Compressor Failures due to CO_2 Corrosion

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Objective

- To present failures that occurred with compressors in different production platforms offshore Brazil, due to the presence of CO_2 in process gas.
- To present the actions taken to recover the damages and minimize the corrosion effects.
- To present some references about CO_2 corrosion criteria.

Introduction

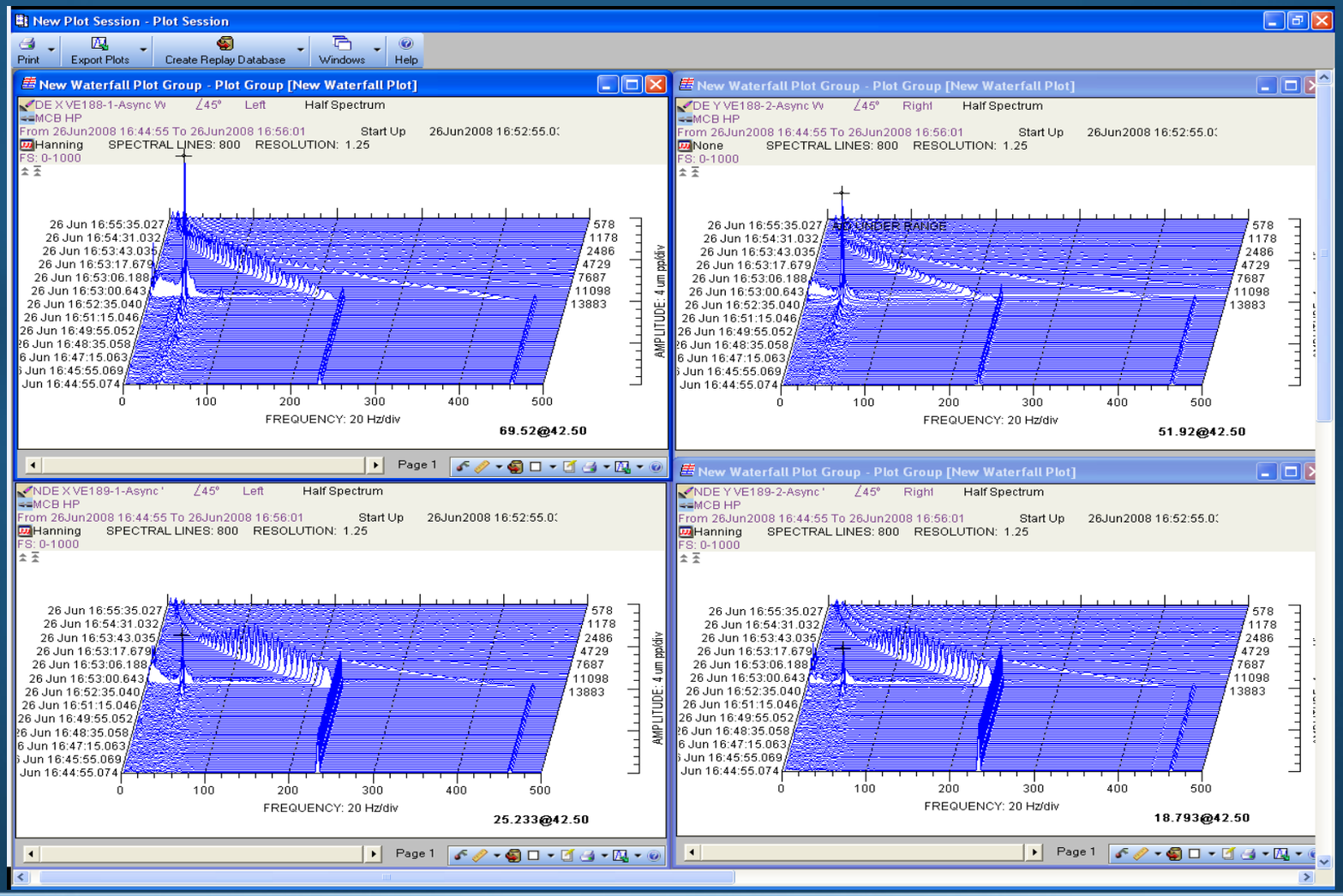
- Theses failures occurred in different production rigs such as P-50, P-51 and P-54.
- The compressors suffered internal damage due to the formation of carbonic acid in unfavourable process conditions.
- The damage found was slightly different on each platform due to specific design characteristics, such as the presence or not of guiding vanes and different manufacturers.

Compressor Description – P-50

- Three 2,000,000 SCMD compression trains installed in a 180,000 bpd FPSO (in operation since April 2006).
- Three stage compressor trains, consisting of a *back-to-back* LP and a *straight-through* HP compressors.
- Amine plant, individual for each train, in between LP and HP compressors for CO_2 capture.
- Degradation in question occurred in a single train (last to enter in operation, in February 2007), due to prolonged unavailability of its associated amine plant.

Compressor Description – P-50

- Between March and July 2008, high pressure compressor C showed high vibration levels during start-ups.
- Further investigation of the event by the Technical Support team found an unstable, rapidly increasing, sub-synchronous vibration in the 40-45 Hz range.
- During this period, in which it failure, a performance monitoring routine was not yet implemented.
- The vibration was diagnosed as an aerodynamic instability.



Compressor Description – P-50

- The HP bundle was removed and sent to the turbomachinery workshop for inspection and posterior repair.
- When disassembled in the workshop, the cause of the aerodynamic instability was clear: severe material loss and deposits in both inlet and diffuser vanes of the first stage and impeller.

Compressor Description – P-50

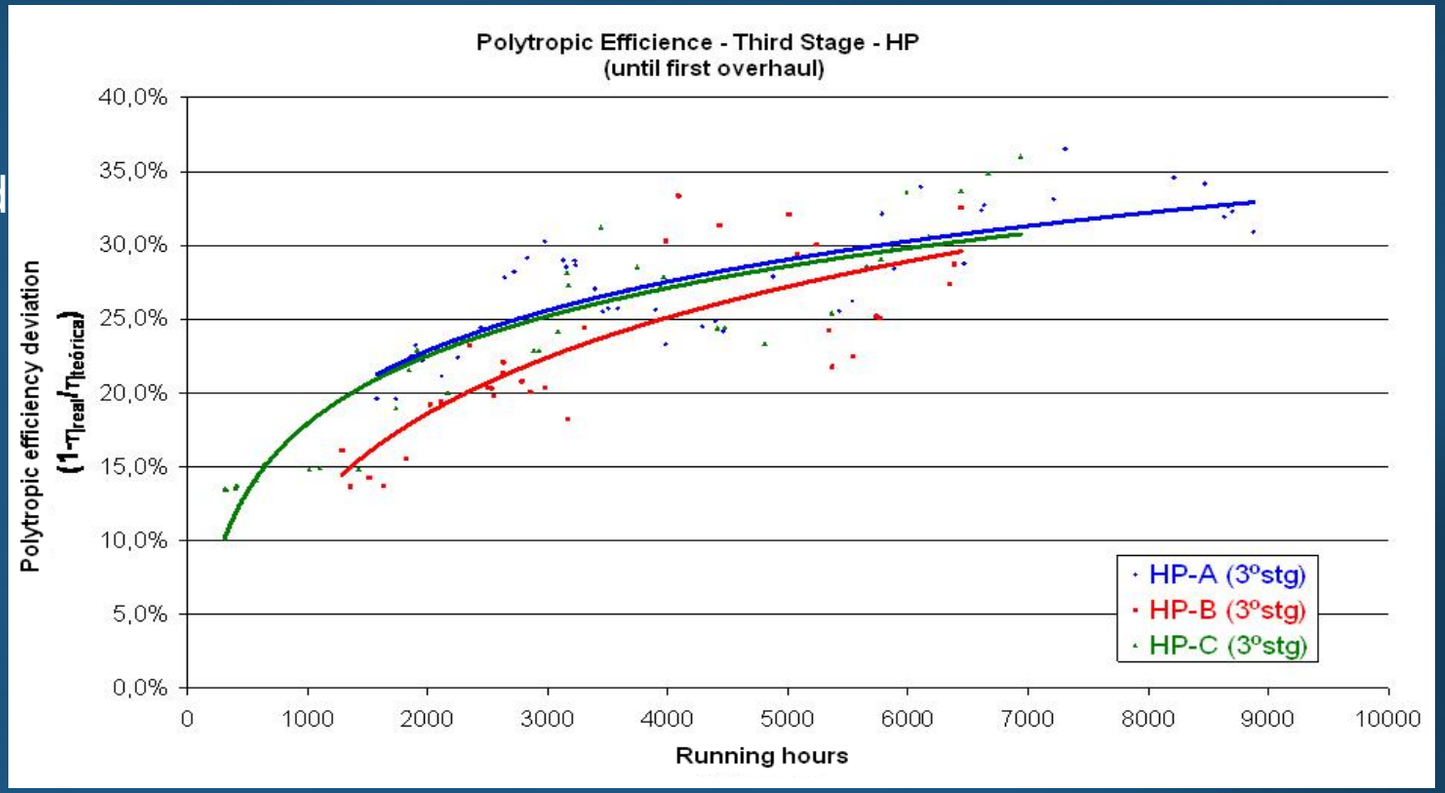
- Repair/replacement of the damaged bundle components took place at operator turbomachinery workshop.
- The inlet guide vanes were rebuilt, the inlet labyrinths and all other consumables were replaced.
- The bundle was reassembled in the compressor and returned to operation.

Compressor Description – P-51

- Three 2,000,000 SCMD compression trains installed in a 180,000 bpd semi submersible platform (in operation since May 2008).
- Three stage compressor trains, consisting of a *straight-through* LP and a *back-to-back* HP compressors.
- Degradation in question occurred in the last compression stage in all three compression trains.

Compressor Description – P-51

- After six month of compressor operation, it was observed a continuous and marked reduction in polytropic efficiency only in the high pressure compressor.
- No high vibration was observed



- In order to restore the design efficiency, HP bundles were disassembled and sent to turbomachinery workshop for inspection and repair.
- Corroded areas were found at both casing and bundle, and heavy deposits at first diffuser and impeller.
- The corrosion product was analyzed and confirmed that the corrosion was due to the presence of CO_2 (Siderite – $FeCO_3$).

Compressor Description – P-51

Corrosion on casing and counter-casing and deposit on first impeller and diffuser

Compressor Description – P-51

- Corrective and mitigation action were carried out to minimize the issue such as: completion of suction lines thermal insulation; review of the scrubbers design; and provision for a corrosion inhibitor system.

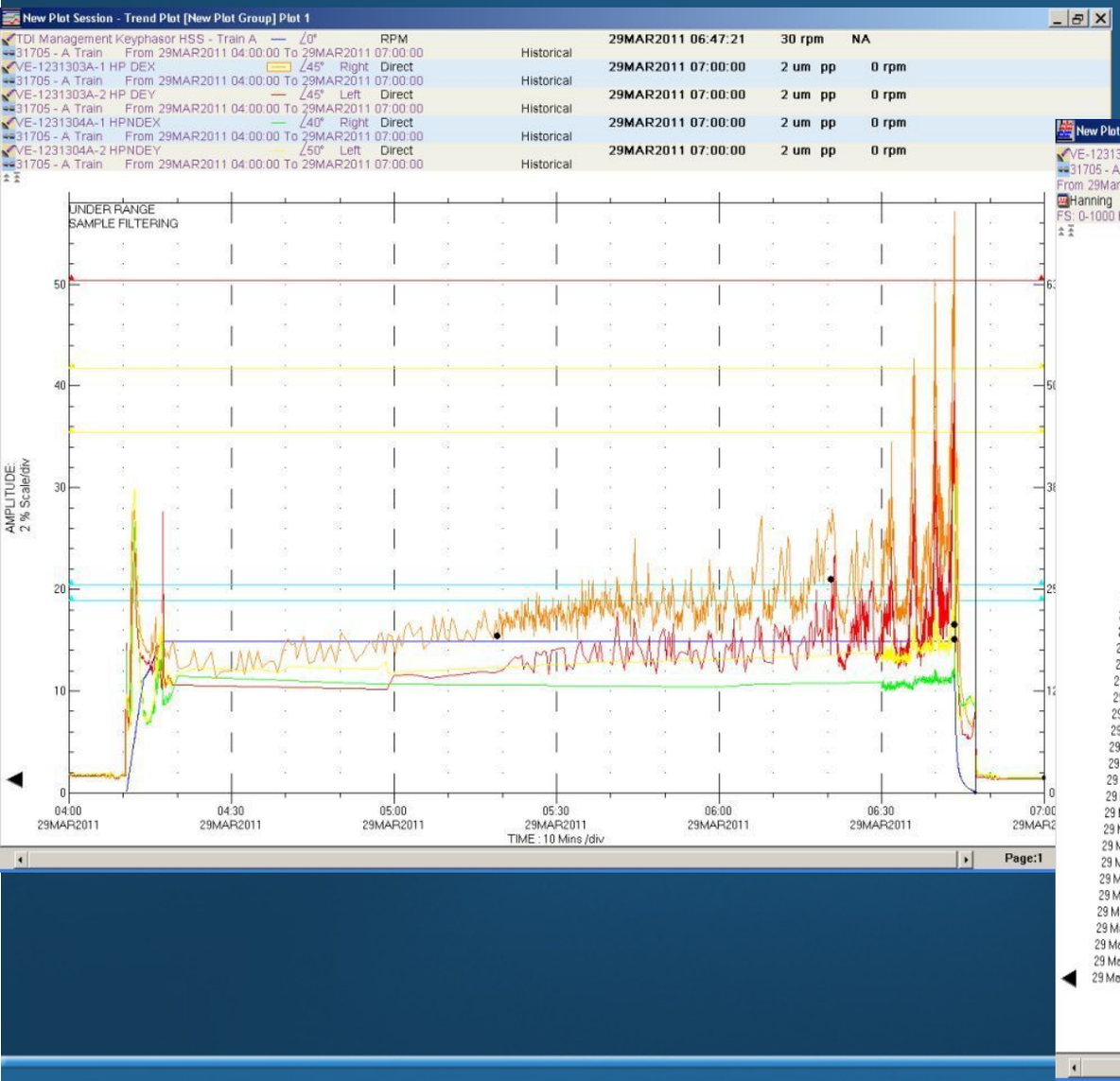
- The chosen action, in agreement with the manufacturer, was to implement an electroless nickel plating on the compressor (casing, counter-casing and first diaphragm) and to superheat the gas at stage suction.

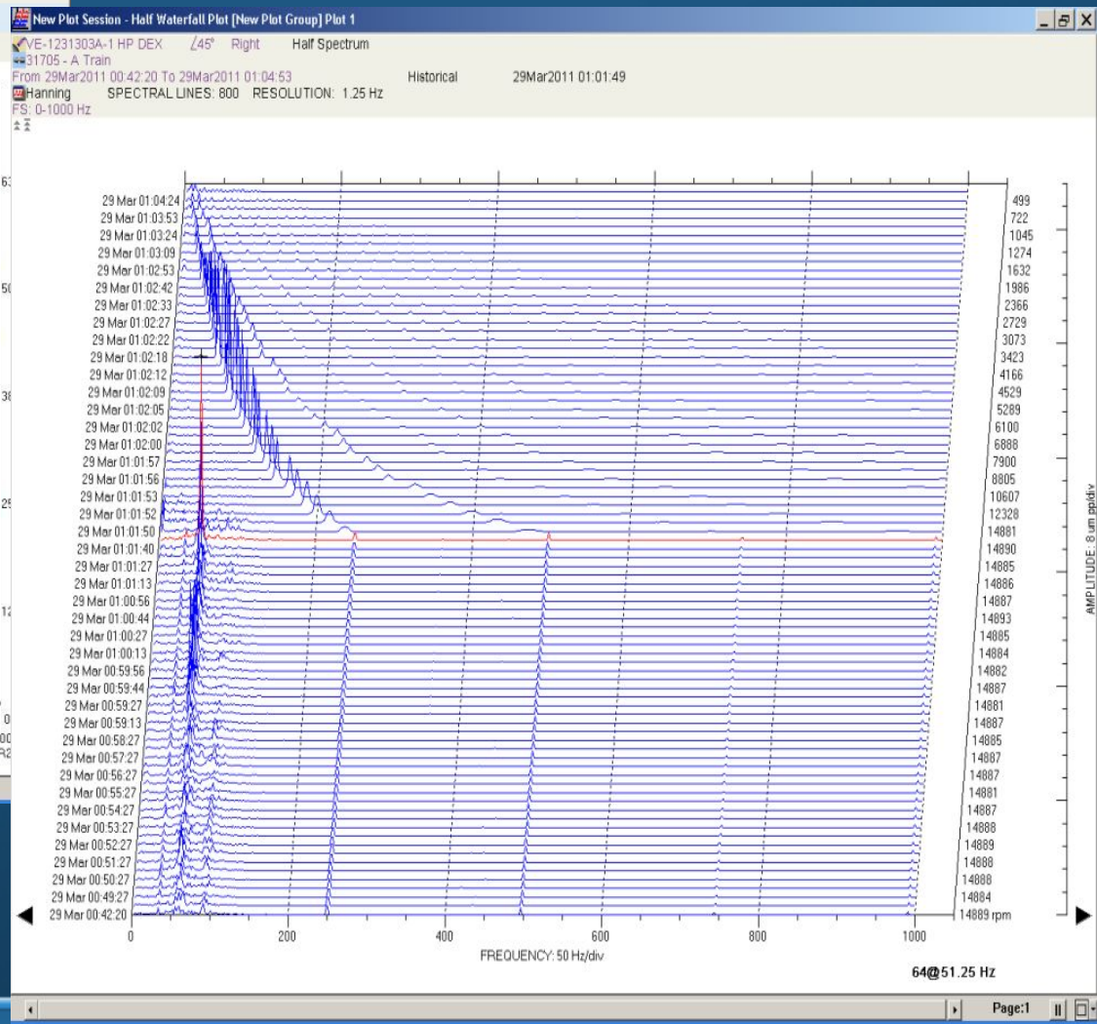
Compressor Description – P-54

- Three 2,000,000 SCMD compression trains installed in a 180,000 bpd FPSO (in operation since Nov/ 2007).
- Three stage compressor trains, consisted of a *back-to-back* LP and a *straight-through* HP compressors.
- A deep degradation in question occurred in all three HP compressors.

Compressor Description – P-54

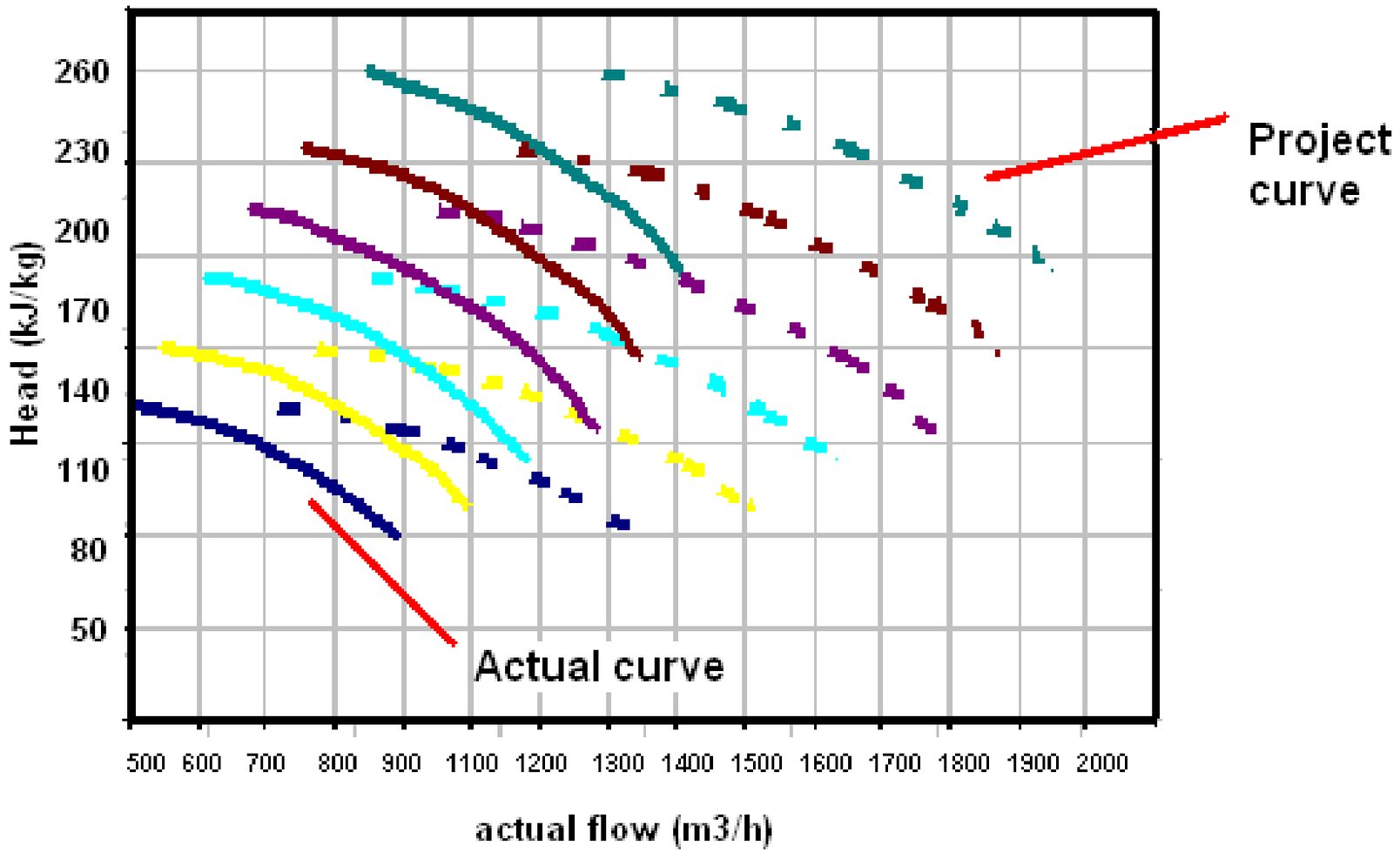
- At the beginning of 2011, HP compressor A faced several trips due to high vibration during normal operation.
- Further investigation of the event by the Technical Support team found an unstable, rapidly increasing, sub-synchronous vibration in the 45-50 Hz range.





Compressor Description – P-54

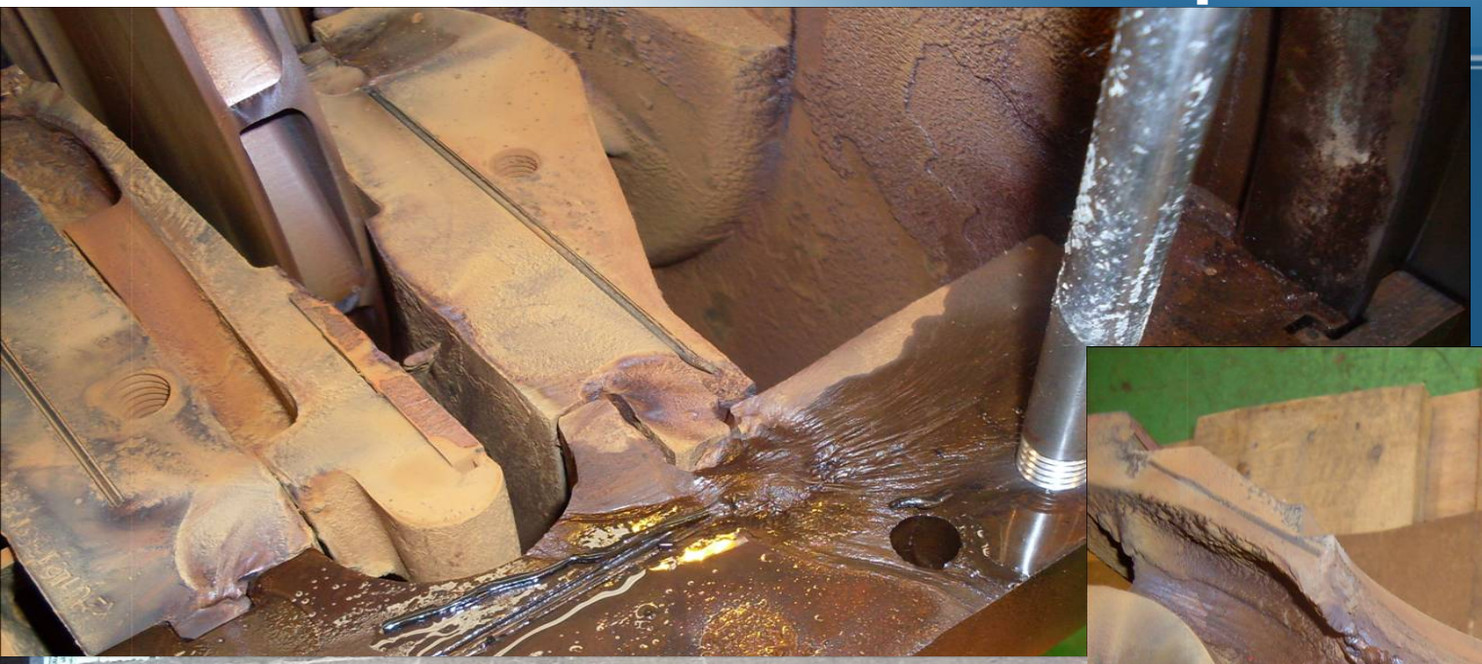
- It was also observed a reduction in both head and polytropic efficiency.



Compressor Description – P-54

- In order to restore the design efficiency, HP bundle was disassembled and sent to turbomachinery workshop for inspection and repair.
- Corroded areas were found at both casing, IGV and diaphragm, and erosion at first, second and third diaphragm.
- The corrosion product was analyzed and confirmed that the corrosion was due to the presence of CO_2 (Siderite – $FeCO_3$).

Compressor Description – P-54



Corrosion and erosion on counter-casing as well as inlet wall

Compressor Description – P-54

- Repair/replacement/cleaning of the bundle components took place at operator turbomachinery workshop.
- The first inlet guide vanes, labyrinths and consumables were replaced.
- Final solution is under analysis. Two possibilities are being considered: same coating solution used in P-51 or new components entirely manufactured in material resistant to CO_2 corrosion.

Discussion

- All of the components had failure mode associated with CO_2 attack.
- All of the failed components were manufactured with carbon steel or low alloy steel.

Components	P-50	P-51	P-54
Casing	ASTM A266 CL4	ASTM A350 LF3	ASTM A266 CL4
IGV	ASTM A36	--	ASTM A36
Counter-casing	--	ASTM A182 F22	--
Diaphragm	ASTM A36	ASTM A350 LF2	ASTM A36

Discussion

- API Specification 6A (Specification for Wellhead and Christmas Tree Equipment)

Retained Funds	Relative Corrosivity	Partial Pressure of CO_2 (psia)	(MPa)
General Service	noncorrosive	<7	(<.05)
General Service	slightly corrosive	7 to 30	(.05 to .21)
General Service	moderately to highly corrosive	>30	(>.21)
Sour Service	noncorrosive	<7	(<.05)
Sour Service	slightly corrosive	7 to 30	(.05 to .21)
Sour Service	moderately to highly corrosive	>30	(>.21)

Discussion

- User has an internal standard for monitoring, interpretation and corrosion control in pipes, which combines CO_2 partial pressure, gas velocity and temperature to classify relative corrosivity. The CO_2 partial pressure limit in the internal standard is close to the API Spec 6A limit.

Conclusion

- The analysis of the compressor internal materials should be more careful in the design phase.
- For the compressor materials specification, if the process gas composition has CO_2 and H_2O, manufacture shall consider plant ineficiencies, such as scrubber liquid carry-over and pressure/temperature loss in pipings. Compressor non running, cold and pressurized conditions should also be considered.
- API 6A – 7^{th} Edition- November,1999 is a good reference for CO_2 corrosion criteria and material selections.

Conclusion

- As a rule of thumb to protect the compressor from CO_2 corrosion, for upstream service the gas should be considered saturated with water and all surfaces in contact with wet process gas should be protected.
- Gas should be considered wet if its temperature is lower than 10°C above its dew point.
- The compressor failures were detected through different way, which shows that the condition monitoring of machine should have different diagnostics tools.

Questions / Contact

- Questions?

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