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CO_2 Compressor Controls & Operation Efficiency Improvements

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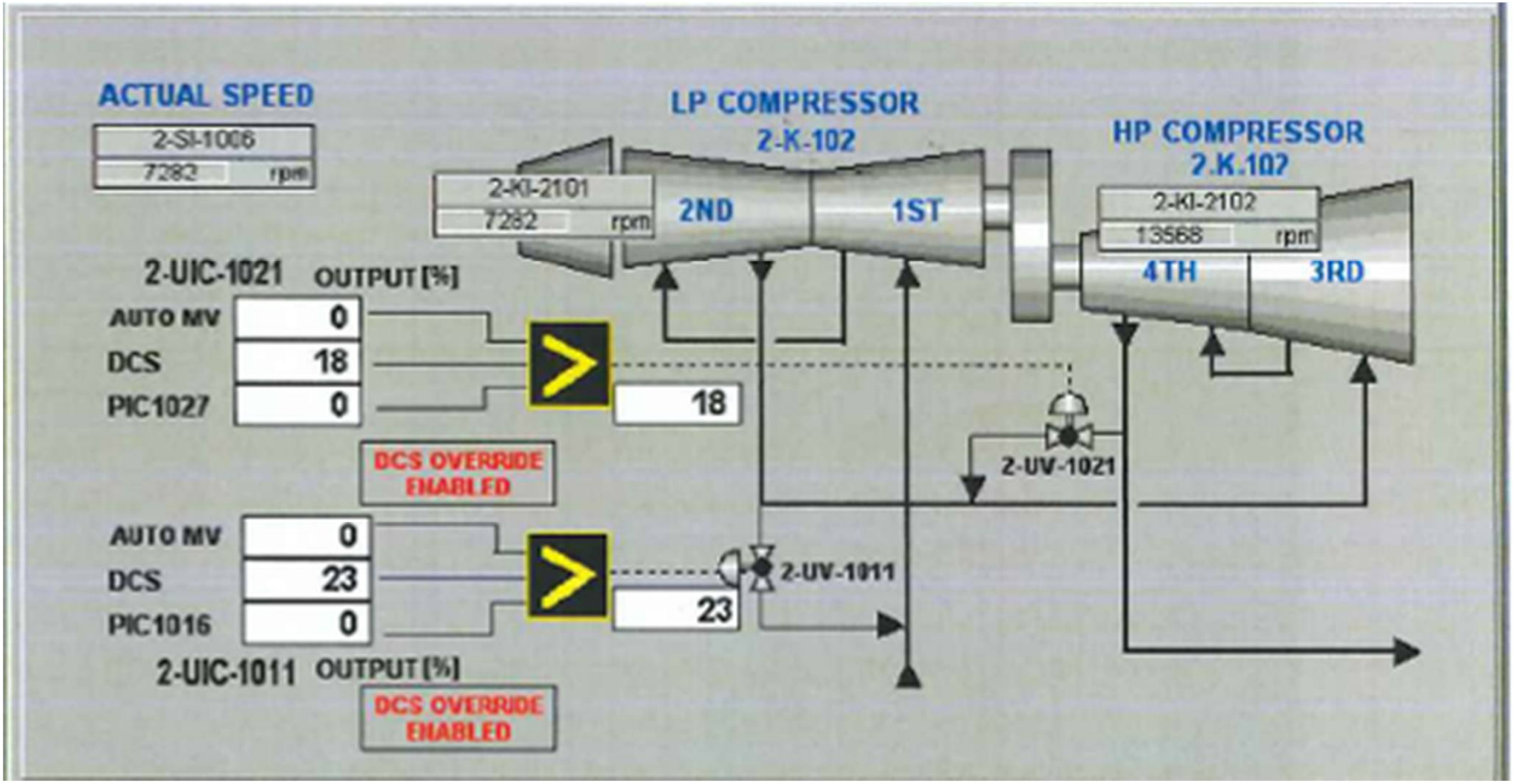
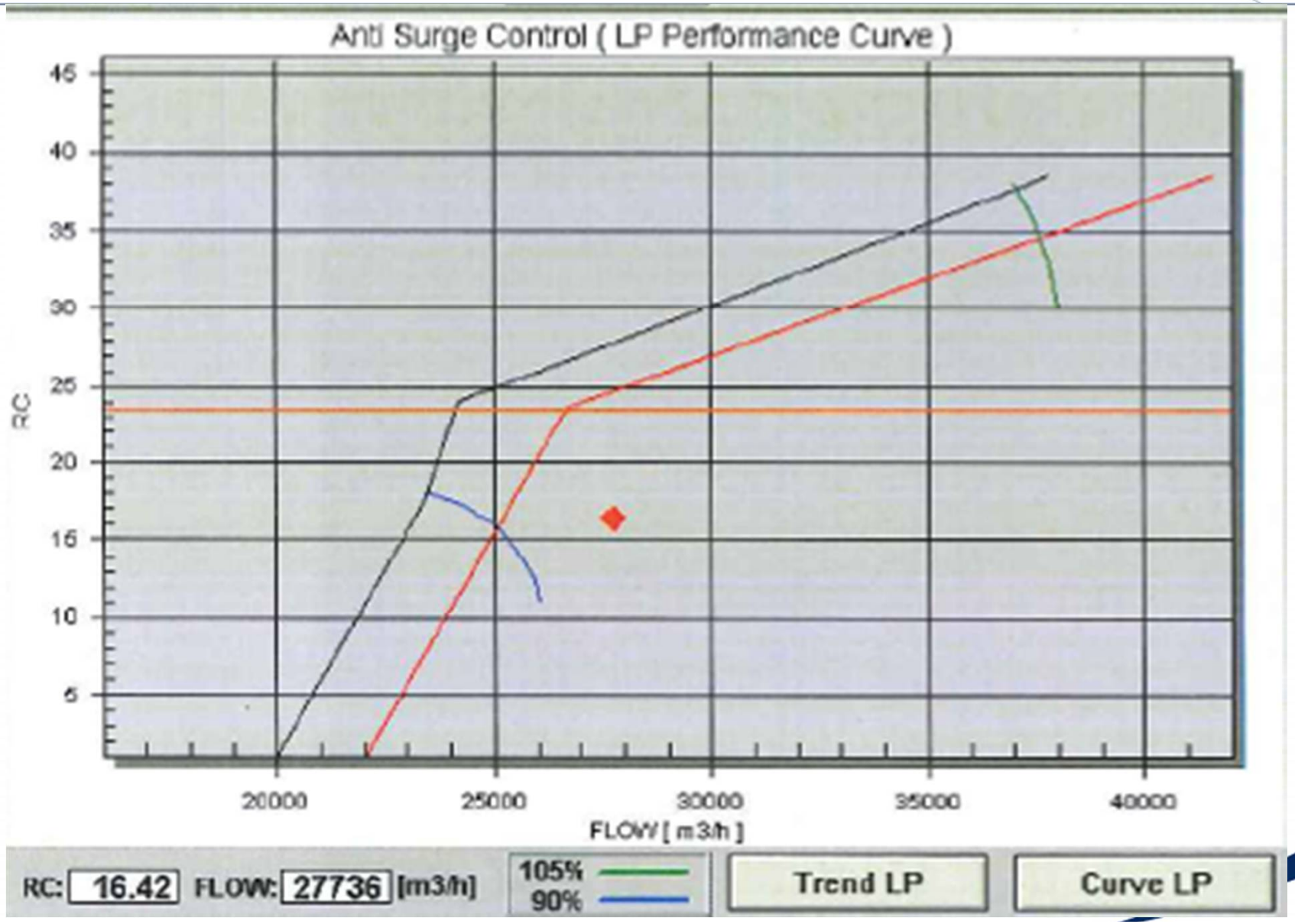
Project Background Information

- A fertilizer plant having a steam turbine-driven CO_2 Compressor with PLC antisurge controls, which tripped whenever there was a process disturbance.
- Compressor Controls Corporation (CCC) surveyed the site, found that LP & HP casing recycle valves were opened ~23% and ~18% respectively (see DCS screenshots next).
- In addition, user purposefully ran excessive CO_2 through the compressor so as to maintain operating points well to right of surge control lines (excessive surge margin) against process disturbances.

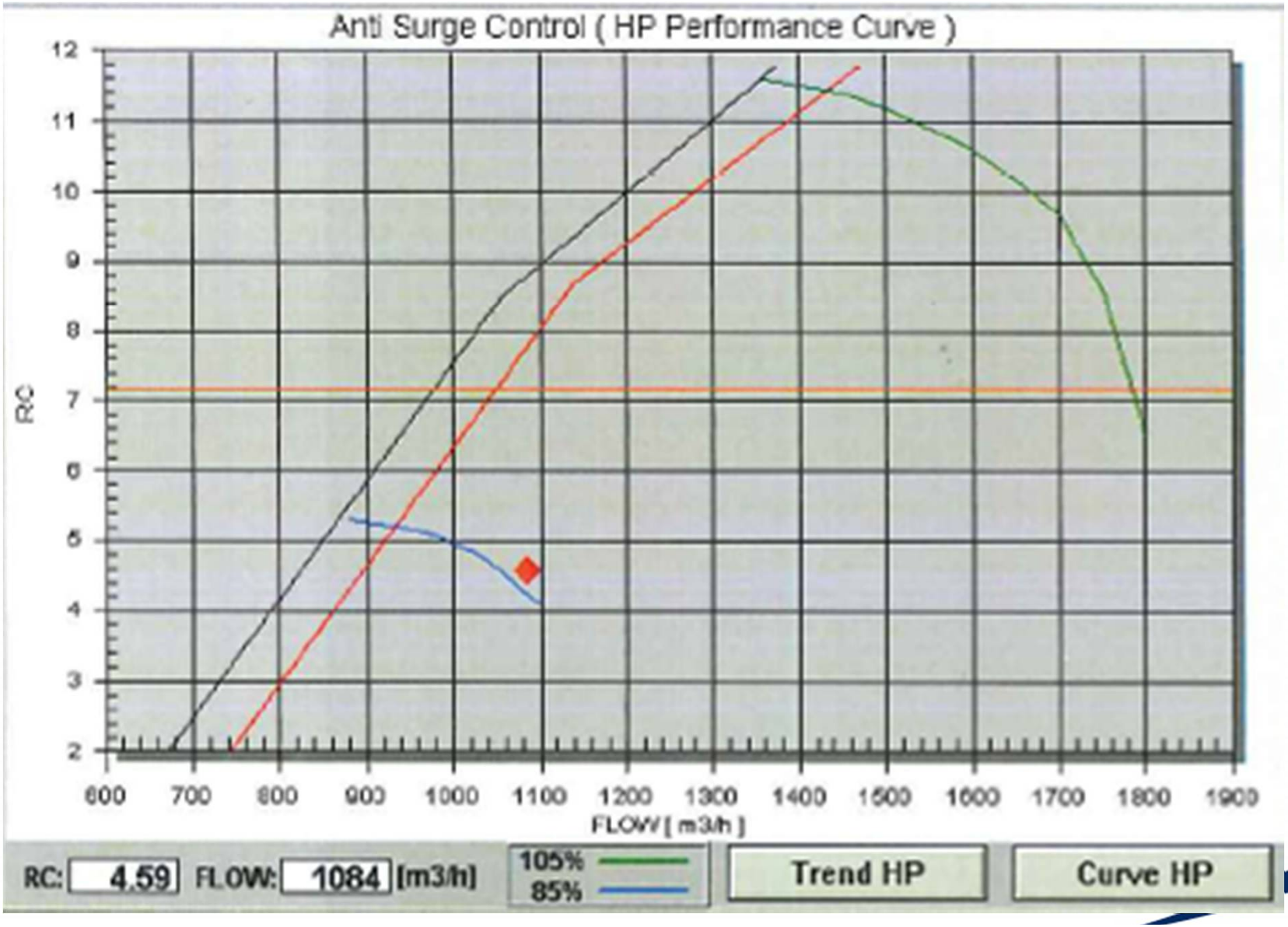
DCS Screenshot – Recycle Valve Openings



DCS Screenshot – LP Compressor Map



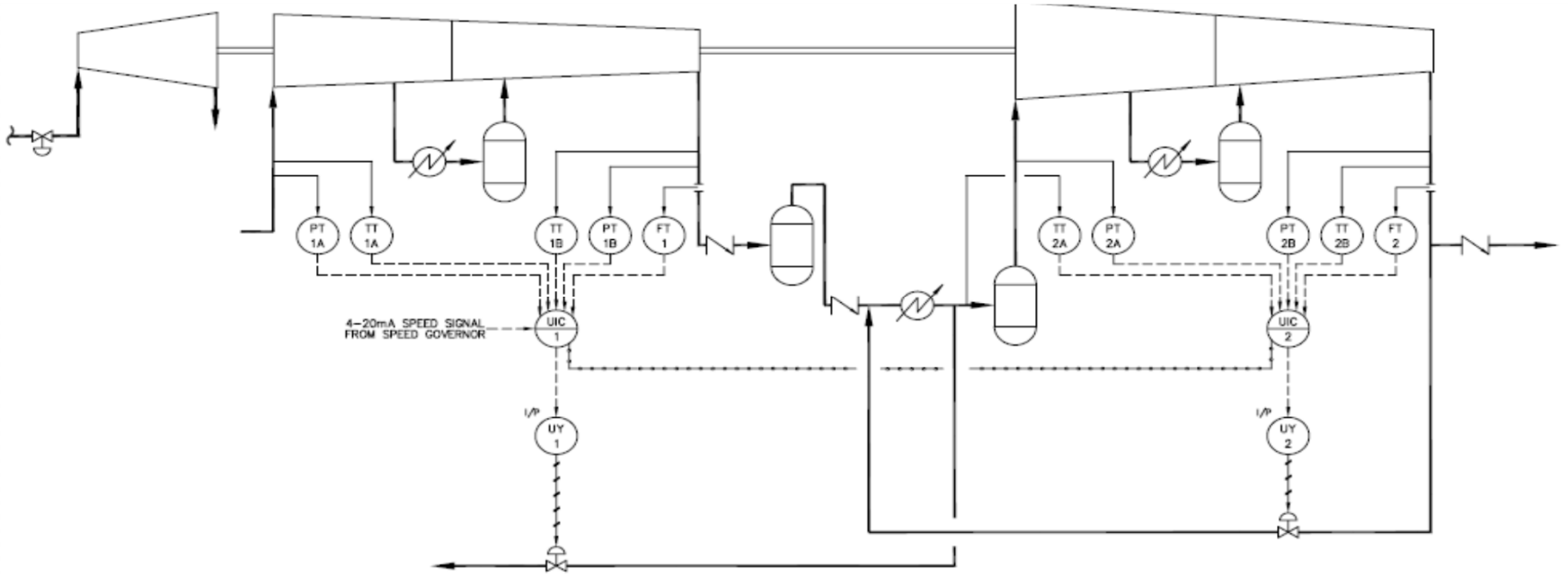
DCS Screenshot – HP Compressor Map



Site Survey Findings #1

Criss-Crossed Recycle Loops

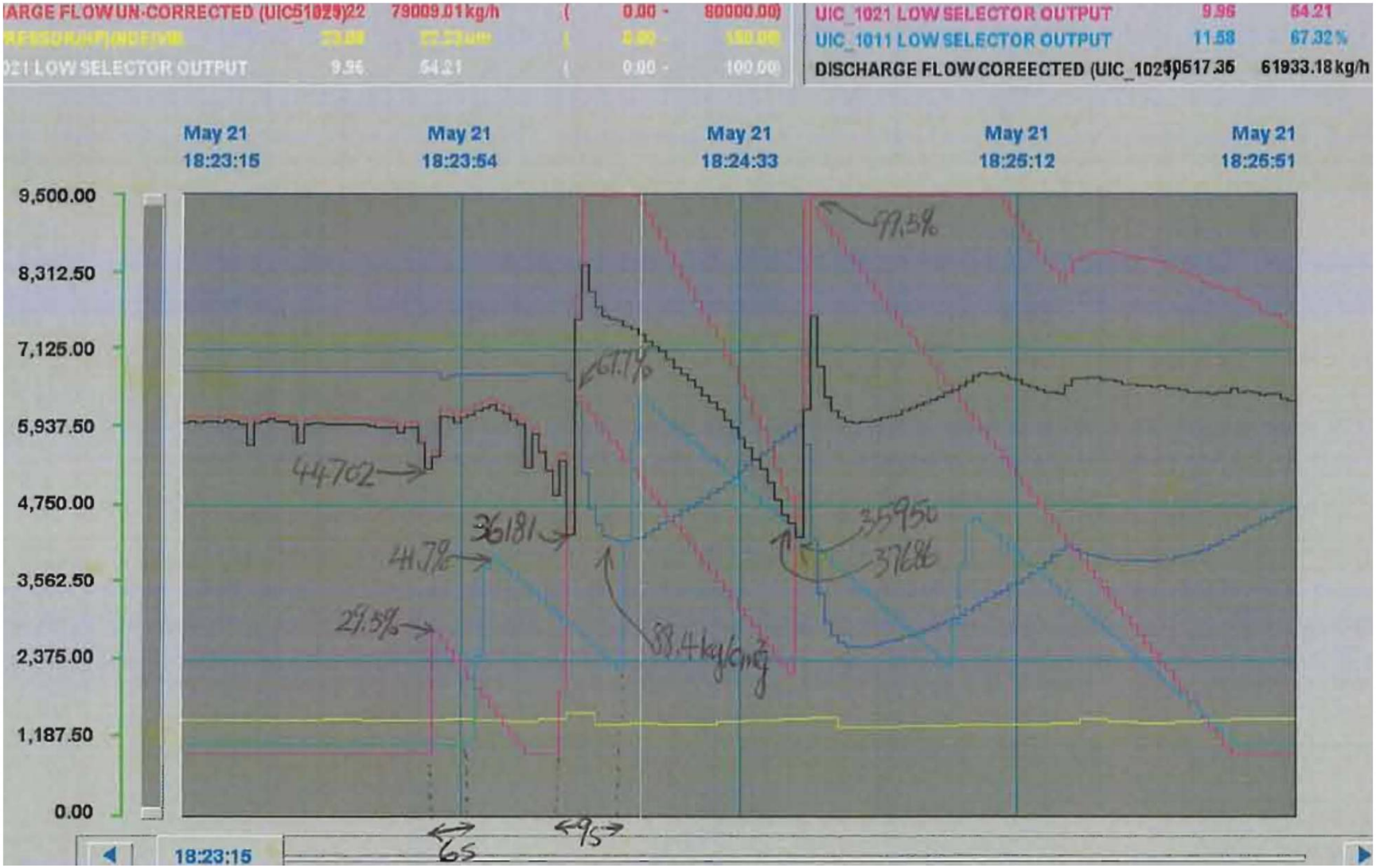
- The two recycle loop criss-crossed each other for sharing the inter-stage cooler between LP & HP casings, which creates a large piping & instrumentation volume for the LP recycle valve to handle and therefore undermines the effectiveness of LP antisurge control.



Other Site Survey Findings

#	Deficiencies	Impact	Remarks
2	Too large antisurge control closed-loop gains	Gains too large for normal operation, yet not high enough to save compressor from surge.	Lack of open-loop antisurge control
3	No position transmitters for recycle valve position feedbacks	Recycle valve position can change without being commanded to do so due to piping or recycle valve vibration.	
4	Oversized recycle valves	Small opening can cause a large flow change, creating control instability.	
5	No coordination between two antisurge control loops	Lead to recycle valve hunting during process disturbance.	

Recycle Valve Hunting



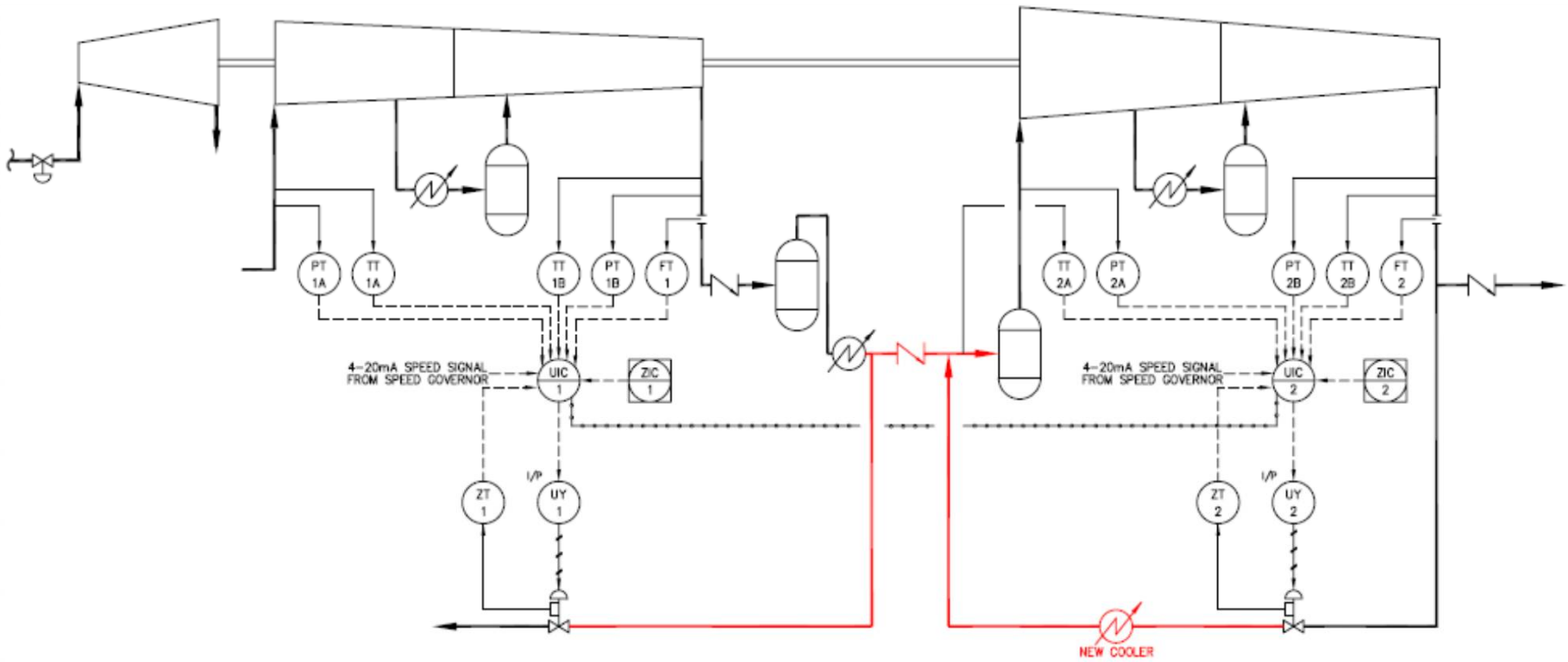
Other Site Survey Findings (Continued)

#	Deficiencies	Impact	Remarks
6	No fallback strategies for transmitter failures	A transmitter failure means control system shutdown.	
7	Low trending resolution in DCS	Difficult to analyze what had happened from the DCS trends.	

Recommendations

Solution to Criss-Crossed Recycle Loops

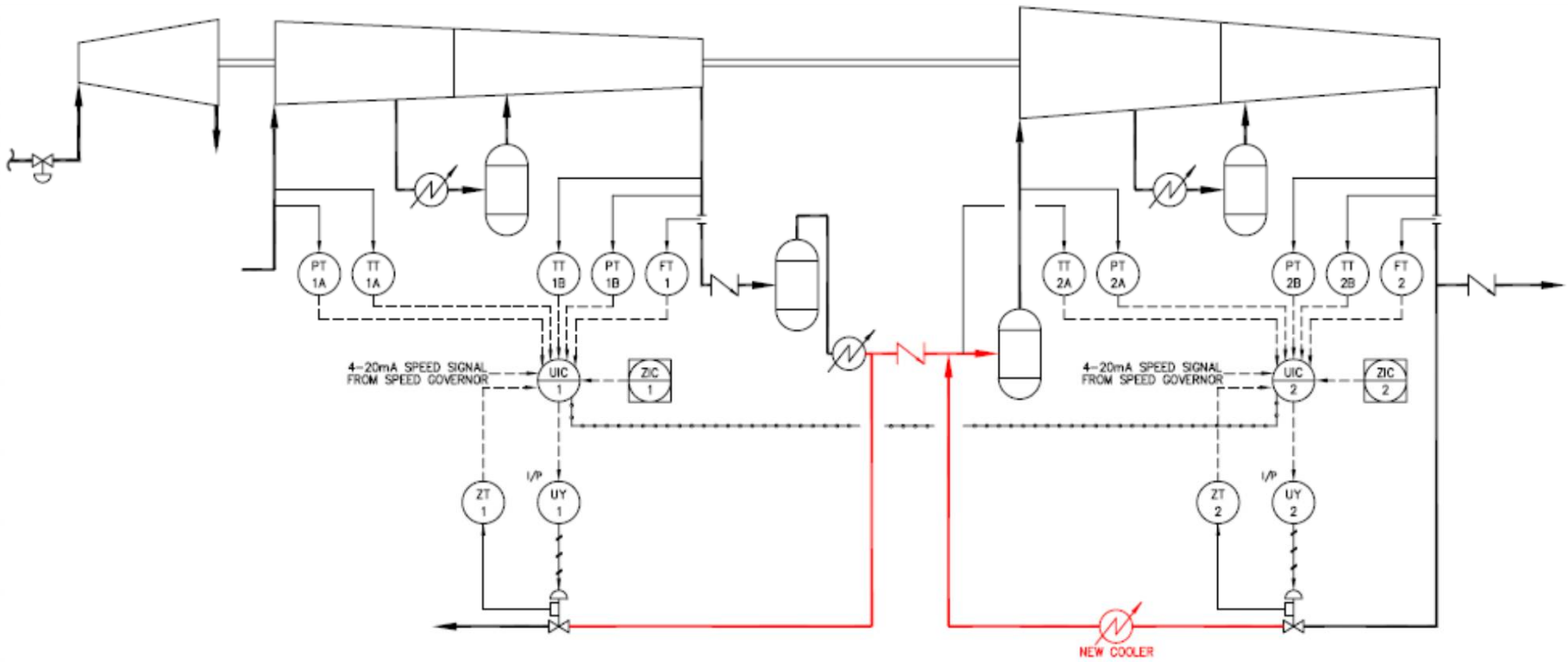
- CCC recommends the criss-crossed recycle loops to be modified to “untangle” the two recycle loops as shown below with an additional new cooler, if possible. The end result is that LP stage antisurge control handles a smaller piping & instrumentation volume.



Recommendations

Solution to Criss-Crossed Recycle Loops

- CCC strongly recommends proper consultation with piping & instrumentation during FEED stage such that in case there is such kind of error, it can be corrected during FEED stage.



Recommendations To Users

#	Recommendations	Impact	Remarks
2	Use dedicated antisurge controls which utilize both closed-loop PI & open-loop algorithms (Too large antisurge control closed-loop gains)	Closed-loop PI response handles the mild process disturbances while open-loop response handles the large process disturbance.	
3	Install recycle valve position transmitters (No position transmitters)	Antisurge controller can correct recycle valve position should there be an error in valve position.	
4	Replace the oversized recycle valves, or fine-tune the dedicated antisurge controllers to partially offset the excessive recycling effect (Oversized recycle valves)	Eliminates or partially offsets excessive recycling.	

Recommendations To User

#	Recommendations	Impact	Remarks
5	Use dedicated antisurge controllers with decoupling function (No coordination between two antisurge control loops)	Coordinated antisurge controls eliminates recycle valve hunting during process disturbance & increases control stability.	
6	Use dedicated antisurge controllers (not a general PLC controller for antisurge controls), which have fallback strategies (No fallback strategies for transmitter failures)	Fallback strategies enable antisurge controllers to operate in a conservative mode during transmitter failure, thus increases control system availability.	

Recommendations To User

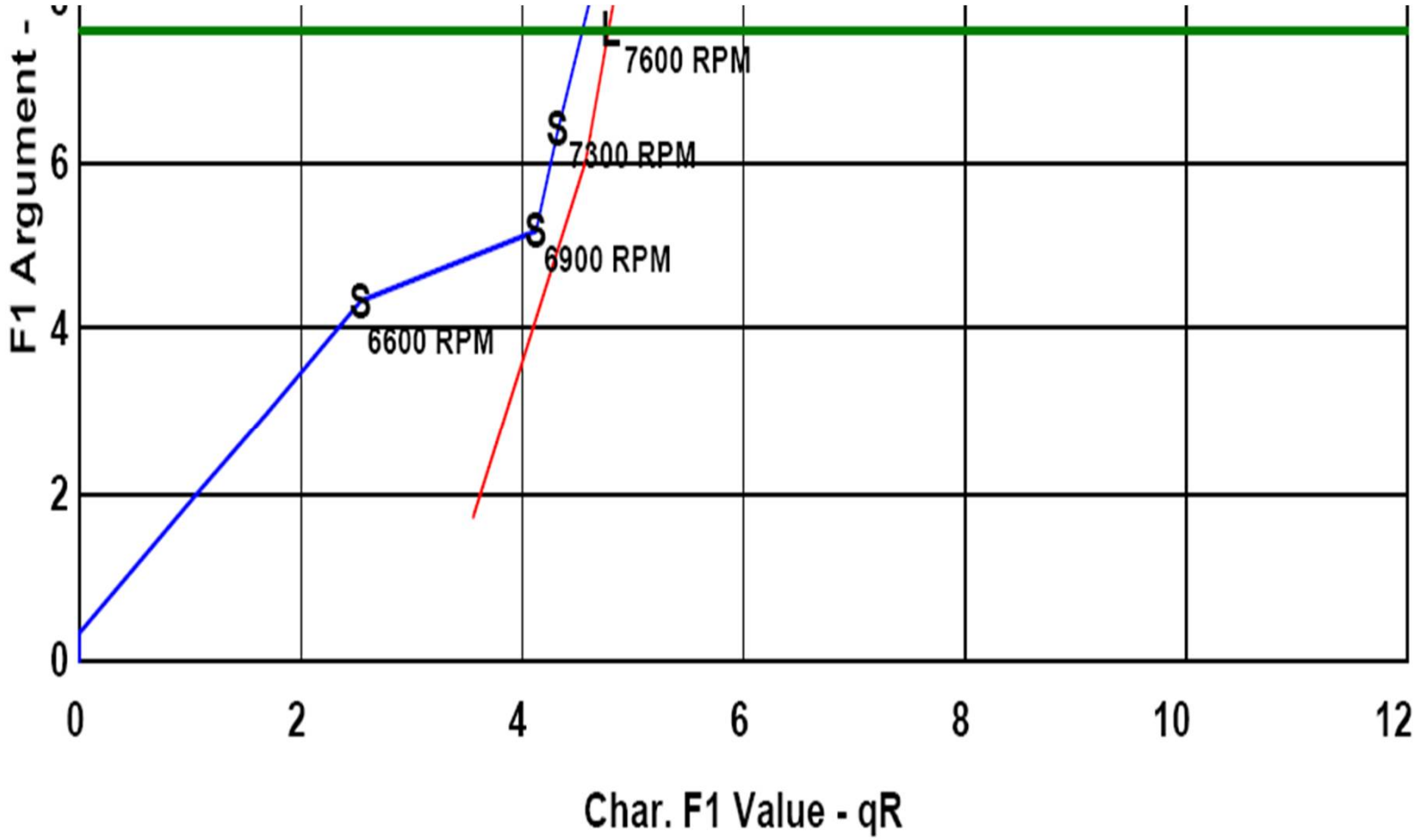
#	Recommendations	Impact	Remarks
7	Install dedicated antisurge control HMI for high speed trending (Low trending resolution in DCS)	High resolution trends empower user to diagnose more easily.	

Solution Implementation

- CCC collected technical information, performed control system engineering and pre-configured two antisurge controllers (one for each casing) in CCC factory.
- CCC Field Service Engineer (FSE) hand-carried the pre-configured antisurge controllers to site, & connected it with field signals.
- CCC FSE surge-tested the compressor in Nov 2015 & found LP & HP casing as-tested surge lines were to the left of OEM's surge lines.
- CCC re-calibrated CCC's antisurge controllers to as-tested surge line & successfully fully closed both LP and HP casing recycle valves.
- Estimated energy savings due to closing of both LP and HP recycle valves to be ~US$488k per year.

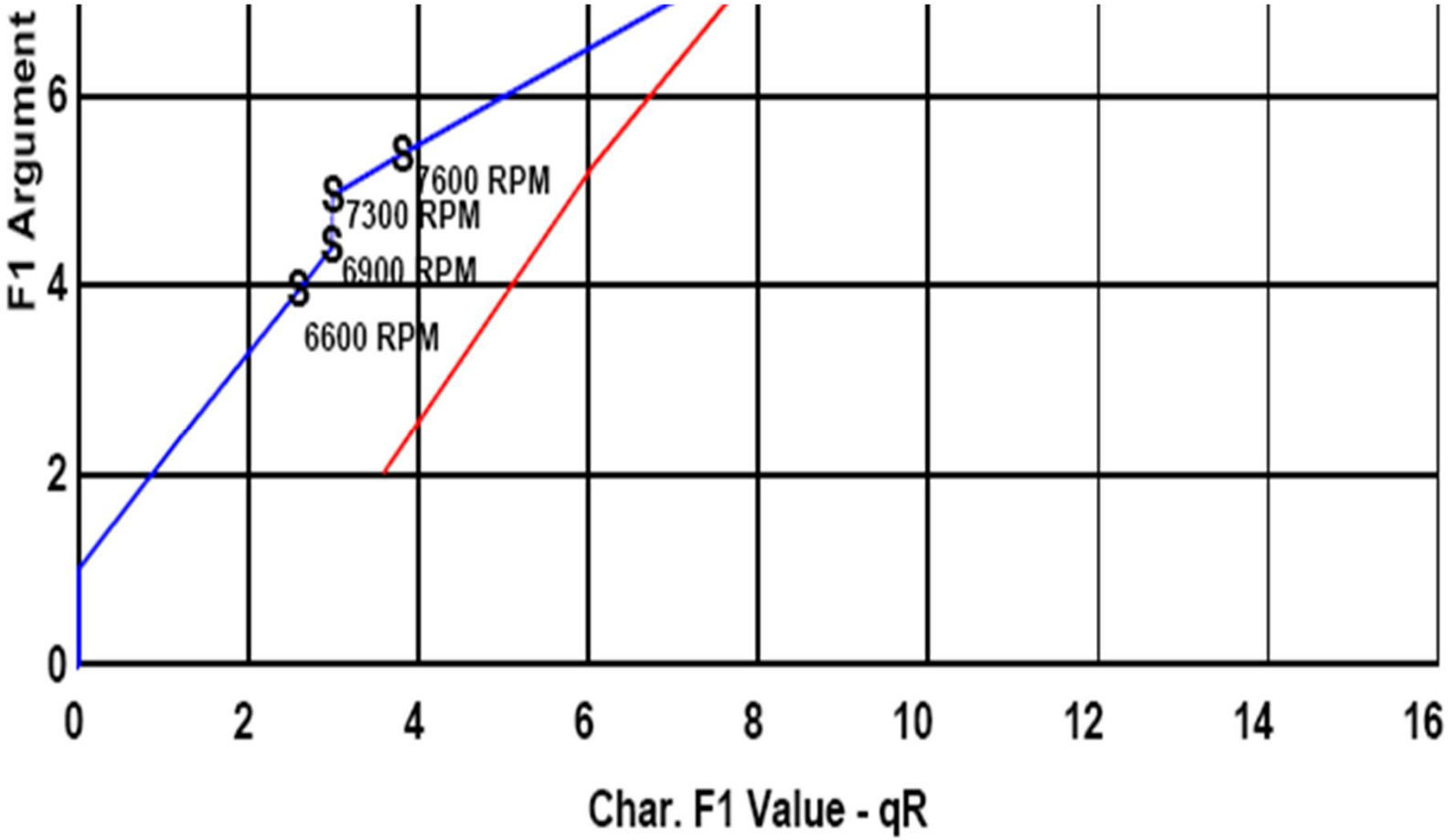
Surge Test Result (LP Stage)

PLC SLL
CCC As-Tested SLL
S = Tested Surge Points
L = Process Limit



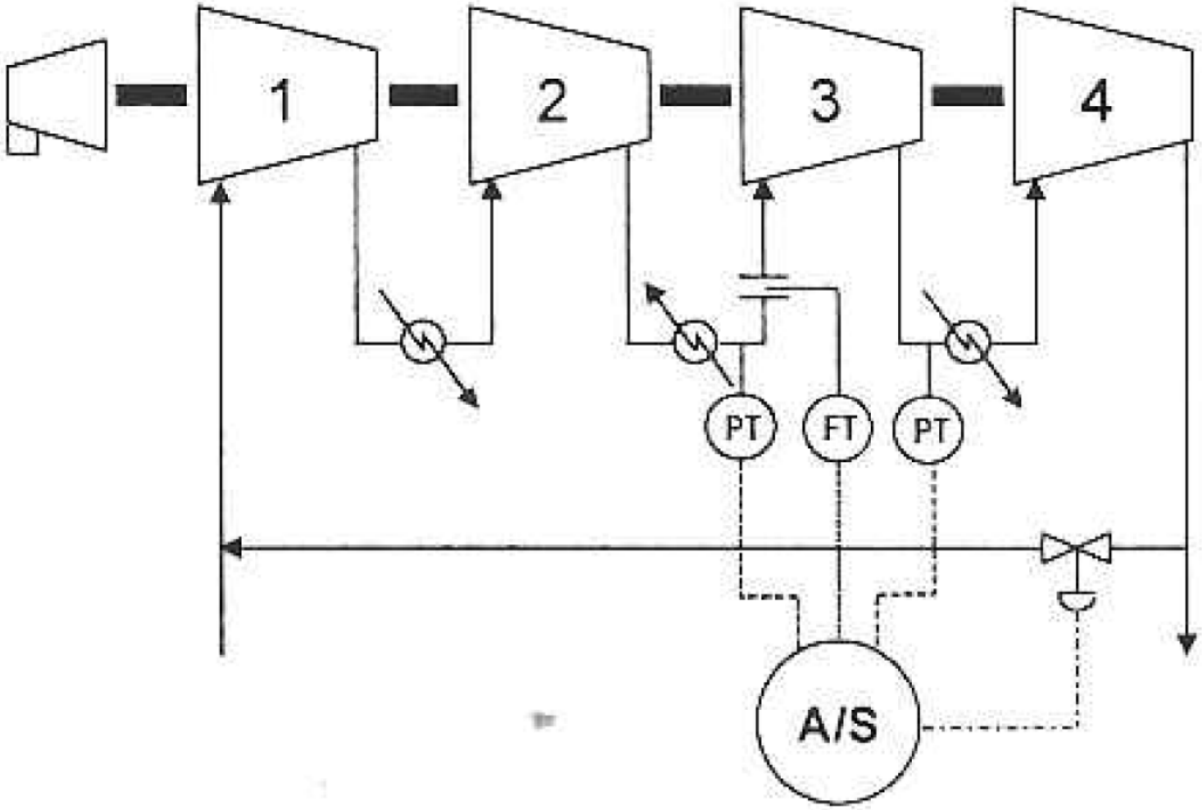
Surge Test Result (HP Stage)

PLC SLL
CCC As-Tested SLL
S = Tested Surge Points



Appendix – One Recycle-Valve Design

- Older CO_2 Compressor design may only have one recycle valve
- Issues of recycle valve freezing due to too high compression ratio (150-180)
- Stage mismatch (1st stage surging while 4th stage choking)
- Solution is to use at least 2 recycle valves (4th stage discharge to 3rd stage suction, & 2nd stage discharge to 1st stage suction) with non-criss-crossed piping



Conclusion

- By having the correct compressor piping & instrumentation design, employing advance compressor antisurge control technologies, coupled with fertilizer plant compressor controls technologies and experience, CCC can improve compressor control stability, cut down energy waste and maximize profits.
- Compressor energy savings can be achieved by reducing recycling and expanding compressor operating envelope.
- CO_2 compressor needs to have at least 2 recycle valves due to high compression ratio.
- CCC offers site survey & consultation services for your turbomachinery controls need.