INNOVATING NUCLEAR TECHNOLOGY

ANALYSIS AND MEASUREMENT SERVICES CORPORATION

Advanced Process Instrumentation System for Next-Generation Nuclear Reactors

Presented by:

Ryan O'Hagan

Sr. Engineer and Marketing Manager

Presented to:

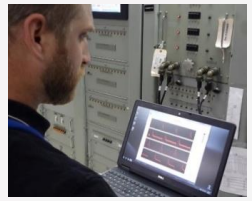
DOE-NE FY23 ASI Program Annual Review Webinar

November 1st, 2023

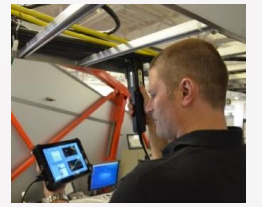
We Test the I&C Systems of Nuclear Power Plants

- All U.S. nuclear power plants
- Nuclear plants in Europe, Asia, Africa, Middle East, and South America
- Government Facilities including Y-12, Sandia, Savannah River, HFIR/ORNL, and ATR/INL

I&C MAINTENANCE



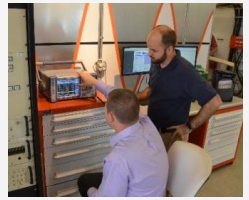
ROD CONTROL



CABLE TESTING

SOFTWARE RELIABILITY

EMC/WIRELESS



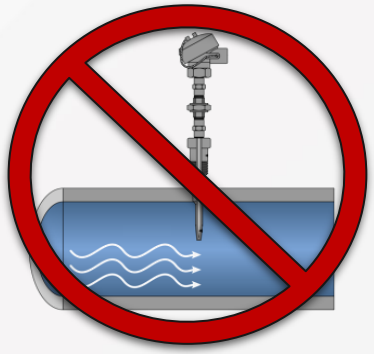
REACTOR DIAGNOSTICS

MATERIALS TESTING

ONLINE MONITORING

I&C Challenges for Next-Generation Reactors

- **Harsh process conditions**
  - Elevated temperatures
  - High radiation
  - Corrosive coolants
- **Limited hands-on maintenance**
  - Extended refueling cycles
  - Online refueling
  - Remote installation (limited on-site staff)
- **Physical design constraints**
  - Compact containment vessel
  - Integral reactor (no loops / piping)



Reactor	Type	Coolant	Output	Temperature	Refueling/Cycle
NuScale VOYGR	iPWR SMR	Water	77 MWe	300°C	24 Months
Holtec SMR-160	PWR SMR	Water	160 MWe	316°C	42 Months
GE Hitachi BWRX-300	BWR SMR	Water	300 MWe	287°C	12-24 Months
TerraPower MCFR	MSR	Molten Salt	780 MWe	755°C	Online
TerraPower Natrium	SFR	Sodium	≥ 345 MWe	540°C	24 Months
X-Energy Xe-100	PB HTGR	Helium	80 MWe	565°C	Online
Kairos Power FHR	PB MSR	Molten Salt	140 MWe	650°C	Online
Ultra Safe Nuclear MMR	Micro-HTGR	Helium	5 MWe	630°C	20 Years
Westinghouse eVinci	Heat-Pipe MR	N/A	1-5 MWe	> 750°C	48-60 Months
Oklo Aurora	Heat-Pipe MR	N/A	1.5 MWe	> 500°C	20 Years
BWXT BANR	Micro-HTGR	Gas	17 MWe	> 750°C	5 Years
General Atomics	HTGR	Helium	50 MWe	800°C	104 Months
ARC-100	SFR SMR	Sodium	100 MWe	510°C	20 Years

PWR – pressurized water reactor, iPWR – integral PWR, BWR – boiling water reactor, MSR –molten salt reactor, SFR – sodium-cooled fast reactor, HTGR – high-temperature gas-cooled reactor, PB – pebble bed

STTR R&D Objective & Project Team

Objective: Develop a sensor incorporating the HTIR-TC developed at INL that can measure temperature, flow, and level simultaneously in harsh next-generation reactor environments

AMS Executive Research Advisory Team


H.M. Hashemian


Greg Morton


Brent Shumaker


Casey Sexton


Chad Kiger

AMS STTR R&D Team


Alexander Hashemian (PI)


Jacob Houser


Shawn Tyler


Edwin Riggsbee


Dan McCarter

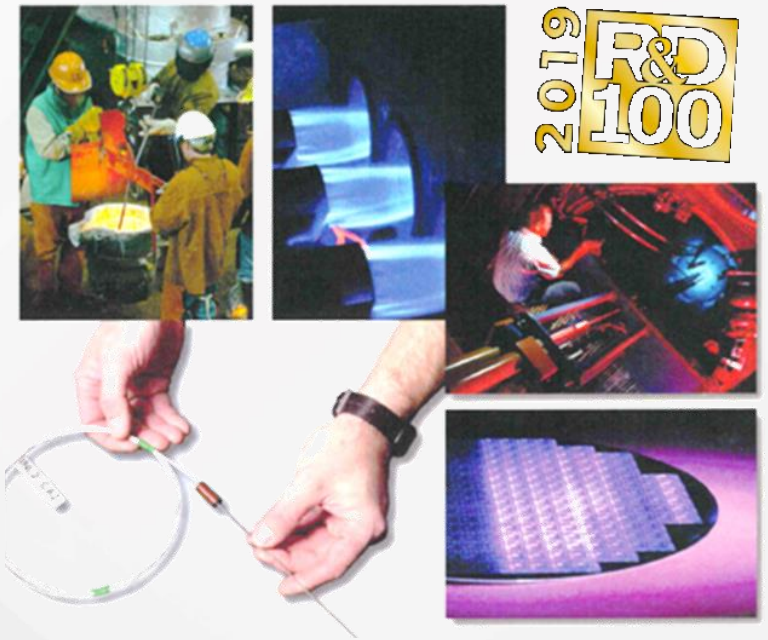

Keith Ryan

INL R&D Scientist


Dr. Richard Skifton

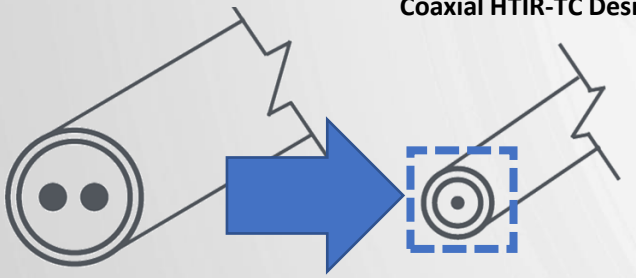
Background of the INL HTIR-TC

- Developed for use in materials testing reactors
- Demonstrated in INL Advanced Test Reactor (AGR-5/6/7)
- Winner of 2019 R&D100 Award
- Qualified through DOE-NE ASI Program
- Licensed to Idaho Laboratories Corp. in 2020 through SBIR award

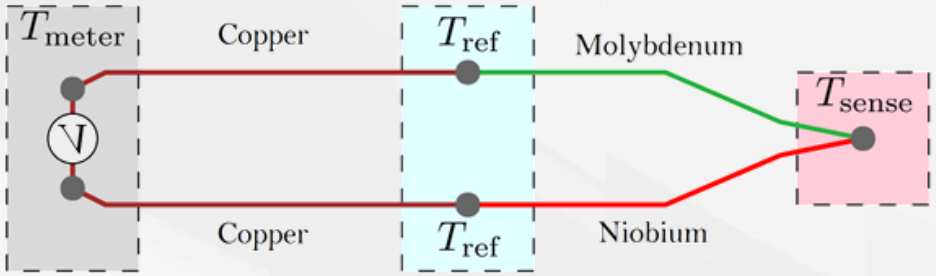


Conventional TC Design

Coaxial HTIR-TC Design*



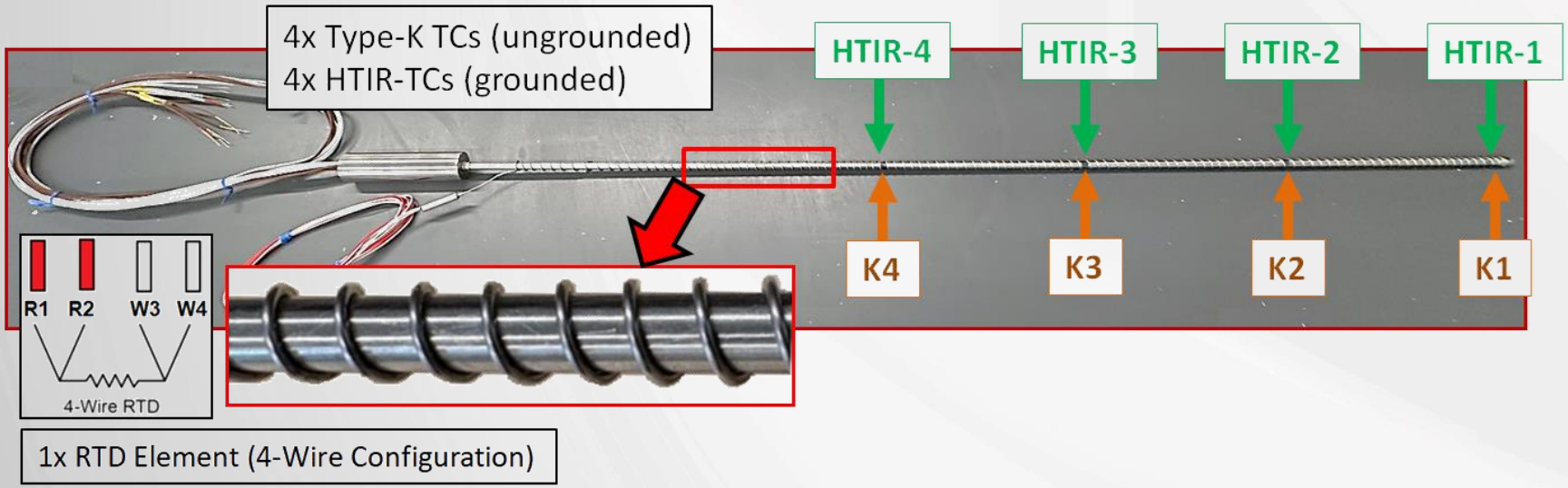
- ✓ **Longer lengths**
- ✓ **Smaller diameters**
- ✓ **Faster response**
- ✓ **Better performance**

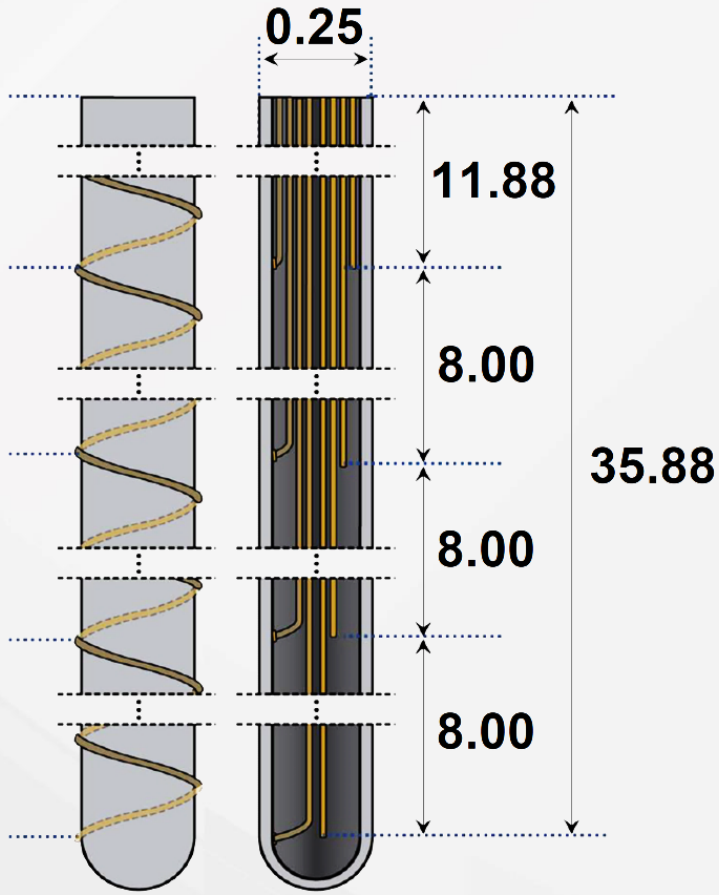


*Patent Pending (Skifton, Daw – USPTO Application US16/690,630)

Prototype Sensor Design

- **0.25-inch diameter, 4-ft length**
- **8x Thermocouples**
  - 4x grounded-junction HTIRs
  - 4x ungrounded-junction Type-K TCs
- **1x 4-Wire Self-Heated RTD**

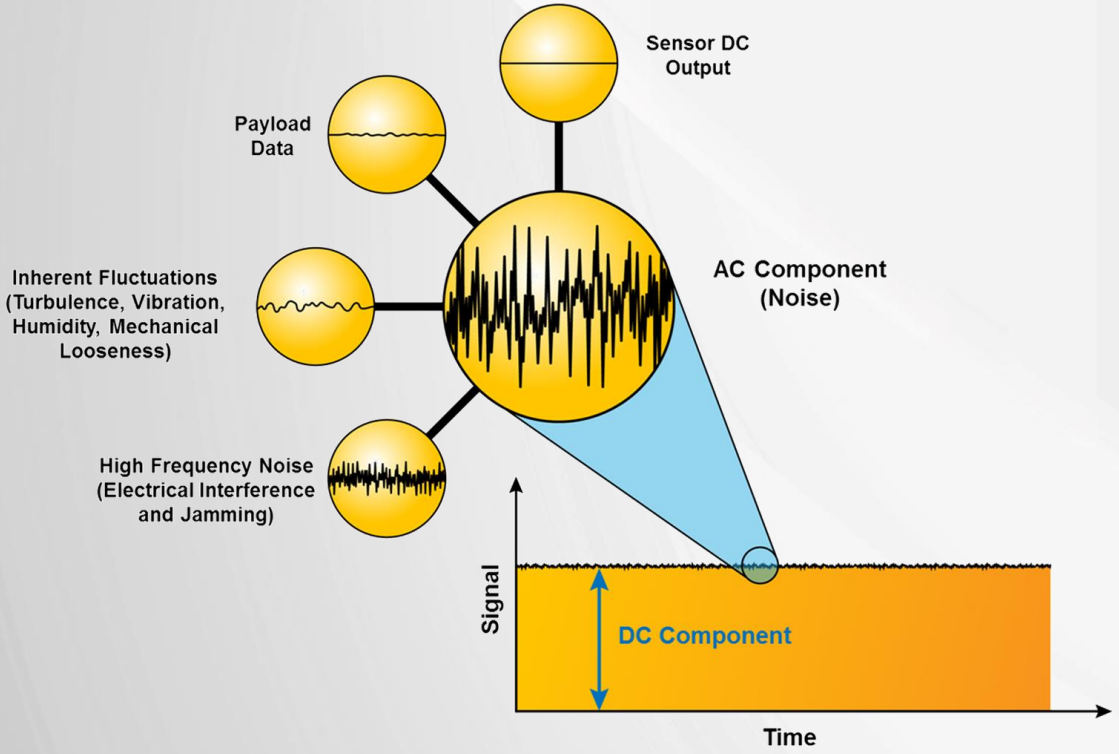


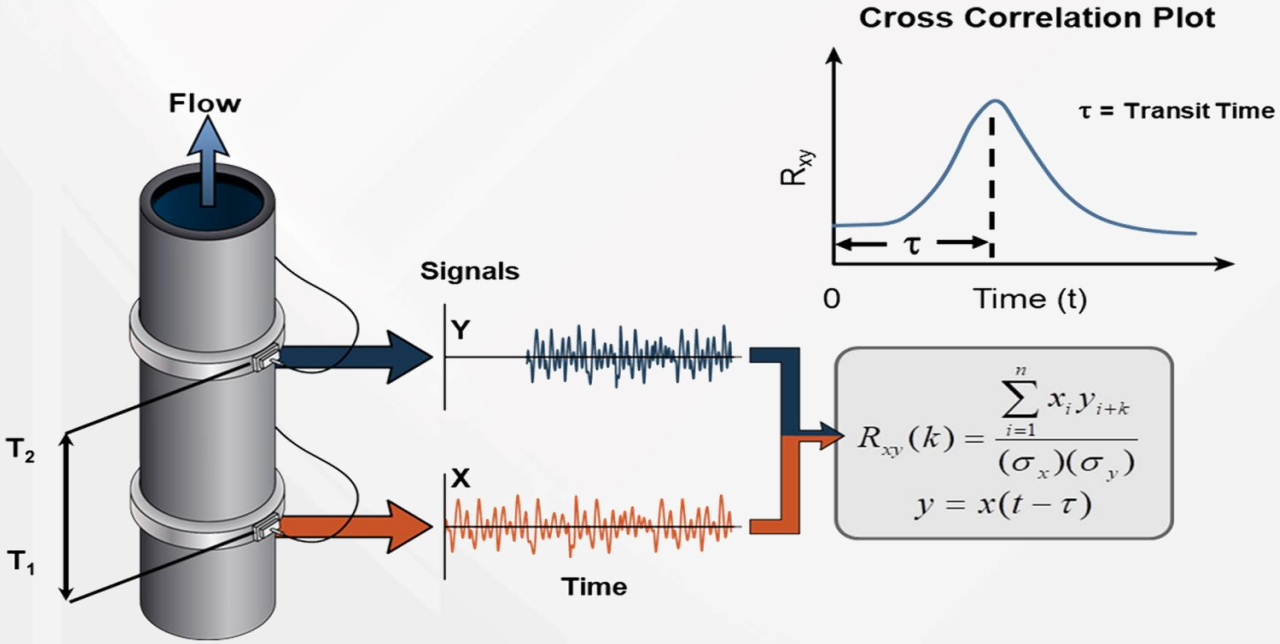


Noise Analysis and Transit Time Flow Measurement (TTFM)

Natural fluctuations (noise) in sensor output can be analyzed to:

- Determine sensor response time
- Identify blockages in sensing lines (using pressure transmitter data)
- Quantify core barrel vibration (ex-core neutron detectors)
- **Measure RCS flow via transit time flow measurement (TTFM)**





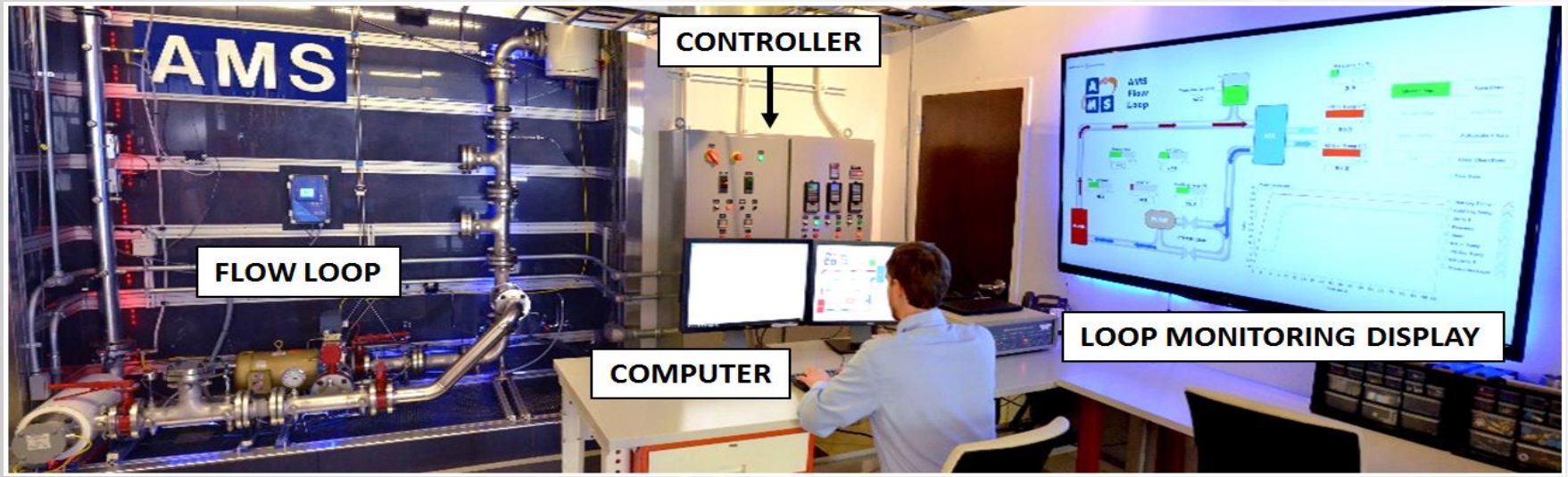
Transit Time Flow Measurement:

- Requires at least one up/down-stream sensor (can be “unlike” sensors)
- Demonstrated by AMS using RTDs, TCs, neutron detectors
- Accuracy dependent on plant process conditions and sensor characteristics

INL and AMS Sensor Test Facilities

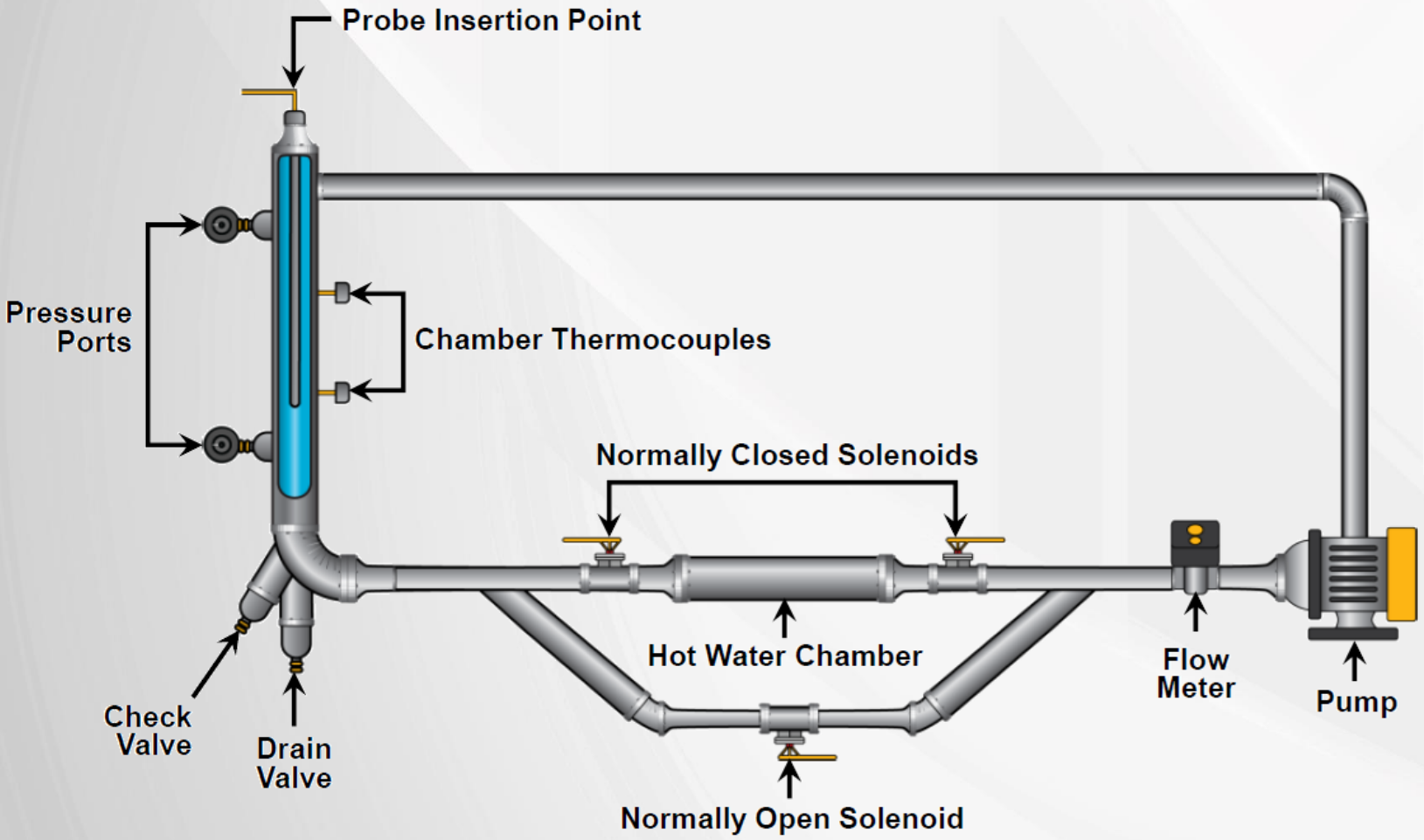
- **INL Flowing Autoclave System (FAS)**
  - Water-filled test loop
  - Up to 608°F and 2500 PSI
- **AMS Thermal-Hydraulic Test Loop**
  - Water-filled test loop
  - Up to 200°F and 200 PSI

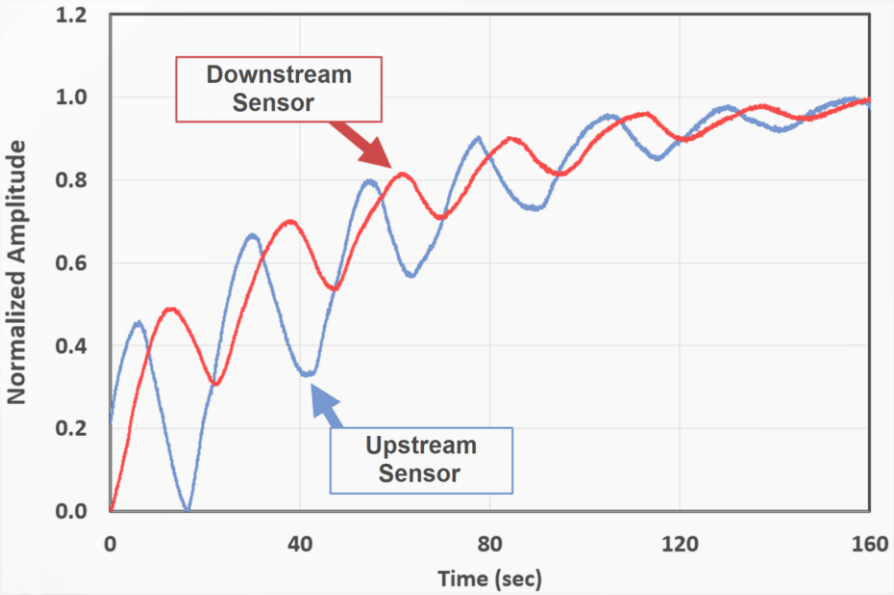
AMS Engineers Training Dr. Skifton on TTFM Data Collection



INL Flowing Autoclave System Facility

Custom Built Testbed for Prototype Sensor

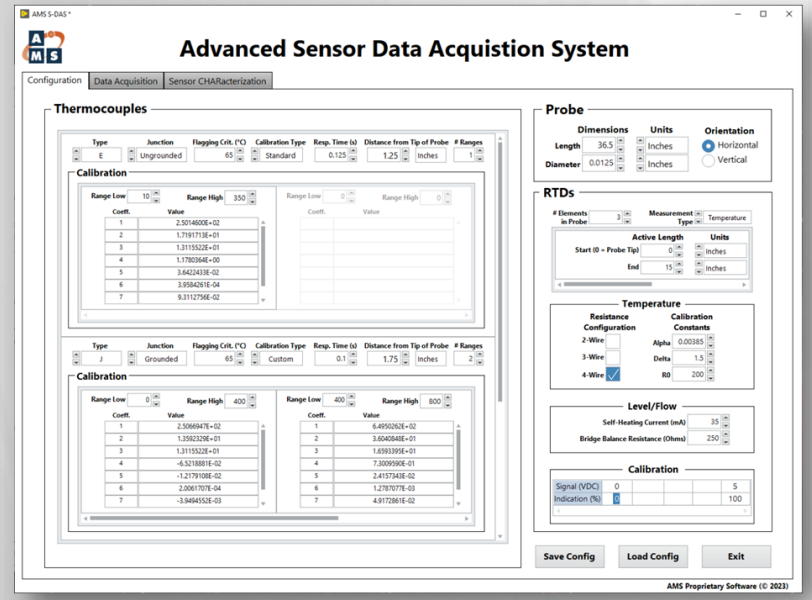


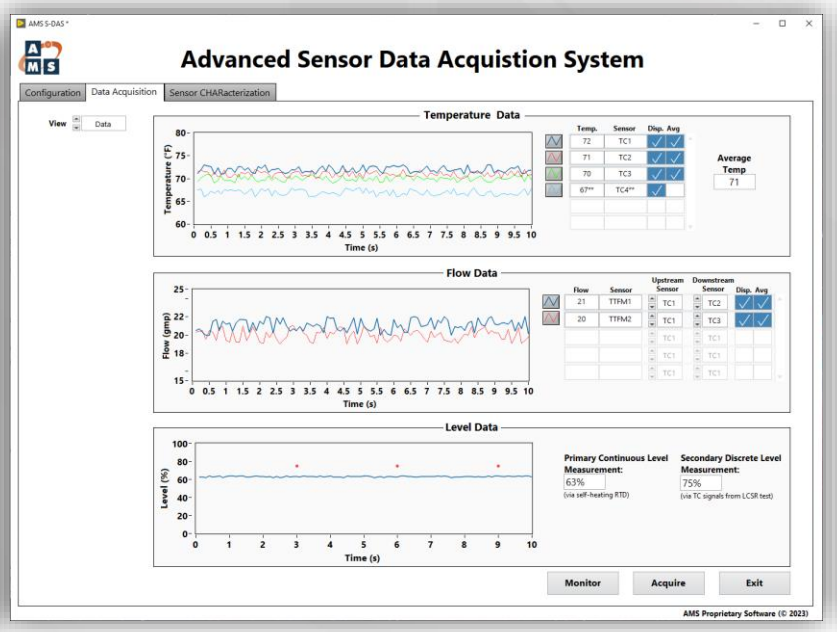


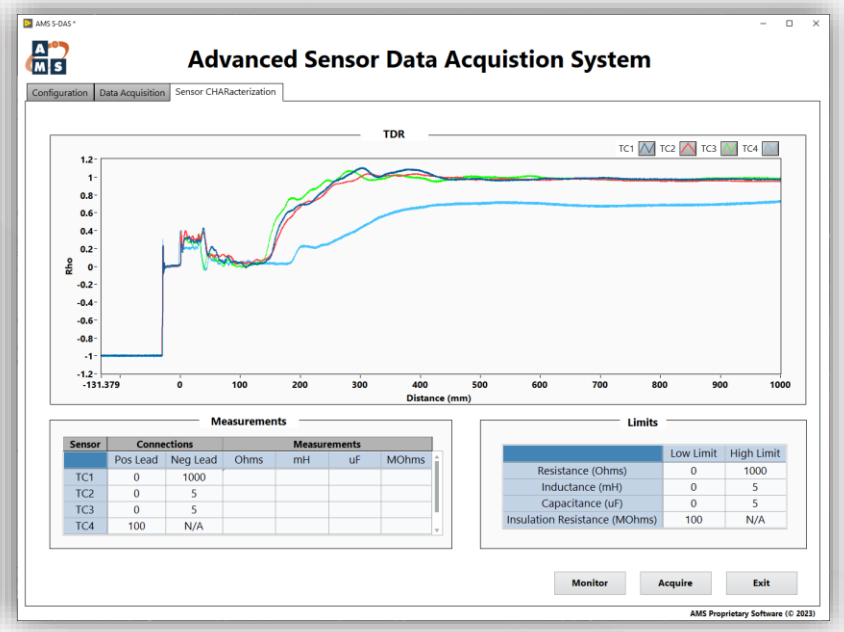
Actual Flow	Average Calculated Flow	Percent Error
0.100 ft/s	0.108 ft/s	7.8 %
0.200 ft/s	0.193 ft/s	-3.5 %

Key Accomplishments of the STTR Project

- Demonstrated TTFM using HTIR-TCs for flowing water and air processes
- Designed and built a new custom testbed for prototype sensor testing at AMS
- Designed a prototype multi-element sensor probe (fabricated by Idaho Laboratories Corp) and determined baseline sensor performance through laboratory testing – patent pending
- Established software and sensor data acquisition system hardware requirements





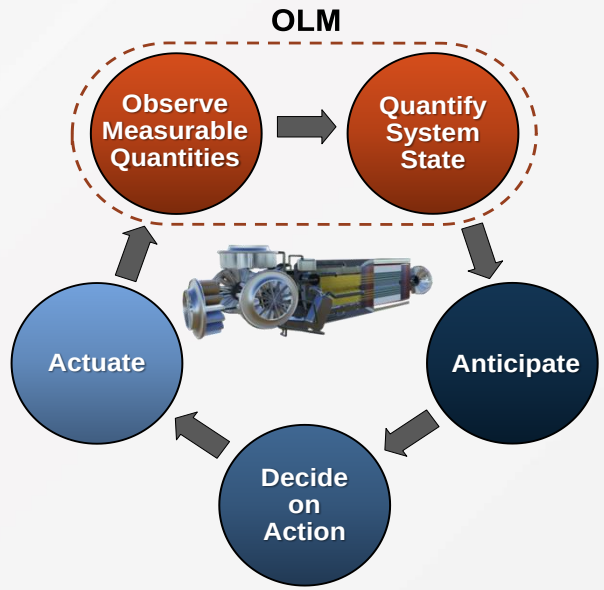


Other R&D Related to Next-Generation Reactors

DOE Phase 2 SBIR: Online Monitoring (OLM) for Autonomous Microreactors

Objective: Develop OLM for microreactor sensors, equipment, processes, and SSCs

- Evaluate AI/ML techniques for fault detection, diagnostics, prognostics
- Produce and demonstrate prototype OLM system for microreactors



DOE Phase 2 SBIR: Development of Cable Insulation Materials for Advanced Reactors

GOAL: Identify suitable cable insulation materials for Advanced Reactors

- Subject potential insulation materials to SMR/Adv Rx conditions
- Measure material properties to determine suitability for use

Recently Concluded Projects	
Program	Project Title
SBIR	I&C System Design for SMRs
	Methods for Verifying Embedded Sensor Performance in AM Components
GAIN	Cable Derating and Survivability, Sensor Performance Characterization at SMR Conditions
	Radiation Aging of Nuclear Power Plant Components

AMS Materials Test Laboratory

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Thank You

Questions?