Transient Analysis of STELLA-2 using MARS-LMR

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이제환 (Jewhan LEE)

SFR NSSS Design Div.

KAERI
한국원자력연구원
Korea Atomic Energy Research Institute

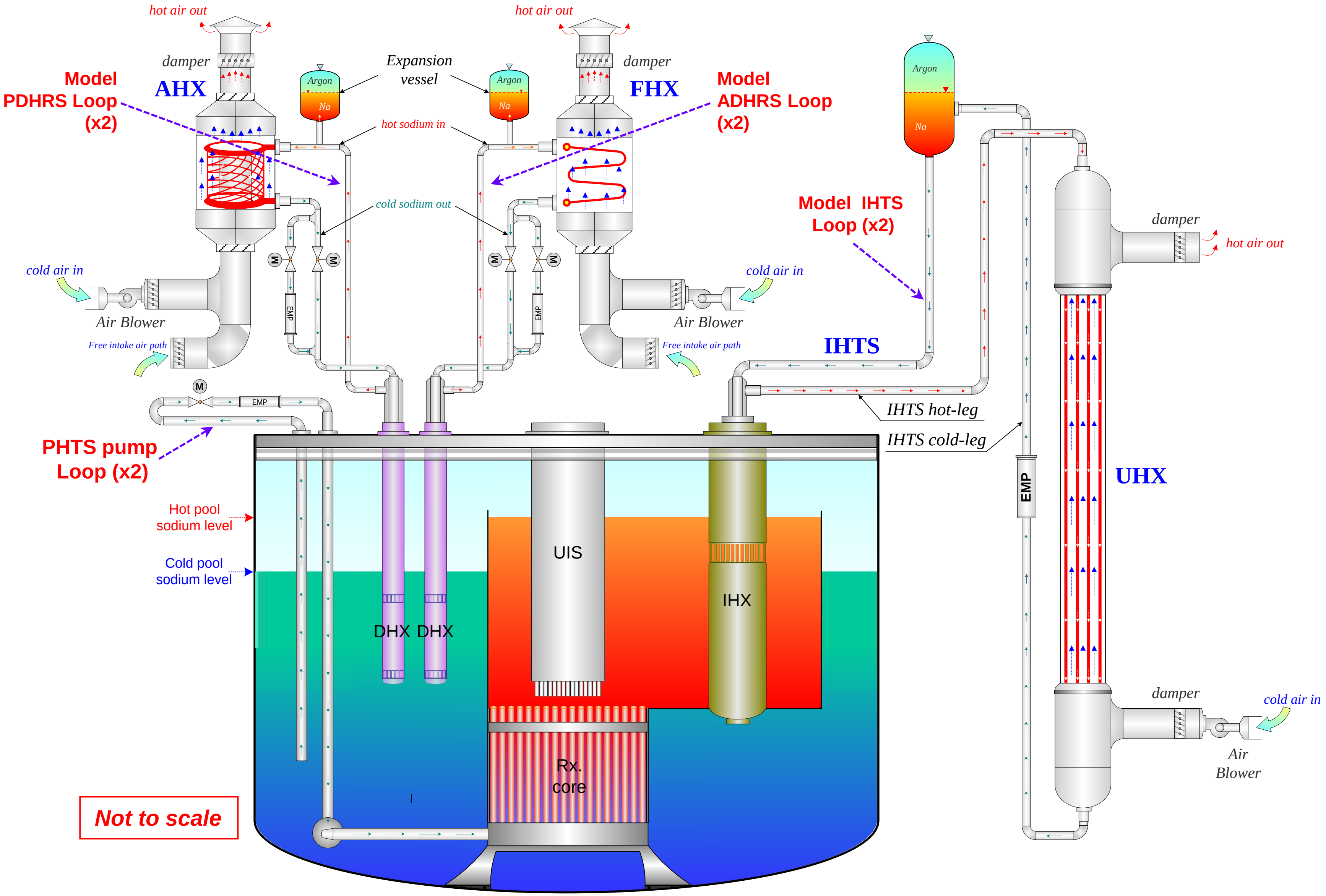
Contents

Introduction

□ STELLA-2

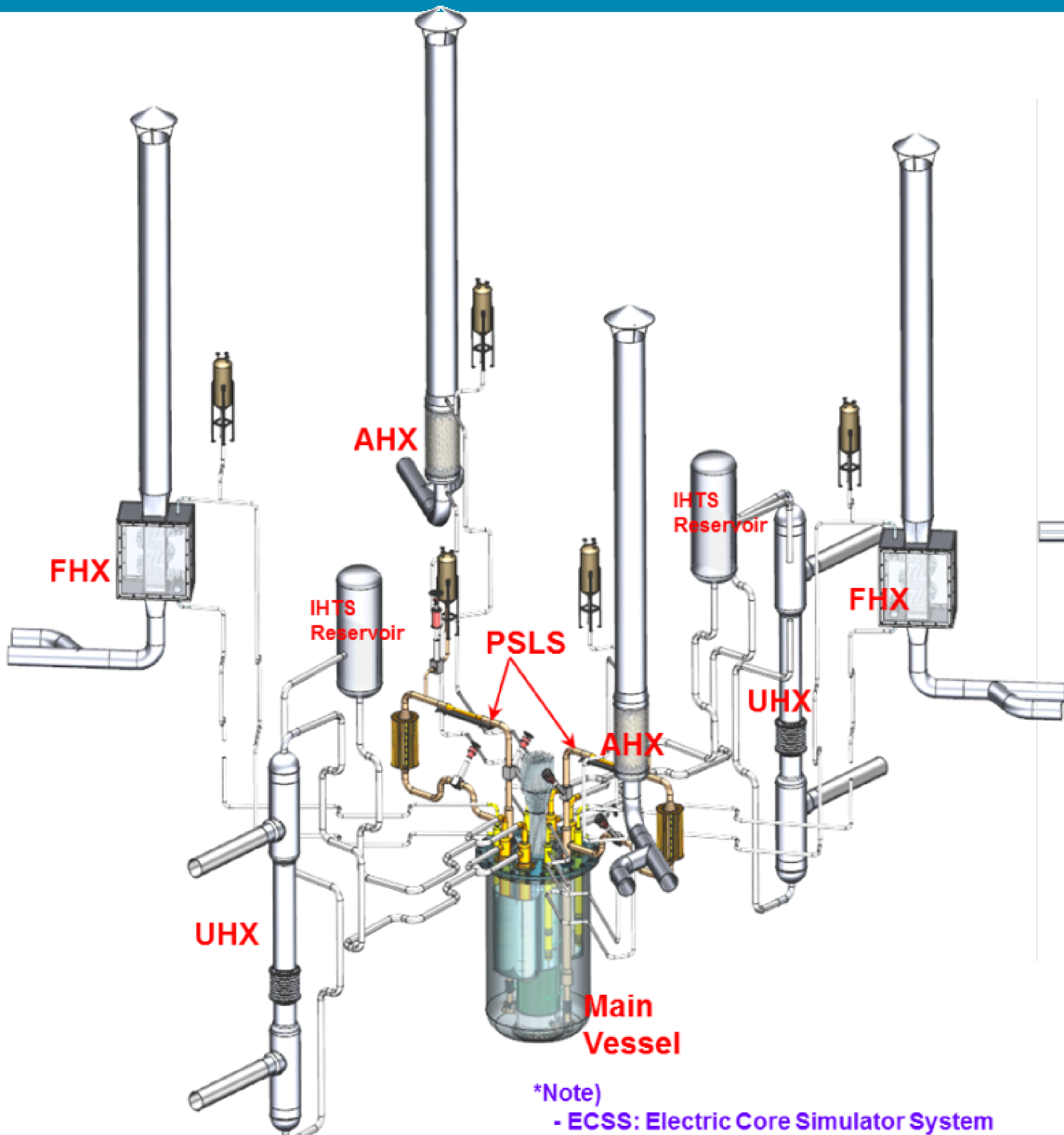
- Large-scale integral effect test facility
- Main purpose
  - To support the specific design approval for licensing
  - Safety analysis code V&V (MARS-LMR)
- Reference reactor
  - Prototype Gen IV SFR (PGSFR)
- Design Features
  - All PGSFR systems are considered
    - ✓ Pool-type PHTS with 2 PSLS
    - ✓ 2 IHTS – 4 IHXs and 2 UHXs
    - ✓ 4 DHRS – 4 DHXs, 2 AHXs, and 2 FHXs
    - ✓ Purification System
    - ✓ RVCS, Reactor Head Cooling System and etc.

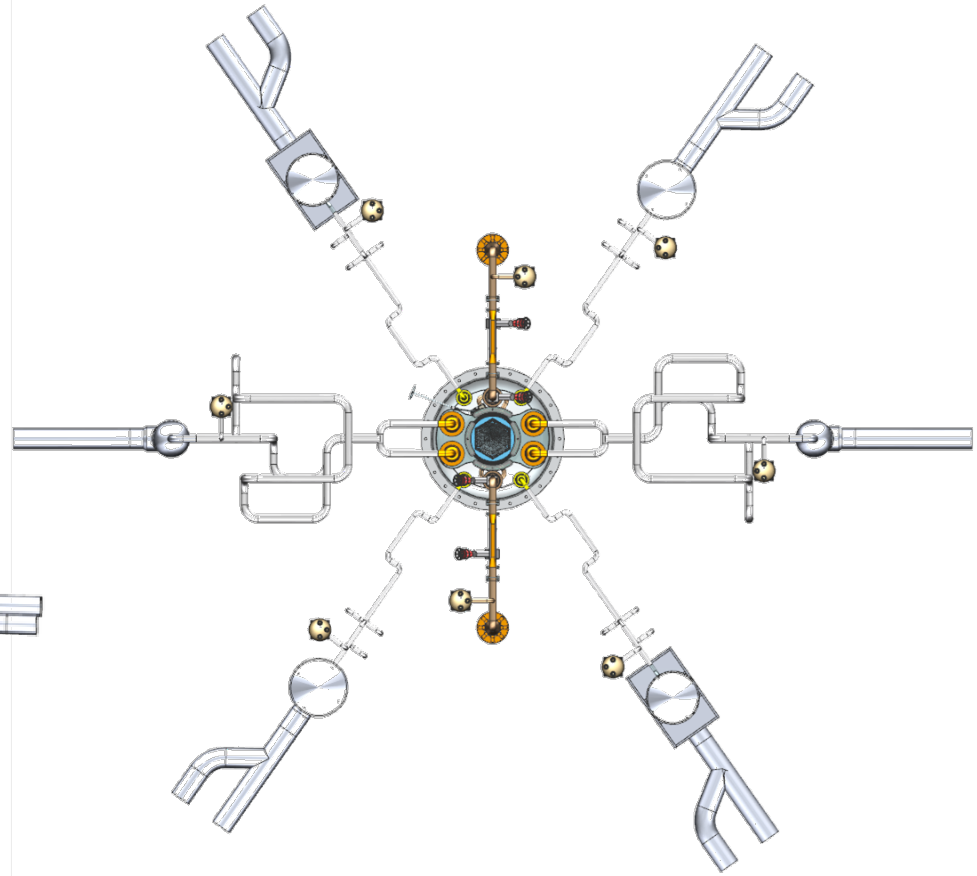
STELLA-2 Schematic



Not to scale

STELLA-2 3D Model





*Note)
- ECSS: Electric Core Simulator System
- PSLS: PHTS Pump Simulation Loop System

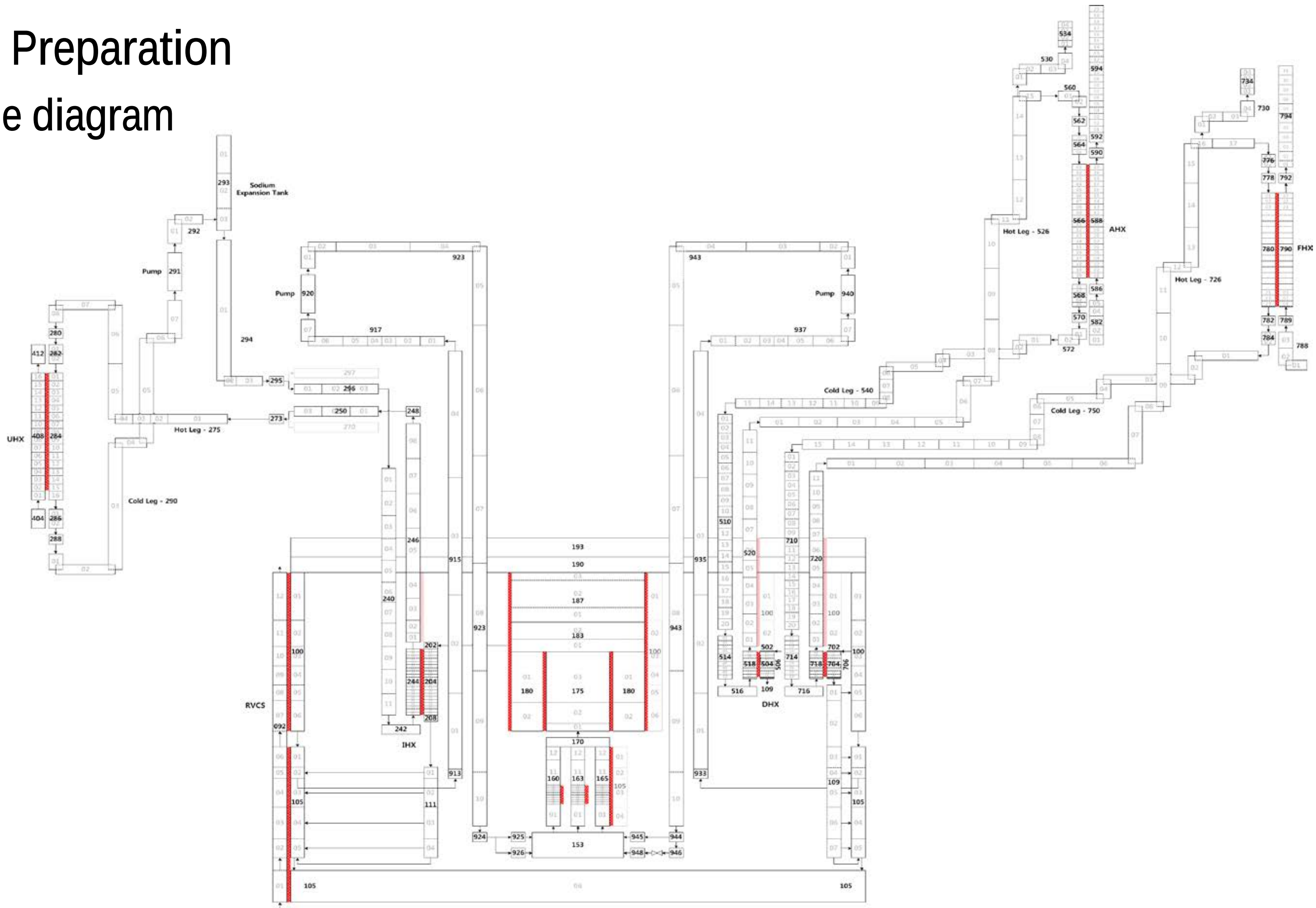
Design Basis Event

- ☐ Loss Of Flow (LOF)
  - – Occurs when all power to the pump is lost
  - – Major causes include;
    - Single/Double failure of pump, Pump discharge pipe break, Pump rotor lock, Pump shaft break and etc.
    - Loss Of Off-site Power (LOOP)
- ☐ Loss Of Heat Sink (LOHS)
  - – Occurs when the SG is isolated and/or the IHTS is isolated
  - – Major causes include;
    - Feedwater pipe break, IHTS pipe break, Sodium leak in SG, and etc.
    - Loss Of Off-site Power (LOOP)
- ☐ For conservative safety analysis, LOF+LOOP and LOHS+LOOP is assumed
- ☐ In this study, LOF+LOOP is the target DBE

MARS-LMR Analysis

□ Input Preparation

– Node diagram



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MARS-LMR Analysis

□ Difference between STELLA-2 and PGSFR

- PHTS
  - Core – heater assemblies
  - Pump Simulation Loop System – EMP, EMF, valves and piping
  - Additional sodium volume under IHX and DHX
- IHTS
  - Ultimate Heat Exchanger (UHX) – sodium to air heat exchanger
  - IHTS EMP modeling
- DHRS
  - 4 loops system
  - Stand-by and operation condition (air temperature)
  - Realistic K factor

MARS-LMR Analysis

□ Steady-state Results

Variables	Temp(℃) Target	Temp(℃) ST2	MARS Component	Description
Inlet Plenum	390	391.92	153	
Core Out	545	546.95	170	
HotPool	545	545.38	183	IHX shell inlet
Cold Pool	390	451.79	100	DHX shell inlet
	390	389.83	105	PSLS intake
IHX	545	545.29	202	IHX shell inlet
	390	389.7	206	IHX shell outlet
DHX (Passive)	390	449.94	502	DHX shell inlet
	353.04	405.93	506	DHX shell outlet
DHX (Active)	390	449.86	702	DHX shell inlet
	353.04	407.24	706	DHX shell outlet
AHX	379.6	436.77	564	AHX tube inlet
	352.2	403.29	568	AHX tube outlet
FHX	379.6	437.3	778	FHX tube inlet
	352.2	405.07	782	FHX tube outlet
UHX	528	525.97	282	UHX tube inlet
	322	319.14	286	UHX tube outlet
Air	376.47	435.72	590	AHX shell outlet
	342.91	392.55	792	FHX shell outlet
	162.04	163.99	408	UHX shell outlet

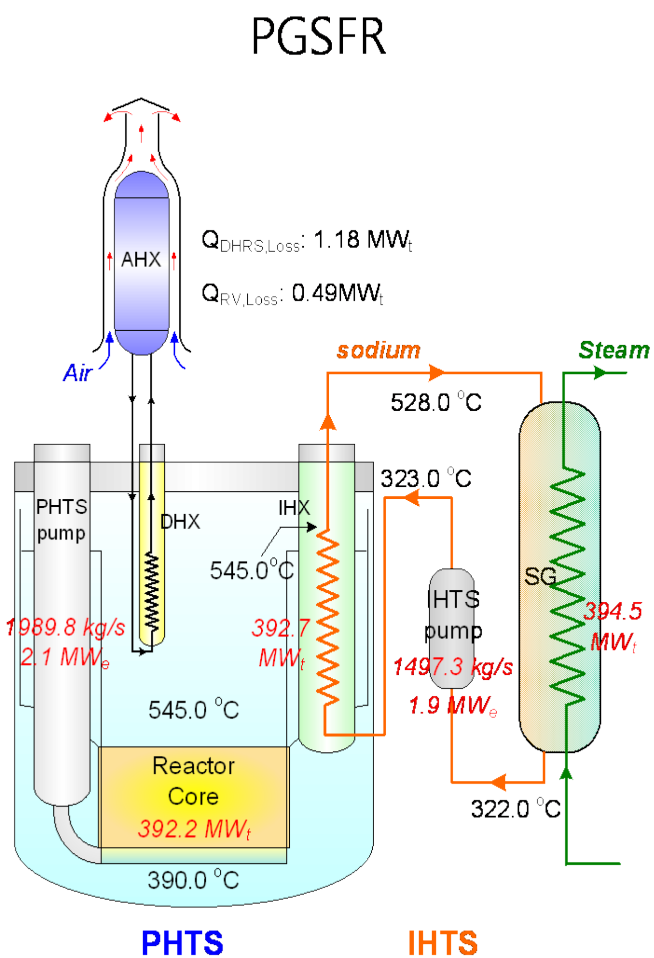
Variables	Flow(kg/s) Target	Flow(kg/s) ST2	MARS Component	Description
PSLS	17.7978	17.795	914	Intake 1
	8.8989	8.8975	925	Discharge 1
	8.8989	8.8975	926	Discharge 2
	8.8989	8.8975	945	Discharge 3
	8.8989	8.8975	946	Discharge 4
IHX	8.8989	8.8999	203	Shell
DHX	0.11234347	0.1299	503	Shell (Passive)
	0.11234347	0.1238	703	Shell (Active)
AHX	0.15116279	0.16826	565	Tube
FHX	0.15116279	0.16286	777	Tube
UHX	13.4	13.389	281	Tube

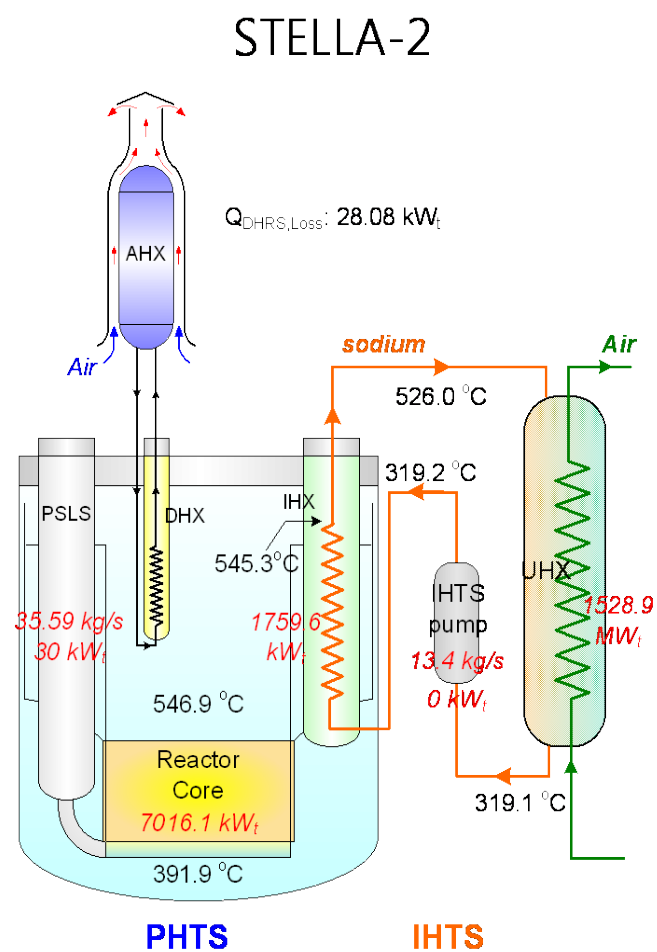
Variables	Power (kW)		ΔT (℃)		Avg. Temp (℃)	
	Target	ST2	Target	ST2	Target	ST2
Core	7016.1	7016.1	155.0	155.0	467.5	469.44
IHX	1752.70	1759.57	155.00	155.59	467.5	467.50
DHX (Passive)	5.35	7.30	36.96	44.01	371.52	427.94
DHX (Active)	5.35	6.74	36.96	42.62	371.52	428.55
AHX	5.35	7.20	27.40	33.48	365.9	420.03
FHX	5.35	6.71	27.40	32.23	365.9	421.19
UHX	3527.37	3539.95	206.00	206.83	425	422.56
UHX(Air)	3686.70	3509.95	142.04	143.99	91.02	91.995

MARS-LMR Analysis

□ Steady-state Results

– Heat balance of the system





MARS-LMR Analysis

□ Transient Analysis

- STELLA-2 time scale :
  - $\frac{1}{\sqrt{5}}$ ~ 1/2.24
- Accident scenario
  - PHTS pumps stop and coast-down : 4.47 s
  - IHTS pumps stop : 4.47 s
  - UHX air blow stops : 4.47 s
  - Core heater starts to decay : 6.7 s
  - Damper (AHX & FHX) opens : 8.94 s
- Total analysis time ~ 22,000 s
  - corresponds to 50,000 s in PGSFR

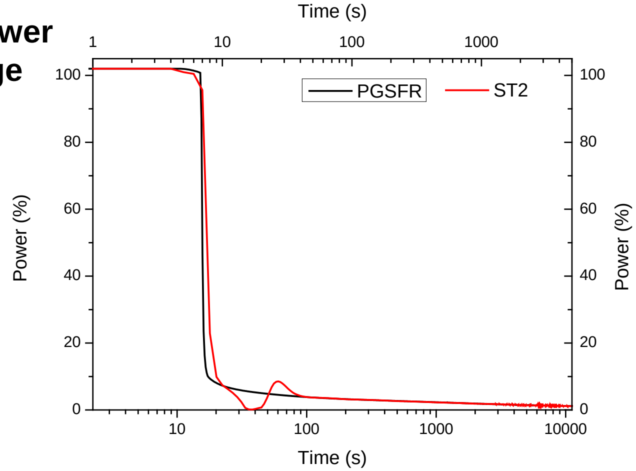
Comparison with PGSFR Safety Analysis

□ Temperature Trend

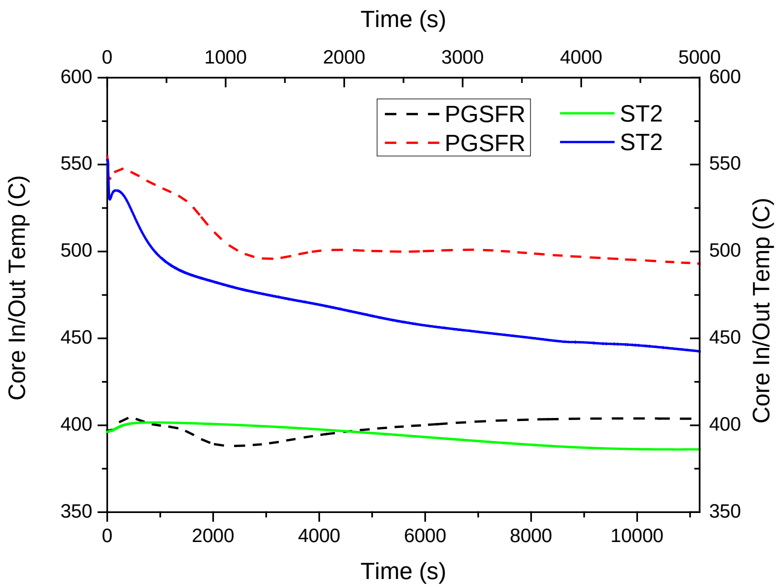
– STELLA-2 results are lower than PGSFR in PHTS behavior

– For DHRS, the realistic friction (K factor) setup influenced the temp of DHX shell

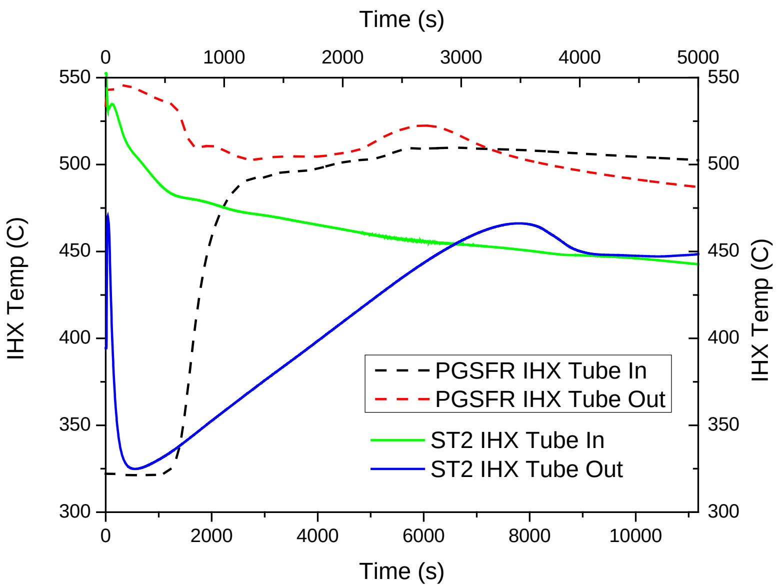
Core Power Change



PHTS Temp Trend

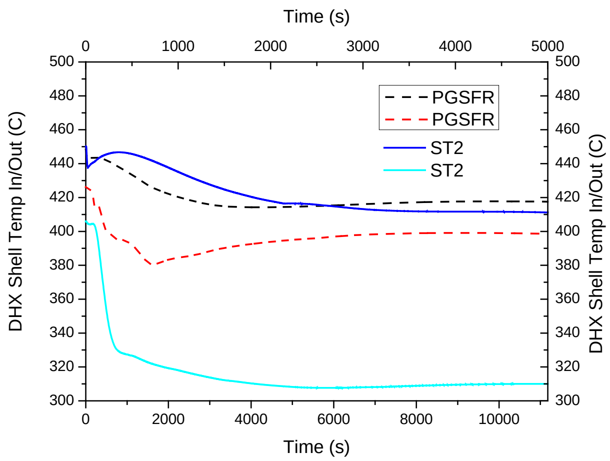


IHTS Temp Trend

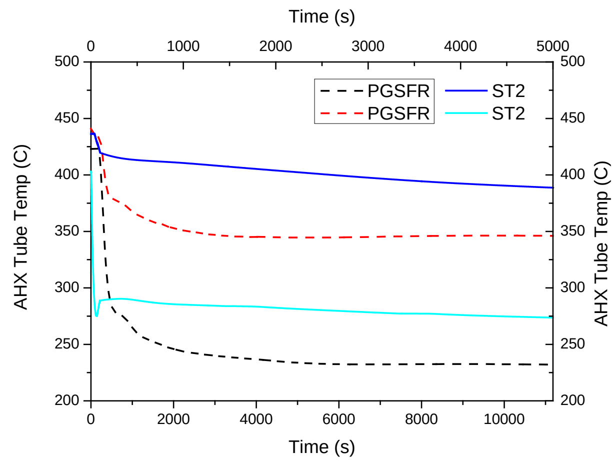


Comparison with PGSFR Safety Analysis

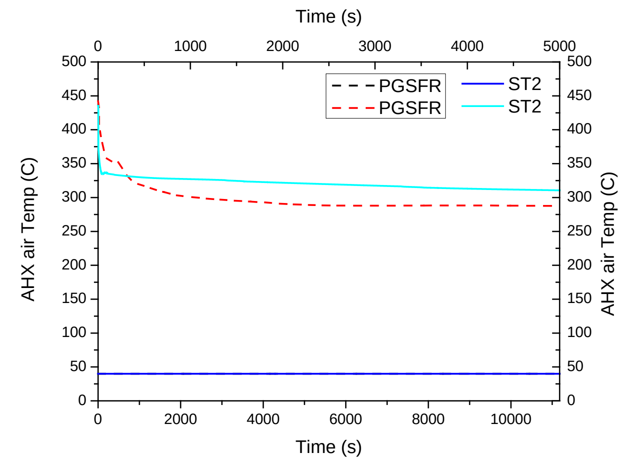
DHX(Passive) Shell Temp



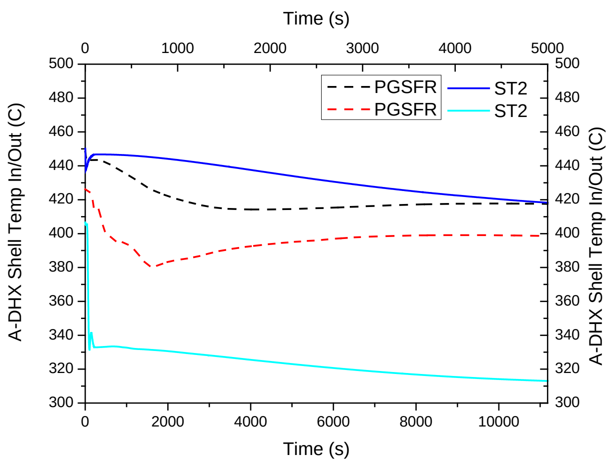
AHX Tube Temp



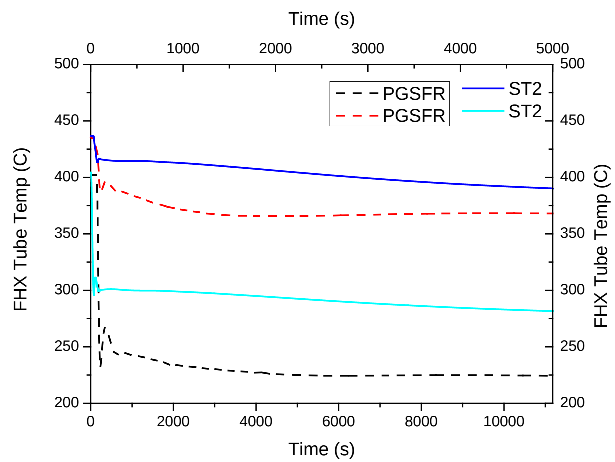
AHX Shell (Air) Temp



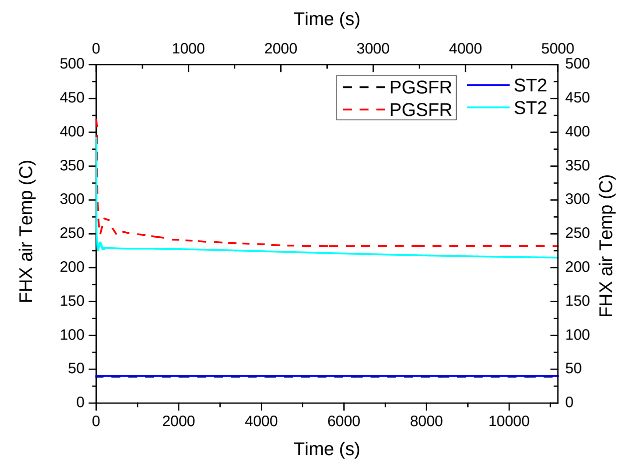
DHX(Active) Shell Temp



FHX Tube Temp



FHX Shell (Air) Temp



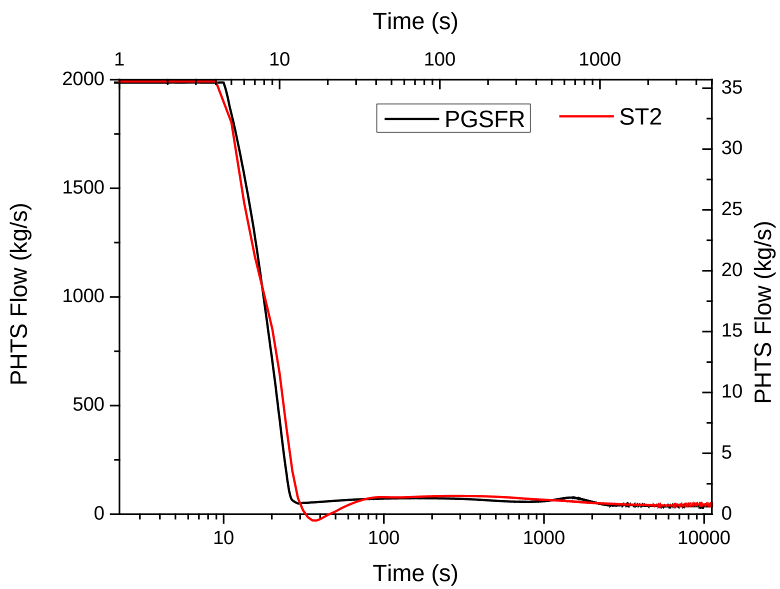
Comparison with PGSFR Safety Analysis

□ Flow Trend

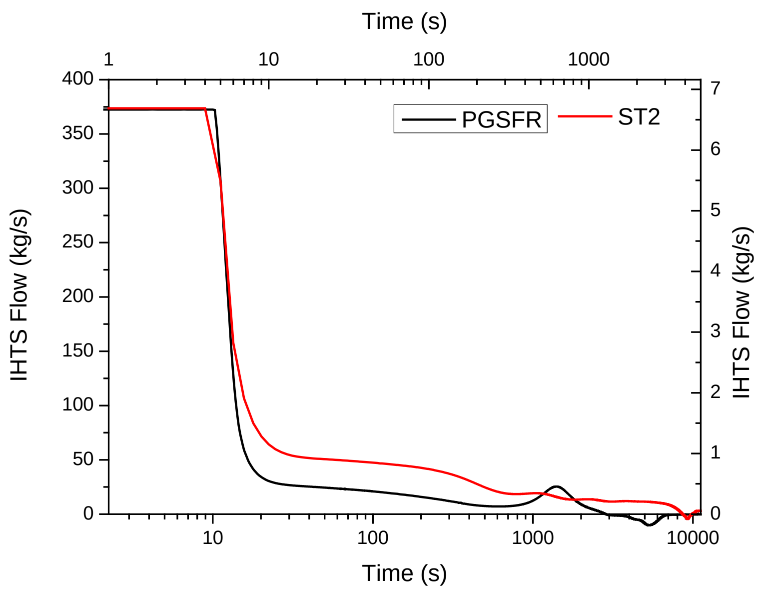
– PHTS flow is in good agreement with PGSFR results

– IHTS flow shows slight difference, but the influence to PHTS pool behavior is negligible

PHTS Flow Trend (Log Scale)



IHTS Flow Trend (Log Scale)



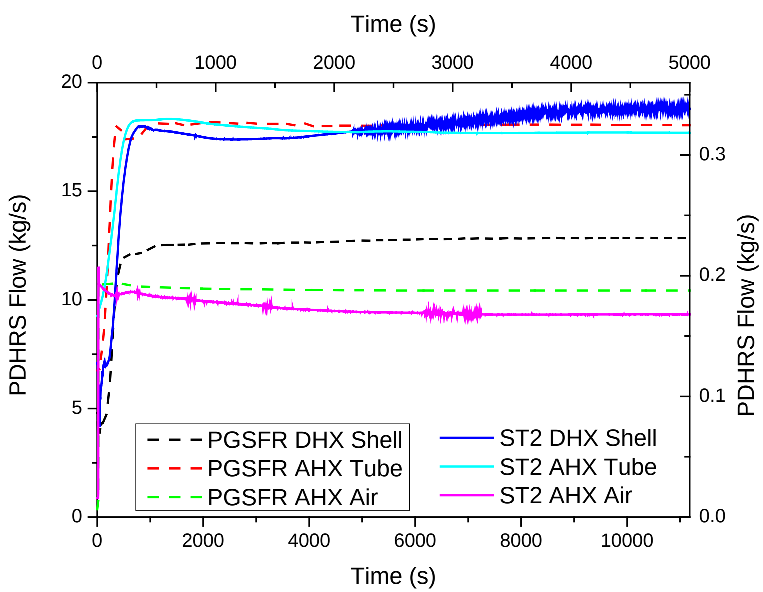
Comparison with PGSFR Safety Analysis

□ Flow Trend

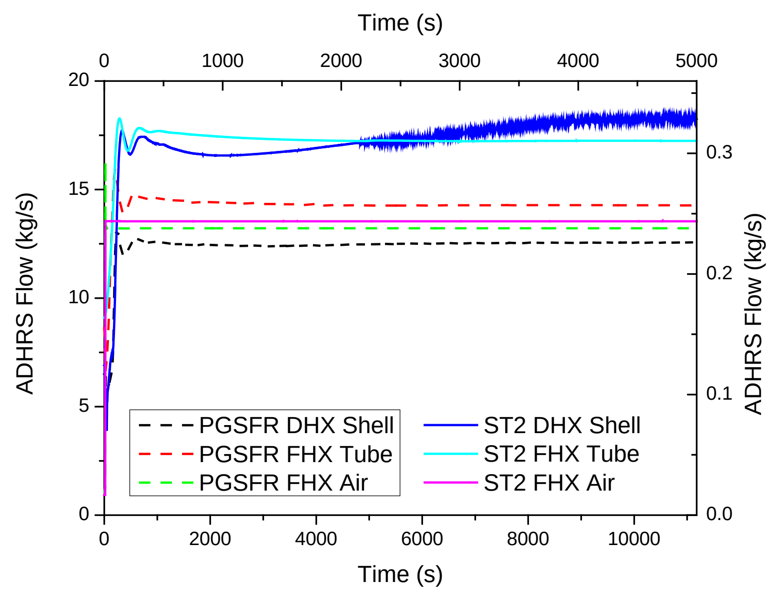
– Due to realistic friction (K factor) setup in DHX Shell side, relatively large discrepancy is observed in both PDHRS and ADHRS

– However, the final heat removal by air flow is approximately same

PDHRS (AHX) Flow Trend



ADHRS (FHX) Flow Trend



Conclusions

- □ A Part of design evaluation of STELLA-2
  - MARS-LMR analysis of steady-state and transient
- □ Representative DBE for the transient analysis
  - LOF with LOOP
- □ Comparison between STELLA-2 and PGSFR results
  - In good agreement within reasonable range
  - Some discrepancy observed due to different system, but minor effect
- □ For further study, various sensitivity test will be needed

References

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- Jung YOON, “Thermal-hydraulic Analysis Report of the STELLA-2 Model PHTS,” KAERI SFR Design Report, SFR-720-TF-302-023 Rev.00, 2016.