

Commissioning and Simple Cycle Testing of the STEP Main Compressor

Joshua Warren (Southwest Research Institute)

Michael Kutin (GTI Energy)

Ya-Tien Chu (GE Vernova)

Agenda

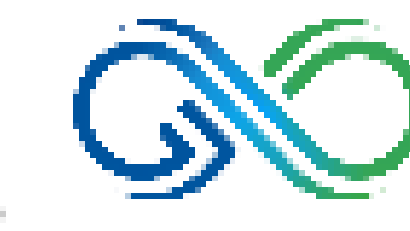
- Overview of cycle configuration
- Installation
- Commissioning Timeline
- Performance Test data
- Closing remarks



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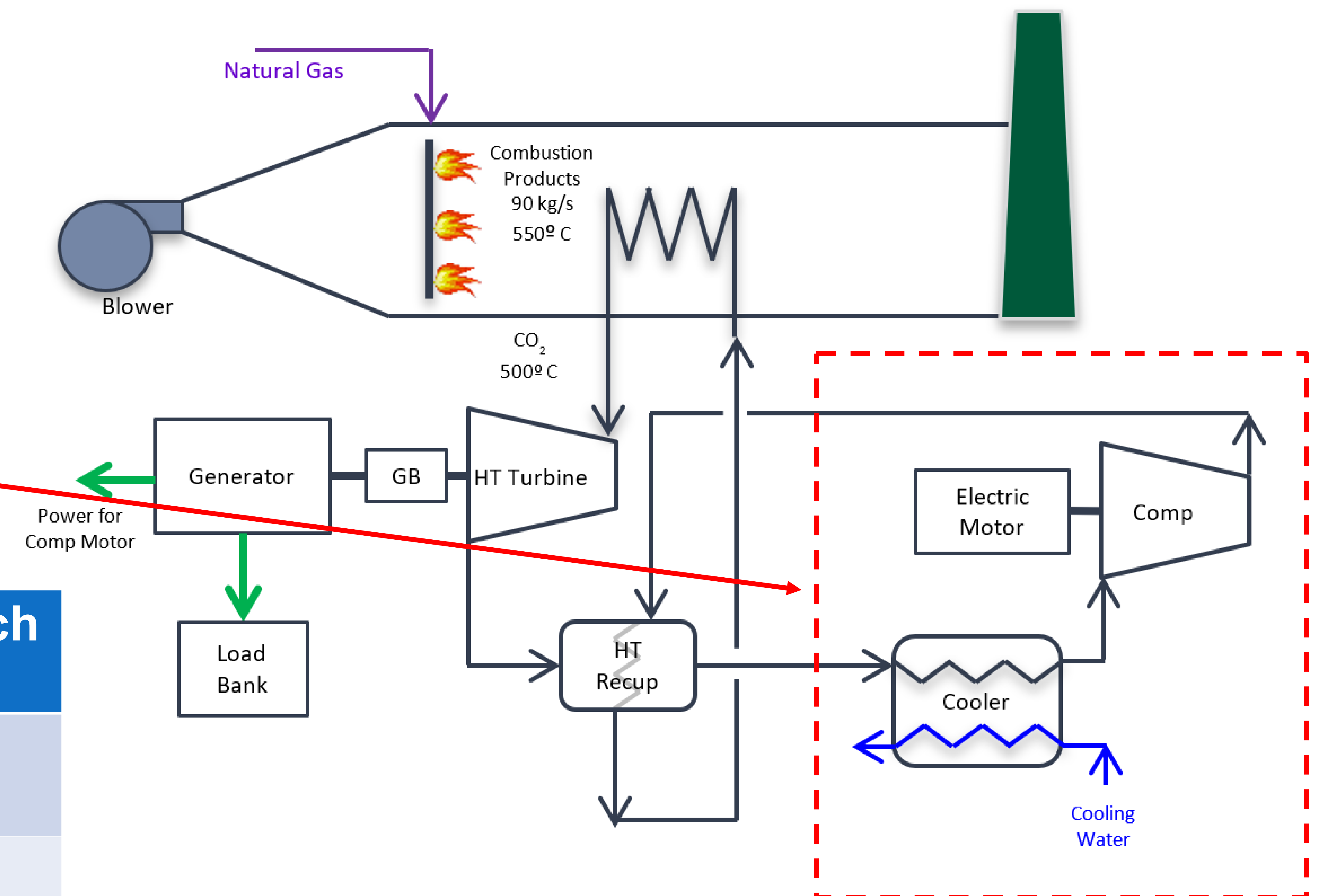
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Simple Cycle Configuration

- Only main compressor, no bypass compressor
- Low Temp Recuperator removed
- 2 planned inlet conditions for performance data collection
- Compressor commissioning performed in full recycle

Condition	Comp Inlet Temp	Comp Inlet Press	Comp Disch Temp	Comp Disch Press
Simple Max 20700 RPM	35 °C	90 Bar	57 °C	196 Bar
Simple Min 27000 RPM	34 °C	76 Bar	84 °C	165 Bar



Installation of Main Compressor

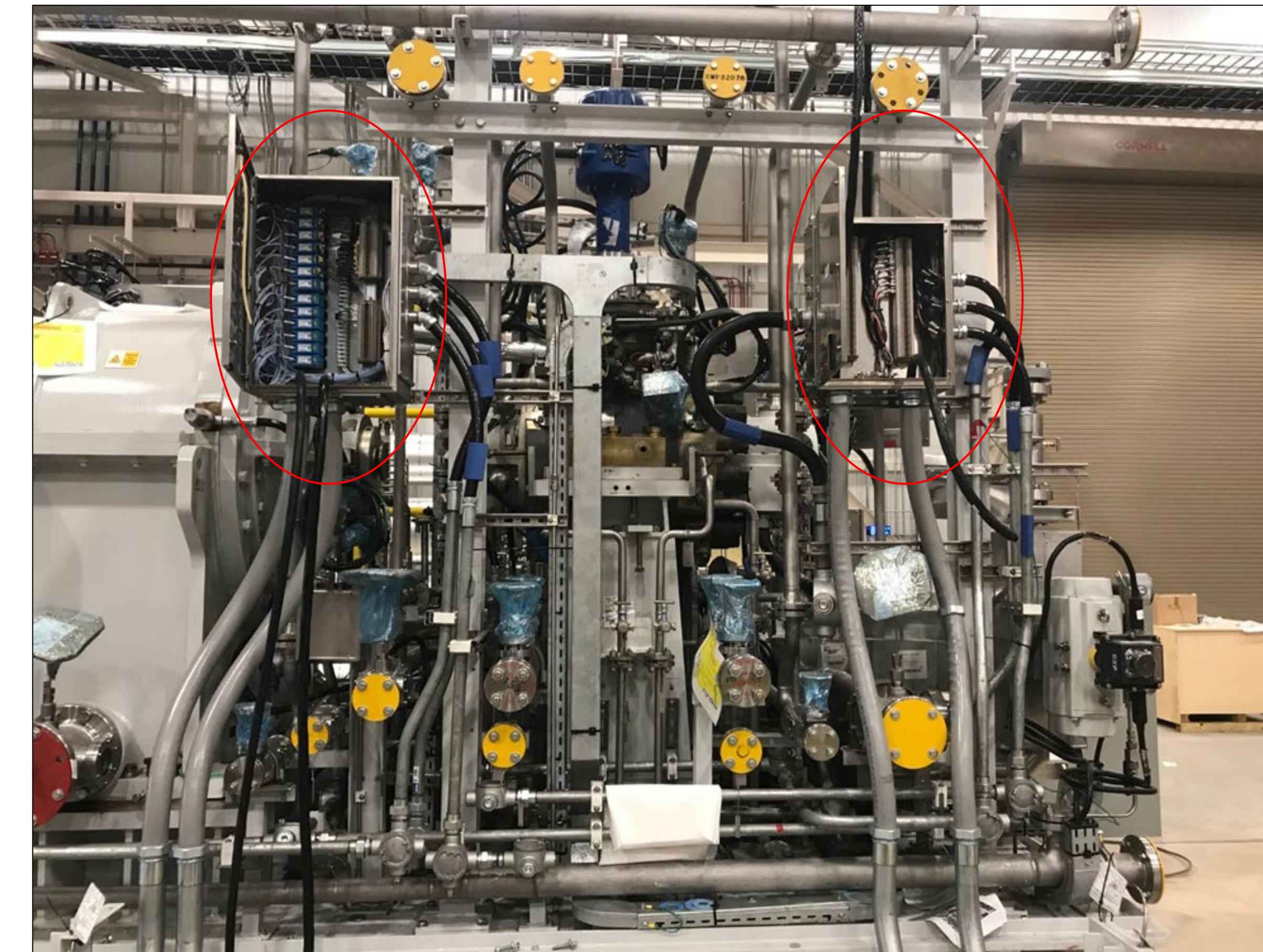
- PO signed August 1, 2018
- Compressor received at SwRI on December 23, 2020
- Start of installation on January 8, 2021
- Installation completed on September 12, 2022



Delivery to SwRI, Dec 2020



Set in B294, Jan 2021



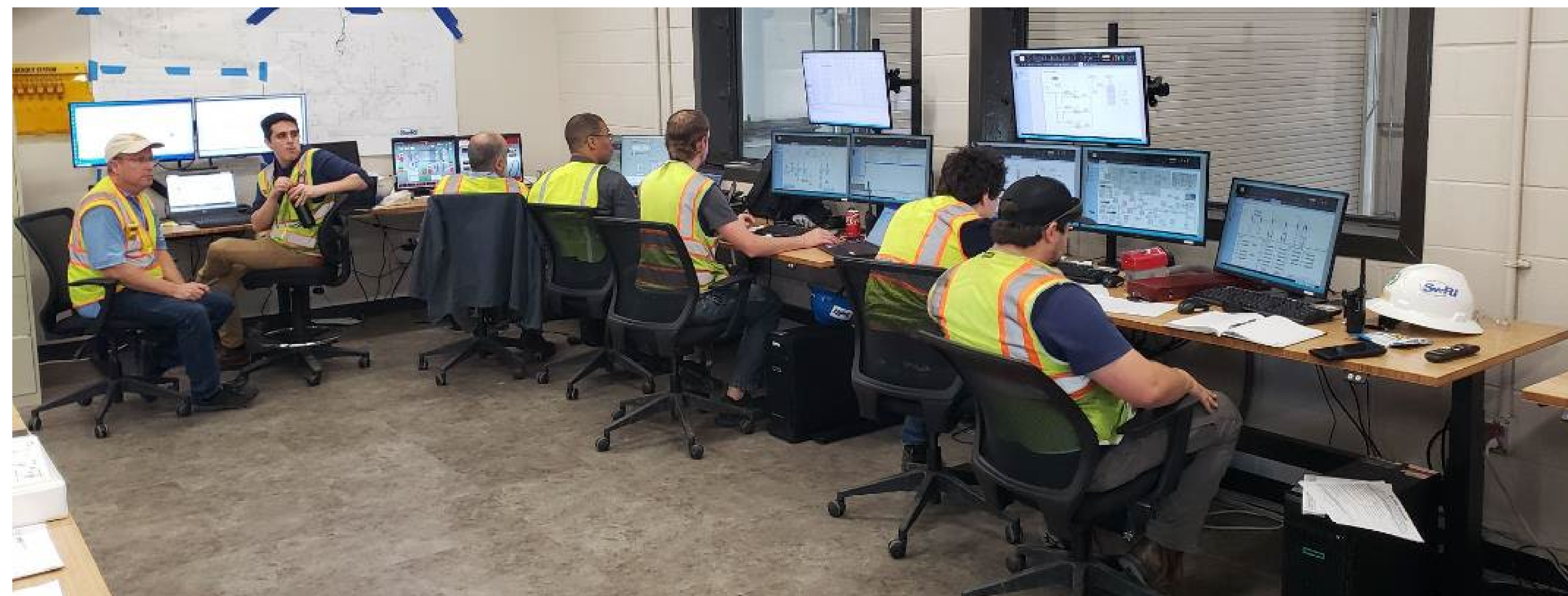
Electrical terminations completed, Apr 2021



DGS installation & Warrantee work, Mar 2022

Compressor Commissioning

- Team
 - SwRI Personnel operated facility
 - Manufacturer Field Service Personnel controlled compressor parameters
- Major Operating Systems Online
 - Main Compressor
 - Cooling Tower
 - Inventory Management System



Control Room



Compressor Commissioning

Timeline

- Nov. 2022, Start of commissioning
- Dec. 2022, Gearbox bearing failed
- Feb. 2023, IGV actuator found damaged
- May 2023, Initial operation showed discrepancy regarding expected performance maps

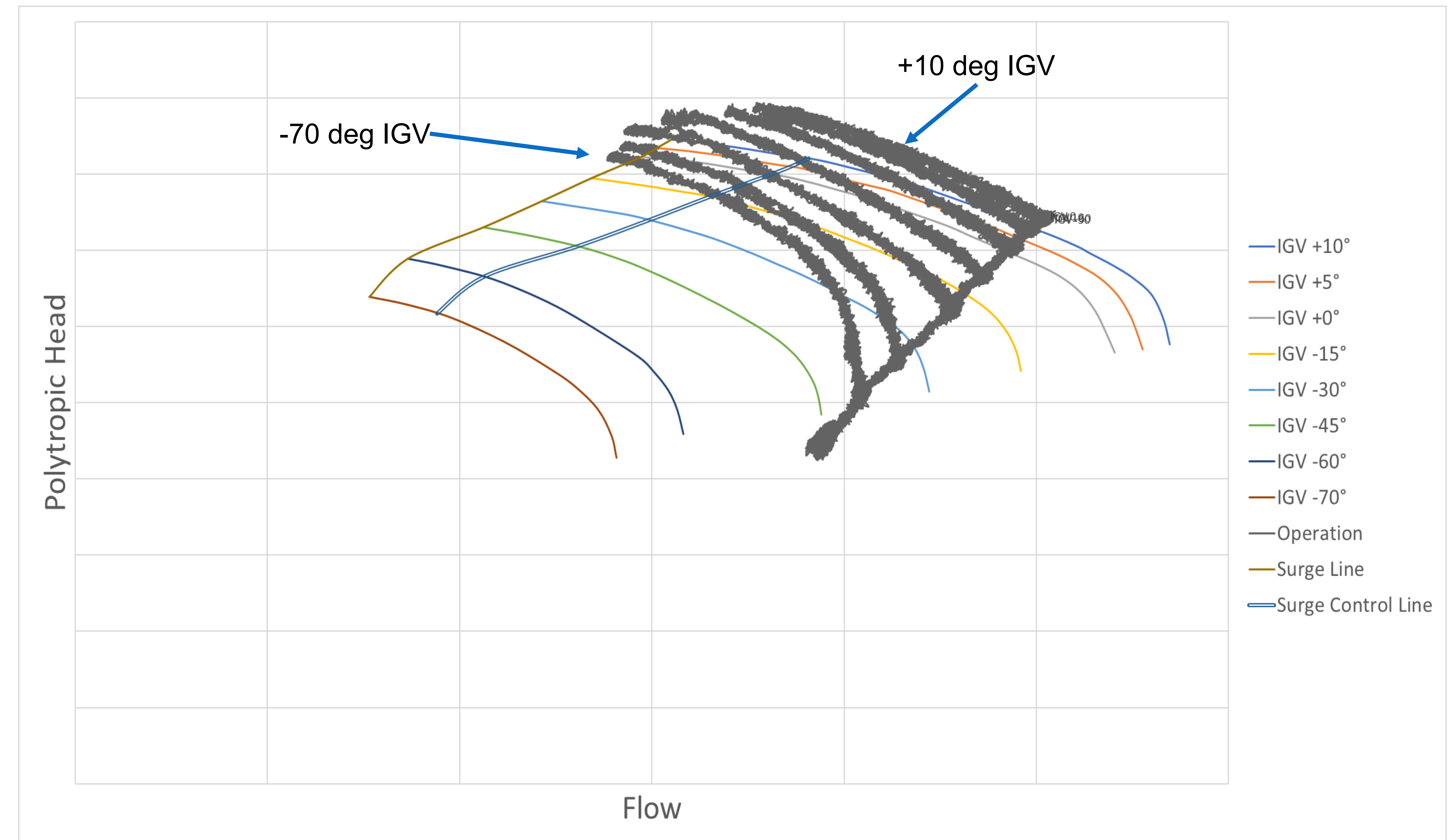
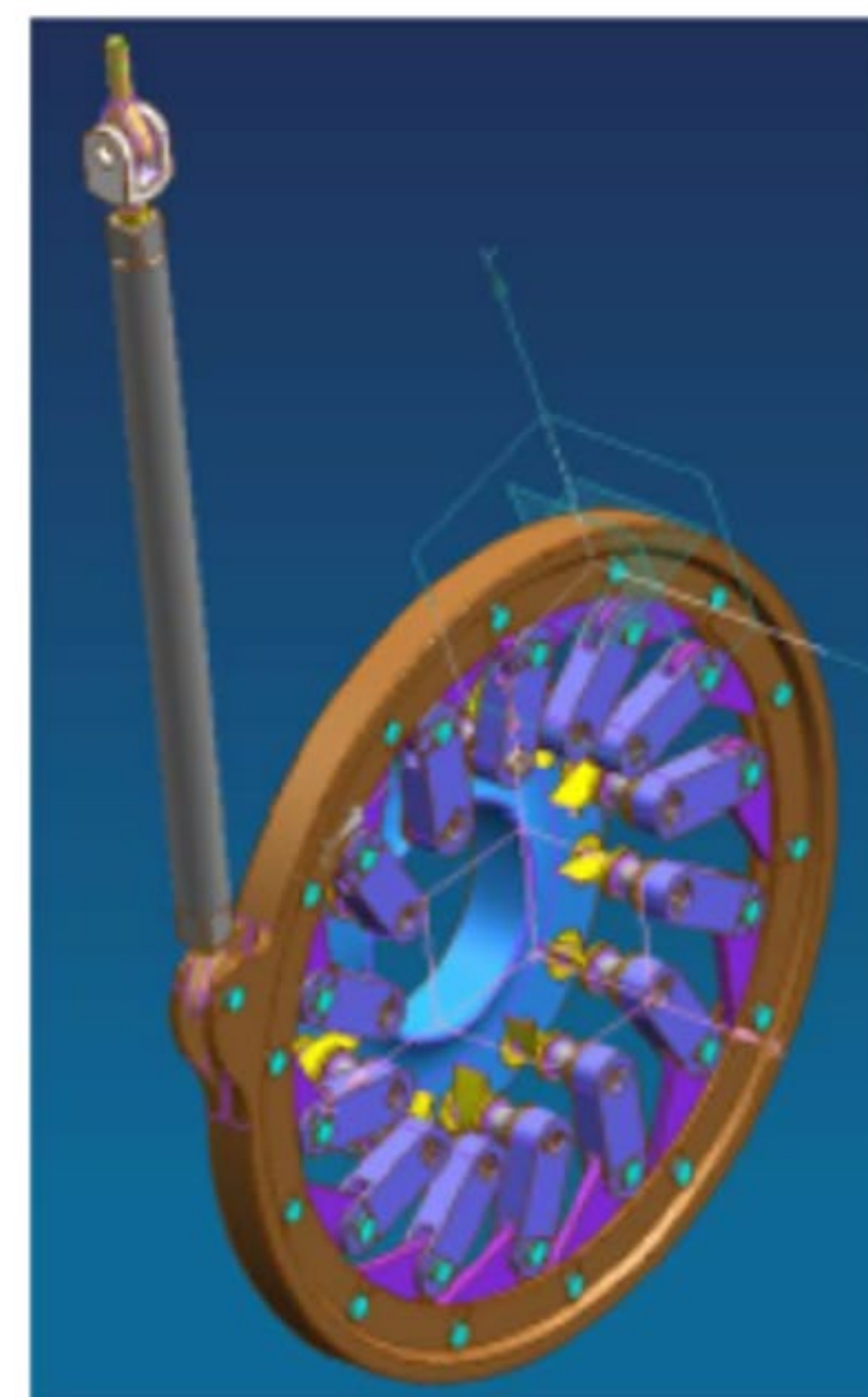


Upper,
attached to
actuator



Lower,
attached to
IGV

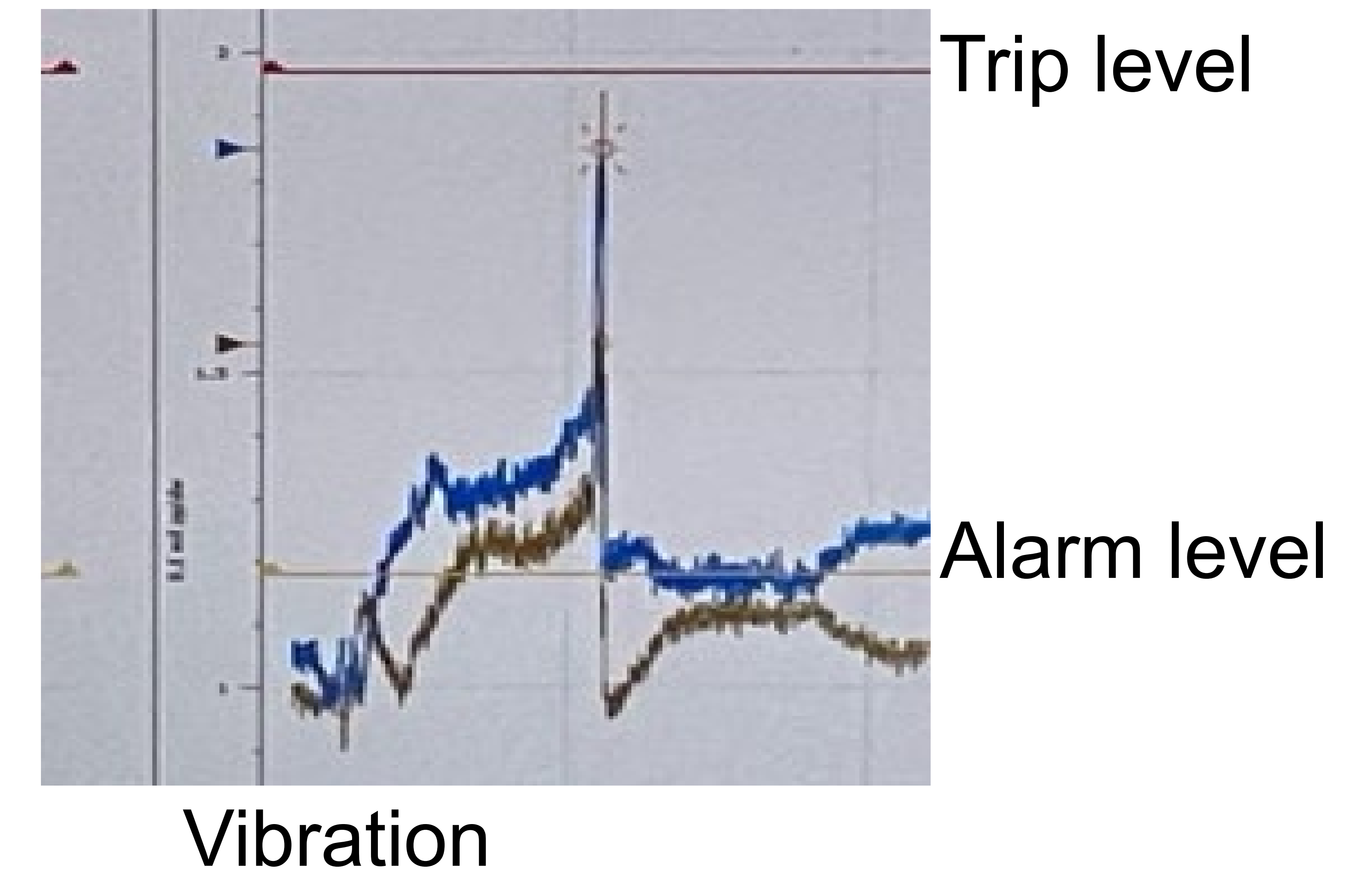
Actuator
attachment
to IGV



Compressor Commissioning

Timeline

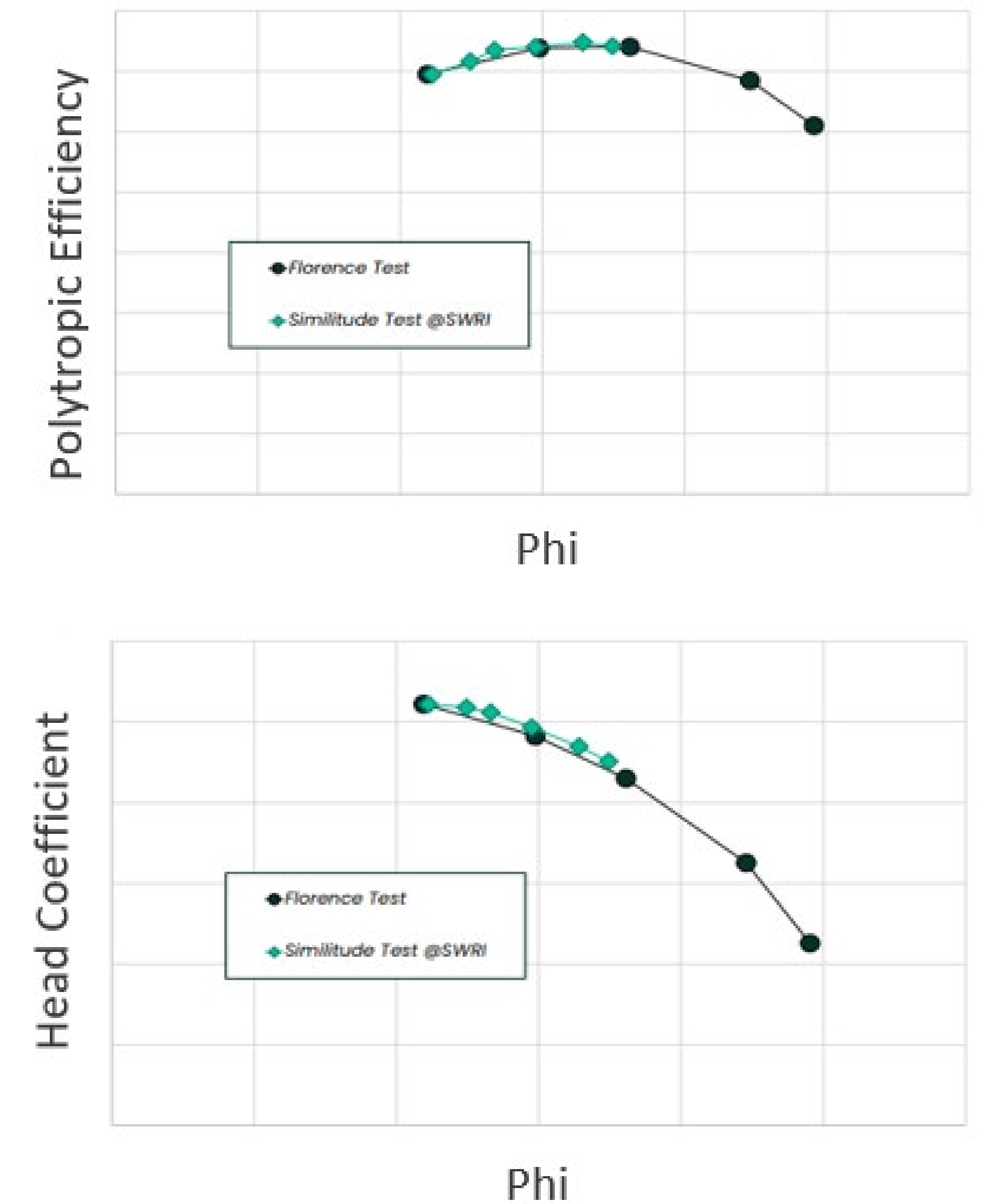
- June 2023
 - High vibration noted and near-surge event occurred
 - Performed trim balance of compressor NDE
 - PRV actuated at lower pressure than expected



Compressor Commissioning

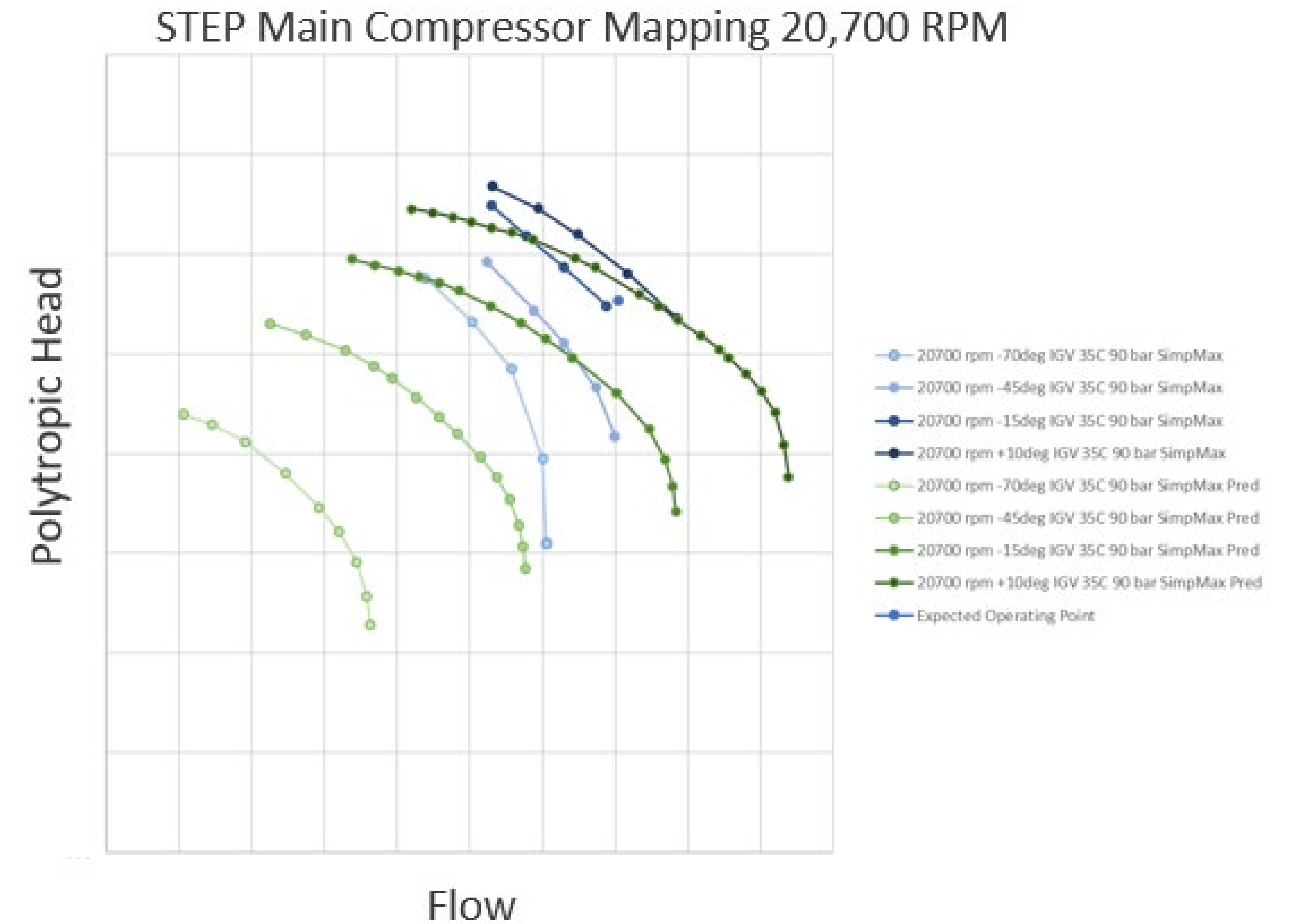
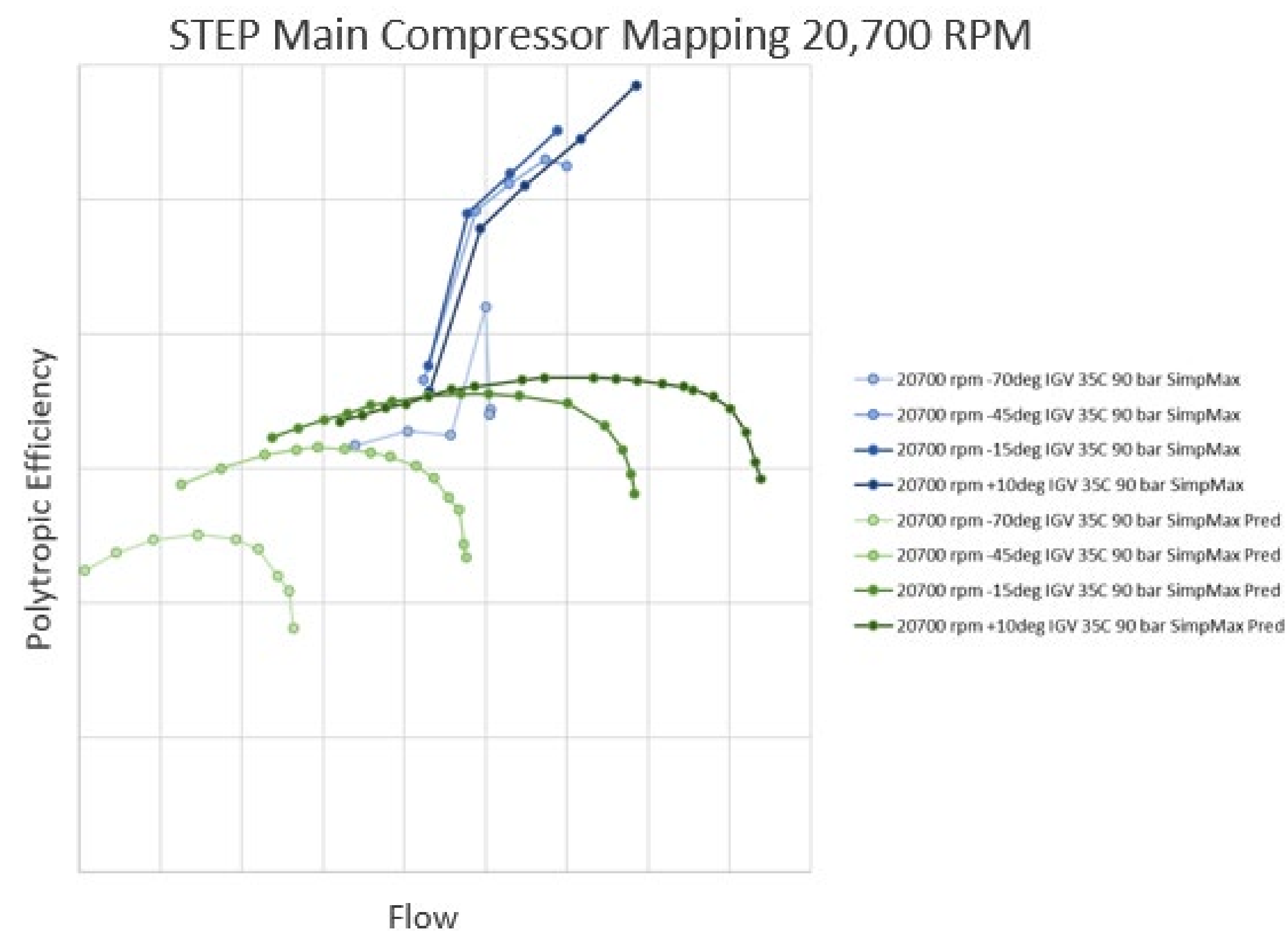
Timeline

- August 2023
 - Attempted to correct issues regarding performance discrepancy
 - Tuned balance piston valve
 - Lowered inlet temperature
 - Performed ASME PTC-10 Type 2 similitude test to FAT to verify no physical changes had occurred
 - Began manual surge verification exploration
 - Began compressor performance mapping



Compressor Performance

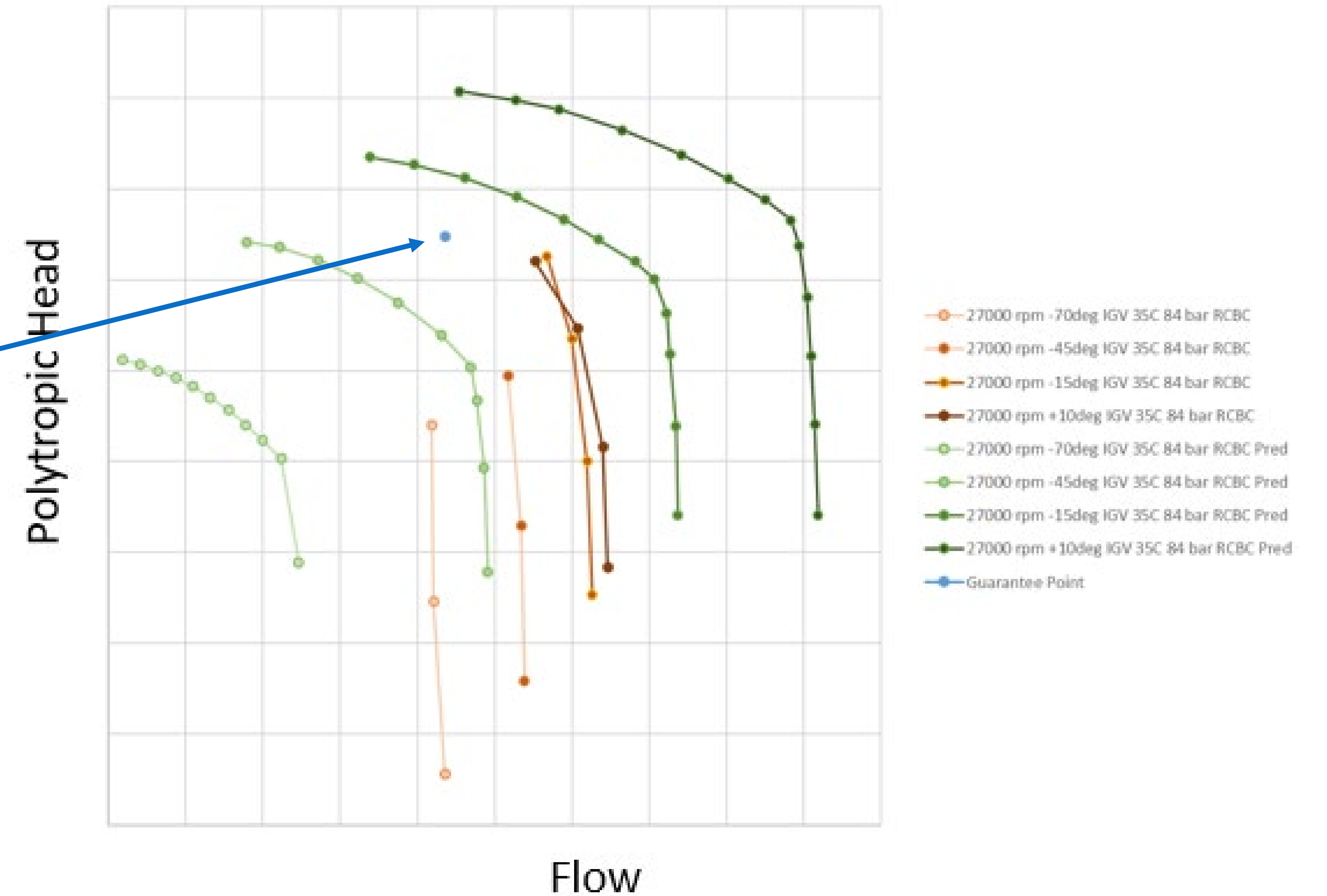
- For Simple Cycle Max operating point (20700 RPM, slower speed operation) the operating profile was centered on the right edge of the map.
- Characteristic curves are similar but do not quite match the slope of the predicted curves
- Efficiency data collected is suspect and more investigation is needed for better understanding



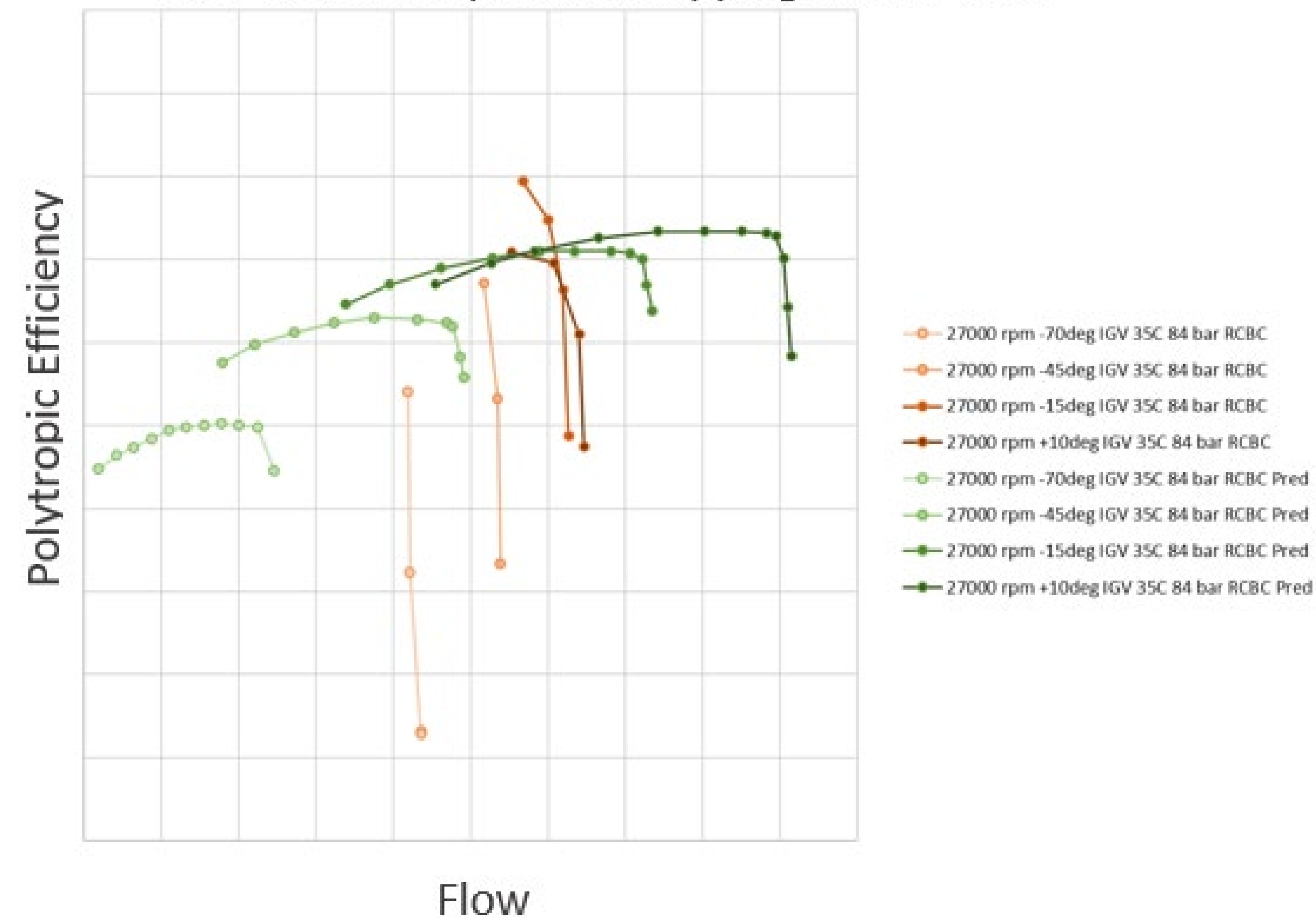
Compressor Performance

- For RCBC condition, performance was limited to the middle of the map
 - Unable to reach higher flows
 - Very limited turn-down
- Operation at higher IGV settings (0 deg and +10 deg) was limited due to predicted surge control line
- Due to performance not matching predictions, STEP team had to re-explore the surge map and make modifications
- After modifying surge control mapping, we are unable to meet the guarantee point

STEP Main Compressor Mapping 27,000 RPM



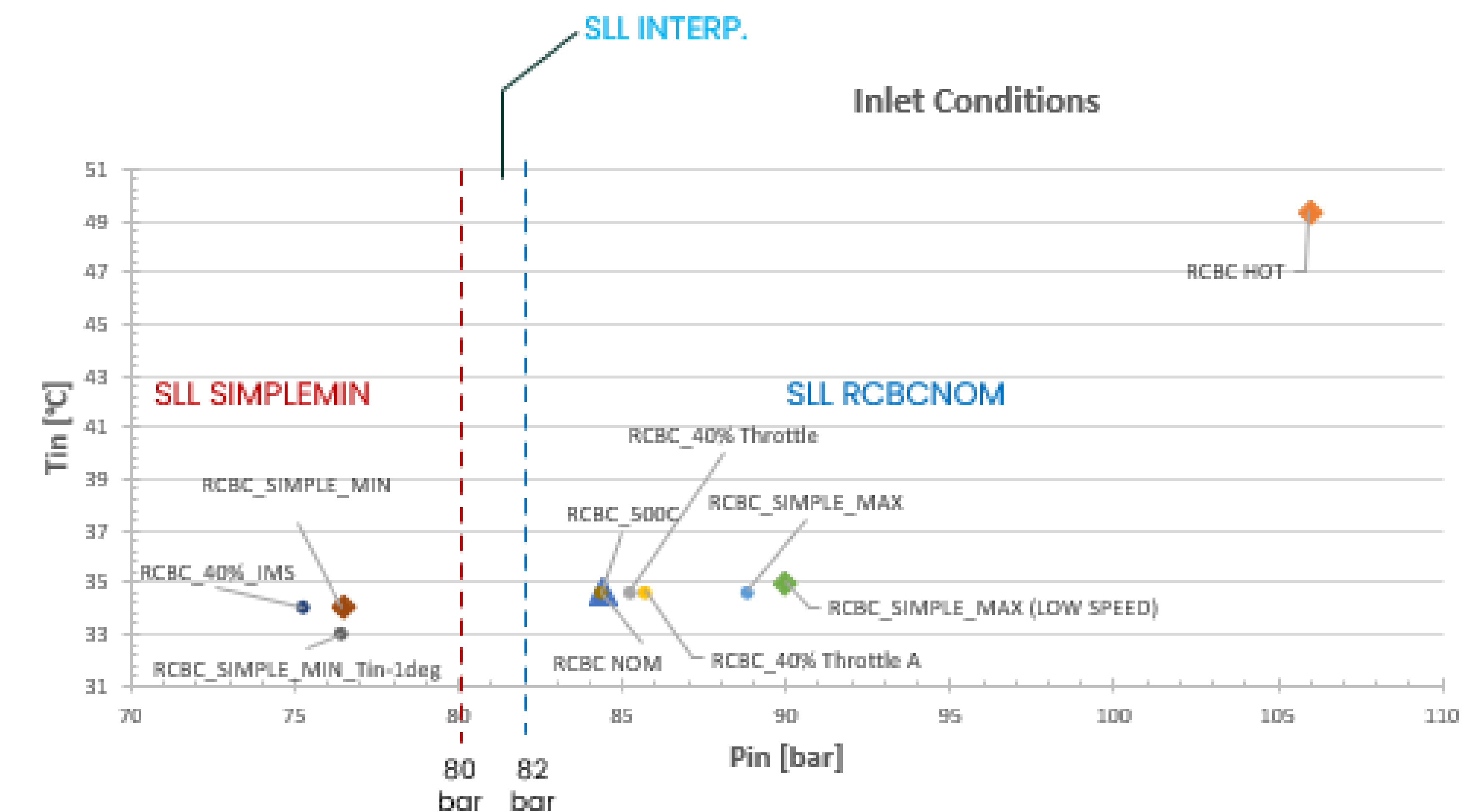
STEP Main Compressor Mapping 27,000 RPM



Compressor Commissioning

Timeline

- November 2023
 - Implemented new anti-surge logic allowing surge control line shift based on inlet pressure
 - Demonstrated operation at the guarantee point with the revised anti-surge control logic
 - Investigated source of 70 and 210 Hz vibration frequencies that become present while throttling
 - Performed anti-surge verification for RCBC hot day inlet conditions



Closing Remarks

Achievements:

- Main Compressor operated >150 hrs. thru Nov. 2023
- Aside from trim balances, the compressor showed good critical speed response and rotordynamic stability
- Liquid start successfully achieved from sub-critical pressurized hold

Recommended future research:

- Investigate source of discrepancy between predicted performance vs. actual operational data
- Consider options for surge control logic improvements that actively follow inlet conditions (press, temp, speed, etc.) vs. a fixed predicted line
- Continue research into new sensor technology to increase accuracy of compressor inlet fluid property conditions

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