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Revision 0

Demonstrate HTIR performance in flowing autoclave for fuel center line temperature measurement in PWR conditions

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Summary

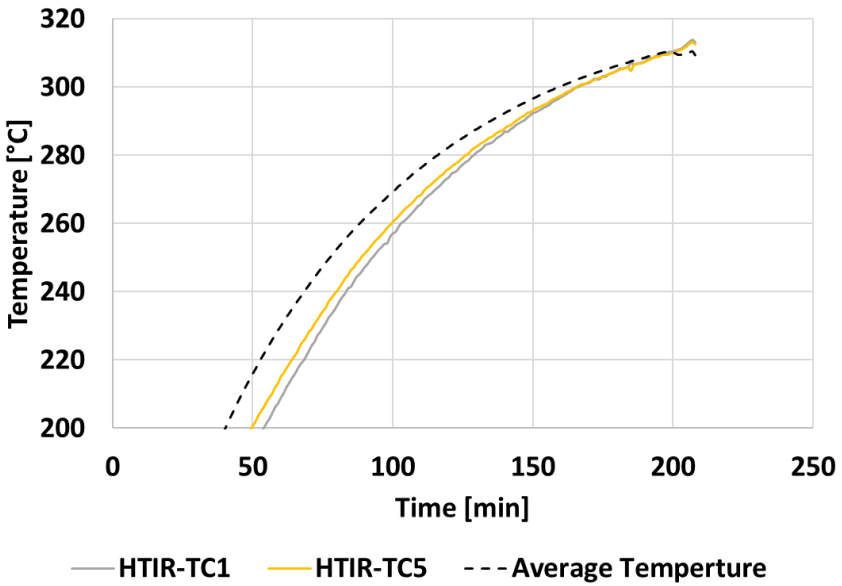
Real-time temperature measurement is arguably the most important operational parameter to measure for the characterization of irradiation experiments and the control of power plant systems. In FY21 demonstration activities focus on the application of High-Temperature Irradiation-Resistant thermocouple (HTIR-TC) technology to PWR conditions for their planned deployment in the INL's Advanced Test Reactor (ATR) center loop.

The PWR conditions were achieved in the INL's Flowing Autoclave System (FAS). Further, the HTIR-TCs were installed in 1) fuel pin surrogates and then into 2) an experiment test train. The test cycled from room temperature to >300°C a total of 10 times to show the functionality of the HTIR-TC and reliability of the TC feedthroughs into the fuel pin.

Flowing Autoclave System
ATF-2 Instrumented Fuel Pin Mockup

- ATF-2 Instrumented Fuel Pin Mockup
  - Thermal cycled FAS between room temperature and 310°C for 10 days.
  - High Temperature Irradiation Resistant Thermocouples installed in ATF-2 fuel pin mockups.
  - Flow induced vibration measurements made on FAS test section during operation.

Figure 1: The temperature profile during heating of the ATF-2 instrumented fuel pins. A slight delay in temperature during heating due to the fast heat up and insulative properties of the fuel pin.



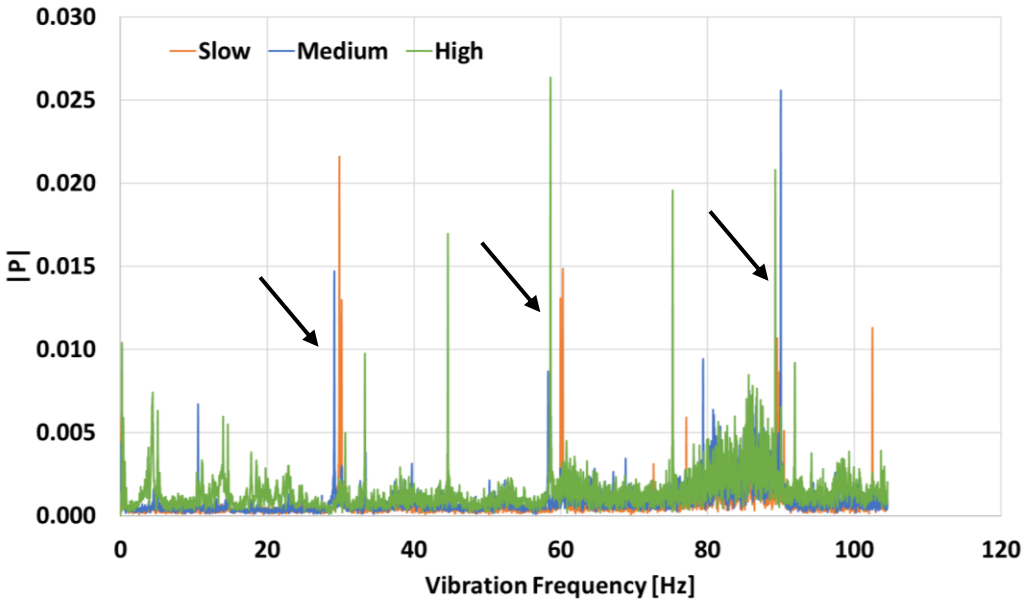


Figure 2 Flow induced vibration magnitude shows clusters of vibrations at various pump speeds—namely ~30Hz, ~60Hz, and ~90Hz. X-, Y- and Z-components of vibration not shown but provide further detail to flow induced vibration.

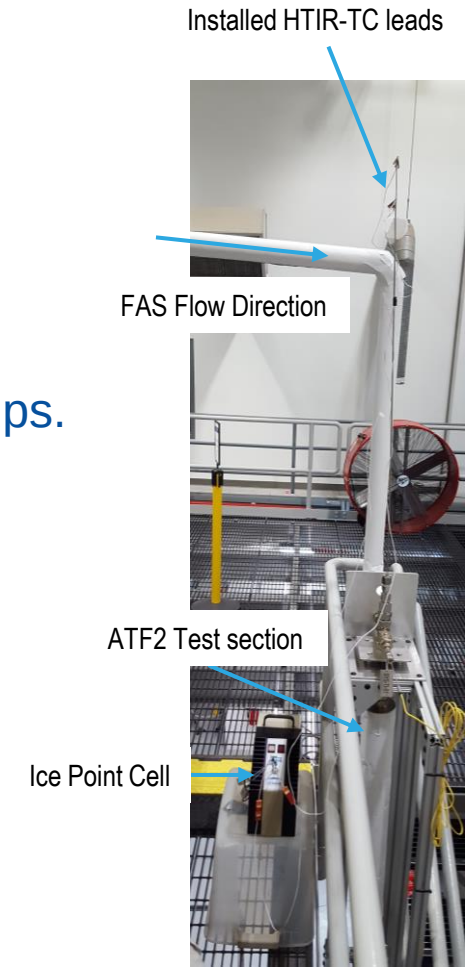


Figure 3: The ATF-2 instrumented fuel pin mockup installed in the flowing autoclave.

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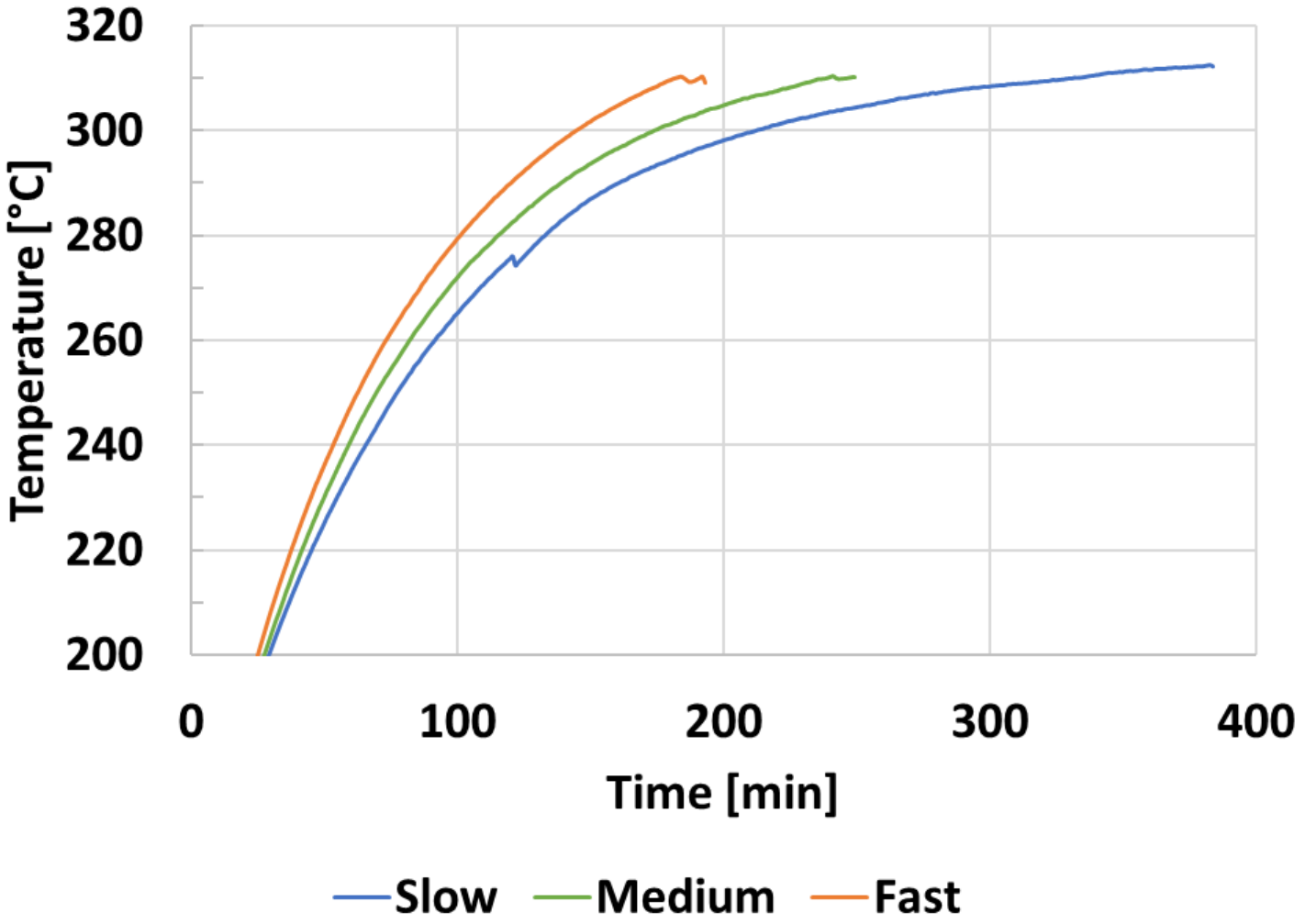
Average Temperature for Heating the Flowing Autoclave System (FAS)



- Three flow regimes were used to heat up the Flowing Autoclave
- Two (2) redundant HTIR-TCs were installed in the Accident Tolerant Fuel (ATF2) mockup pins and temperature was recorded
- Two (2) Type K TCs were also installed for verification

FAS Pump Speed at 30 Hz

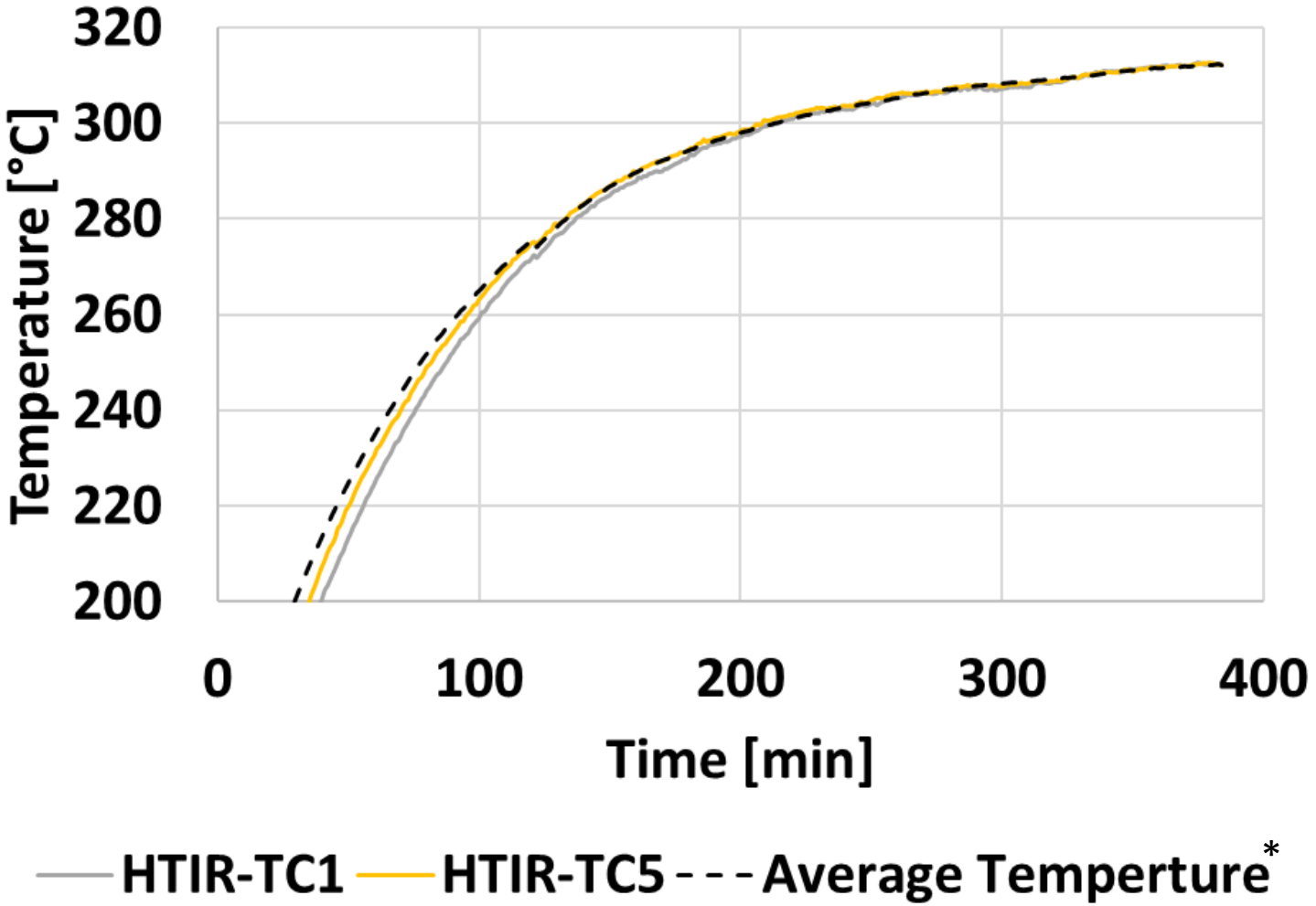


Figure 1: The heat up of the FAS during low flow.
*The average temperature is of the Flowing Autoclave System

- The relatively slow flow allowed for the HTIR-TC to keep up with temperature during the heat up
- 310°C was reached at approximately 6 hours
- The average temperature is of the Flowing Autoclave System itself

FAS Pump Speed at 40 Hz

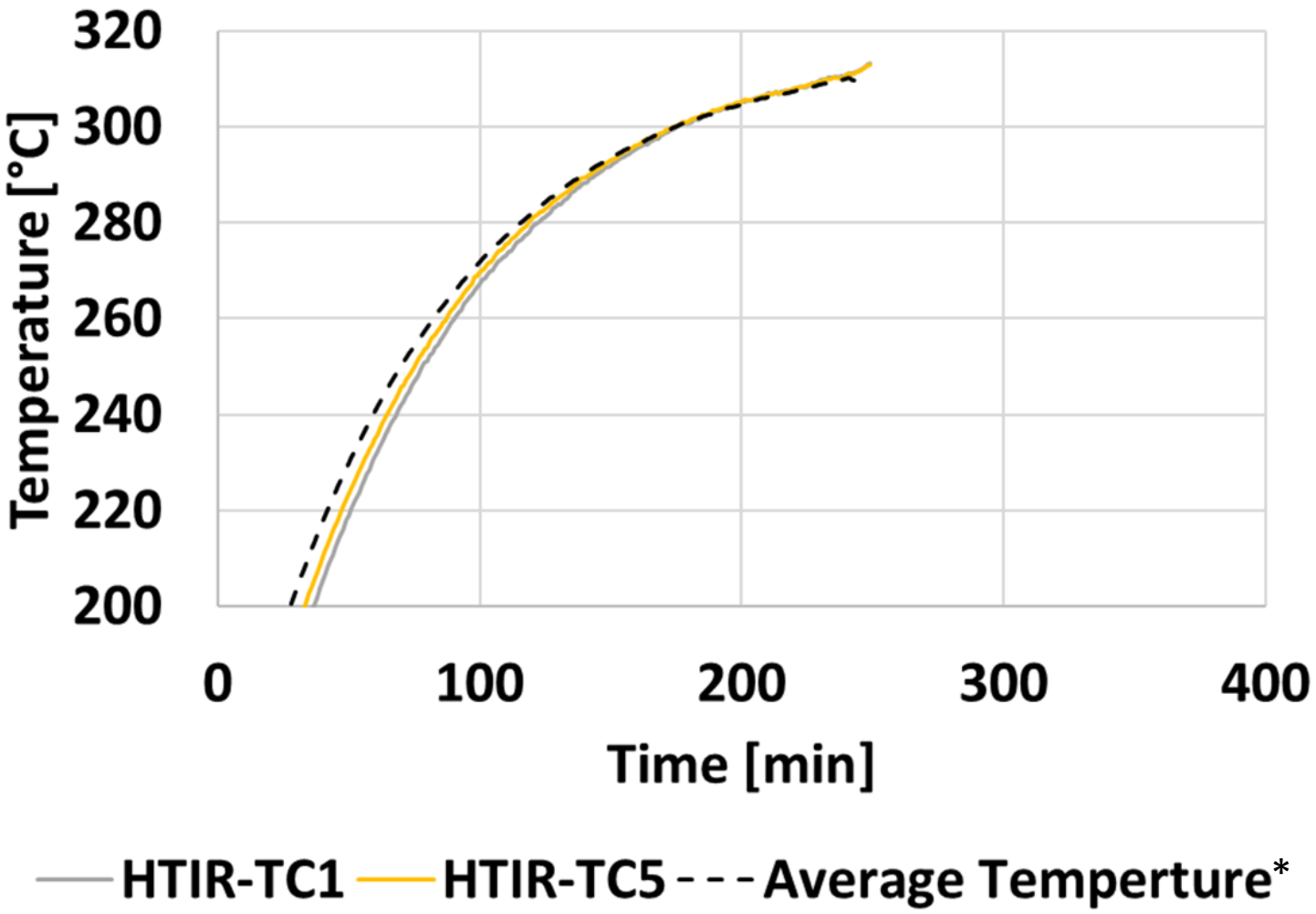


Figure 1: The heat up of the FAS during mid range flow.
*The average temperature is of the Flowing Autoclave System

- For the faster flow rate, 310°C was reached at approximately 4 hours

FAS Pump Speed at 45 Hz

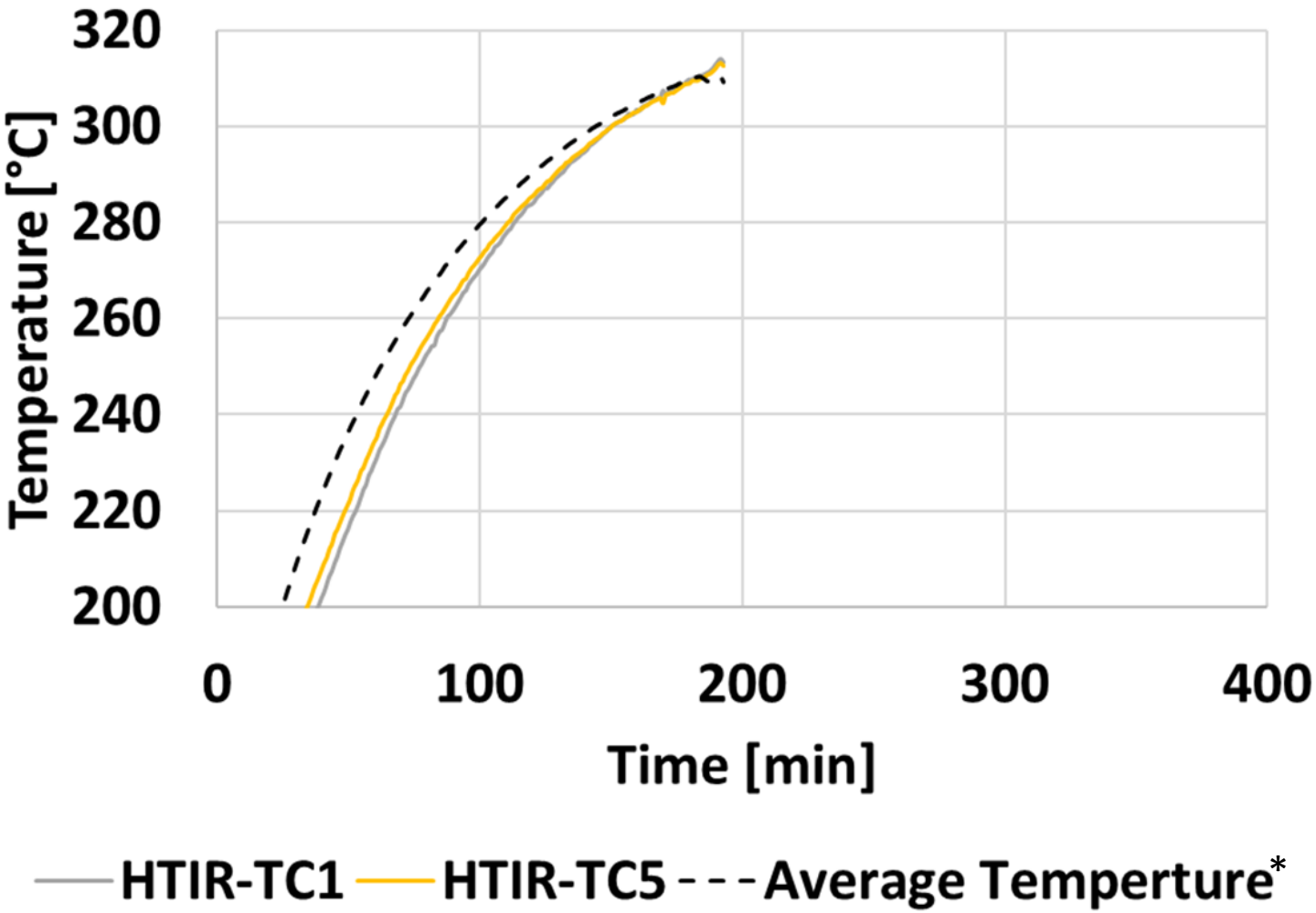


Figure 1: The heat up of the FAS during high flow.
*The average temperature is of the Flowing Autoclave System

- The relatively high flow shows the HTIR-TC lagging with temperature during the heat up due to the insulative properties of the ATF-2 Fuel Pin mockup.
- 310°C was reached at approximately 3 hours
- The higher flow adds significant energy to the system.

Flow Induced Vibration in FAS of the ATF-2 Fuel Pin Mockup and Test Section

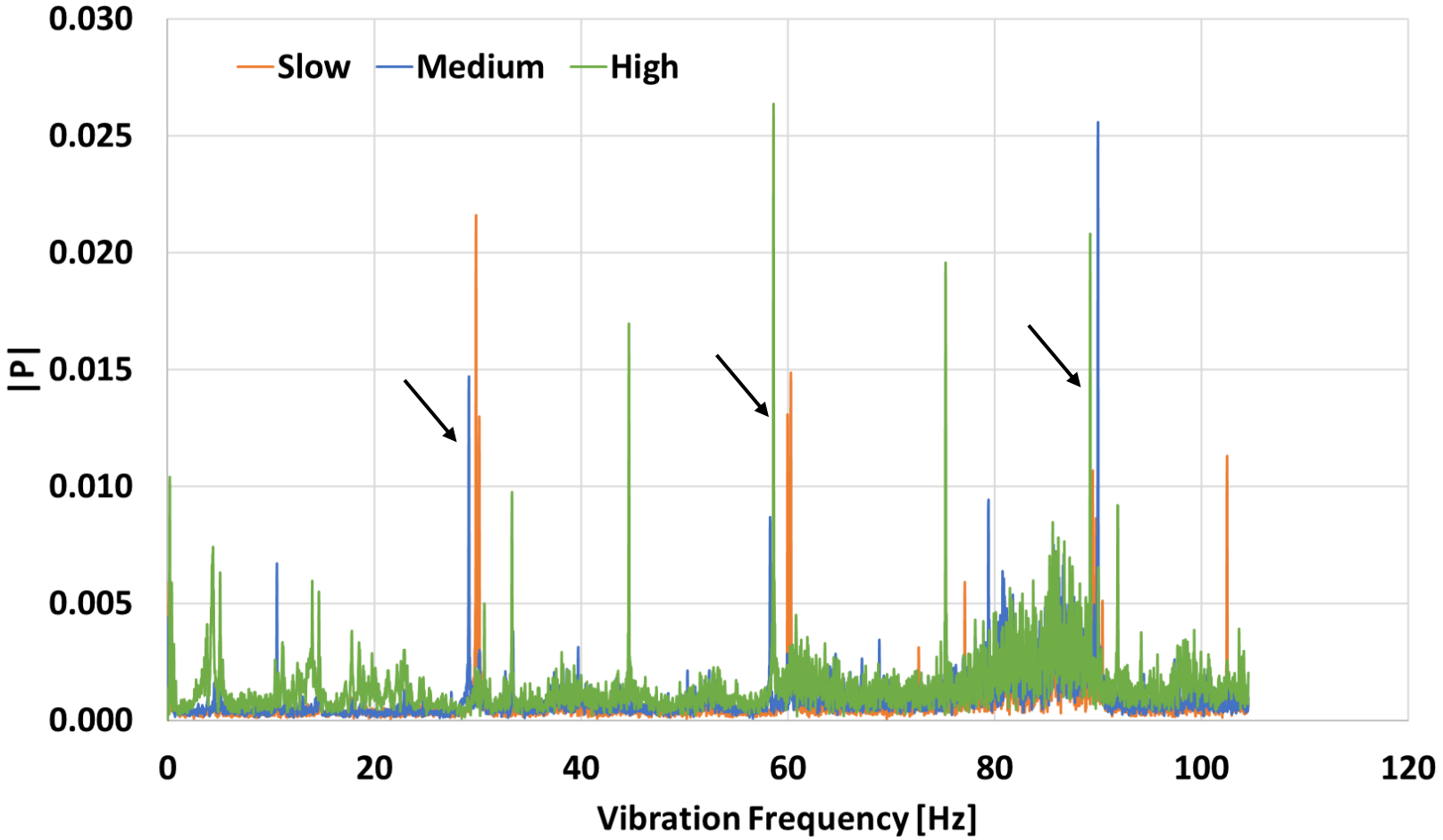


Figure 1: The flow induced vibration frequencies and intensities during three different flow regimes

- The three flow regimes show significant similarities in the range of approximately 30, 60, and 90 Hz–as shown with arrows

Flow Induced Vibration in FAS of the ATF-2 Fuel Pin Mockup and Test Section

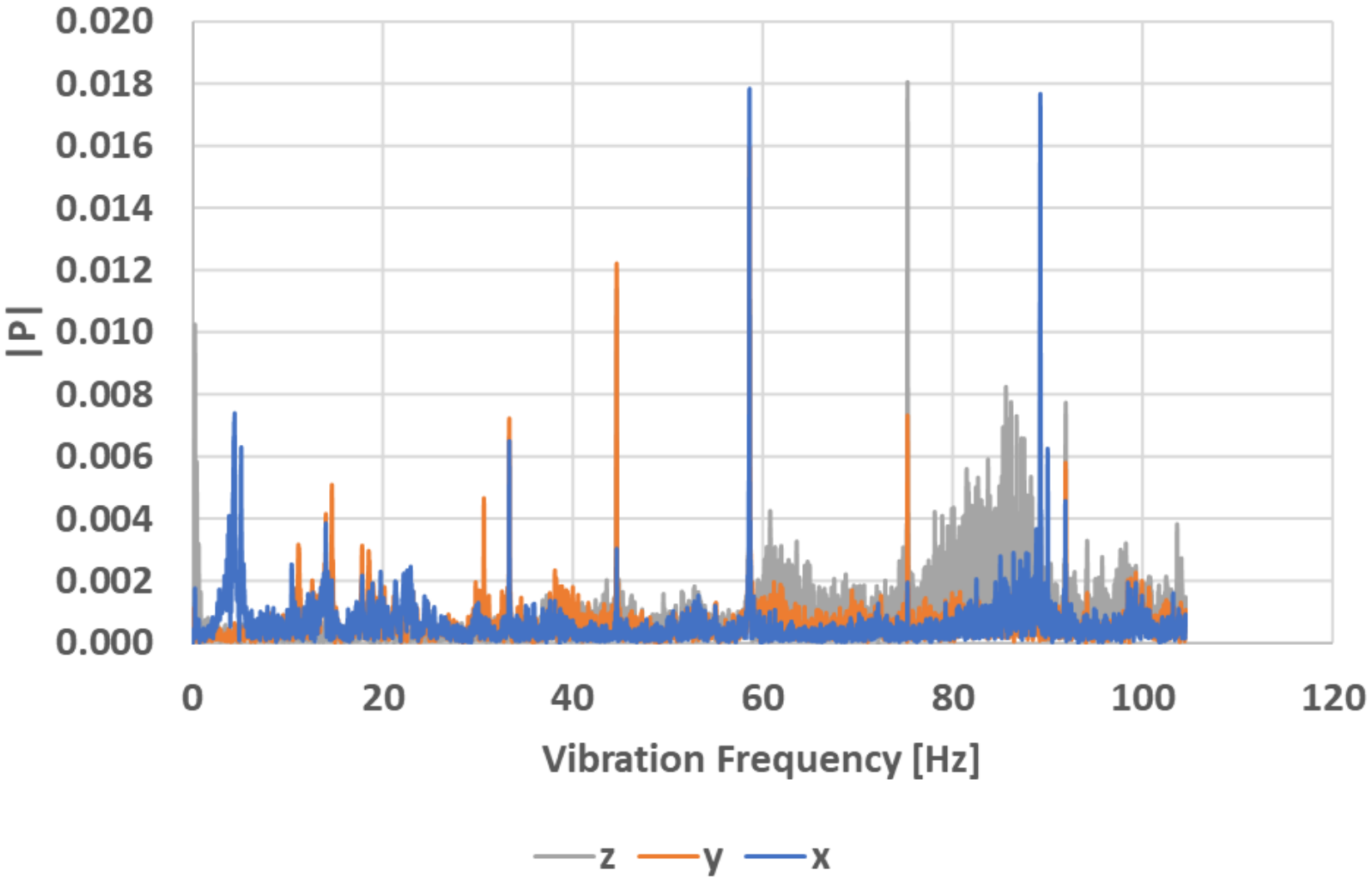
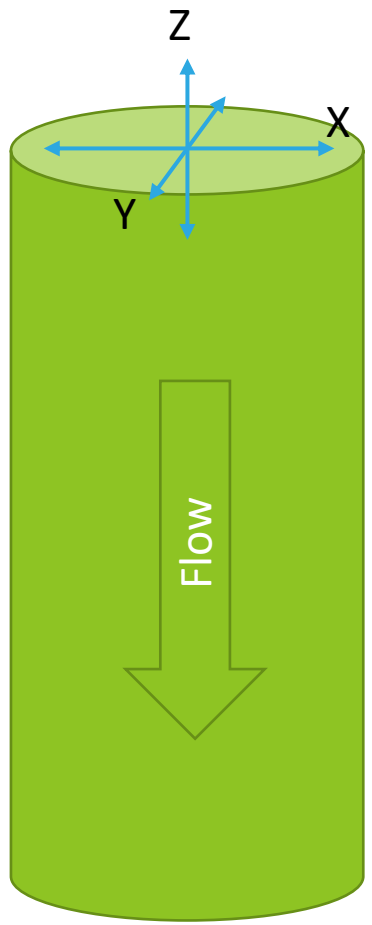


Figure 1: The flow induced vibration frequencies and intensities of the highest flow regime, as broken down by individual x-, y-, and z- components.

FAS Test Section (cross section)



- Looking at the x-, y-, and z-component of the flow induced vibrations shows x- and y- as the most prevalent.