R&M Technology

Unexpected Hazard of Switching into a Close Drum Isolation Valve

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Refining & Logistics

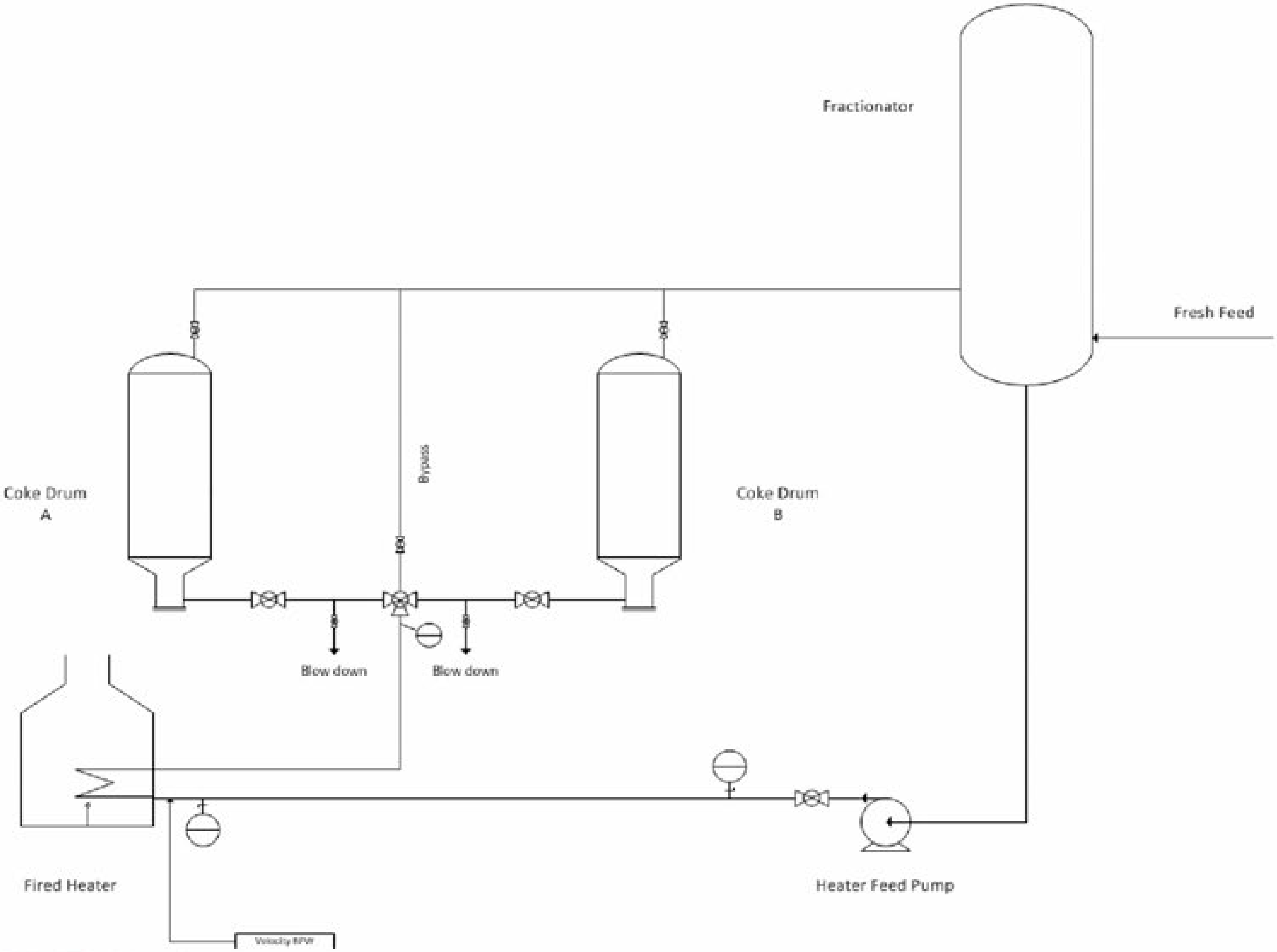
Summary of Incident

- Switched into a closed inlet isolation valve (SP-6)
  - Coupling between valve actuator and valve failed
  - Interlock was based on position indication of actuator
- Heater transfer line pressured up and flange at switch valve began to leak
  - This leak caught fire immediately
  - Many of the flanges in the transfer line between the heater and the switch valve leaked
- Loss of hydrocarbon flow tripped the burners off
- High pressure on the transfer line prevented the switch valve from moving to bypass position

Incident Summary - continued

- Drain line between switch valve and inlet isolation was used to depressurize line to the blow down system
  - As pressure decreased the leaks stopped
  - Once the pressure was down the switch valve could be moved to the bypass position
- As the pressure decreased, the velocity media (BFW in this case) began to flow
- During the incident the heater feed pump was shut down remotely. The discharge block valve was shut remotely a short time later
- System had been blocked in for approximately 35 minutes
- There were no injuries associated with this event

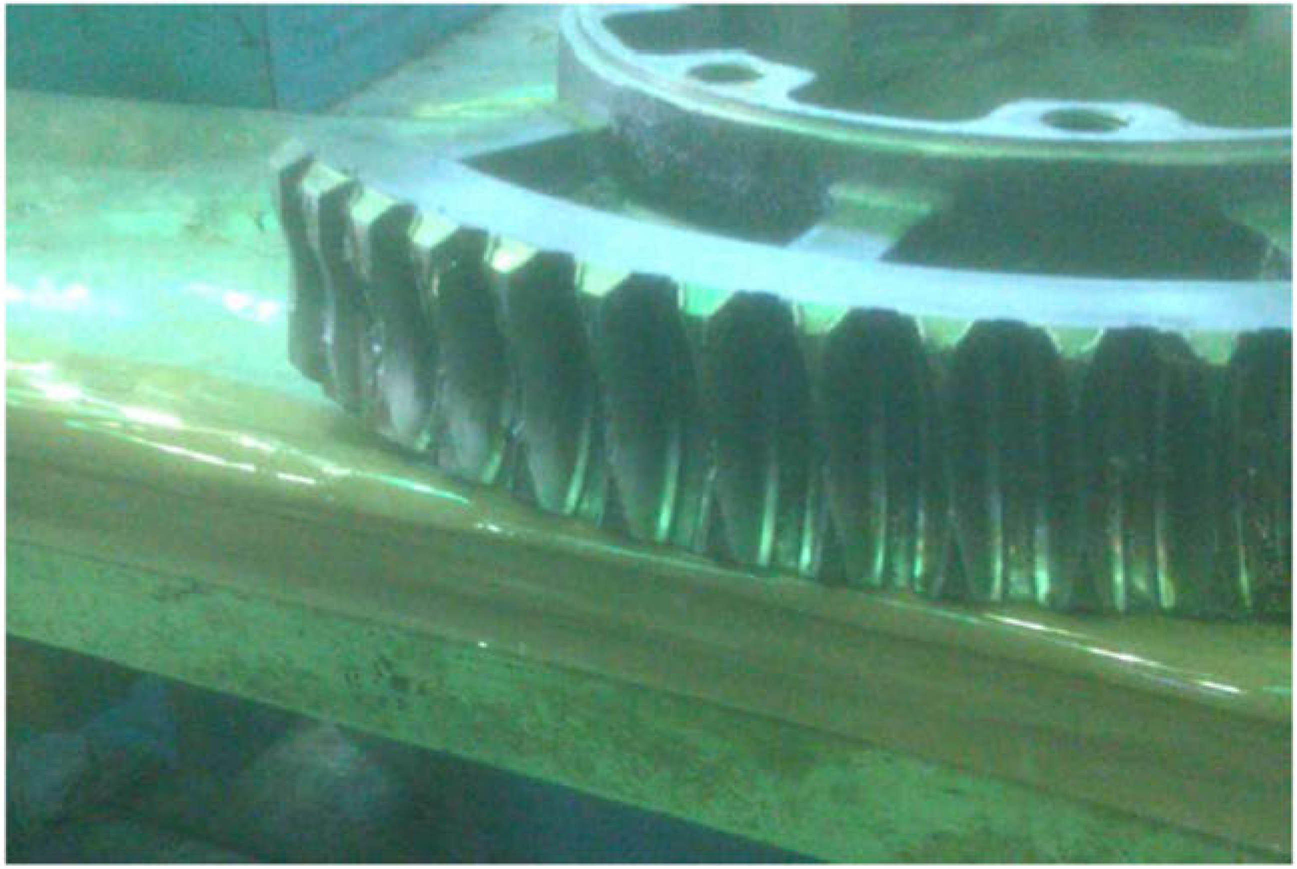
Sketch of Heater Feed System



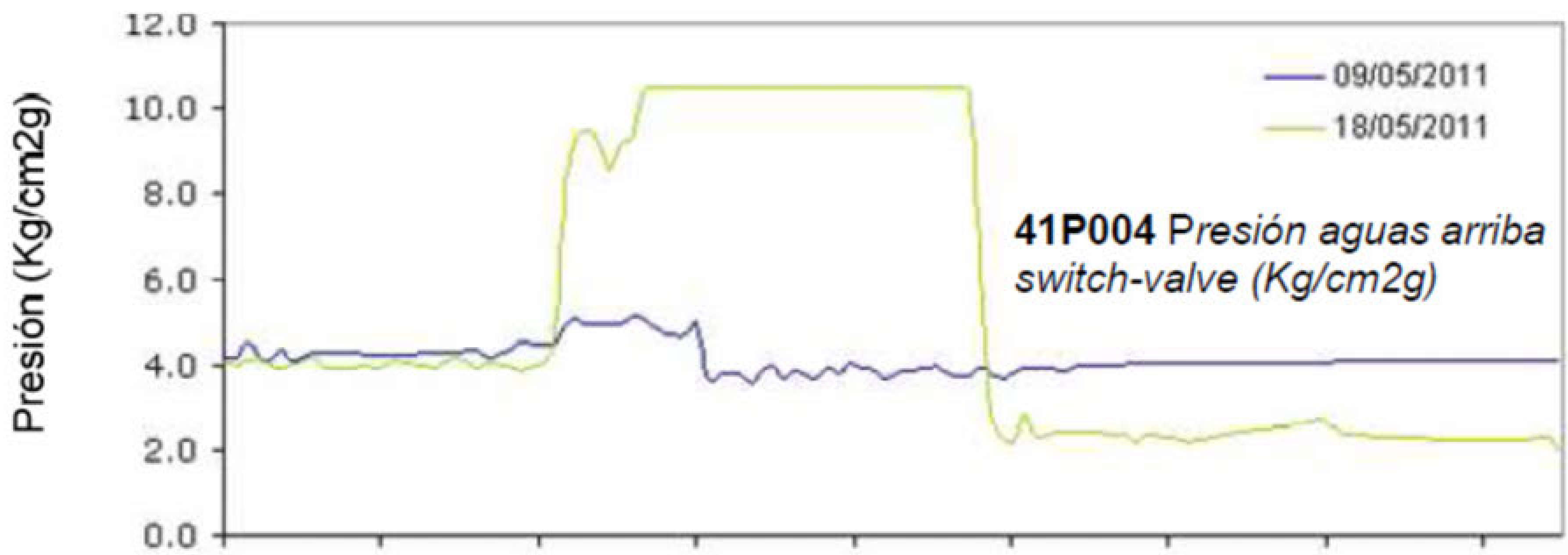
Events leading up to the Incident

- Initial start-up of this unit was Feb 2009
- Inlet isolation valve involved in incident required more torque to turn starting May 2010, one year prior to the incident
  - Site had been in contact with valve manufacturer. Had increased the available torque from the actuator to move valve
  - In Aug 2010, a pneumatic assist was used to get the valve to close as the actuator was not always able to close the valve. Limited the air pressure to 70 psig.
  - March 2011 the actuator had the gears replaced as they were severely worn due to the excessive force required to close the valve
- Steam purges for this valve came from steam generated on site from the HCGO steam generator

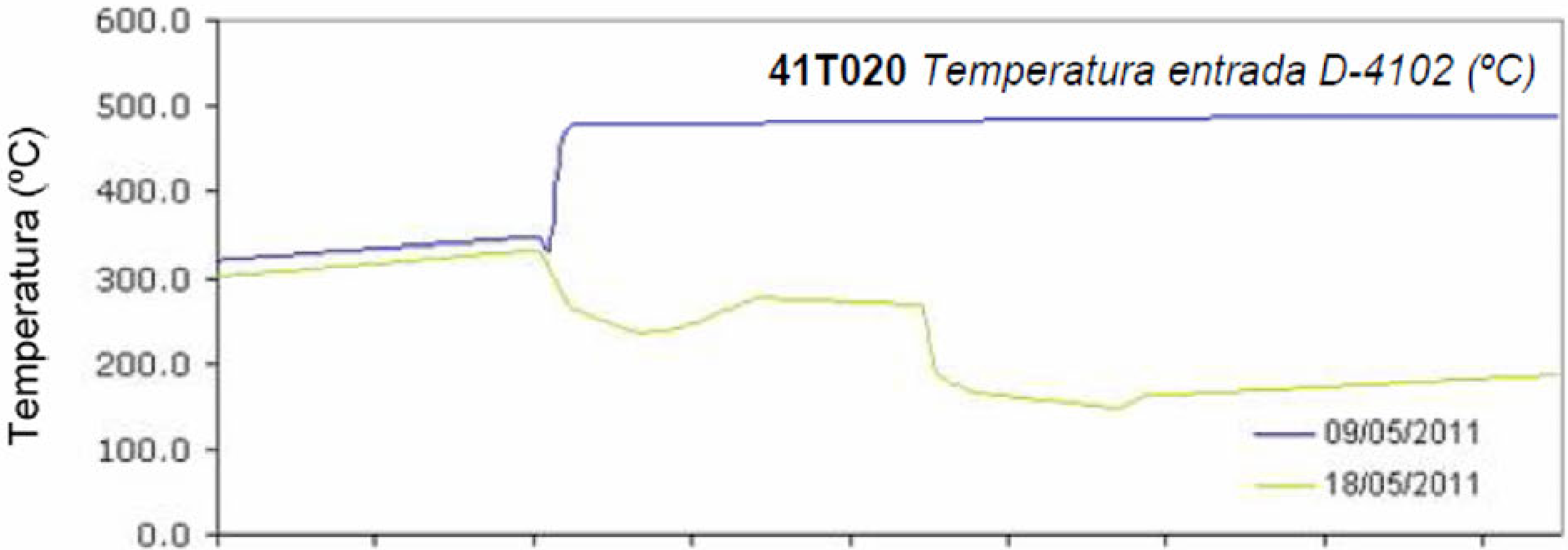
Actuator gear wear



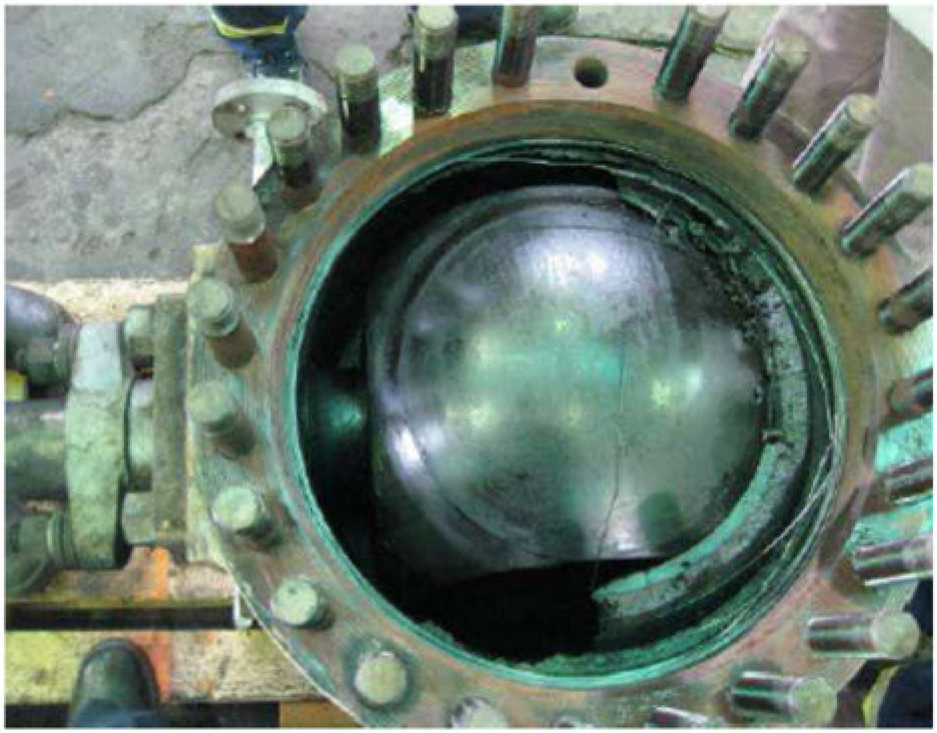
Plot of Transfer Line Pressure at the Switch Valve



Plot of coke drum inlet temperature



Photos of Coke in the Inlet Isolation Valve

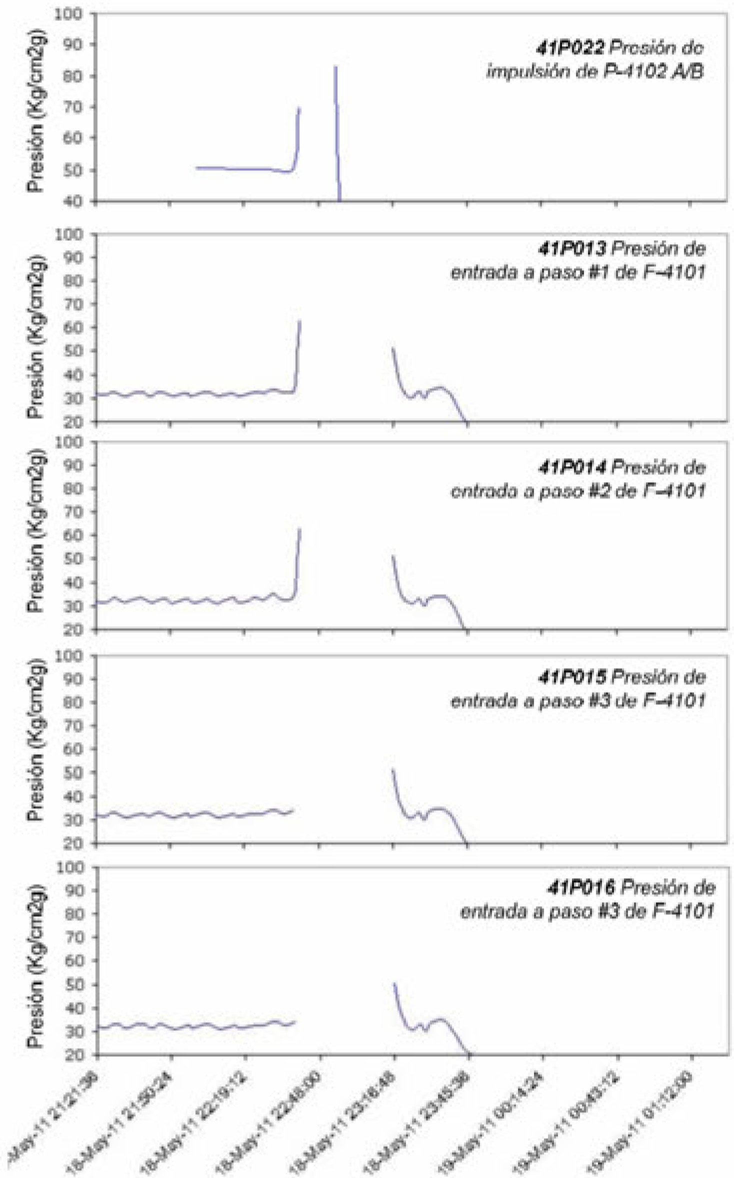


Pressures at Feed Pump and Heater Pass Inlet – Unexpected pressures

Heater feed pump shut off Pressure is 58.5 kg/cm2 (832 Psig)

Pressure at heater feed pump exceeded 84 kg/cm2 (1195 psig)

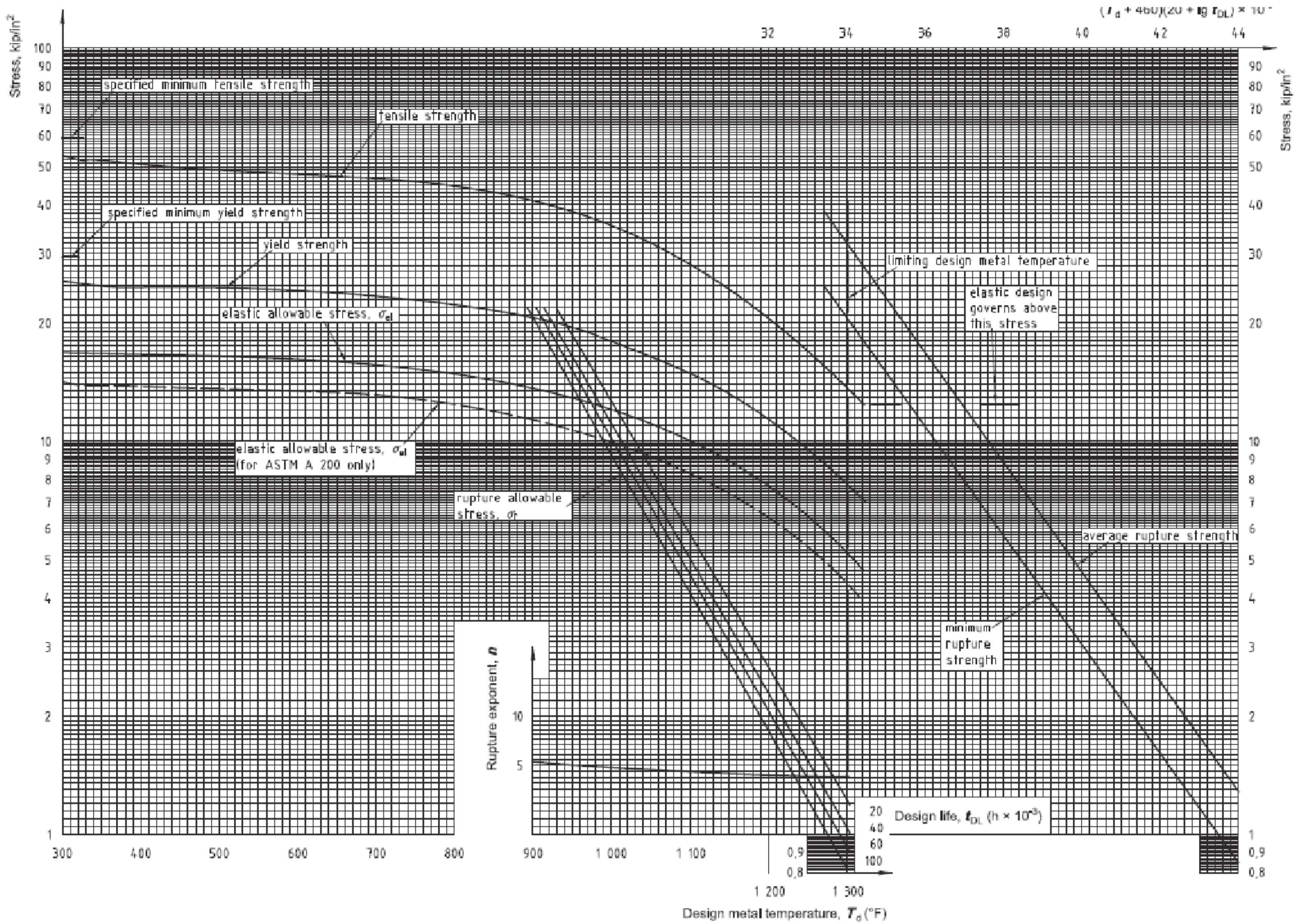
Pressure at the heater pass inlet exceeded 60 kg/cm2. Transmitters were at the maximum range



Standard methods of protecting the heater transfer line

- Two primary methods have been used to protect the heater transfer line from over pressurization.
  - Relief valve on the heater outlet routed to the bottom of the fractionator
    - Concern with relief valve or nozzle plugging. Have experienced this at multiple sites
  - Designing heater transfer line for blocked discharge pressure
    - Heater tubes designed for pump shut-off pressure at 1300°F using the elastic limit and not creep-rupture limit
    - Low flow on the heater passes trips burners. Should prevent tubes from rupturing. Heater pass will coke from heat stored in firebox
  - ASME B31.3 allows 33% over design pressure for 10 hr per incident and no more than 100 hrs per yr

Allowable stress curve for 9% Cr – 1% Mo Heater tubes – API Std. 530



E Broken lines indicate the elastic allowable stresses for the A 200 grade. This figure does not show the yield strength of the A 200 grade. The yield strength of the A 200 grade is 83 % of the yield strength shown. The tensile strength, rupture allowable stress, re strength, and rupture exponent for the A 200 grade are the same as for the A 213 and A 335 grades.

Figure F.10 — Stress curves (USC units) for ASTM A 200 T9, ASTM A 213 T9 and ASTM A 335 P9 9Cr-1Mo steels

Transfer line design conditions

- To cover the blocked discharge case, the heater transfer line was designed for the following:
  - 66.2 kg/cm2 (942 psig) at 513°C (955°F)
  - Line class used 600# flanges and valves. These conditions are within the allowable using the 33% excess pressure of B31.3
- Heater outlet flanges are 900# class. The rest of the transfer line is 600# class.
  - None of the 900# class flanges leaked. Using the same 33% excess pressure at the design temperature calculates to 101.6 bar-g.

Flange ratings by class from ASME B16.5

By interpolation, the Allowable pressure for These 9% Cr – 1% Mo Flanges is 67.8 bar-g

Same calculation for the 900# class flanges results in 101.6 bar-g

Table 2-1.14 Pressure–Temperature Ratings for Group 1.14 Materials

Nominal Designation	Forgings		Castings		Plates		
9Cr–1Mo	A 182 Gr. F9		A 217 Gr. C12 (1)				
Working Pressures by Classes, bar							
Class / Temp., °C	150	300	400	600	900	1500	2500
−29 to 38	20.0	51.7	68.9	103.4	155.1	258.6	430.9
50	19.5	51.7	68.9	103.4	155.1	258.6	430.9
100	17.7	51.5	68.7	103.0	154.6	257.6	429.4
150	15.8	50.3	66.8	100.3	150.6	250.8	418.2
200	13.8	48.6	64.8	97.2	145.8	243.4	405.4
250	12.1	46.3	61.7	92.7	139.0	231.8	386.2
300	10.2	42.9	57.0	85.7	128.6	214.4	357.1
325	9.3	41.4	55.0	82.6	124.0	206.6	344.3
350	8.4	40.3	53.6	80.4	120.7	201.1	335.3
375	7.4	38.9	51.6	77.6	116.5	194.1	323.2
400	6.5	36.5	48.9	73.3	109.8	183.1	304.9
425	5.5	35.2	46.5	70.0	105.1	175.1	291.6
450	4.6	33.7	45.1	67.7	101.4	169.0	281.8
475	3.7	31.7	42.3	63.4	95.1	158.2	263.9
500	2.8	28.2	37.6	56.5	84.7	140.9	235.0
538	1.4	17.5	23.3	35.0	52.5	87.5	145.8
550	...	15.0	20.0	30.0	45.0	75.0	125.0
575	...	10.5	13.9	20.9	31.4	52.3	87.1
600	...	7.2	9.6	14.4	21.5	35.9	59.8
625	...	5.0	6.6	9.9	14.9	24.8	41.4
650	...	3.5	4.7	7.1	10.6	17.7	29.5

Potential sources of excess pressure

- Two potential causes were identified by the incident investigation team
  - Liquid water from the velocity BFW or from the emergency BFW entered the heater and vaporized, pressurizing the heater feed circuit
  - The hydrocarbon in the heater transfer line continued to react, similar to a soaker drum on a Visbreaker. The increased number of moles of material due to thermal cracking caused the pressure to increase.

Conclusions

- The rate of pressure increase was faster than what could be justified by thermal cracking
- Heater feed temperature at the point of velocity BFW injection is 300°C (572°F)
  - Vapor pressure of water at this temperature is 87.6 kg/cm2 absolute (1246 psia)
  - Required heater feed temperature to reach 101.6 bar-g is 313°C (595°F)
- Most likely cause was liquid water used as velocity media entering the heater and vaporizing with the heater feed pump isolation valve closed.

Recommendations and Mitigations

- Resize restriction orifices on steam purge to hot valves
  - Need to be sized on minimum differential between steam header pressure and process pressure
- Modify interlock logic to monitor drum inlet temperature and not allow switch to be completed if inlet temperature does not increase
- Monitor torque required to move valves. Repair or replace valve when torque value exceeds pre-set limit
- Monitor purge steam flow rates. Ensure purges are flowing when needed
- Reduce the time from loss of flow to burner trip from 20 seconds to 10 seconds