

# Hydrate Occurrence in Centrifugal Compressor Systems

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# Hydrate Occurrence in Centrifugal Compressor Systems

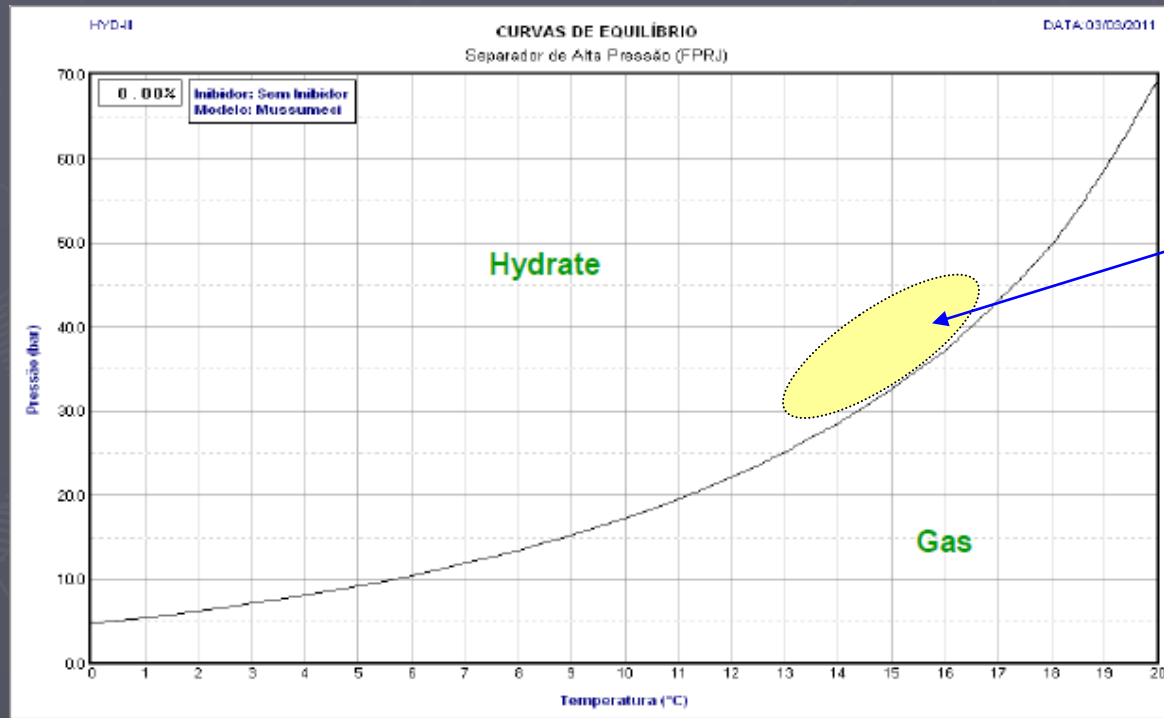
- Hydrates are composed of water and light hydrocarbons in a solid matrix that resembles ice. They are formed at low temperatures such as downstream of throttling a high pressure, saturated gas across a control valve.
- Hydrate formation is not easily detectable in compressor systems because instrumentation and protective controls are not normally provided for this purpose.
- Hydrate leaves no trace, when systems are examined for the potential cause, the temperature and pressure are normally at ambient conditions and the hydrates have evaporated.
- Control strategies should be developed and devices should be provided to detect and avoid damaging hydrate formation in compressor systems.
- There have been a number of compressor repairs required where the root cause of failure has not been clearly identified.

# Hydrate Occurrence in Centrifugal Compressor Systems

## Hydrates Envelope

-Hydrate composition is basically water and methane. Other compounds may occur in quantities no greater than 2 %.

Natural Gas Hydrate  
Equilibrium Curve

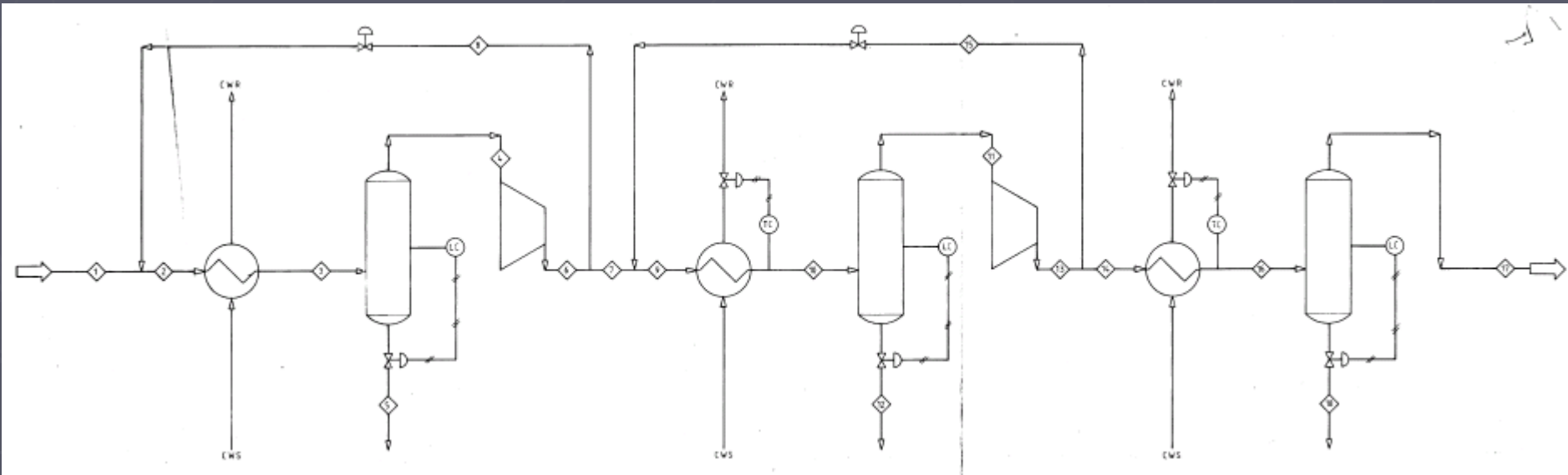


Most common area of  
hydrate formation  
observed

Courtesy of Petrobras

# Hydrate Occurrence in Centrifugal Compressor Systems

## Compressor Train Configuration

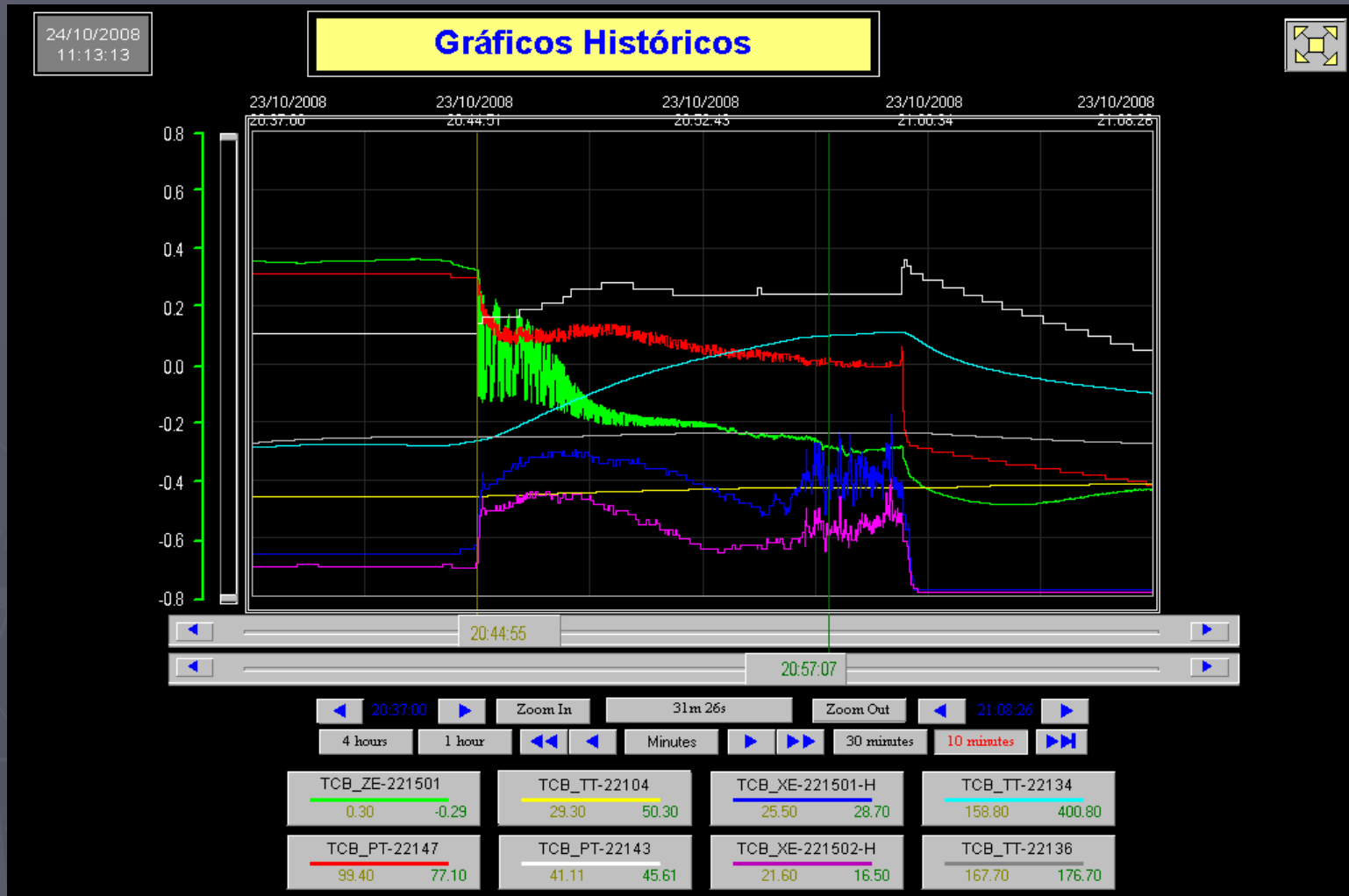


# Hydrate Occurrence in Centrifugal Compressor Systems

## Brief history of compressor failure:

- Compressor was re-started after maintenance activity completed at 20:44 hours.
- Field operator went to visually inspect compressor shortly after start-up and noted smoke coming from discharge piping.
- Operator returned to control room and noted the HP unit discharge temperature was 734 F.
- Operator notified maintenance team. By the time the maintenance personnel arrived to the control room, the compressor discharge had risen to 932 F.
- Compressor was shut down at 20:59 hours.
- A re-start was attempted but was unsuccessful because the rotor was locked.

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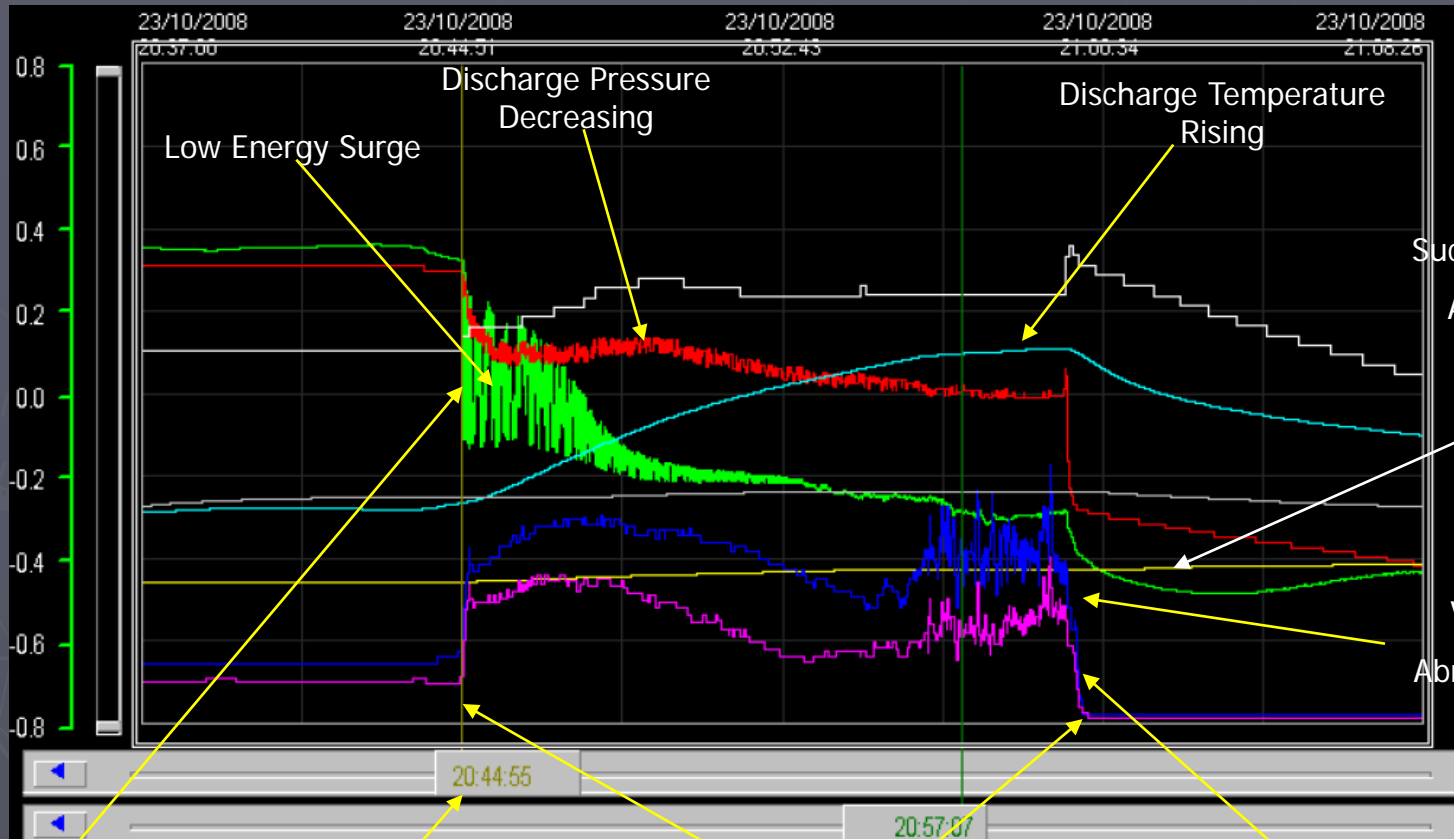


█ ZE-221501 – HP Axial Displacement  
█ PT-22147 – HP Discharge Pressure  
█ TT-22104 – HP Suction Temperature  
  PT-22143 – HP Suction Pressure

█ XE-221501-H – HP NDE Vibration Horizontal  
█ XE-221502-H – HP DE Vibration Horizontal  
█ TT-22134 – HP Discharge Temperature  
█ TT 22136 – LP Discharge Temperature

# Hydrate Occurrence in Centrifugal Compressor Systems

## Event Trend Analysis



Shaft Axial Displacement  
High Frequency

Event Beginning  
20:44 hours

Event Total Time 15 minutes

Compressor Stopped  
20:59 hours

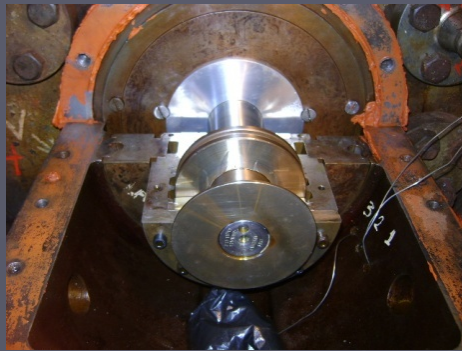
Suction Temperature  
Almost Constant  
But 30% Lower

Vibration with  
Abnormal Behavior



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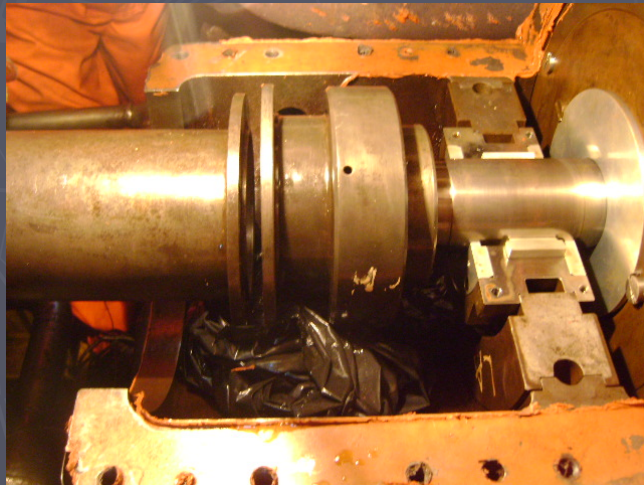
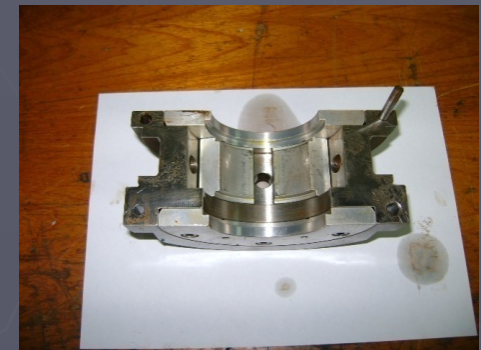
## Compressor Internals Inspection



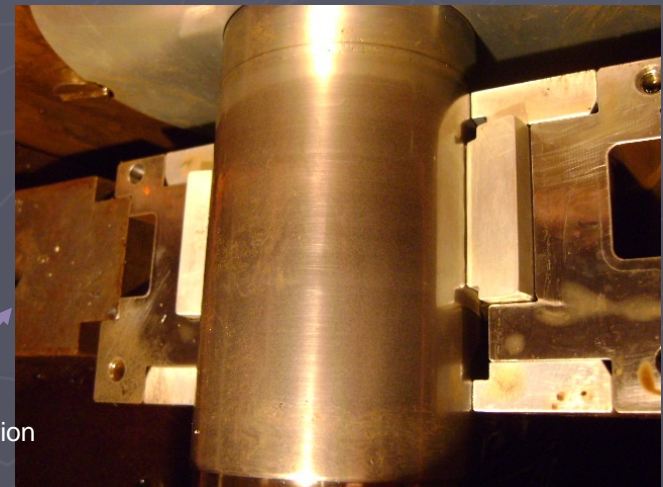
HP Shaft Thrust Bearing End



HP Thrust and Radial Bearing  
No Visible Damage



Radial Bearing Shaft Position  
No Visible Damage



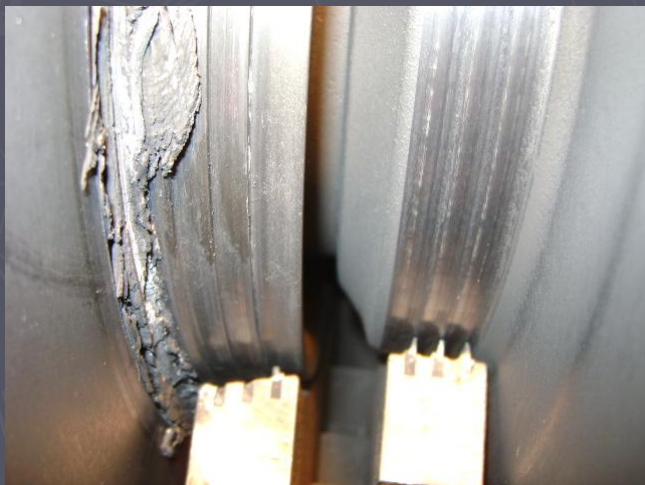
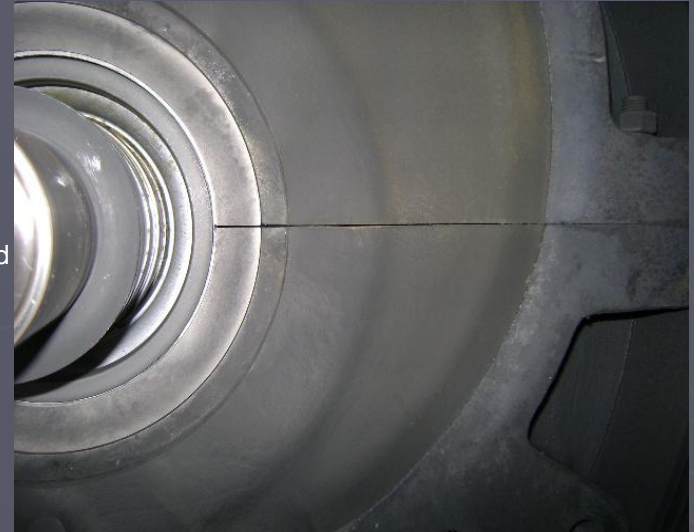


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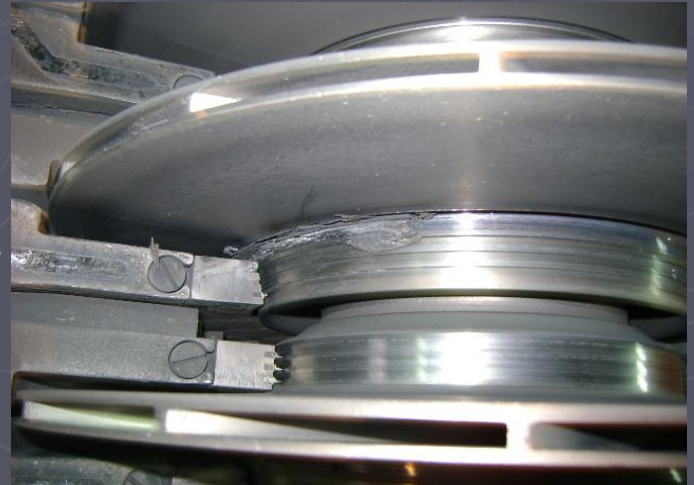
## Compressor Internals Inspection



Diaphragms Deformed



Labyrinth Seals  
Melted and Impellers  
Damaged



# Hydrate Occurrence in Centrifugal Compressor Systems

## Compressor Internals Inspection



In general, the damage was caused by high temperature estimated to be approximately 1,112 F (600 C)

# Hydrate Occurrence in Centrifugal Compressor Systems

Hydrate formation in the suction side of a compressor may result in the following:

- Reduction in suction temperature.
- Reduction in discharge pressure.
- Reduction in compressor flow.
- Low energy surge (the most dangerous event).
- Increase in discharge temperature.

# Hydrate Occurrence in Centrifugal Compressor Systems

## Why didn't the Protection System work properly?

- Failure of high discharge temperature switch.
- Pneumatic Anti-Surge Detector didn't work in presence of low energy surge.
- Anti-Surge Control System did not include any fallback strategies for instrument failure.
- Vibration not high enough to activate vibration shutdown.
- Surge condition not possible to be recognized by Operators.
- Low suction temperature control not implemented.



# Hydrate Occurrence in Centrifugal Compressor Systems

## How Can Hydrate Formation Be Prevented

- Maintain operation within the design range.
- Provide active suction temperature control with existing coolers.
- Provide low suction temperature alarm when operation approaches the border of hydrate envelope.
- Use process transmitters instead of switches to improve process control reliability and reduce failure potential.
- Review surge control system control strategies including fallback (or instrument failure) strategies.



# Hydrate Occurrence in Centrifugal Compressor Systems

## Where Are Hydrates Commonly Found

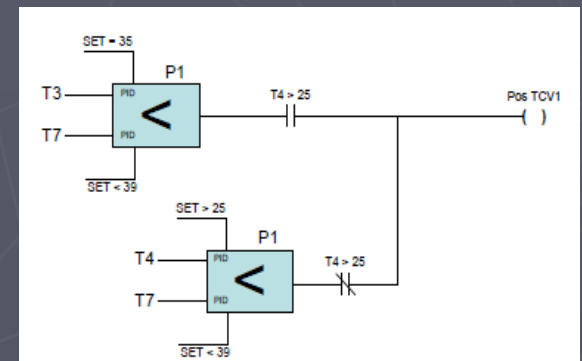
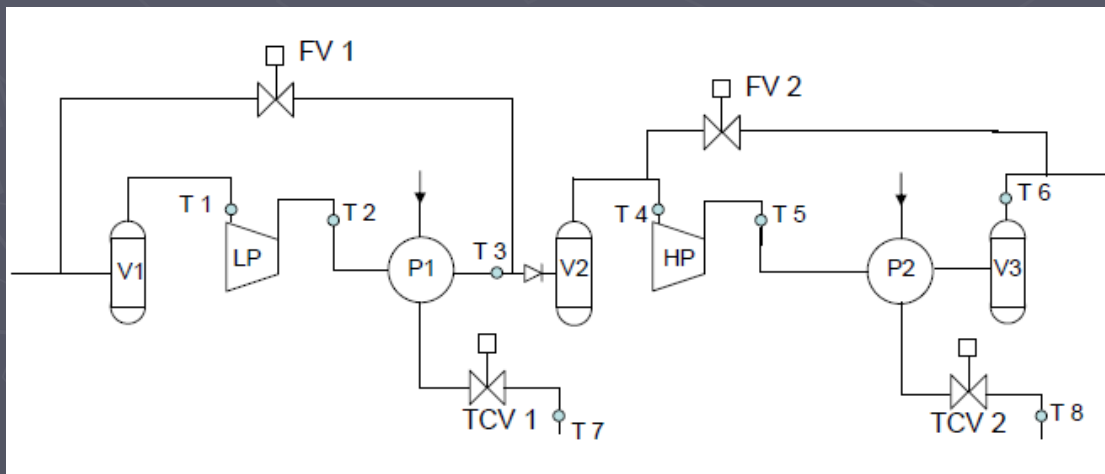
- Upstream oil & gas primary separation facilities where water saturated gas may be processed.
- Suction permanent and temporary filters.
- Anti-Surge loop piping, upstream and downstream of compressor control valves, depending upon pressure and temperature.
- Balance line in back-to-back compressor designs.

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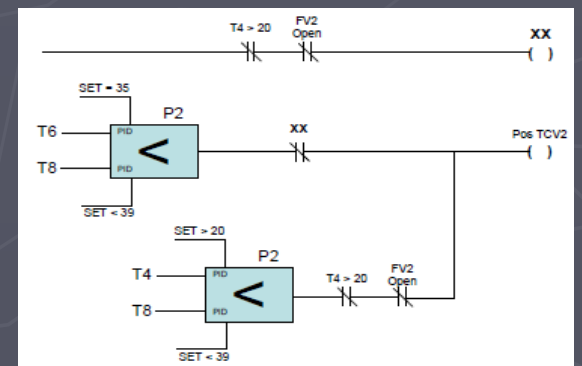
## Three Final Recommendations

1 - Spend time during the engineering phase to avoid layout mistakes. After installation any required changes are much more difficult and costly, if not impossible, to achieve.

2 – Use cooler control logic as illustrated to enhance suction temperature control system.



Temperature Logic Control for Cooler P1



Temperature Logic Control for Cooler P2

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## Third and Last Recommendation

In case of potentially unsafe operating conditions combined with an unknown control systems strategy, use ODCCPL logic inserted at PLC as described below:

► If compressor RPM  $\Rightarrow$  90%; Flow  $\leq$  20%; Time  $>$  10 seconds;  
Then Shutdown. Signaling in the control panel: Suction low flow or blocked Suction.

ODCCPL means: Orlando Donda Centrifugal Compressors Protection Logic.

# Hydrate Occurrence in Centrifugal Compressor Systems

The End.

Thank You.

