EMERSON EXCHANGE 2025

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[3-1604] Pushing SIS To New Limits with Exothermic Reaction Monitoring

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Agenda

Eric Schulz	Synthomer Roebuck DeltaV Background
Eric Schulz	Process Overview
Eric Schulz	Overfill SIS Strategy
Harrison Hix	Monomer Accumulation SIS Strategy
Harrison Hix	Benefits and Challenges
Harrison Hix	Lessons Learned

Synthomer Background

Our Products Are All Around You

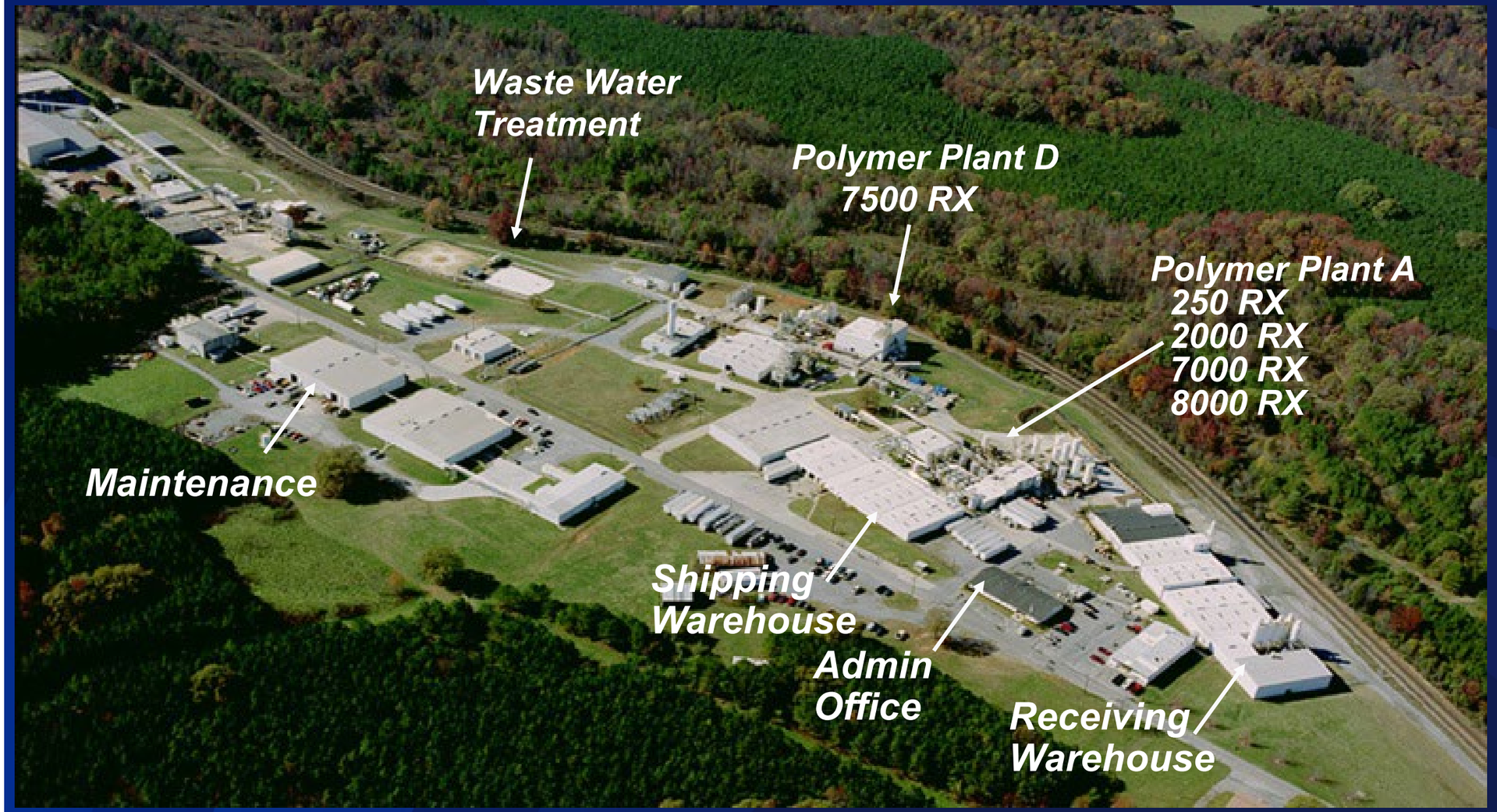
Our high-performance, highly specialised polymers and ingredients help customers make products that bind the world together.

- Employ 4,200 people working across Europe, US, Middle East, and Asia
- 30 Manufacturing sites + 4 innovation centres of excellence
- Headquartered and listed in London, UK
- 2023 revenues were £2.0 billion and EBITDA £142 million
- 3 Global Divisions aligning to end markets
  - Coatings & Construction Solutions
  - Adhesive Solutions
  - Health & Protection and Performance Materials

Roebuck, SC site

- **5 Acrylic Dispersion Reactors**
  - 250
  - 2000
  - 7000
  - 7500
  - 8000

- **16 Hour Avg Cycle Time**
- **200 + Products**
- **37 kTon Annual Capacity**



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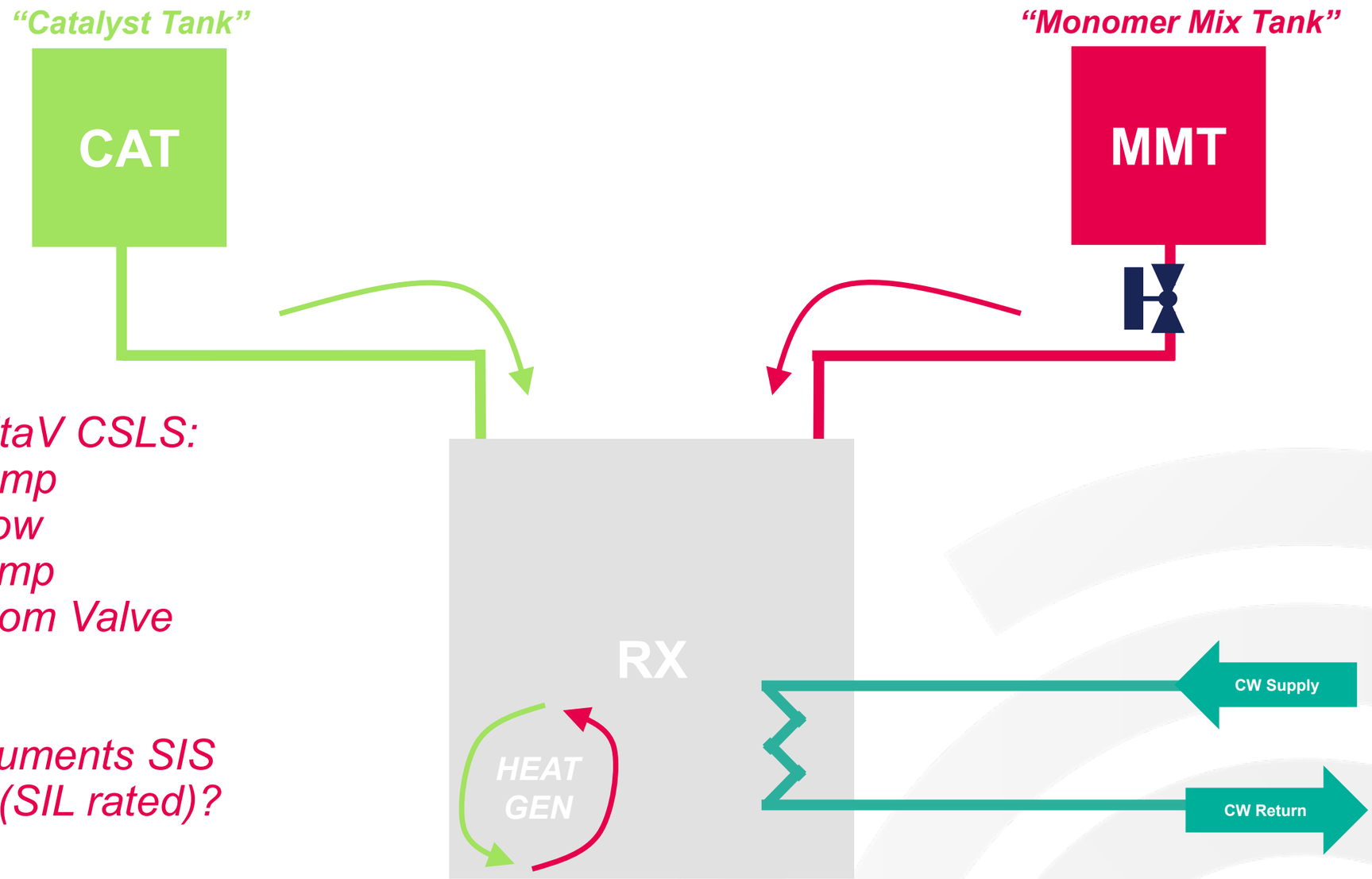
Process Overview

Exothermic Polymerization

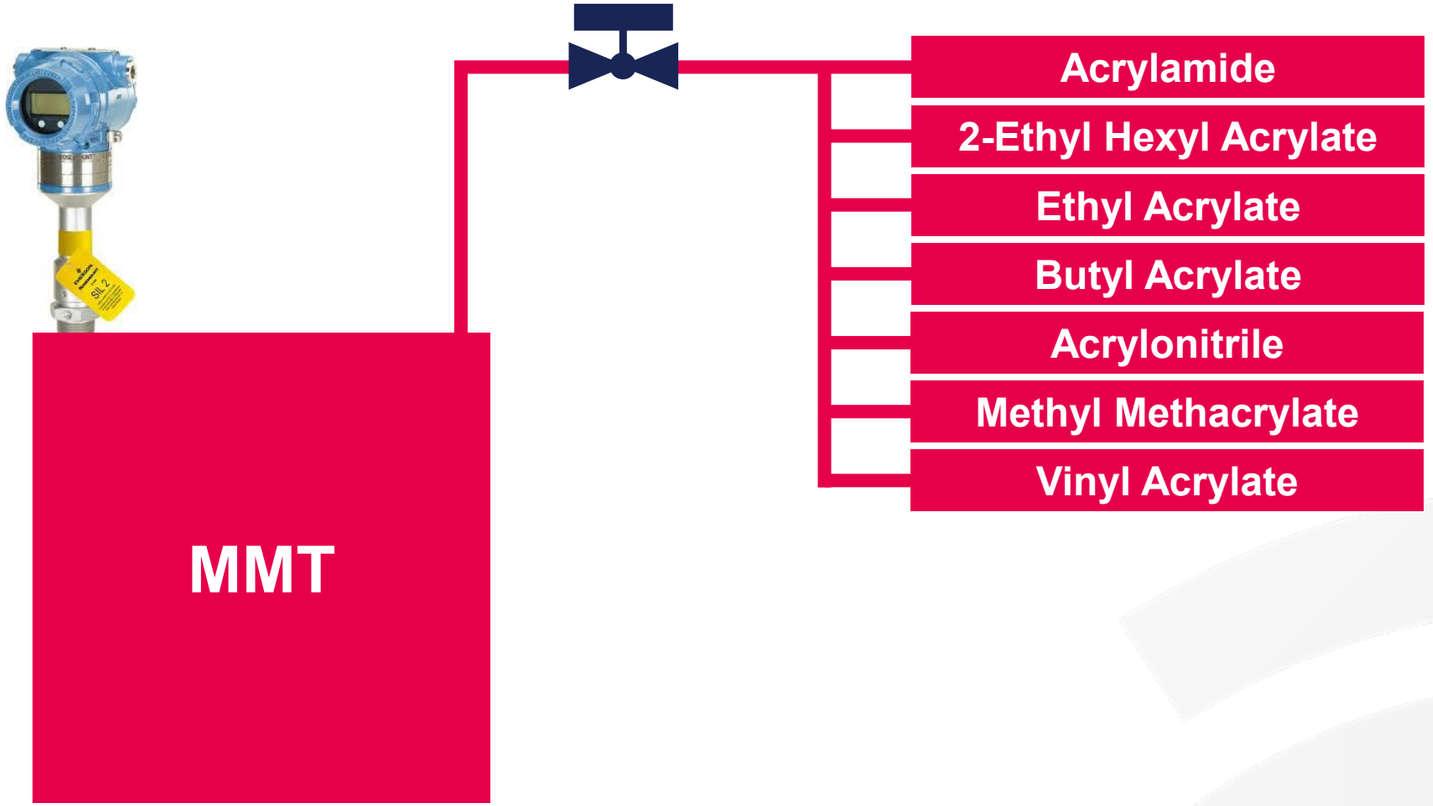


Wired to DeltaV CSLS:

- *CTWR Temp*
- *CTWR Flow*
- *CTWS Temp*
- *MMT Bottom Valve Solenoid*

Are the instruments SIS instruments (SIL rated)?

Overfill Protection



R8000 SIS Protection

	HY2313 (Water Header)	HY2390 (MMT1 Charge)	HY2391 (MMT2 Charge)	HY2300 (MMT1 Bottom)	HY2326 (MMT2 Bottom)
MMT1 High Level	X	X			
MMT2 High Level	X		X		
Monomer Accum				X	X

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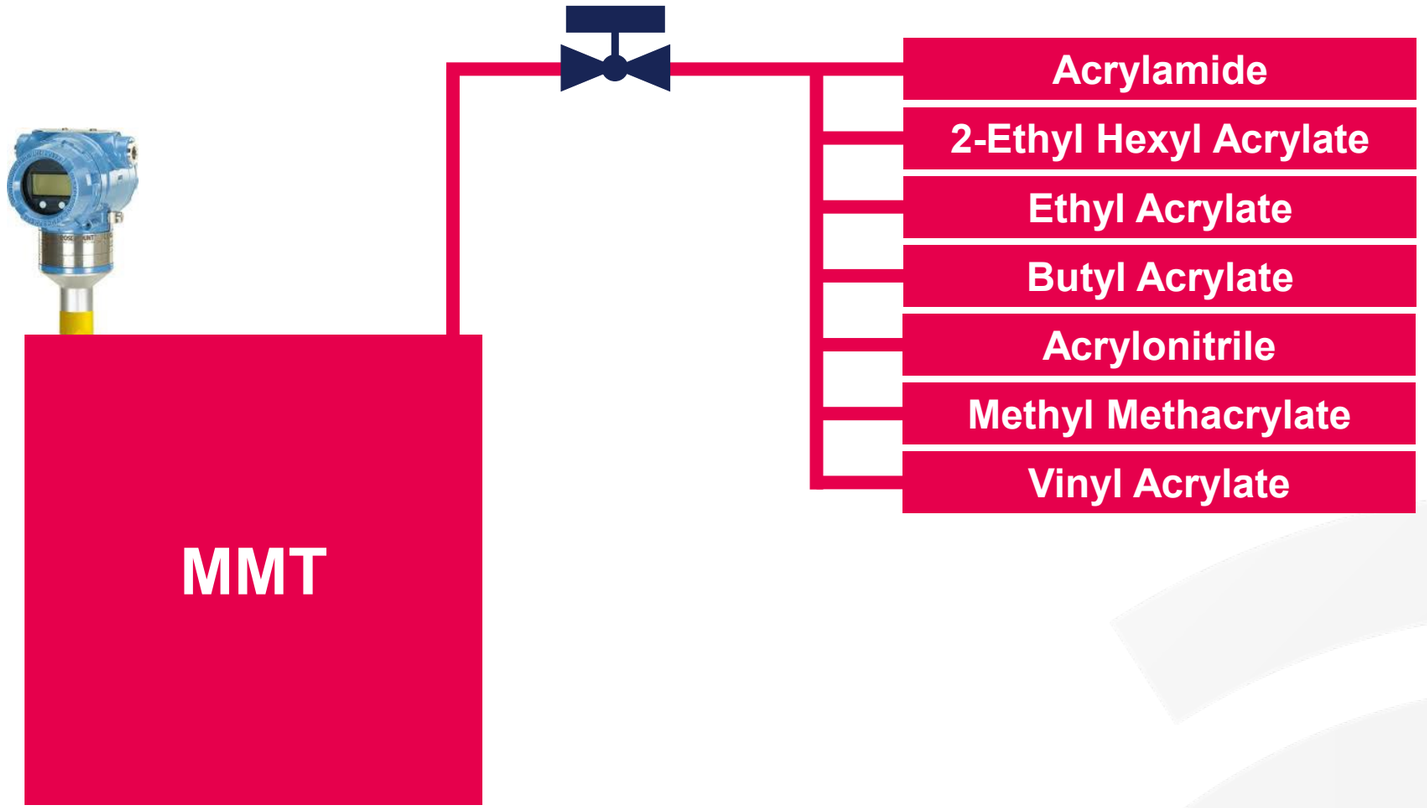
Overfill SIS Strategy

Overfill Protection



Highly flammable and hazardous monomers. Would never want the tank to overflow and monomer continued to be pumped into it. Tank is sealed but the monomer will go somewhere….

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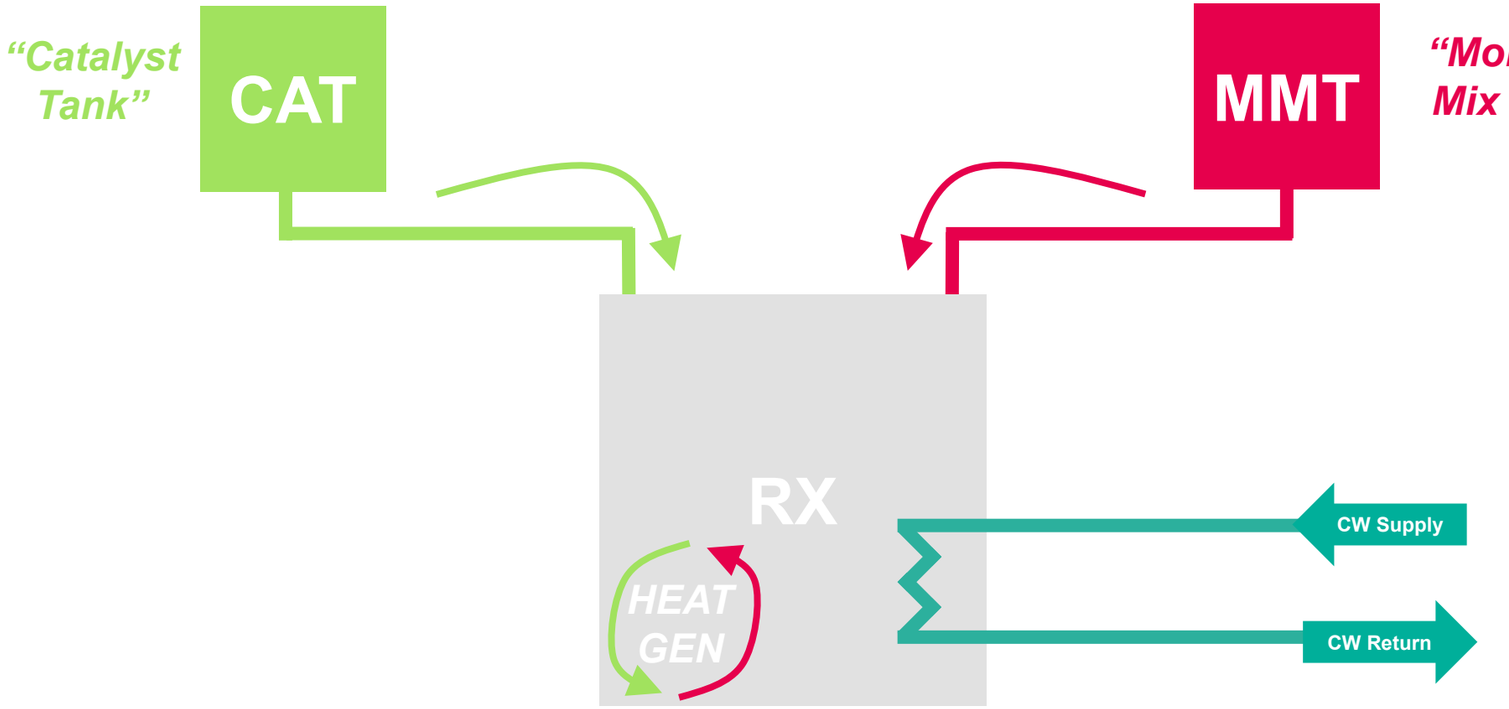
Monomer Accumulation SIS Strategy

R8000 SIS Protection

	HY2313 (Water Header)	HY2390 (MMT1 Charge)	HY2391 (MMT2 Charge)	HY2300 (MMT1 Bottom)	HY2326 (MMT2 Bottom)
MMT1 High Level	X	X			
MMT2 High Level	X		X		
Monomer Accum				X	X

Exothermic Polymerization



Heat Removal Calc:

HR = ΔT x Mass Flow

HR = (T_{Return} – T_{Supply}) x Mass Flow

Where is the heat going?

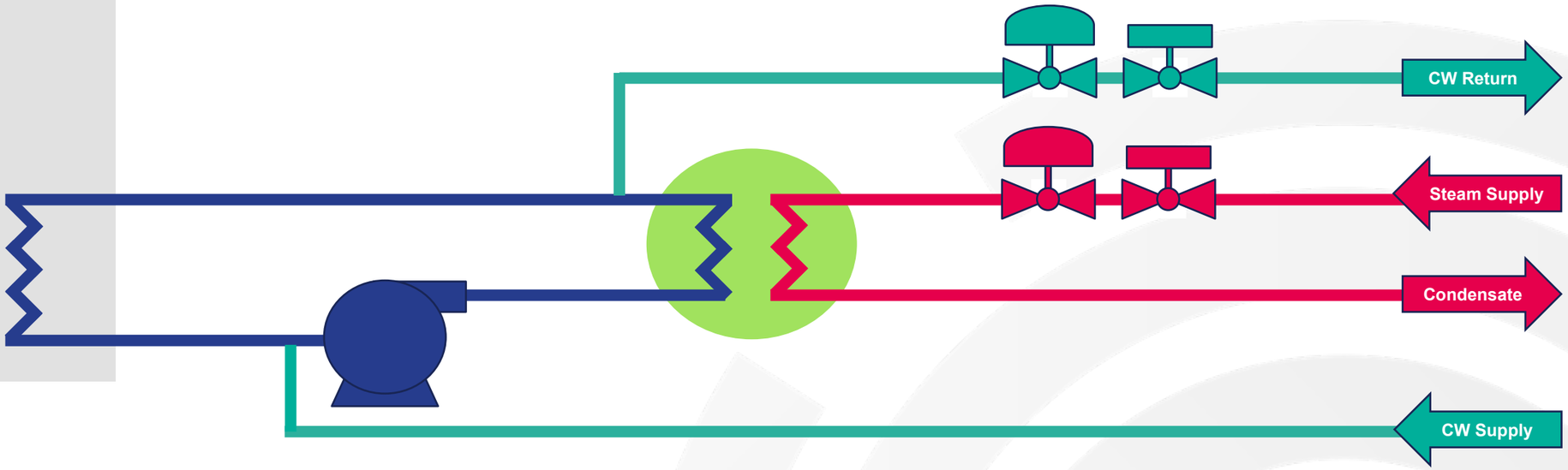
1. *Heat removal in cooling water (Majority of heat)*
2. *Heating up mon mix. MMT is ~60F, RXN run at 180F (45k lb)*

Assumed Minimal Heat Losses:

3. *CAT is ~40-80F (Water Temp) (2k lb)*
4. *Condenser on top of RX condensing material*
5. *Heat lost to room through tank*
6. *Heat added through agitator turning.*
7. *Others?*

Jacket Cooling/Heating System

RX



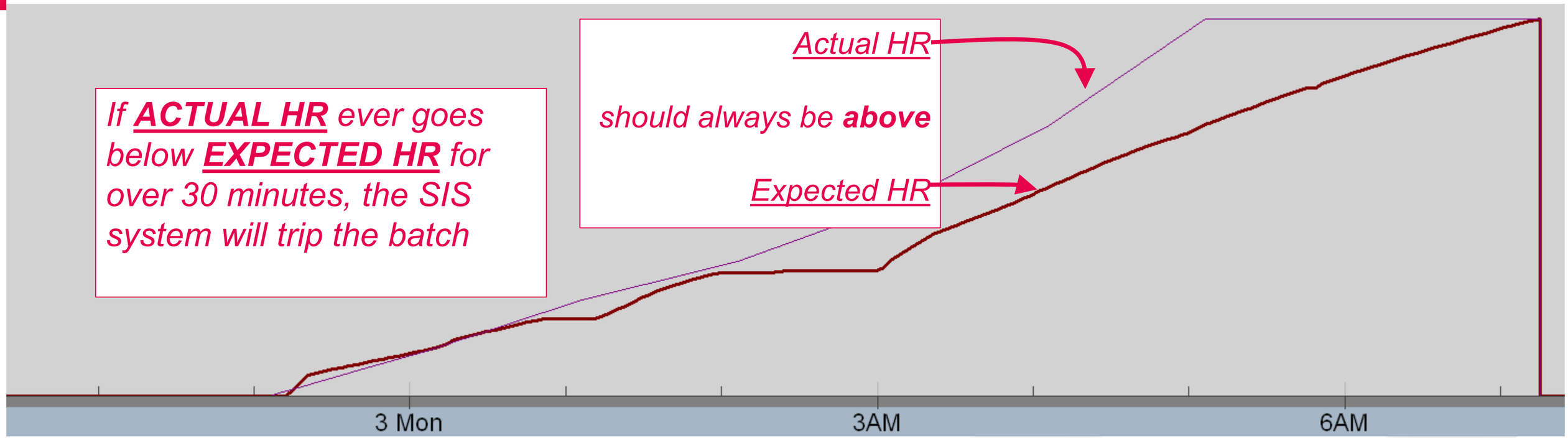
Exothermic Polymerization

*If **ACTUAL HR** ever goes below **EXPECTED HR** for over 30 minutes, the SIS system will trip the batch*

Actual HR

*should always be **above***

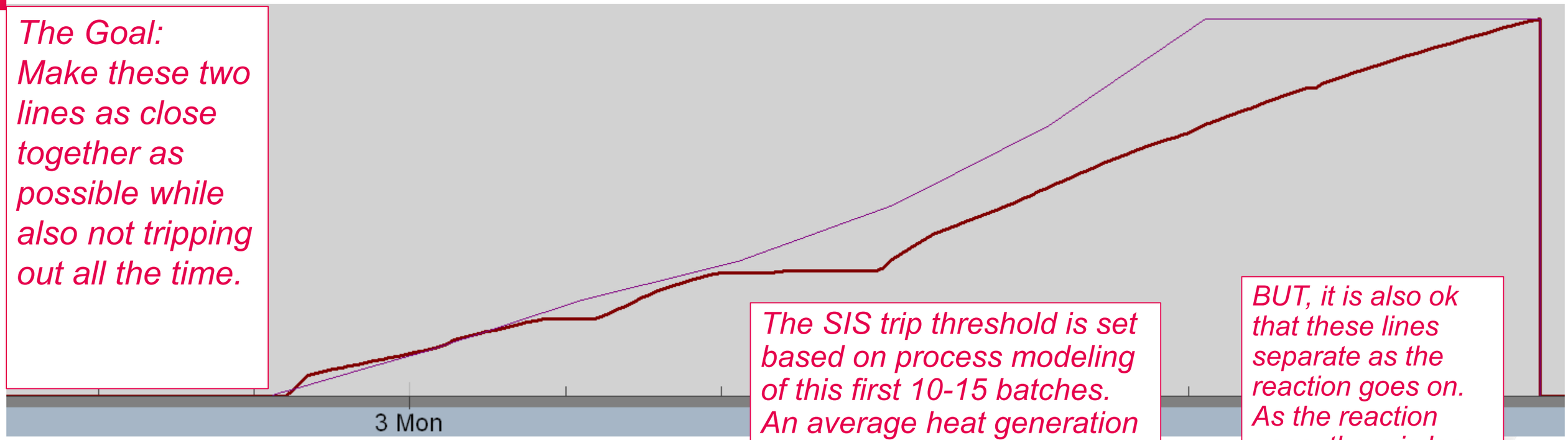
Expected HR



Parameter Reference	Descriptor	Value	Units	Timestamp
ESD_R8000/MON_ACCUM/BTU_RATE.CV	ESD 8000 Reactor	9999.00		2/2/2025 9:19:25 PM
ESD_R8000/MON_ACCUM/LSCALC1/OUT2.CV	ESD 8000 Reactor	216.13		2/2/2025 9:19:25 PM
* ESD_R8000/MON_ACCUM/LSCALC1/OUT1.CV	ESD 8000 Reactor	0.00		2/2/2025 9:19:25 PM
ESD_R8000/MON_ACCUM/TOTAL_CALC_BTU.CV	ESD 8000 Reactor	0.00		2/2/2025 9:19:25 PM

Exothermic Polymerization

The Goal: Make these two lines as close together as possible while also not tripping out all the time.



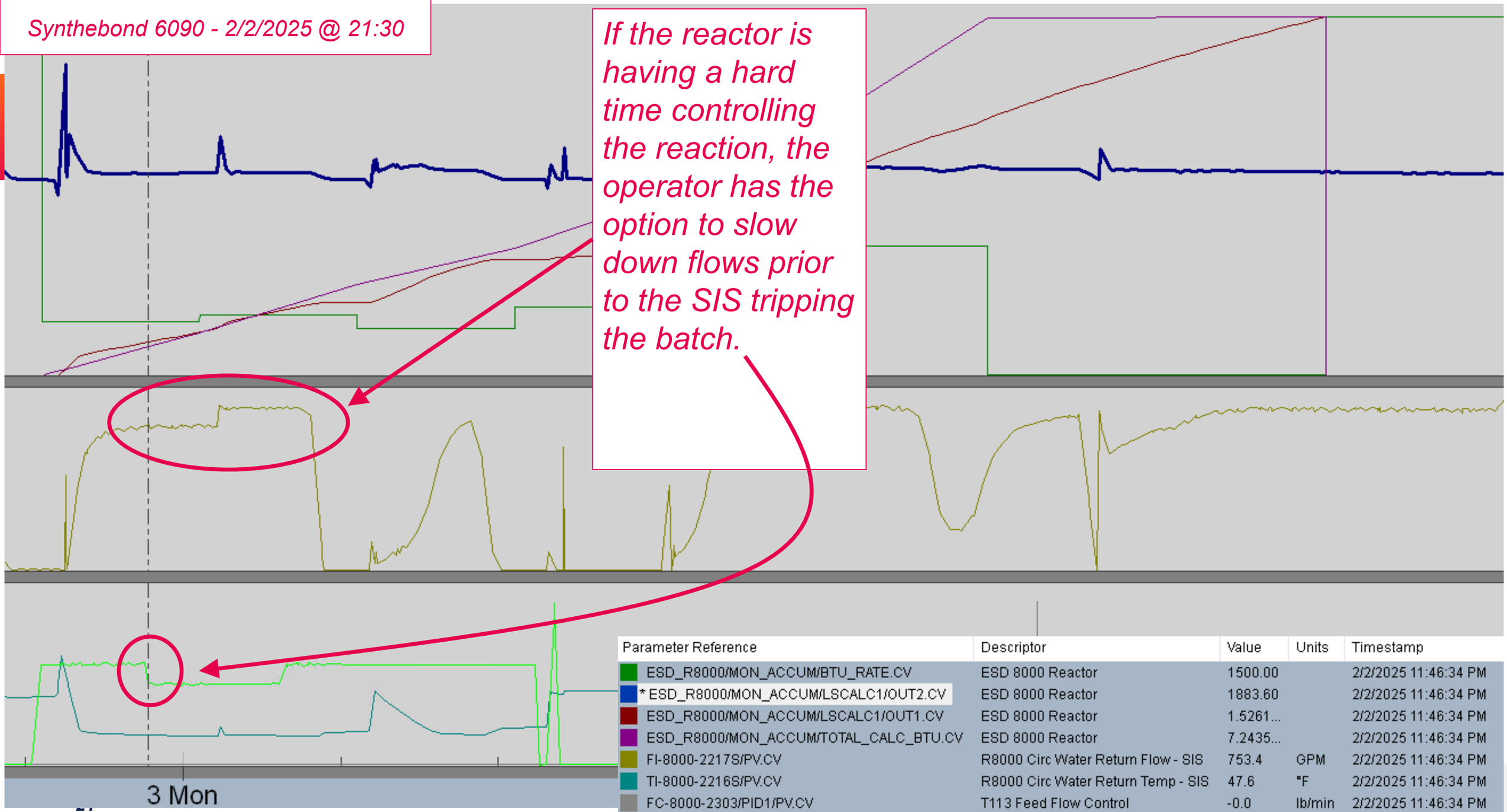
The SIS trip threshold is set based on process modeling of this first 10-15 batches. An average heat generation is calculated and then used to set this curve.

BUT, it is also ok that these lines separate as the reaction goes on. As the reaction goes, there is less and less monomer to pool, so the risk of huge monomer accumulation (and reaction runaway) goes down.

Parameter Reference	Descriptor		
ESD_R8000/MON_ACCUM/BTU_RATE.CV	ESD 8000 R		9:25 PM
ESD_R8000/MON_ACCUM/LSCALC1/OUT2.CV	ESD 8000 Reactor	216.13	2/2/2025 9:19:25 PM
* ESD_R8000/MON_ACCUM/LSCALC1/OUT1.CV	ESD 8000 Reactor	0.00	2/2/2025 9:19:25 PM
ESD_R8000/MON_ACCUM/TOTAL_CALC_BTU.CV	ESD 8000 Reactor	0.00	2/2/2025 9:19:25 PM

Synthebond 6090 - 2/2/2025 @ 21:30

If the reactor is having a hard time controlling the reaction, the operator has the option to slow down flows prior to the SIS tripping the batch.

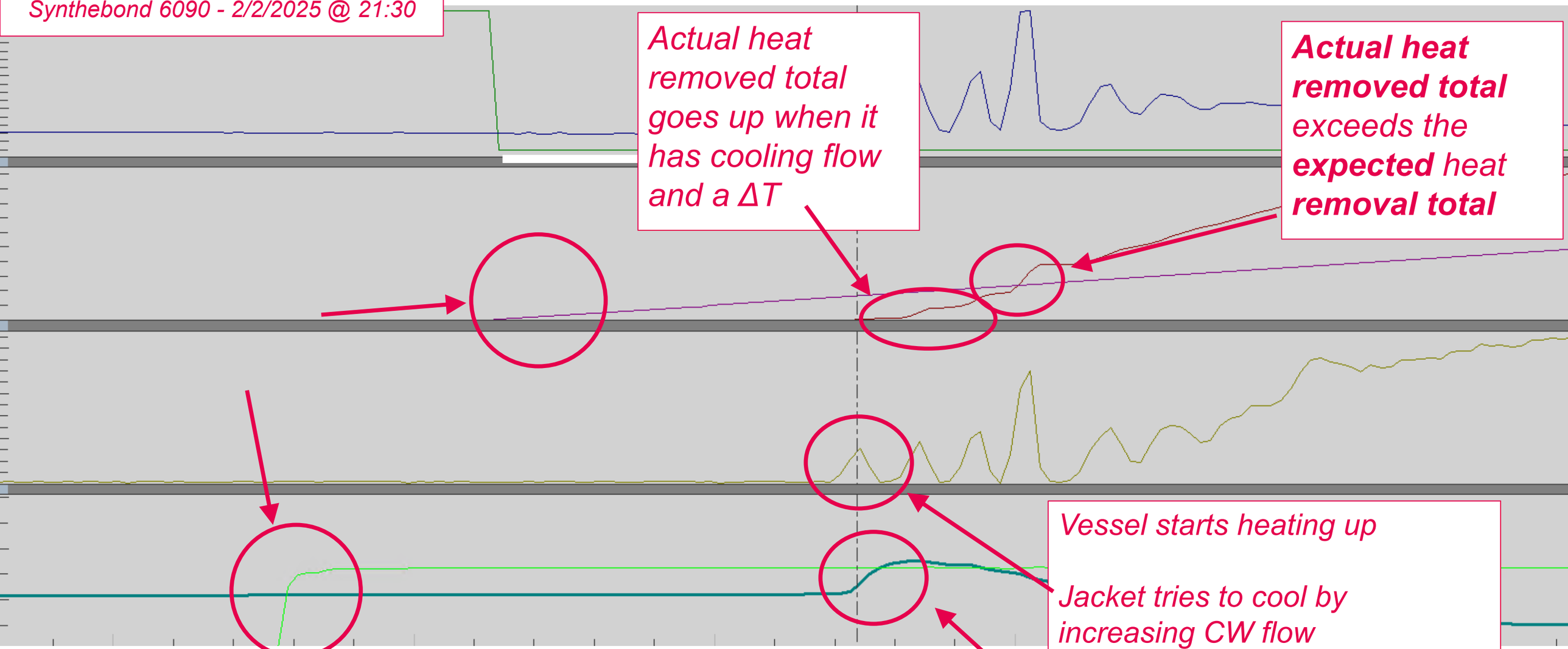


Parameter Reference	Descriptor	Value	Units	Timestamp
ESD_R8000/MON_ACCUM/BTU_RATE.CV	ESD 8000 Reactor	1500.00		2/2/2025 11:46:34 PM
* ESD_R8000/MON_ACCUM/LSCALC1/OUT2.CV	ESD 8000 Reactor	1883.60		2/2/2025 11:46:34 PM
ESD_R8000/MON_ACCUM/LSCALC1/OUT1.CV	ESD 8000 Reactor	1.5261...		2/2/2025 11:46:34 PM
ESD_R8000/MON_ACCUM/TOTAL_CALC_BTU.CV	ESD 8000 Reactor	7.2435...		2/2/2025 11:46:34 PM
FI-8000-2217S/PV.CV	R8000 Circ Water Return Flow - SIS	753.4	GPM	2/2/2025 11:46:34 PM
TI-8000-2216S/PV.CV	R8000 Circ Water Return Temp - SIS	47.6	°F	2/2/2025 11:46:34 PM
FC-8000-2303/PID1/PV.CV	T113 Feed Flow Control	-0.0	lb/min	2/2/2025 11:46:34 PM
FC-8000-2335/PID1/PV.CV	MMT2 to R112 Flow Control	132.8	lb/min	2/2/2025 11:46:34 PM

Synthebond 6090 - 2/2/2025 @ 21:30

Actual heat removed total goes up when it has cooling flow and a ΔT

Actual heat removed total *exceeds the* ***expected*** *heat* ***removal total***



Parameter Reference	Descriptor	Value	Units	Timestamp
ESD_R8000/MON_ACCUM/BTU_RATE.CV	ESD 8000 Reactor	1500.00		2/2/2025 11:12:22 PM
ESD_R8000/MON_ACCUM/LSCALC1/OUT2.CV	ESD 8000 Reactor	-1854.98		2/2/2025 11:12:22 PM
ESD_R8000/MON_ACCUM/LSCALC1/OUT1.CV	ESD 8000 Reactor	12.87		2/2/2025 11:12:22 PM
ESD_R8000/MON_ACCUM/TOTAL_CALC_BTU.CV	ESD 8000 Reactor	1.08539e+07		2/2/2025 11:12:22 PM
FI-8000-2217S/PV.CV	R8000 Circ Water Return Flow - SIS	139.2	GPM	2/2/2025 11:12:22 PM
* TI-8000-2216S/PV.CV	R8000 Circ Water Return Temp - SIS	125.3	°F	2/2/2025 11:12:22 PM
FC-8000-2303/PID1/PV.CV	T113 Feed Flow Control	-0.0	lb/min	2/2/2025 11:12:22 PM
FC-8000-2335/PID1/PV.CV	MMT2 to R112 Flow Control	162.0	lb/min	2/2/2025 11:12:22 PM

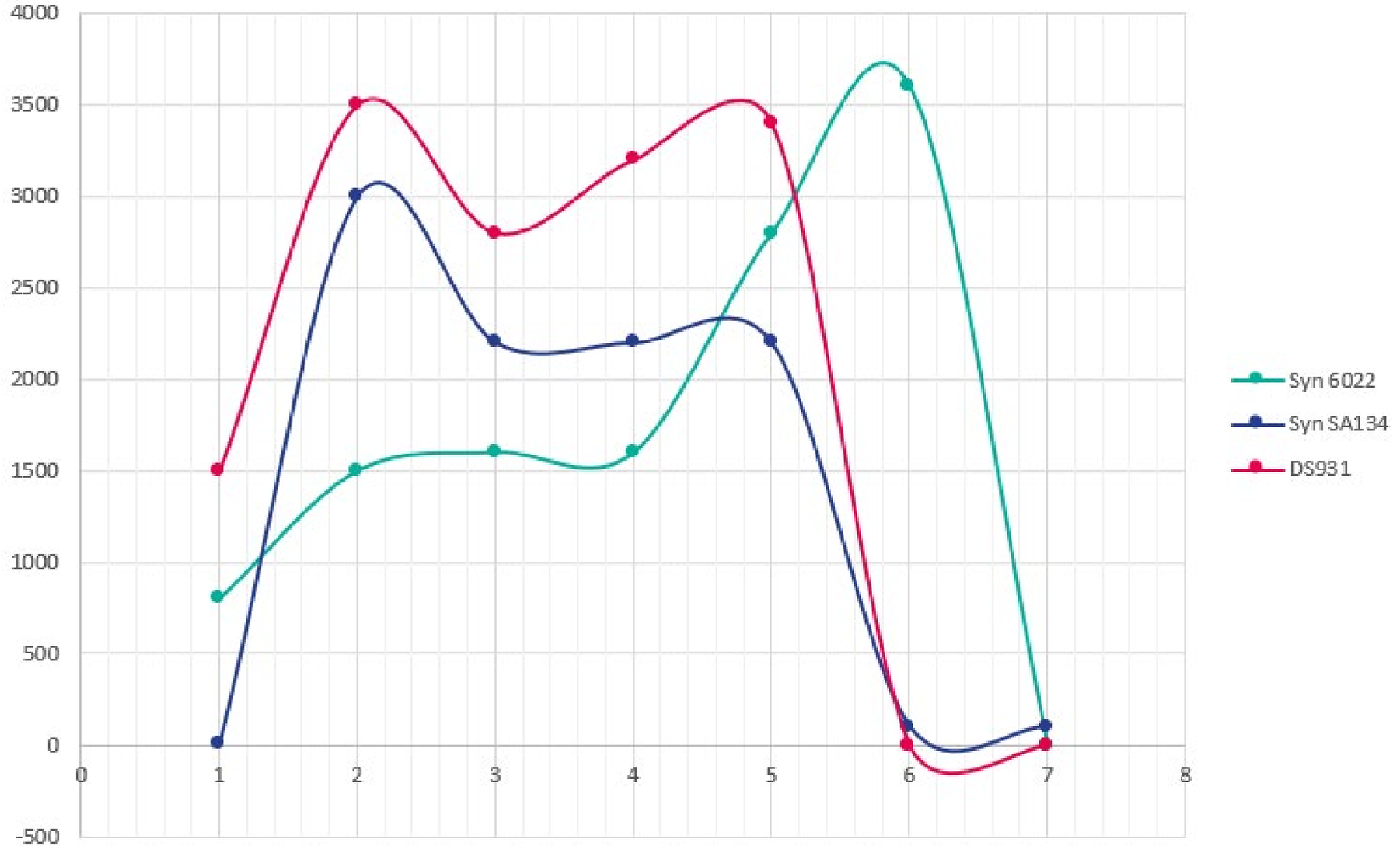
Vessel starts heating up

Jacket tries to cool by increasing CW flow

Return temp jumps up because the RXN has started generating heat and the cooling water is absorbing that heat.

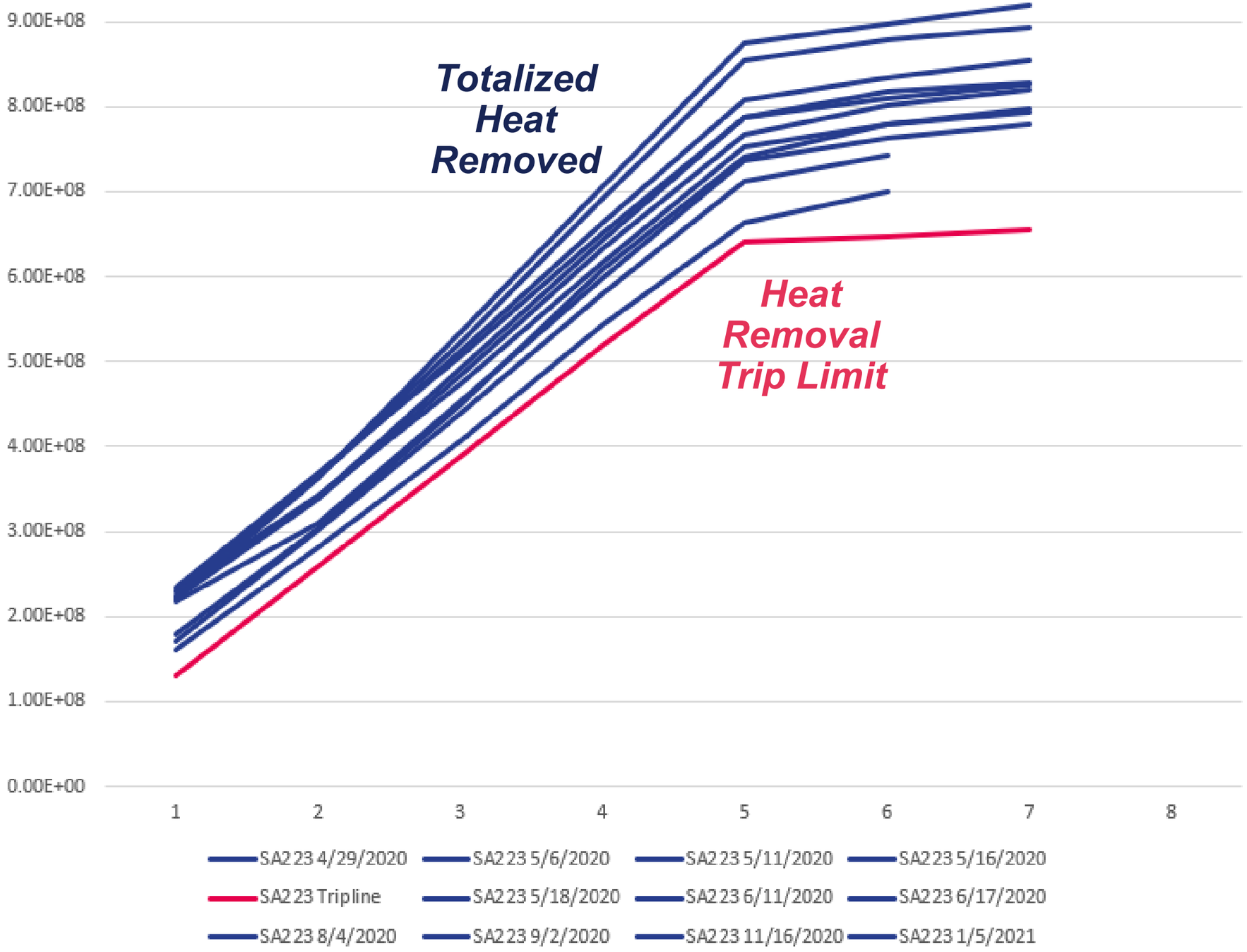
Instantaneous Heat Generation

- *Each product is different*
- *Each hour is different*
- *Some products are more exothermic than others*



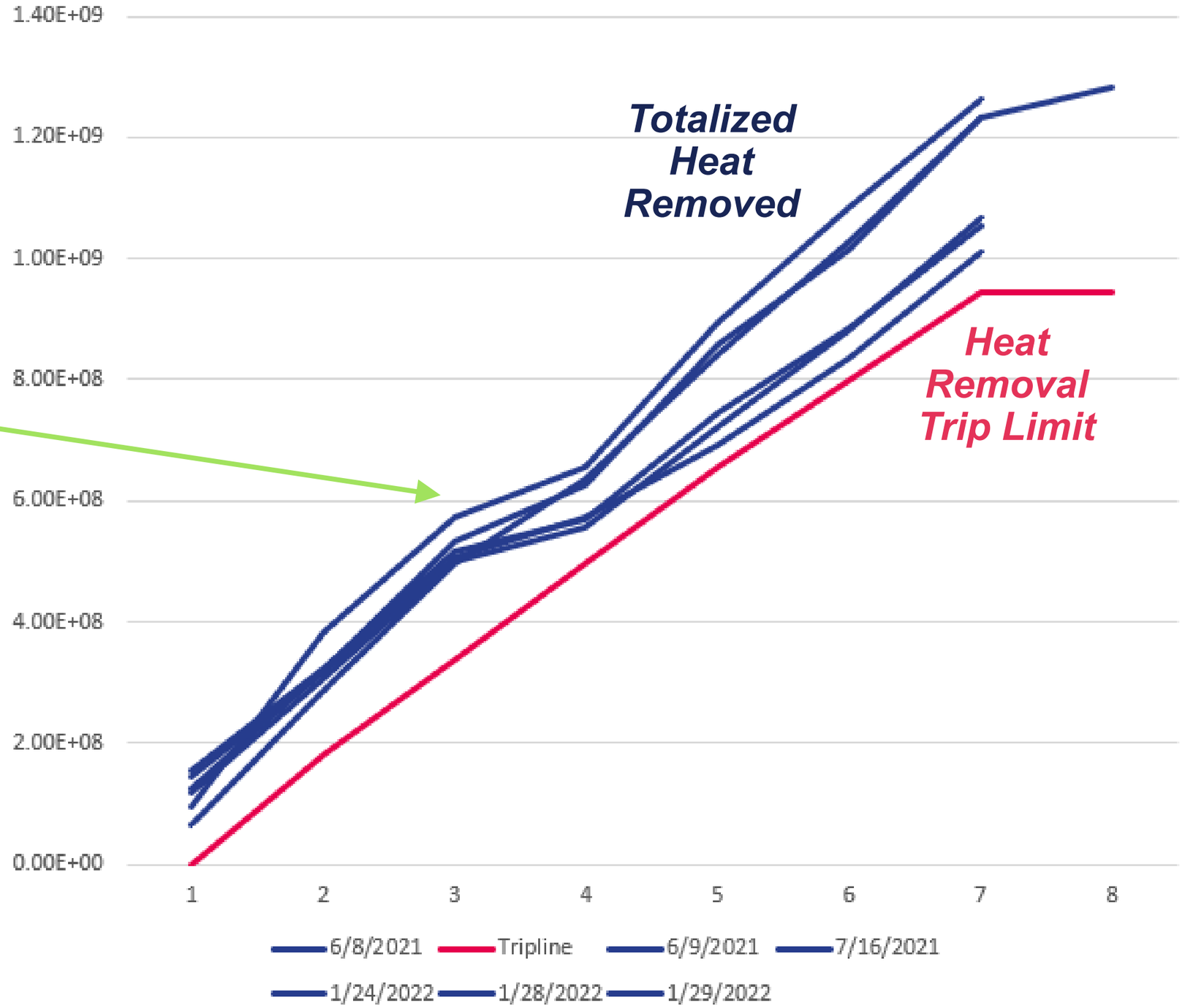
SA223 Trip Line Setting

- *Totalized Heat Removal*
- *What is the goal?*
  - *Tight but robust*
- *Trip is pertinent to sampled product runs*
- *Last hour typically tails off as the reaction dies*



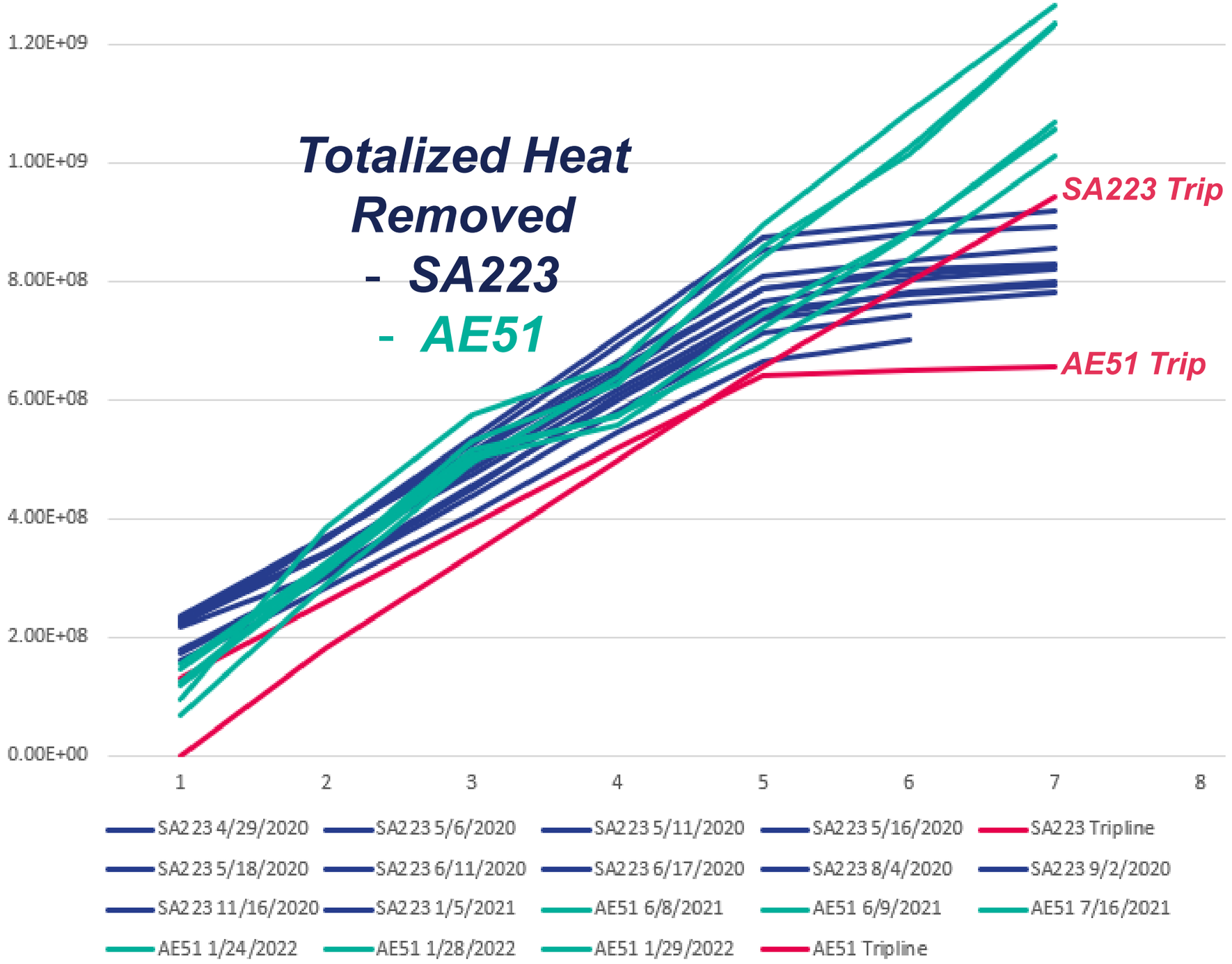
AE51 Trip Line Setting

- *AE51 is a 2-stage flow*
- *Not ever*
- *Point 3*



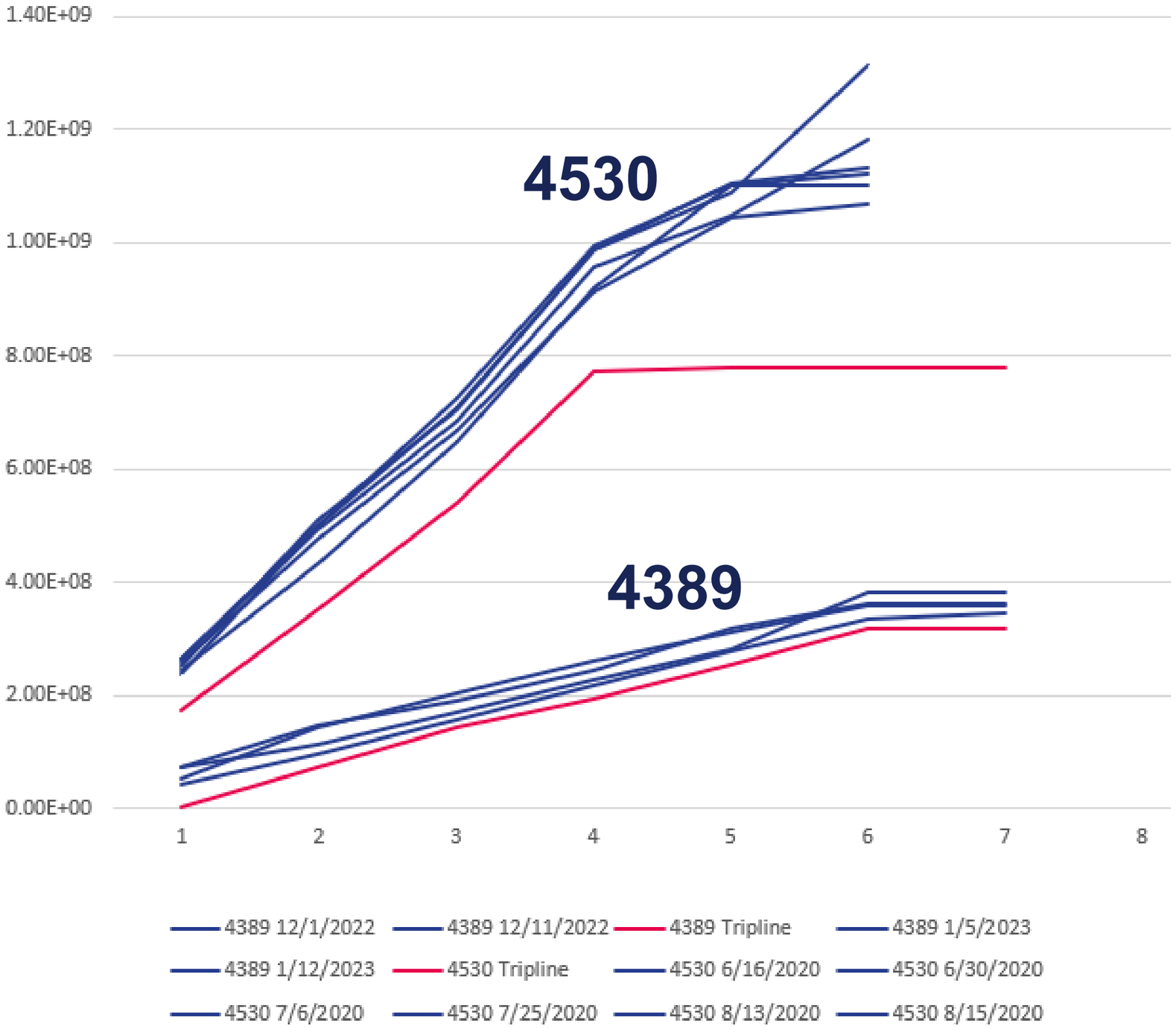
SA223 vs AE51

- *Totalized Heat Removal*
- *What is the goal?*
  - *Tight but robust*
- *Trip is pertinent to sampled product runs*
- *Last hour typically tails off as the reaction dies*



4530 vs 4389

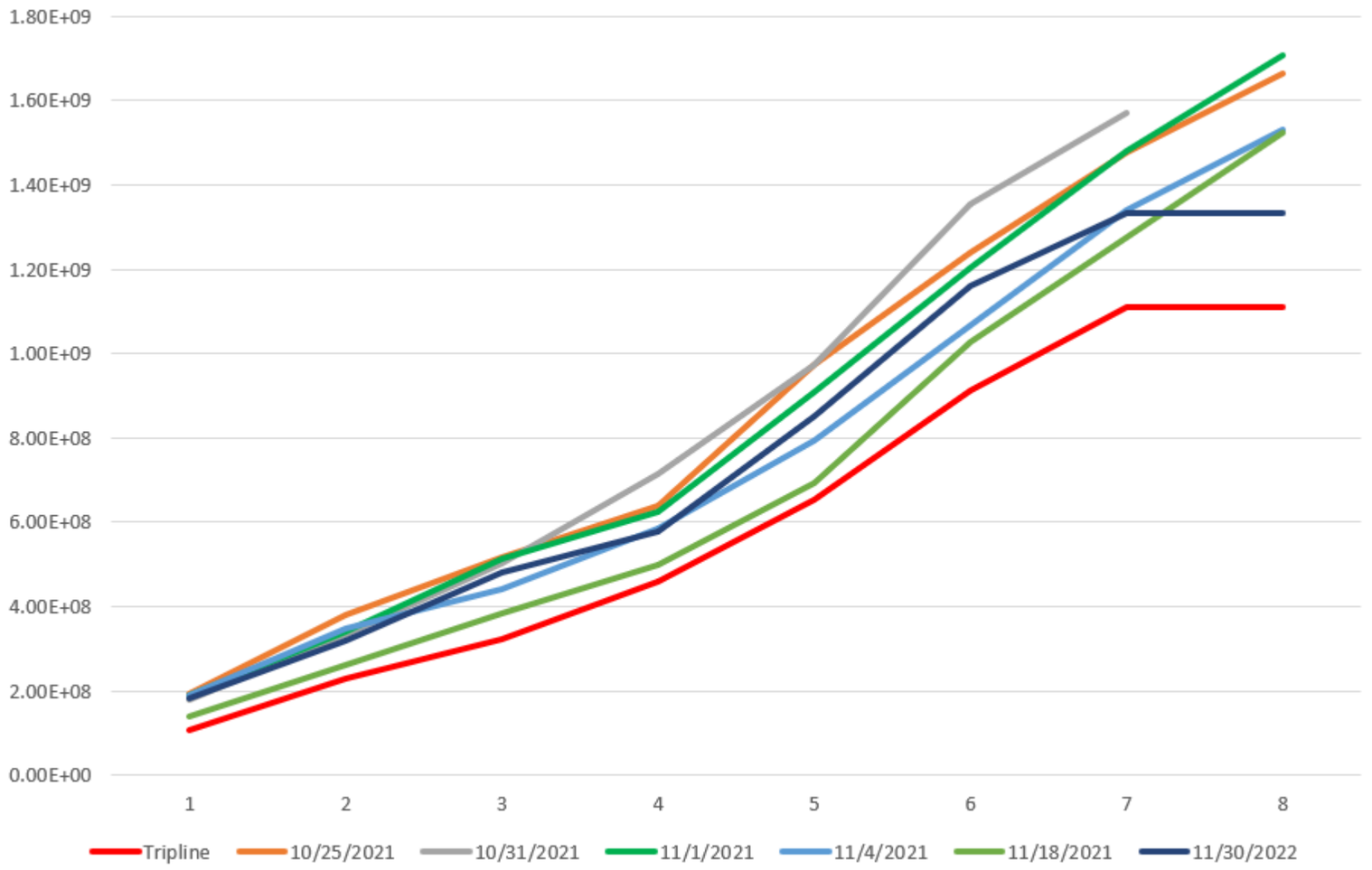
- *4530 Aggressive Reaction*
- *4389 Weaker Reaction*
- *Point 3*



Benefits and Challenges

Challenges

- Delays in the process create false trips (calculated heat removal is totalized over time and expected heat removal is not delayed if the process is tripped)
- Seasonality can shift the data
- Setting the trip threshold:
  - Different products = more work
  - Robustness vs Effective Monitoring
  - Iterative, challenging process
  - Can shift with seasons or overtime



Benefits

- Adds a safety blanket against monomer pooling and rapid exothermic runaway reaction
- Allows for effective monitoring of very different exothermic reactions
  - Each exotherm is different, and the SIS allows for the setting of the trip threshold to be adjusted up and down based on the rate of the heat being generated
- Data collection and processing gives insights into the process. These can change over time and need to be continuously monitored.
  - Heat transfer fouling
- SIS can trip based on other issues as well such as….
  - Raw material mix deviances (Operator mis-charges)
  - Bad raw material quality (Poor catalyst material will lead to poor exotherm)

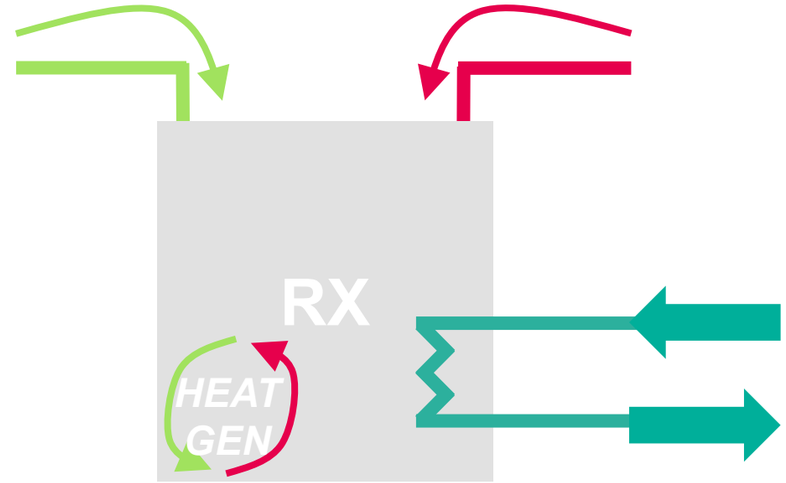
Lessons Learned

Lessons Learned

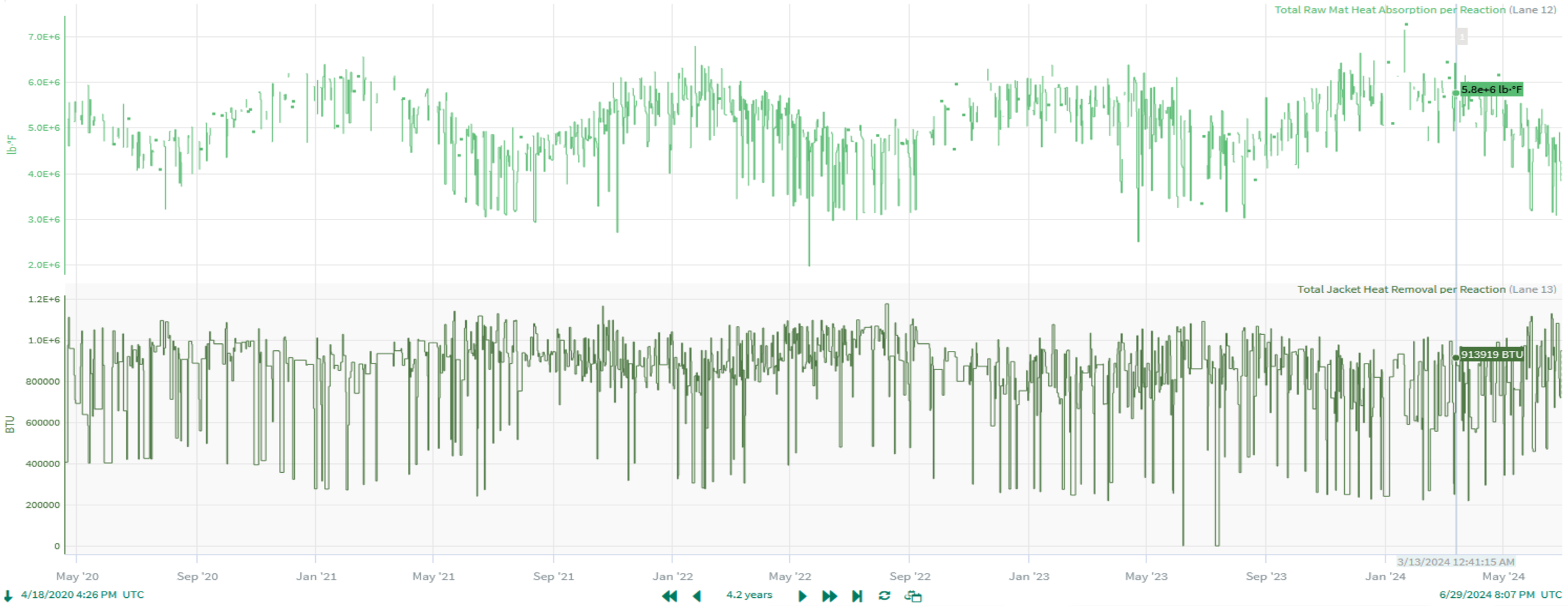
- SIS is a powerful tool to monitor an exothermic process - through process modeling, you can set the trip limit differently for different products.
- Monomer Accumulation is monitored in other reactors in different ways. The way it is monitored in the 7500 is probably the simplest and most simple and robust way.
  - 7500 has a trip – compare reactor temp and circ water temp. If circ water temp is within 10 degrees of reactor temp for more than 30 min and the monomer feed pump is running, then the pump trips. Challenge here is some products that trip frequently. SA225 second flow the jacket is still warm for more than 30 minutes after the flow starts. Probably best to make the temperature difference and trip time delay tunable for different product exotherm intensities.
  - 7000, 2000 just alarms
- Seasonality
- Process interruptions cause trends to shift, false trip

Alternative: Simpler Monitoring

- Interlock on Monomer Pump
- Trip Condition:
  - (TRX - TJKT) < 10 °F & Pump Running for 30 min
- For most of our products, if the reaction is proceeding as it should be in order to maintain the correct reactor temperature the jacket temperature will be 10 °F below the reaction temperature. The key is that we are trying to hold the reactor at a constant temperature.
- SA225 second flow the jacket is still warm for more than 30 minutes after the flow starts. Probably best to make the temperature difference and trip time delay tunable for different product exotherm intensities.



Seasonal Affects on Heat Gen



Summary

- DeltaV SIS is extremely user configurable and can fit any application.
- This configuration strategy allowed us to monitor different exothermic products with customized trip limits to that product.
- Improvements:
  - Make the model adjust for time and process interruptions
  - Seasonality affects
  - More Simple, More Better?
- Data drives insights into your process.

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Thank You

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Appendix

When it trips…

- *Need some screenshots from an example batch when the SIS tripped.*
- *@Eric, can you get me some batches that tripped SIS? When did they start? What was the root cause?*
- *Process shifted around November/December of 2022 and had several trips in a row on multiple products (6090, 6022, etc….). Correction was to shift the heat rates down.*

- *What causes this?*
  - *Bad monomer mix? Mischarge?*
  - *Bad catalyst mix? Mischarge?*
  - *Bad heat removal?*

How many trips?

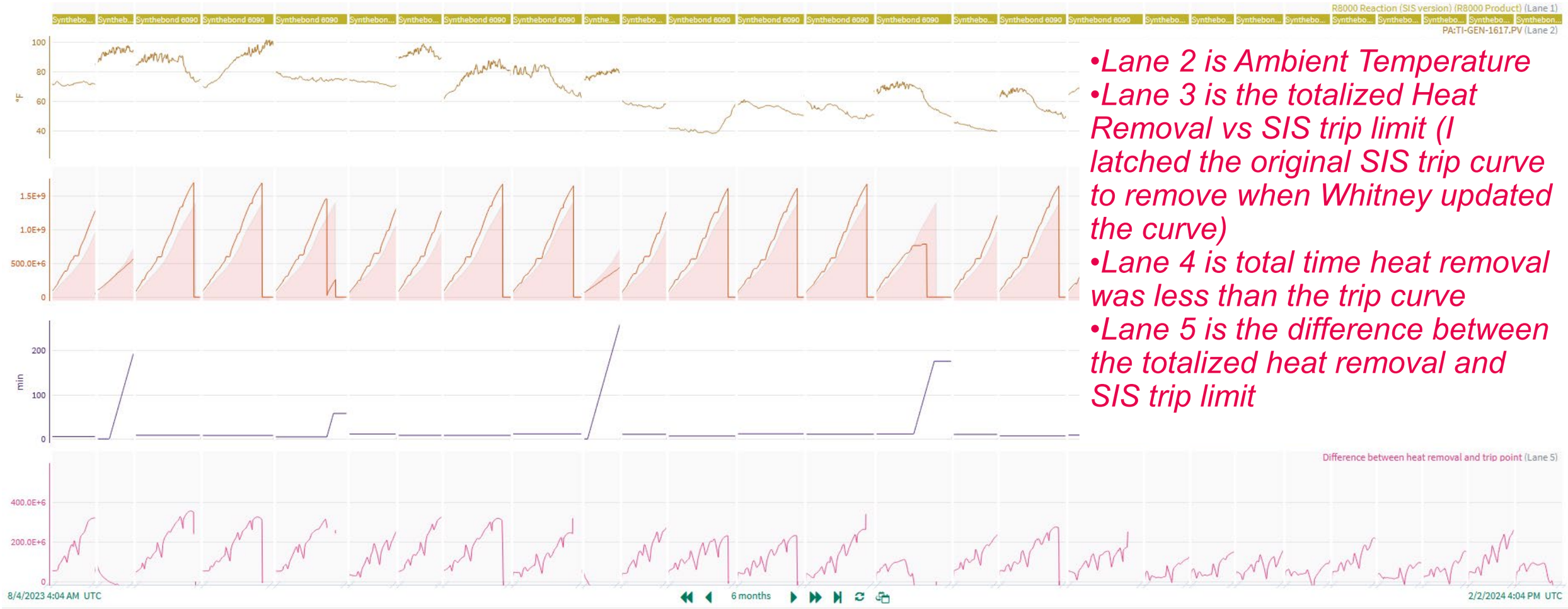
- *We've never actually had this trip from a true monomer pooling situation.*
- *Typically, it trips because there's been a delay in the process. Causes the curves to shift. (CAT re-start bug, recently fixed)*
- *When monomer pooling does happen, the issue is that it doesn't react, it doesn't react, it doesn't react, then it all reacts at once. At that point you have a lot of fuel.*

When it trips…

- *Has there ever been a high-level SIS trip on the R8000?*
  - *No instances (since startup of R8000 in 2019) of real high-level trip.*
  - *True end to end test (every six months)*

- *What would happen if it did overfill? Would monomer spill out or would it remain contained in the vessel?*
  - *Whitney Answer: Tanks are sealed, BUT, the monomer will go somewhere. In the past the tanks were un-sealed and monomer would come into the room. In a sealed tank the monomer would probably go into the vent and into the scrubber system. Could also go into the 4000 or 1500 (open tanks) through the vent system.*

6090 from August 2022 – January 2023



- *Lane 2 is Ambient Temperature*
- *Lane 3 is the totalized Heat Removal vs SIS trip limit (I latched the original SIS trip curve to remove when Whitney updated the curve)*
- *Lane 4 is total time heat removal was less than the trip curve*
- *Lane 5 is the difference between the totalized heat removal and SIS trip limit*

6090 from August 2023 – January 2024