Thermal hydraulic experimental research progress in SINAP

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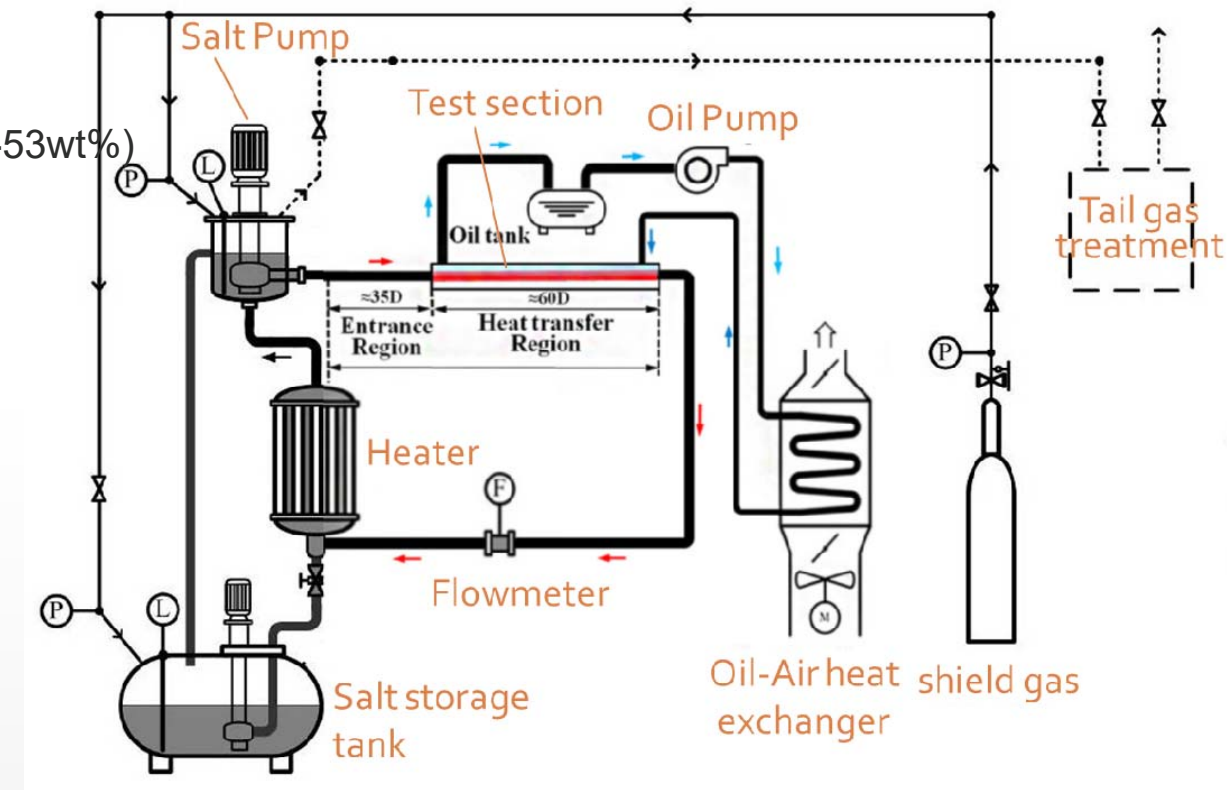
Nitrates test loop

Nitrates test loop

- Heat transfer fluid
  - Hitec salt
    - $NaNO_3$-$NaNO_2$-KNO_3 (7-40-53wt%)
  - Thermal oil (Therminol 66)
- Operation temperature
  - 200-400℃
- Operation salt mass flow
  - 0.2-6m^3/h
- Heater power
  - 120kW



Circular tube HT tests

- Test section
  - Concentric tube
    - Inner tube: Hitec molten salt, din=20mm, l=1200mm
    - Outer tube: thermal oil, din=39mm
- Test parameter range (salt)

Parameters	Range
Flow rate ($m^3 h^{-1}$)	0–6.0
Inlet temperature (K)	470.81–575.52
Outlet temperature (K)	469.02–567.21
Heat transfer coefficient ($W m^{-2} K^{-1}$)	2292–7745
Prandtl number	11–27
Reynolds number	10000–50000
Nusselt number	88–368

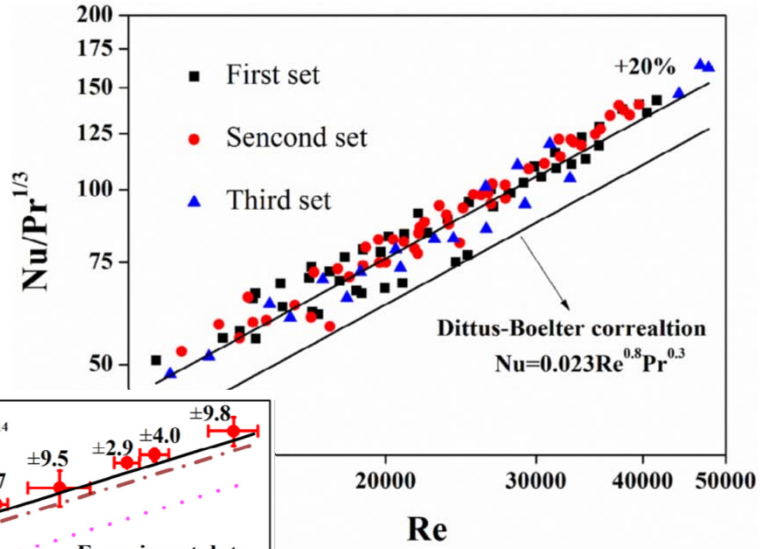
Circular tube HT tests

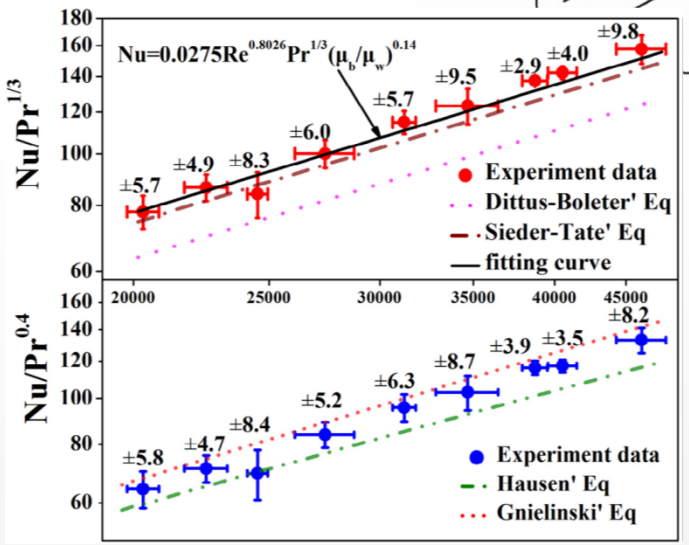
- Suggested new correlation

$$Nu = 0.0275\,\mathrm{Re}^{0.8026}\,\mathrm{Pr}^{1/3}\left(\mu_b/\mu_w\right)^{0.14}$$
$$(20000 < \mathrm{Re} < 50000,\ 11 < \mathrm{Pr} < 27)$$

  - Uncertainty of Nu: ±7.8%

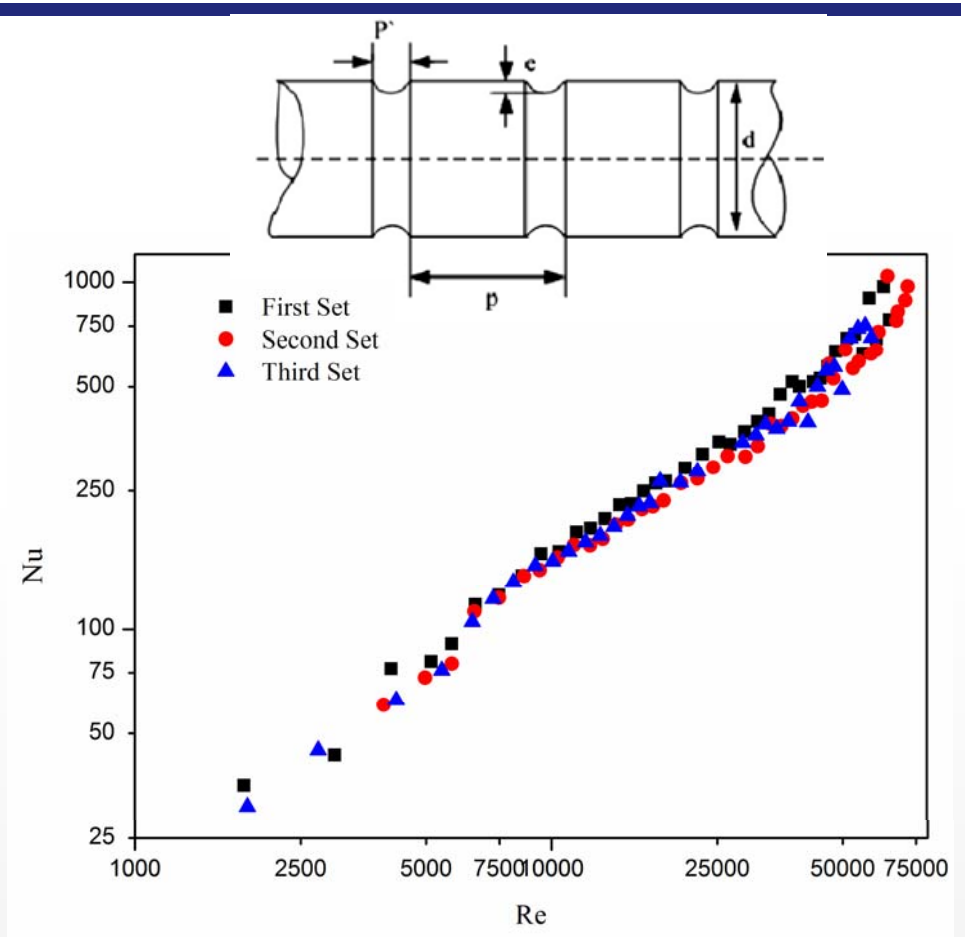
- HT correlations validation
  - Gnielinski (+7%)
  - Sieder-Tate (-8%)
  - Hausen (-10%)
  - Dittus-Boelter (-20%)





Enhanced HT tube tests

- Test section
  - Concentric tube
    - Inner tube: Hitec molten salt
      - Transversally corrugated tube
        - d_{in}=16mm, e=0.73mm
        - P=9.6mm, P'=2mm
    - Outer tube: thermal oil, d_{in}=39mm
- Test parameter range (salt)
  - Temperature: 200-300℃
  - Flow rate: 0-6m^3/h
  - Reynolds number: 200-70000
  - Prandtl number: 11-27



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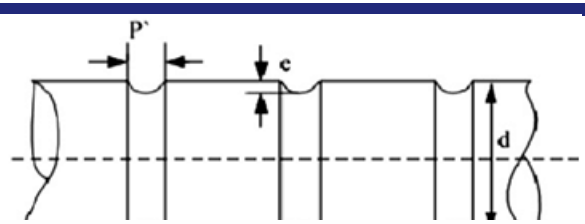
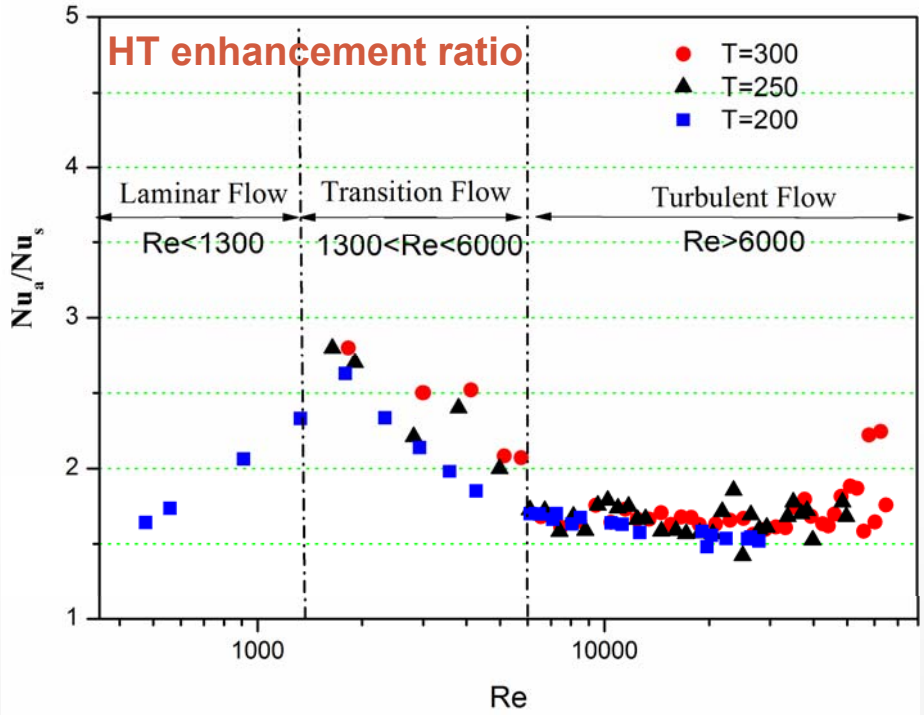
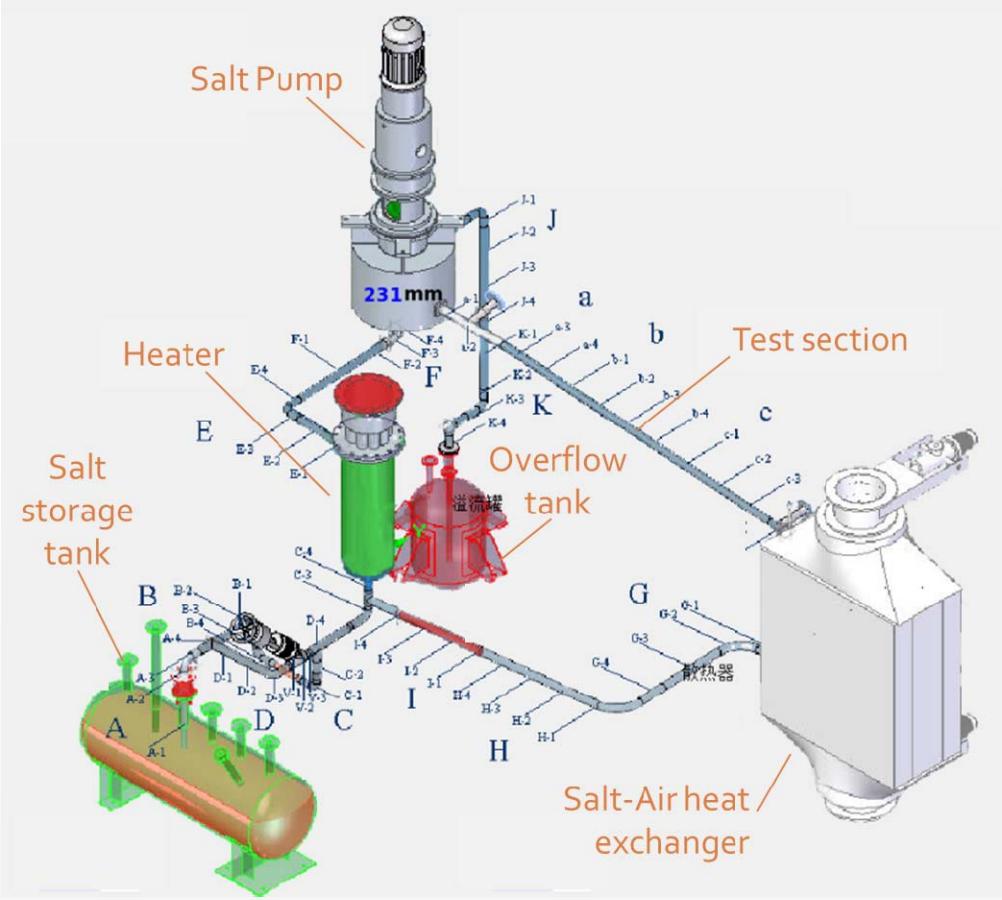




FLiNaK test loop

FLiNaK test loop

- Heat transfer fluid
  - LiF-NaF-KF (46.5-11.5-42mol%)
- Operation temperature
  - 500-600℃
- Operation salt mass flow
  - 17-25m^3/h
- Heater power
  - 200kW

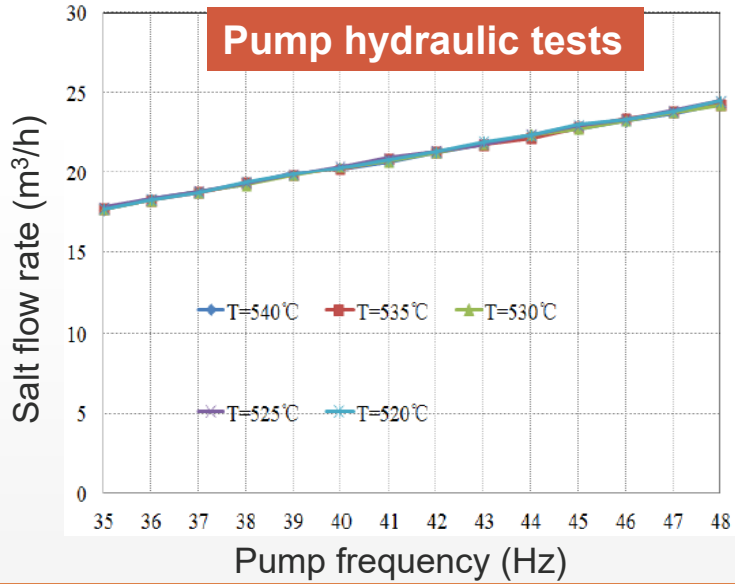


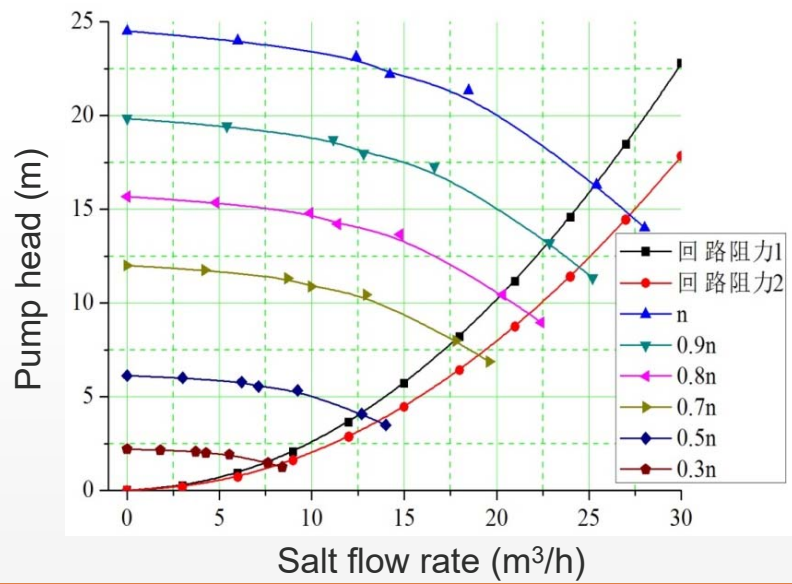
HX & pump preliminary tests

Salt-air HX steady HT tests

Tests	Air fan frequency	Salt flow (m^3/h)	Air flow (m^3/h)	Salt Tin (℃)	Salt Tout (℃)	Air Tin (℃)	Air Tout (℃)
Natural convection	0	20	-	514.0	509.1	42.5	422.4
Forced convection	20Hz	20	1114	515.5	508.5	45.6	355.3
Forced convection	30Hz	20	1896	510.5	501.5	46.5	337.3
Forced convection	40Hz	20	3316	510.4	499.9	46.9	303.8

Pump hydraulic tests



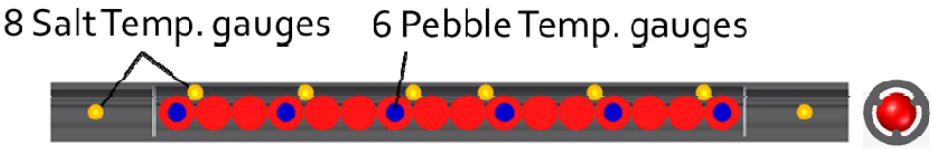


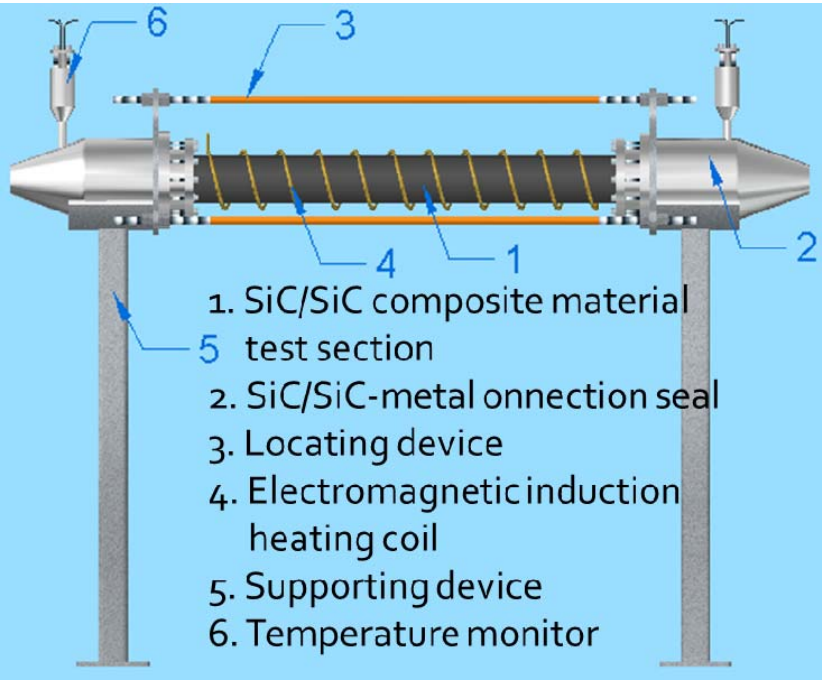
Test plan of FLiNaK loop

- System steady thermal equilibrium test
  - Measure temperatures of equipment, structures and pipes at different steady boundary conditions to obtain system heat loss characteristics
- System steady hydraulic test
  - Measure pressure drops of equipment, structures and pipes at different steady boundary conditions to obtain system hydraulic characteristics
- System transient test (for system code validation)
  - Power transients
  - Salt flow rate transients
  - Heat exchanger load transients

Pebble-bed HT tests

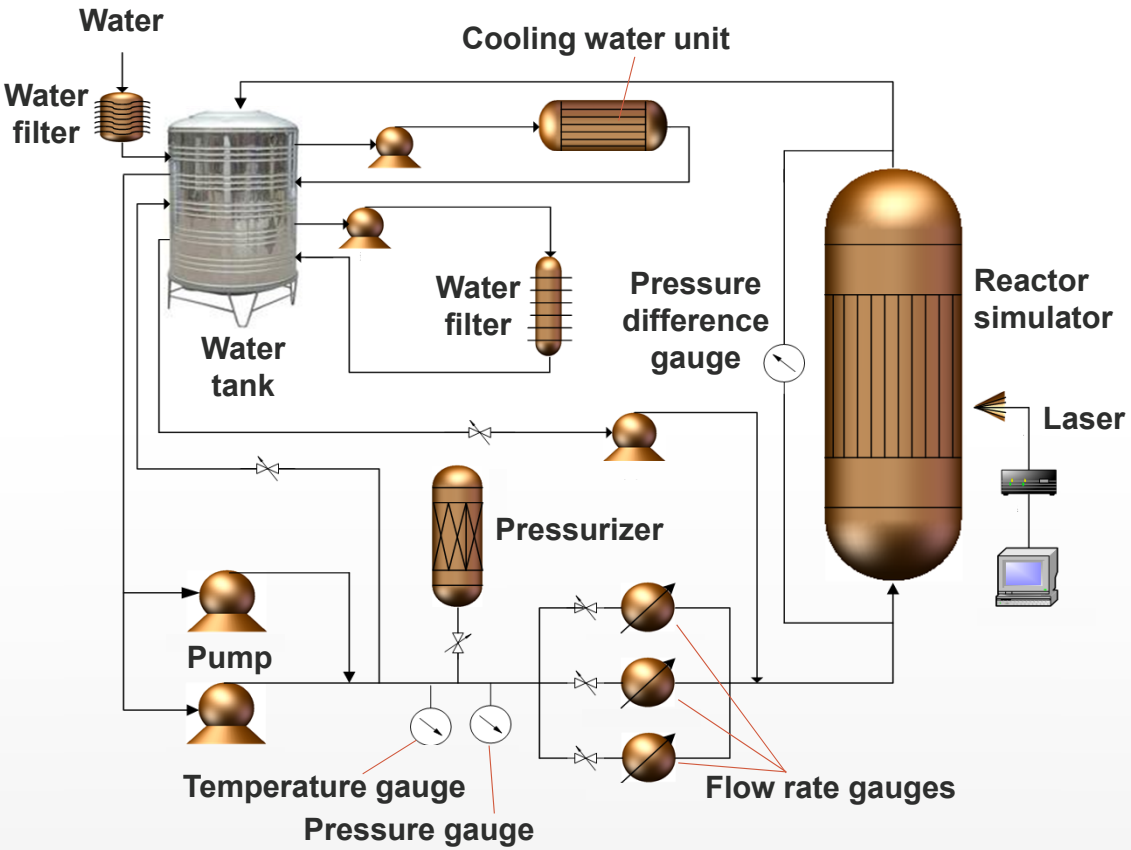
- Pebble-bed channel test section
  - SiC/SiC composite circular pipe
  - Filled with 16 graphite pebbles
    - Pebble diameter: 60mm
    - Pipe diameter: 76mm
    - Filled length: 970mm
  - Electromagnetic induction heating
    - Power: 60kW
- Planned test parameter range
  - Temperature: 500-600℃
  - Flow rate: 0.1-7m^3/h
  - Reynolds number: 200-18000

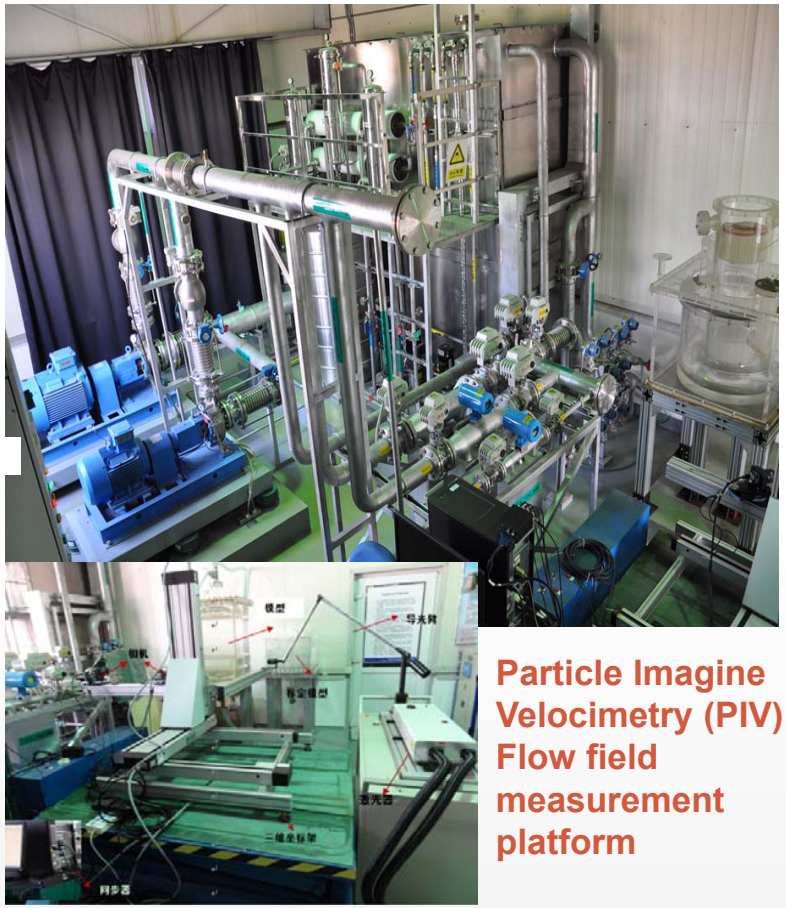




Pebble-bed hydraulic test loop

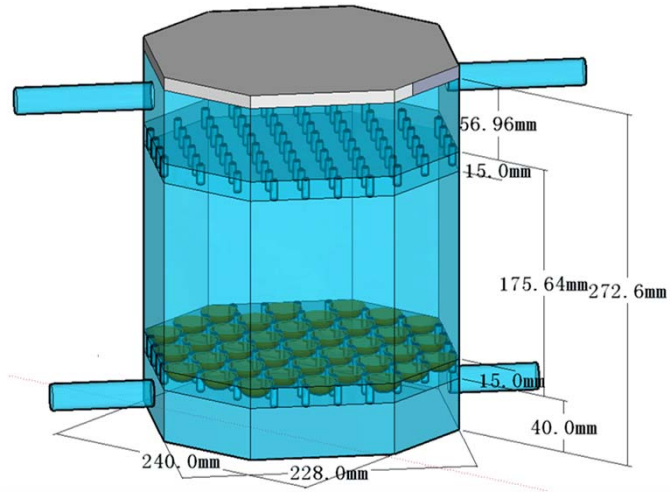
Pebble-bed hydraulic test loop





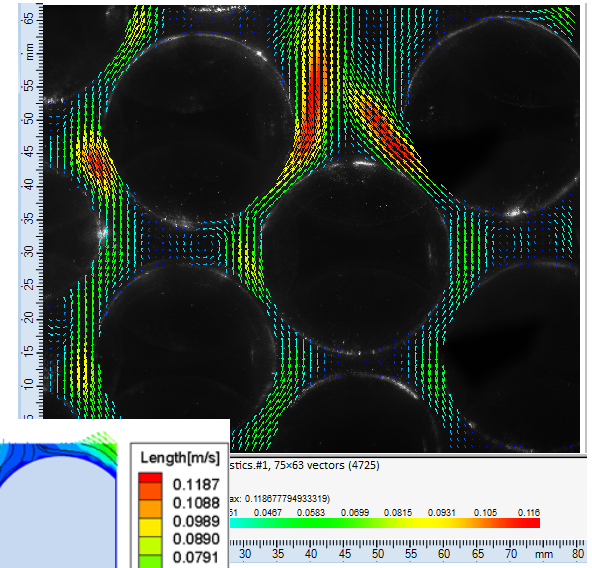
Particle Imagine Velocimetry (PIV) Flow field measurement platform

Flow field test of a small octahedral pebble-bed

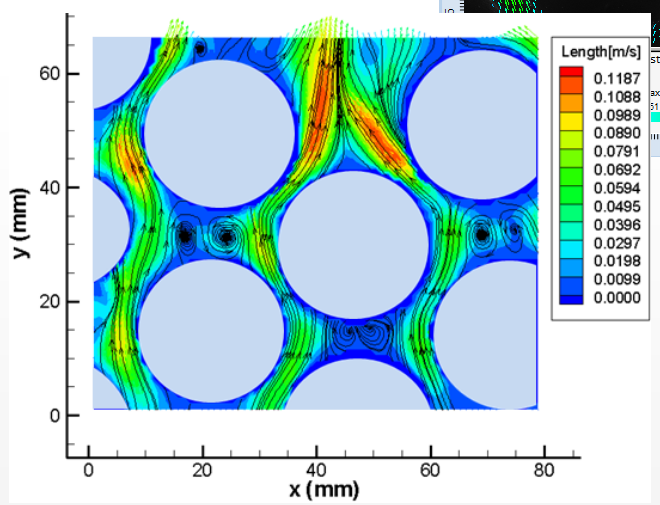


PIV tracer particle:
16μm glass particle with silver coating

NaI: 61.6-64%wt.

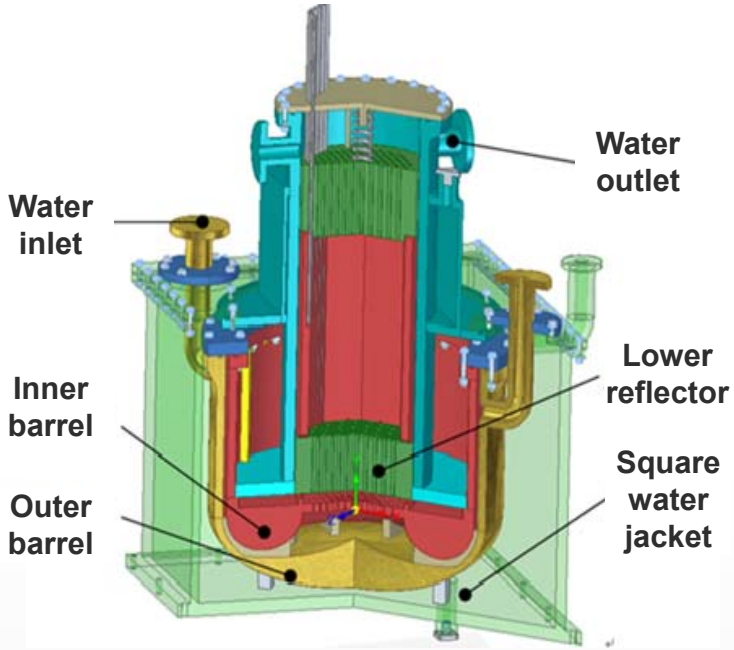


Parameters	Value
Pebble diameter (mm)	30
Packing height (mm)	175.64
Packing manner	Random
Fluid	NaI solution
Mode/pebble/fluid refractivity	1.4912
Re	6-300



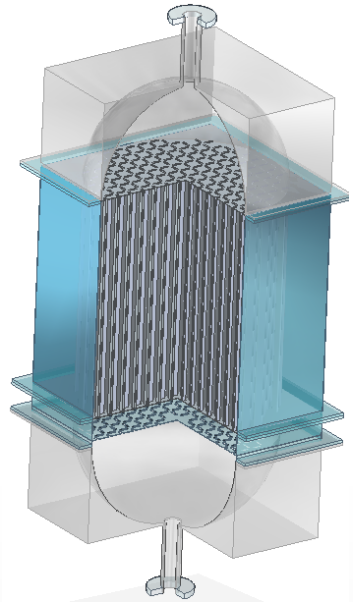
Measured velocity field (Re = 300)

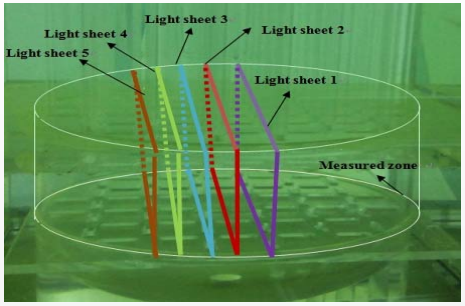
Flow distribution test of TMSR-SF1 1:4 scaling model

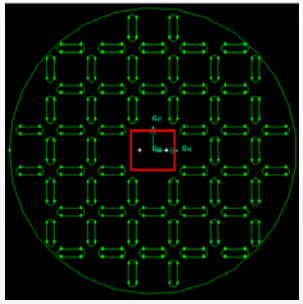


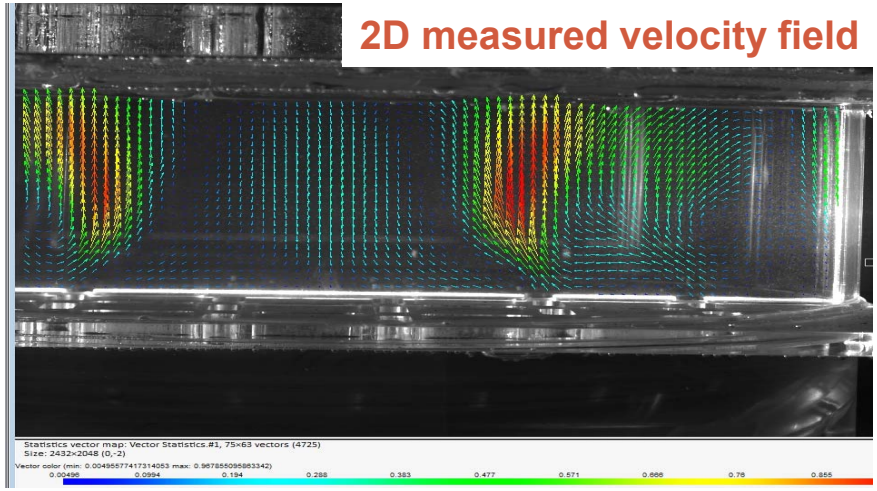
- Pebble-bed: 15mm diameter PMMA pebbles, random packing
- NaI solution: 61.6-63%wt.
- Mode/pebble/fluid refractivity: 1.49

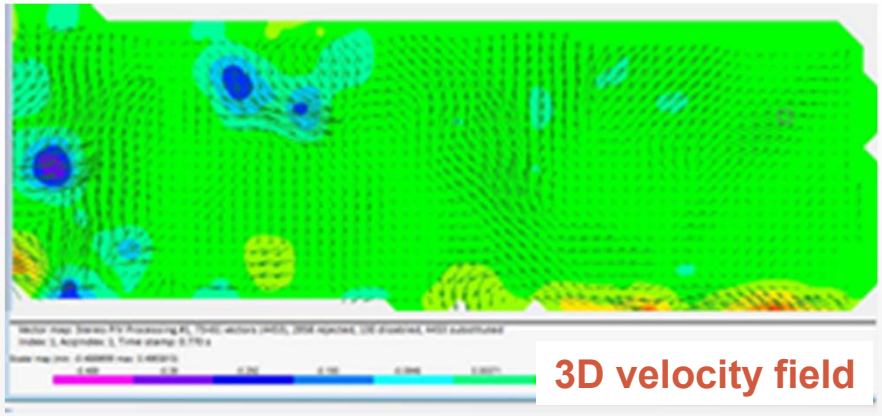
Flow distribution test of TMSR-LF1 1:4 scaling model





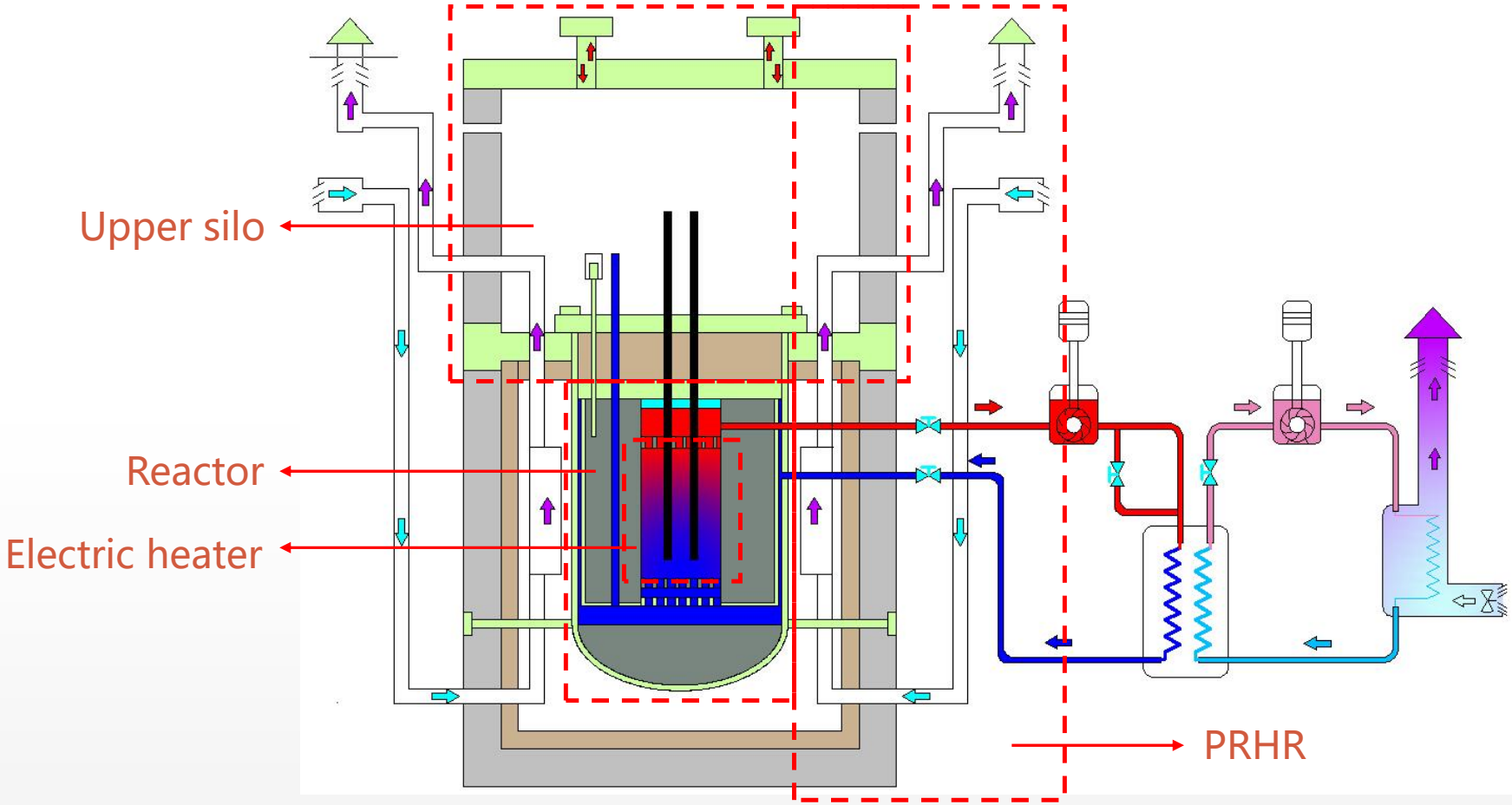






TMSR-SF0 TH test plan

Schematic layout of TMSR-SF0



Key TH parameters of TMSR-SF0

Parameters	Value	Parameters	Value
Core heating power (kW)	0-400	Design temperature of reactor and primary loop (℃)	700
Salt temperature at reactor inlet (℃)	600	Salt temperature at reactor outlet (℃)	650
Salt temperature at IHX inlet (℃)	520	Salt temperature at IHX outlet (℃)	536
Air temperature at salt-air HX inlet (℃)	40	Air temperature at salt-air HX outlet (℃)	180
Coolant in primary loop	FLiNaK (Phase I) FLiBe (Phase II)	Coolant in secondary loop	FLiNaK
Salt mass flow in primary loop (kg/s)	0-10.0	Salt mass flow in secondary loop (kg/s)	0-12.2
Air mass flow in salt-air HX (kg/s)	0-2.6	PRHR power (kW)	12.8
Salt volume in primary/secondary loop (m^3)	1/1	Primary/secondary pump head (MPa)	0.321/0.403
Reactor inlet/outlet pipes	DN50/DN100	Primary/secondary loop pipes	DN50

TH test plan of TMSR-SF0

- Passive residual heat removal system HT capacity validation test
- Transient test of loss of coolant forced convection
- Reactor integrate hydraulic test
  - Reactor friction & form loss test
  - Reactor core coolant bypass flow test
- Heat loss test of the upper lid
- Operation test
  - Start up
  - Shutdown
  - Steady operation at different power level
  - Salt-air HX load swing transient test

TH test plan of TMSR-SF0

- System code validation tests
  - Steady tests
    - System heat loss and thermal inertia test
    - System pressure drop test
    - (both for main equipment, structure and piping in coolant loops)
  - Transient tests
    - Power transients
    - Salt flow rate transients
    - Heat exchanger load transients
    - Loss of heat sink transient
    - Salt flow rate increasing/decreasing in secondary loop transients

Questions?