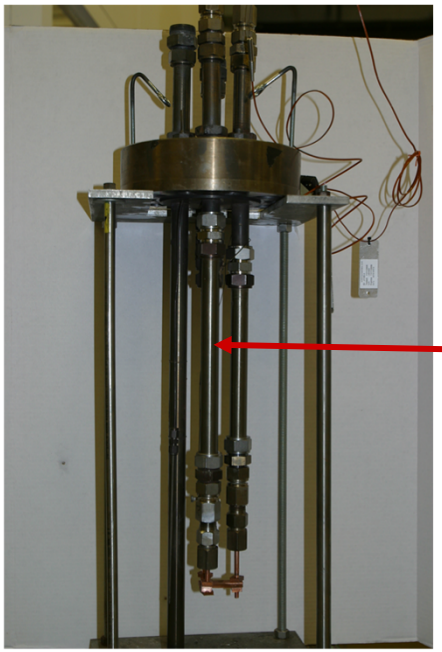
Individual rod power control in FRIGG

Insertion of bundle in test vessel (FRIGG)

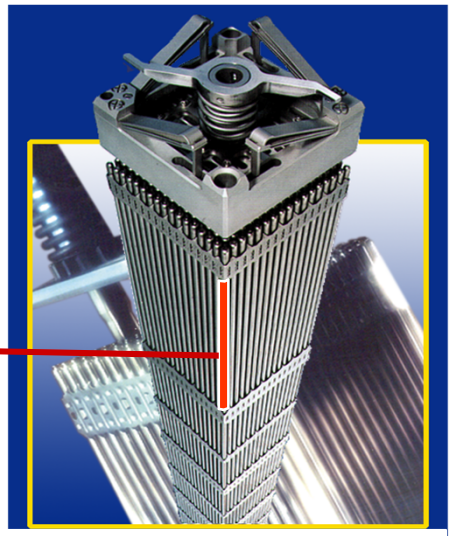
Backup slides

Westinghouse Advanced Loop Tester (WALT)

WALT Loop



Heater Rod in the WALT Test Loop



PWR Fuel Assembly

WALT Loop tests:

- Crud simulation at normal PWR operating conditions and chemistry
- DNB tests successfully conducted in WALT loop
- LOCA tests to be performed soon

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Westinghouse Annular Thermal Crud Hydraulic (WATCH) Loop

- Better understand and simulate crud behavior at BWR operating conditions and chemistry
- LOCA tests
- Validate current friction correlations and pressure drop at crudded fuel rod surface
- Make other measurements, such as fuel rod heat transfer enhancement with 3-D surface roughness or micro particles as well as benchmarking for future CFD two-phase models, etc.

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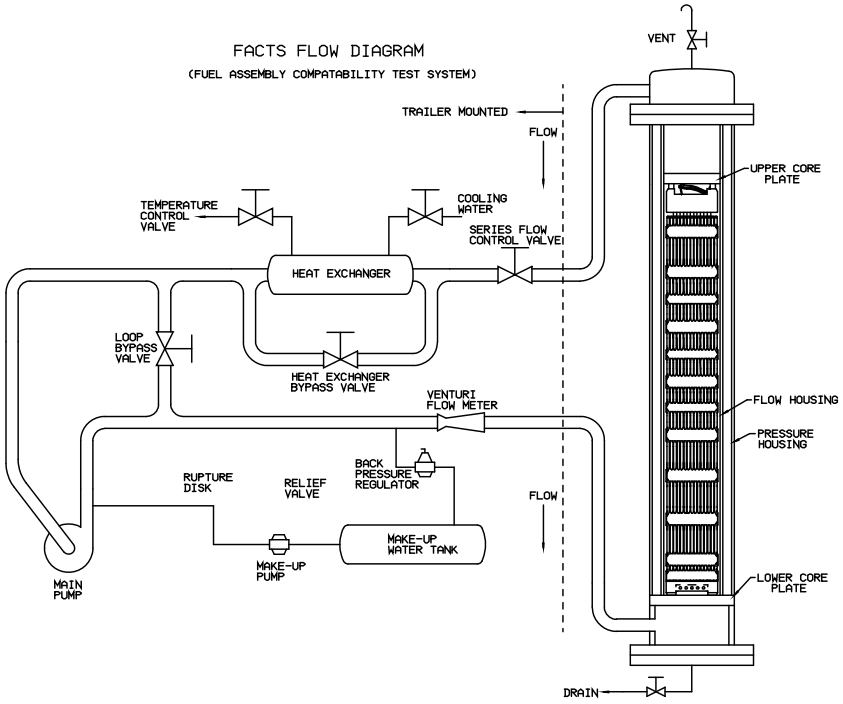
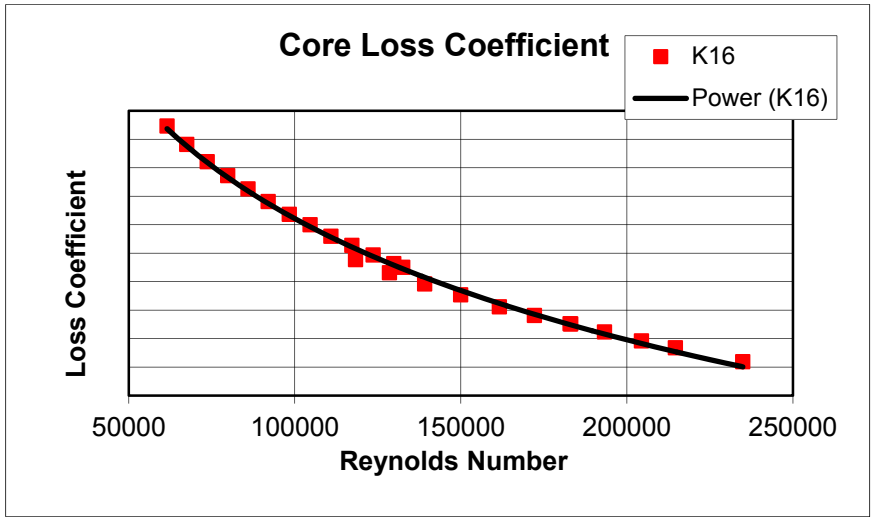
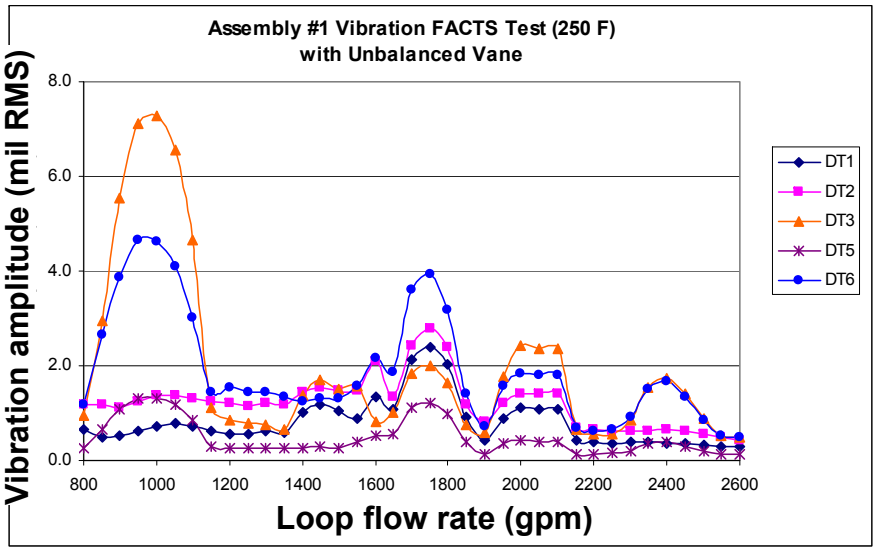
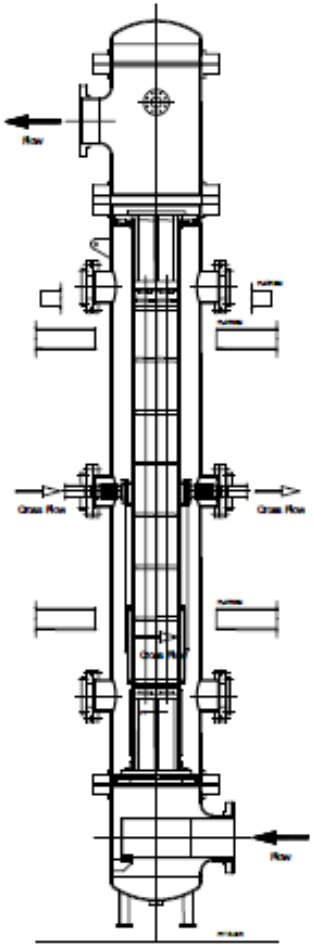
Fuel assembly compatibility test system (FACTS)



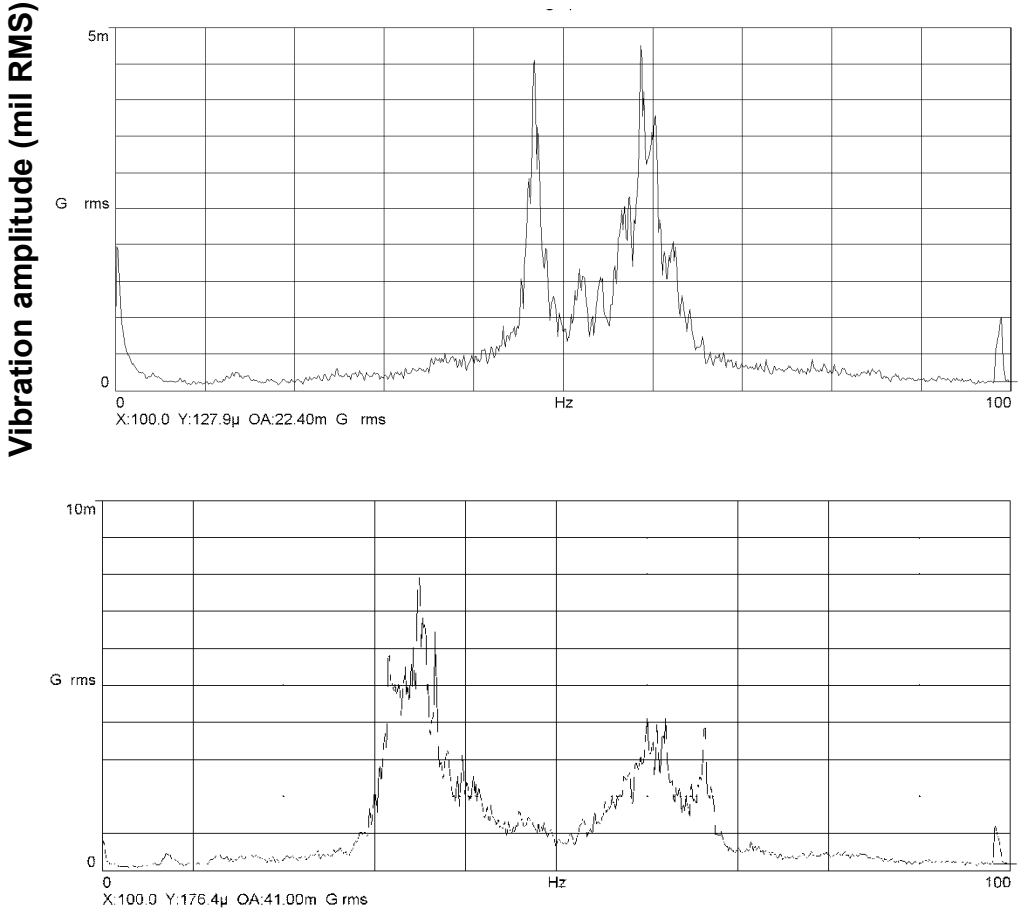




Vibration Investigation and Pressure Drop Experimental Research (VIPER)



VIPER facility



Loop flow rate (gpm)

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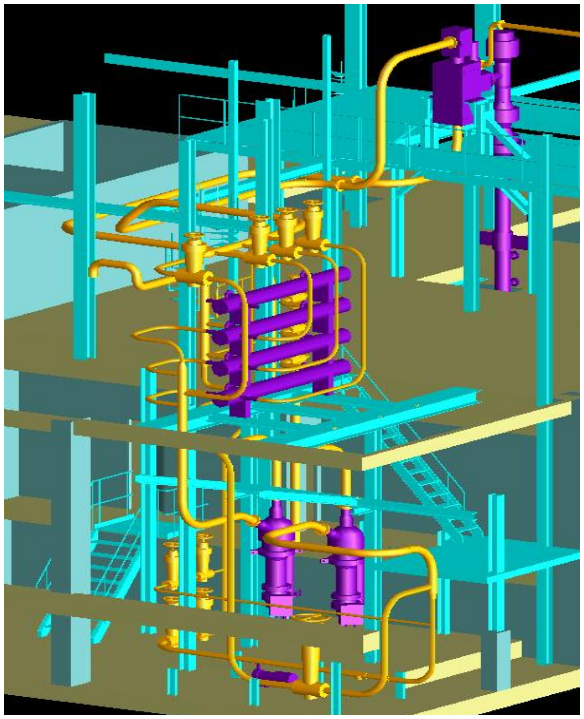
Overview of ODEN



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