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Evaluation of the causes of increasing the pressure drop of fixed bed reactor RCD unit

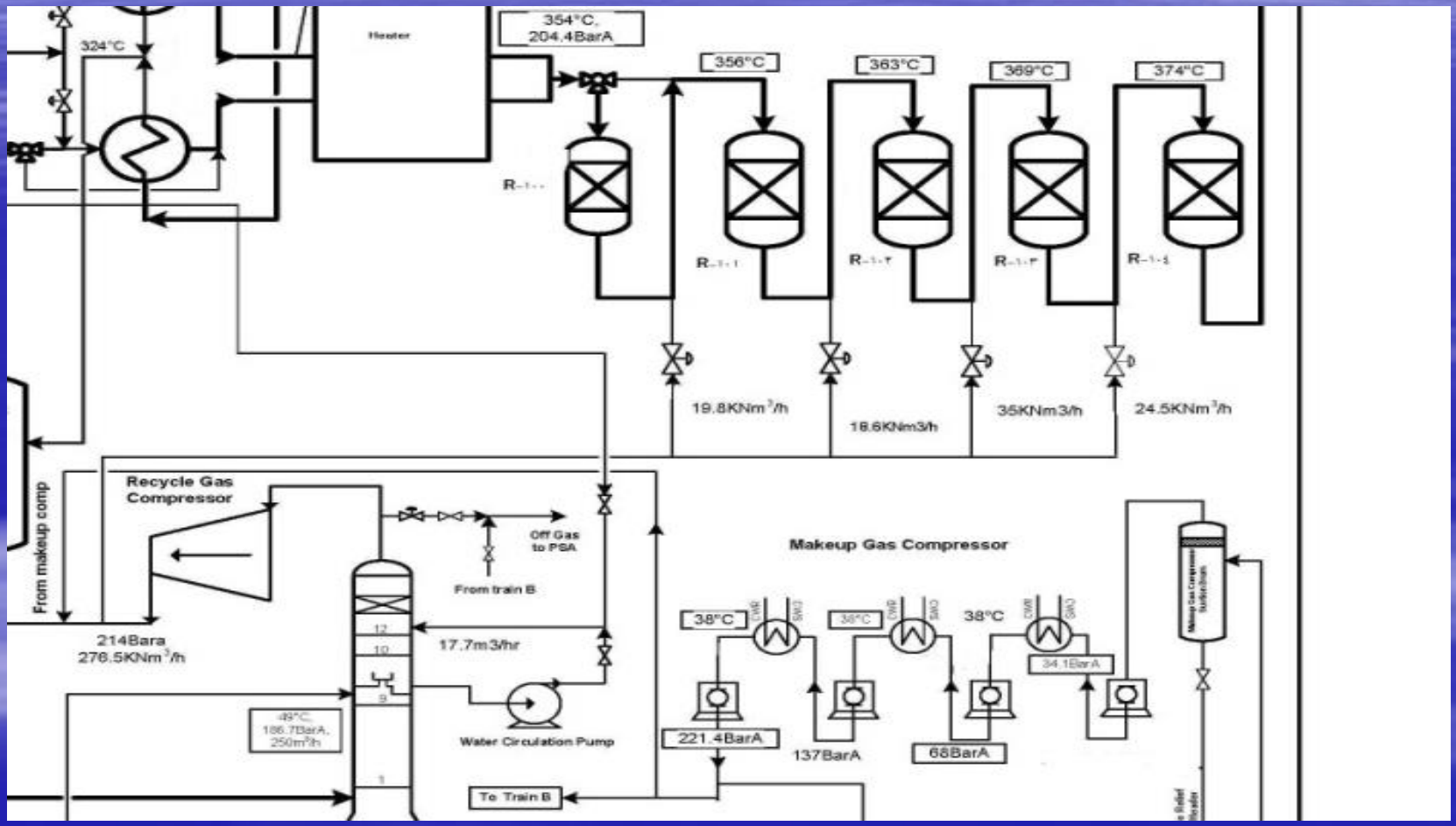
ALI SHAERI NIOEC CO.

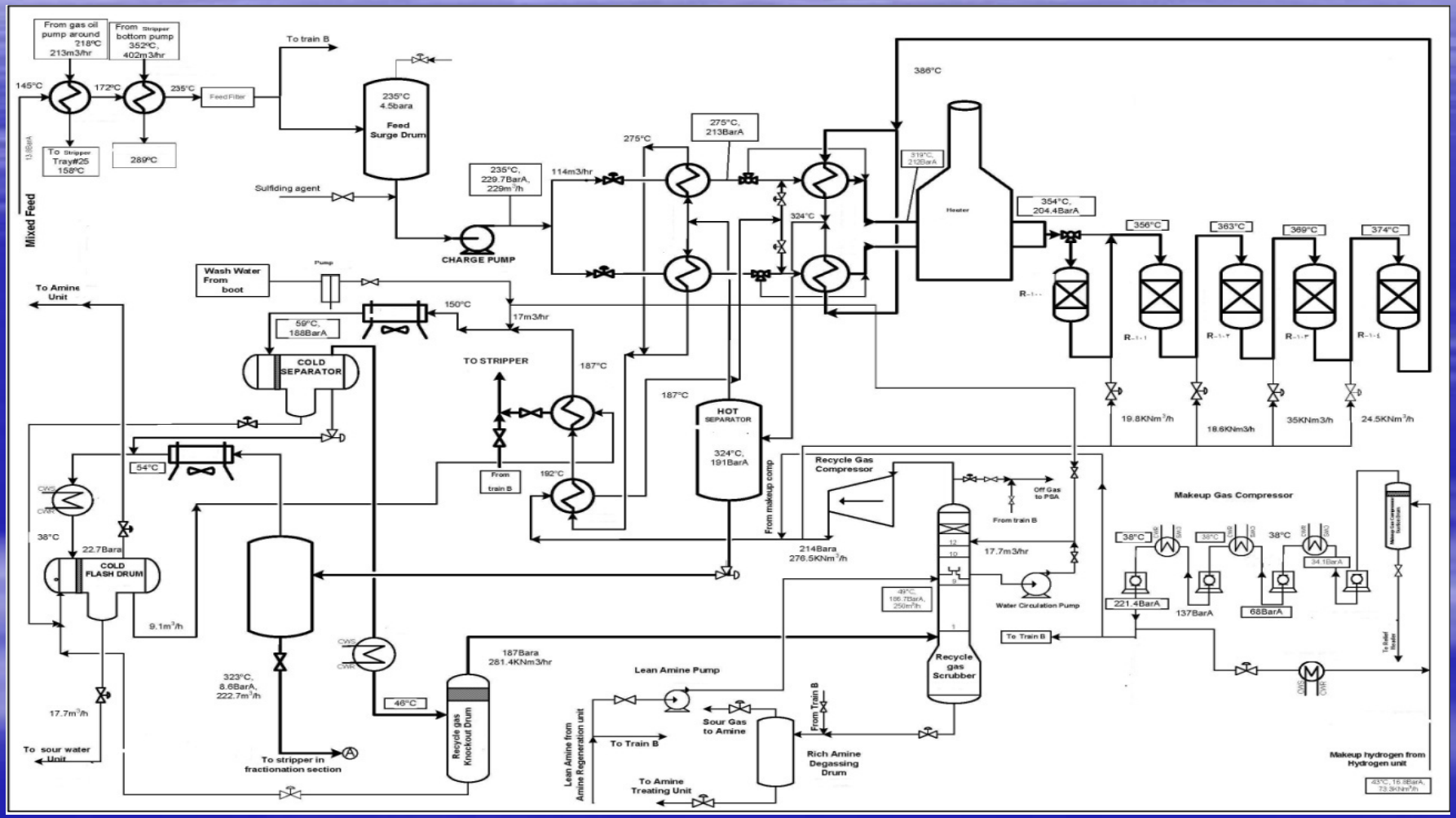
(Reduced CRUDE DESULFURIZATION)

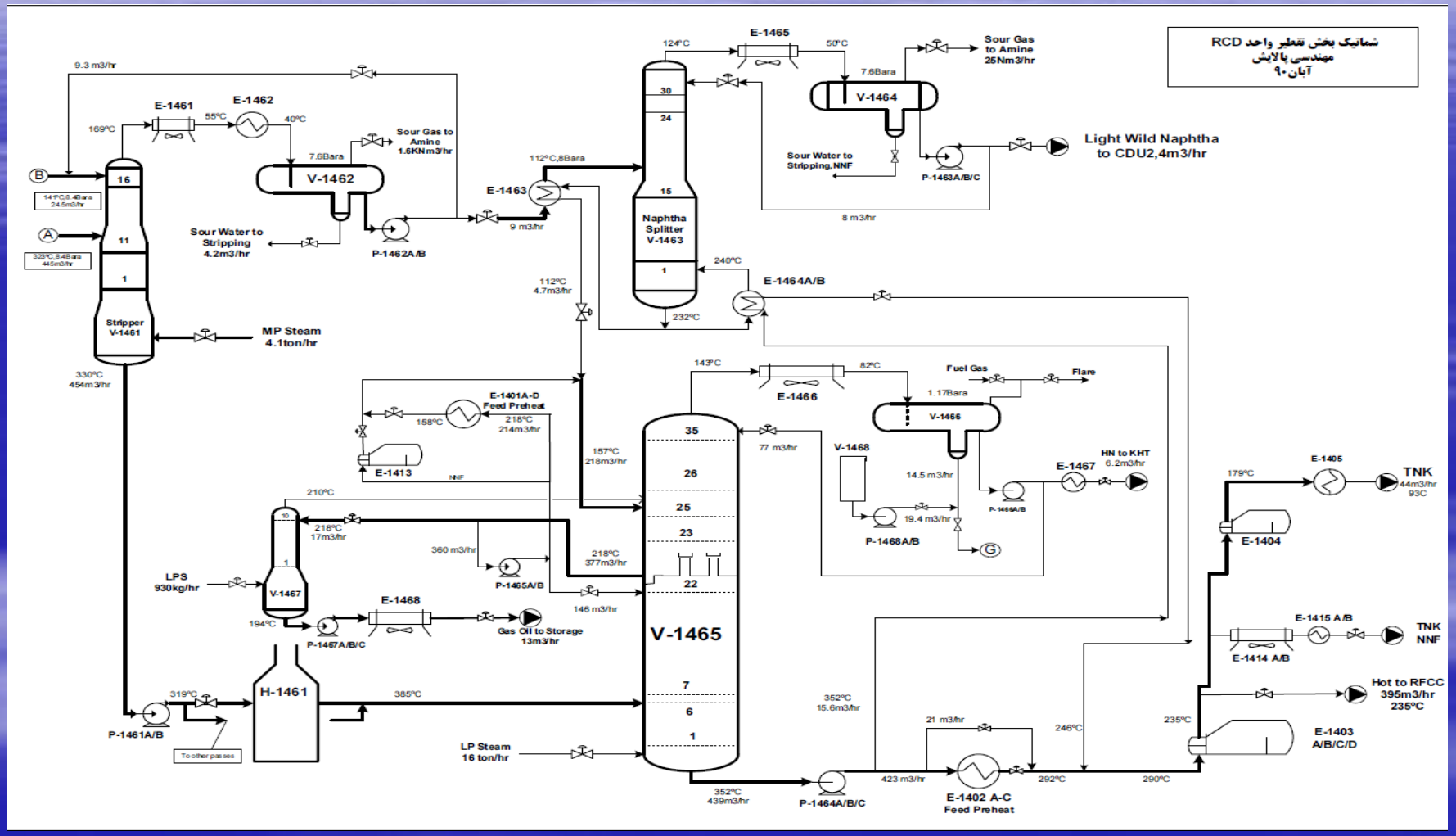
What is RCD?

- Feed : 69000 BPSD
- Divided in two train
- Turn Down : 50%

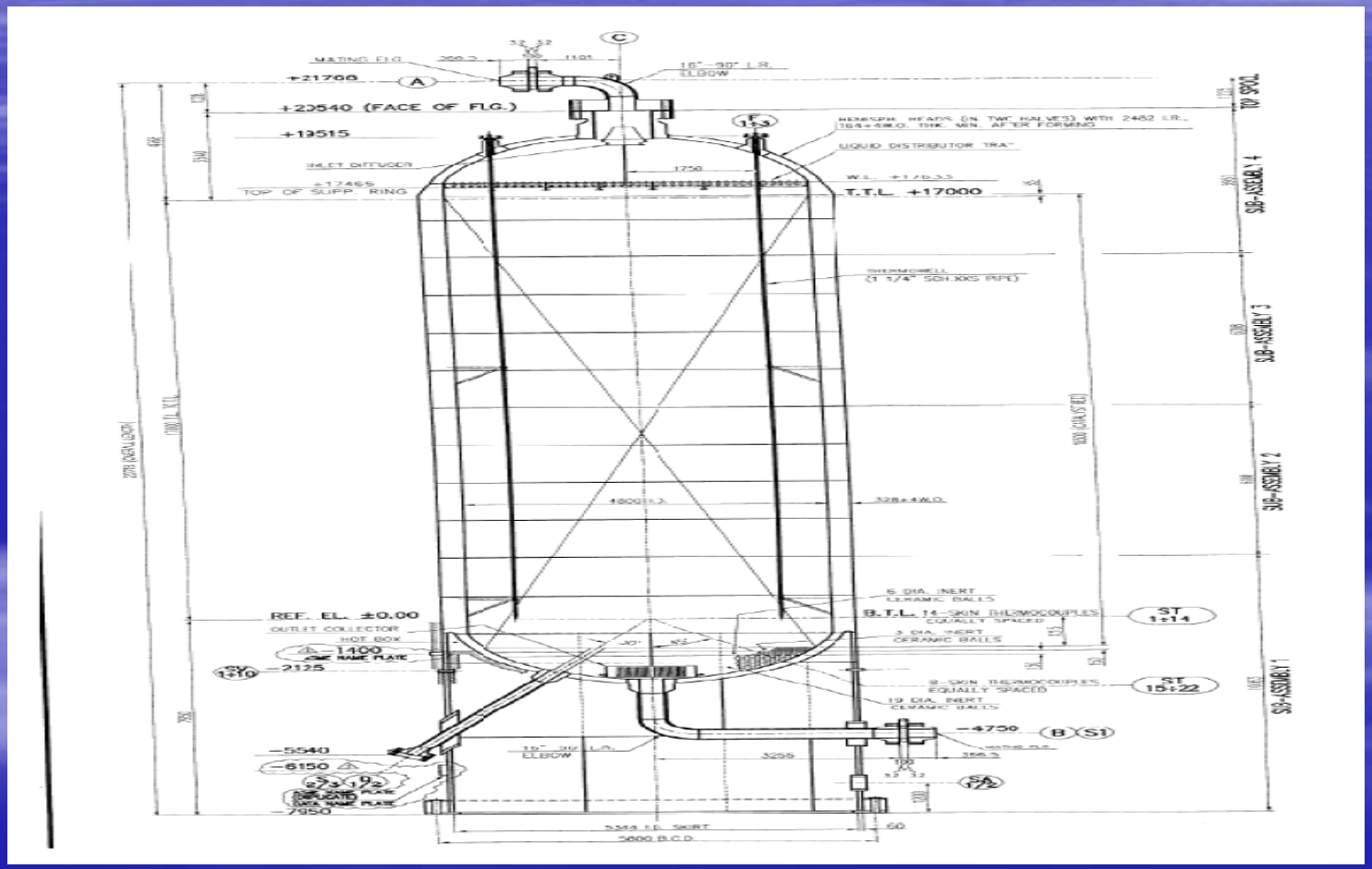
Why H2 injected to the each reactor?




From gas oil pump around 218°C 213m3/hr
From Stripper bottom pump 352°C, 402m3/hr
To train B
145°C
172°C
235°C
Feed Filter
To Stripper Tray#25 158°C
289°C
Mixed Feed
235°C 4.5bara Feed Surge Drum
Sulfiding agent
235°C, 229.7BarA, 229m3/h
CHARGE PUMP
114m3/hr
275°C
275°C, 213BarA
386°C
319°C, 212BarA
Heater
354°C, 204.4BarA
324°C
356°C
363°C
369°C
374°C
R-1-1
R-1-2
R-1-3
R-1-4
19.8KNm3/h
18.6KNm3/h
35KNm3/h
24.5KNm3/h
Wash Water From boot
Pump
To Amine Unit
59°C, 188BarA
150°C
17m3/hr
COLD SEPARATOR
TO STRIPPER
187°C
187°C
HOT SEPARATOR
324°C, 191BarA
From train B
192°C
54°C
CWS
CWR
38°C
22.7Bara
COLD FLASH DRUM
9.1m3/h
Recycle Gas Compressor
From makeup comp
214Bara 276.5KNm3/h
Off Gas to PSA
From train B
17.7m3/hr
Water Circulation Pump
49°C, 186.7BarA, 250m3/h
Recycle gas Scrubber
To Train B
Makeup Gas Compressor
38°C
38°C
38°C
221.4BarA
137BarA
68BarA
34.1BarA
323°C, 8.6BarA, 222.7m3/h
187Bara 281.4KNm3/hr
Lean Amine Pump
46°C
Recycle gas Knockout Drum
17.7m3/h
To sour water Unit
To stripper in fractionation section
Sour Gas to Amine
To Train B
From Train B
Rich Amine Degassing Drum
Lean Amine from Amine Regeneration unit
To Amine Treating Unit
Makeup hydrogen from Hydrogen unit


شماتیک بخش تقطیر واحد RCD
مهندسی پالایش
آبان ۹۰
E-1461
E-1462
E-1463
E-1465
E-1466
E-1467
E-1468
E-1401A-D
Feed Preheat
E-1413
E-1464A/B
E-1402 A-C
Feed Preheat
E-1403
A/B/C/D
E-1404
E-1405
E-1414 A/B
E-1415 A/B
V-1462
V-1463
Naphtha
Splitter
V-1463
V-1464
V-1465
V-1466
V-1467
V-1468
Stripper
V-1461
H-1461
P-1462A/B
P-1463A/B/C
P-1464A/B/C
P-1465A/B
P-1466A/B
P-1467A/B/C
P-1468A/B
P-1461A/B
Sour Gas to Amine
1.6KNm3/hr
Sour Water to
Stripping
4.2m3/hr
Sour Gas
to Amine
25Nm3/hr
Sour Water to
Stripping,NNF
Light Wild Naphtha
to CDU2,4m3/hr
MP Steam
4.1ton/hr
LPS
930kg/hr
LP Steam
16 ton/hr
Gas Oil to Storage
13m3/hr
Fuel Gas
Flare
HN to KHT
6.2m3/hr
TNK
44m3/hr
93C
TNK
NNF
Hot to RFCC
395m3/hr
235°C
To other passes
NNF

Fixed bed reactor
This distributor to avoid channeling



PRODUCTION

HEAVY WILD NAPHTA:

Estimated Properties		
Operation	SOR	EOR
TBP Nominal Cut, deg C	85-205	85-205
Sp.Gr	0.753	0.751
Total Sulfur, wt PPM	55	80
Total Nitrogen, wt PPM	90	110
ASTM D-86 Distillation, deg C		
IBP	109	
5 vol %	116	
10 vol %	128	
30 vol %	145	
50 vol %	154	
70 vol %	167	
90 vol %	184	
95 vol %	197	
FBP, Max	205	

GAS OIL

		Test Method
TBP Nominal Cut, deg C	205-320 °C	
Sp.Gr. (15.6°C/15.6°C)	0.840	ASTM D-1298
Distillation, D86		
IBP	208	
10 vol %	241	
50 vol %	275	
90 vol%	305	
F.B.P.,	330	
Flash Point - Design	Min. 60 °C	ASTM D-93
Sulfur Content	0.05	ASTM D-4294
Cetane Number	45	ASTM D-613
Aromatic Content	50	IP 391

TREATED RESIDUE

Estimated Properties	SOR/EOR	Test Method
TBP Nominal Cut	320 °C + / 320 °C +	N/A
Sp.Gr. (15.6°C/15.6°C)	0.960/ 0.948	ASTM D-1298
Distillation	To be reported	ASTM D-1160
Total Sulfur, wt % - Design	0.4 / 0.4	ASTM D-1552
Metal (Ni + V) Contents - Design	19.8 wt PPM / 20.6 wt PPM	UOP-391 or equivalent
Conradson Carbon Residue - Design	6.0 wt % / 6.2 wt %	ASTM D-189
Nitrogen - Design	2100/2260 wtppm	ASTM D-4629

The unit of RCD was applied for:

- decreasing of Sulfur and CCR
- metals of heavy feeds AR and VB
- prepared the feed of RFCC unit

(With 5000ppmw Sulphur)

The unit includes the following parts:

- Feed Pretreating (Filter) Section
- Reactor Section
- Fractionator Section
- Make-up Hydrogen Compression Section

FEED

Feedstock	AR1	VR	AR2	Blended	Test Method
Source Unit	CDU1	VDU	CDU2	-	
TBP Cut Range, °C	320+	535+	373+		
Blended Ratio, vol%	6.727	42.426	50.847	100.0	
Feedstock Properties					
Sp.Gr. (15.6°C/15.6°C)	0.967	1.026	0.979	0.998	ASTM D-1298
Distillation (°C)					ASTM D1160
IBP	225	479	240		@ 760mmHg
10 vol%	355	550	403		
30 vol%	439	593	470		
50 vol%	505	644	537		
70 vol%	592	714	615		
Total Sulfur (wt%)	3.5	4.6	3.6	4.03	ASTM D-1552
Total Nitrogen (ppmw)	2850	4250	3150	3610	ASTM D-4629
Total Sodium (ppmw)	-	-	-	1.0	UOP-389
Total Iron (ppmw)	-	-	-	10	UOP-389
Conradson Carbon Residue (wt%)	9.9	21.0	11.4	15.5	ASTM D-189
Ni (ppmw)	25	55	30	40.6	UOP-391 or equivalent
V (ppmw)	80	175	90	126.4	UOP-391 or equivalent

- The unit was acted at high temperature and high pressure (454°C, 210Kg/Cm^2).
- The unit was included four series reactors and Guard Sulfure, moreover the impurities of feed can be removed in presence of hydrogen.
- Following reactions were carried out in the reactors and all of them were exothermic:

1-Sulfure removal

2-Nitrogen removal

3-Oxygen removal

4-Olefin saturation

5-Aromatic saturation

6-Metal removal

7-Halides removal

8-Hydro cracking

9-Thermal cracking

CATALYST

The catalyst is composed of several spherical PROMOTER METALS IMPREGNATD based on Alumina. Due to control of pressure drop, suitable distribution of feed, adequate selectivity, and using different compounds were preferred.

Catalyst Name	TNC-HS-A	TNC-HS-B	SPT-C-A	TNC-HM-C
Nominal Size (inch) (inch)	(1/4")	(1/6")	(1/10")	(1/10")
Shape	Macaroni	Macaroni	Quadlobe	Quadlobe
Type	Guard HDM	Guard HDM	Support	HDM
Chemical Compositions				
NiO (wt%)	1.0±0.3	1.0±0.3	1.4±0.3	0.7±0.3
MoO3 (wt%)	5.0±0.5	5.0±0.5	7.0±0.5	3.3±0.5
Physical Properties				
ABD (g/ml)	0.30±0.05	0.30±0.05	0.45±0.05	0.45±0.05
CBD (g/ml)	0.43±0.05	0.43±0.05	0.55±0.05	0.55±0.05
EBD(@SOCK)(1) (g/ml)	0.405±0.05	0.405±0.05	0.405±0.05	0.500±0.05
SA (m2/g)	245±50	245±50	190±30	175±30
PV(H2O) (ml/g)	0. 91±0.07	0. 91±0.07	0.77±0.05	0.83±0.05
Cr.Str. (N/mm)	15Min	15Min	15Min	14Min

hYDROGEN

MAKE UP H_2 FROM HPU (99.9) :

- 3 Reciprocating compressor (4stage)
- Final Pressure Discharge: 221.4 barg
- 74Knm^3/hr

H_2 Recycle supplied by : Centrifugal Compressor Min purity : 70%

What is our problem in the RCD Unit ?

We started up the unit then,
seen huge DP in the first reactor

All data is actual and extract from DCS reports

H_2 Recycle Duties

- Force the heavy liquid to fluidity
- Reactor phase is three
  (solid , Gas and Liquid)
- If H_2 recycle is cut , all liquids hold up in the catalyst bed, goes in the bottom of the reactors

- Because of heavy nature of feed , total Dp (reactors , exchanger , furnace)

  is about 25 bar

Investigate DP in the reactor

In the three phase reactors , DP depends on liquid and gas flow rate and temperature

- WHAT WAS HAPPENING?

- Power failure happened
- The recycle compressor stopped

All liquid hold up in the bed of the reactor goes to the bottom of the reactors

Total Hold up : 600m^3

- Feed pump drivers are Turbine , so the feed was not cut and flow to the train consciously.
- The compressors run again and the speed increase rapidly
- Huge amount of liquid from bottom of Guard reactor transfer to the 1st reactor
- Bed of reactor is not designed with this huge amount of liquid and liquid could not pass through the reactor

- It causes huge liquid present in the top of reactor and plugged route of H2 recycle gas.

- SO DP Happened in the reactor

- Reactor diameter : 4.8 m

- 1bar pressure increasing = 183 tone force to the reactor bed.

- Catalyst is very Porosit and this is very fragile and brittle

- Then increasing of the pressure drop causes :

  crash the catalyst Completely then

  DP increasing more and more

- Dp of the 1st reactor was increasing gradually , finally :

- We had to Shut Down the Unit

- We opened the 1st reactor

What we seen?

1.5 METER OUTAGE

SOLOUTION

1- When the recycle gas compressor stopped for any reason, the feed shall be cut

2- Run the recycle compressor as Full Spillback and the speed increasing slowly,

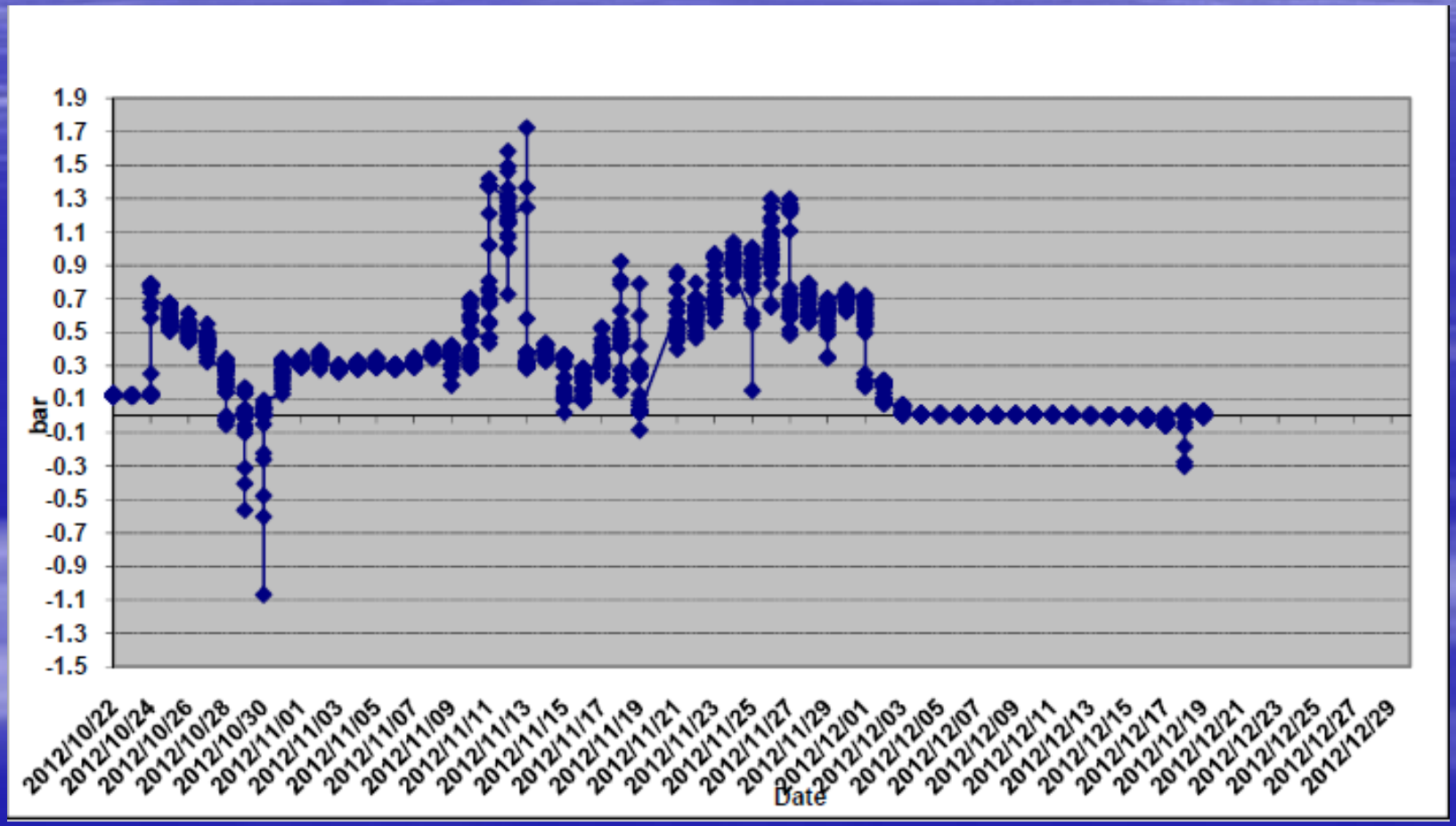
3- Spill back shall be closed slowly till the hold up exit from the reactor.

If We had done that , we would never had shut down and lost the money

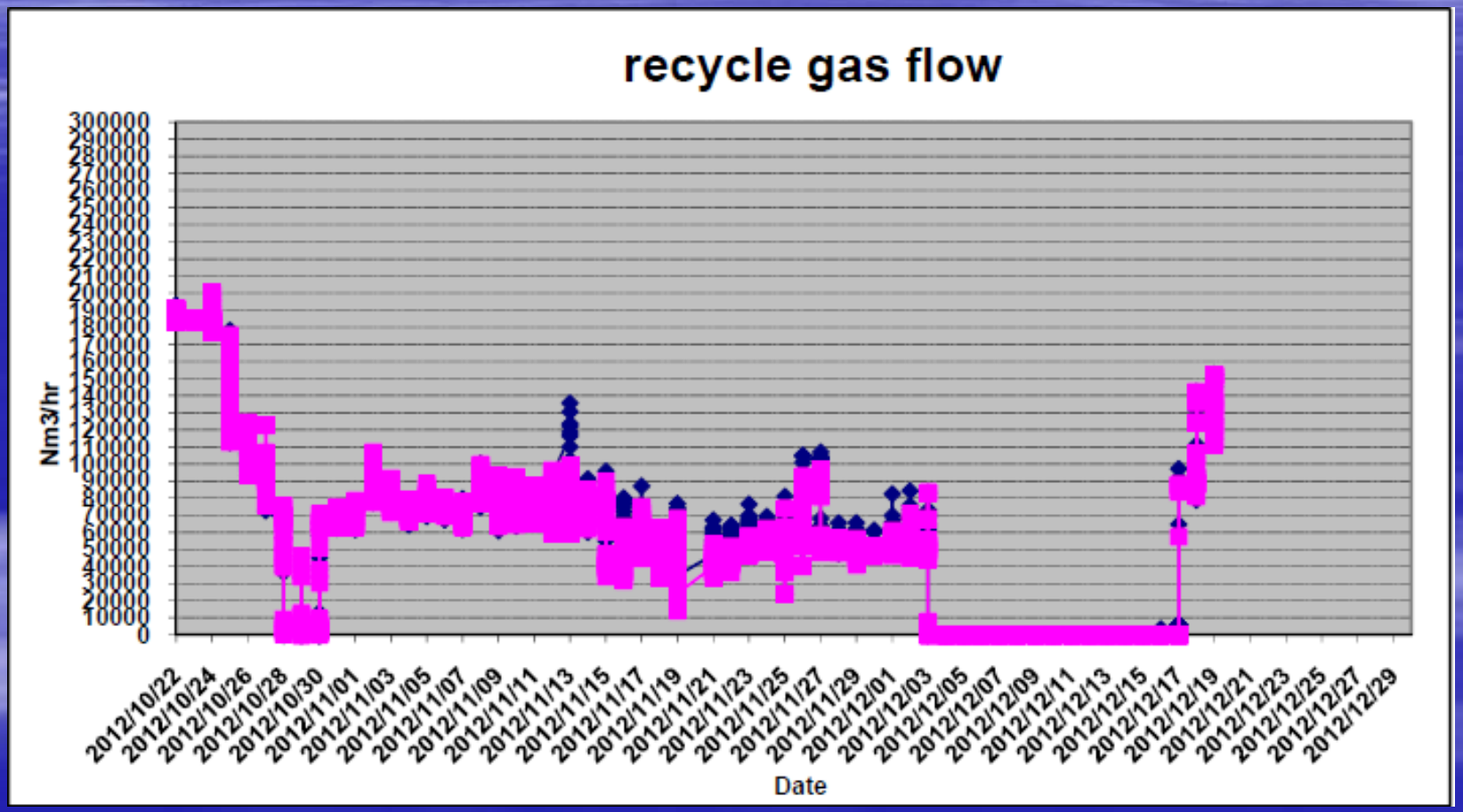
SOLOUTION

- TIT of the reactor inlet temperature does not work good, Control by hand
- So fluctuation was so high
- And effect on H_2 flow rate

Pressure drop of R-100 Guard versus time



Changes of amount of circulating gas

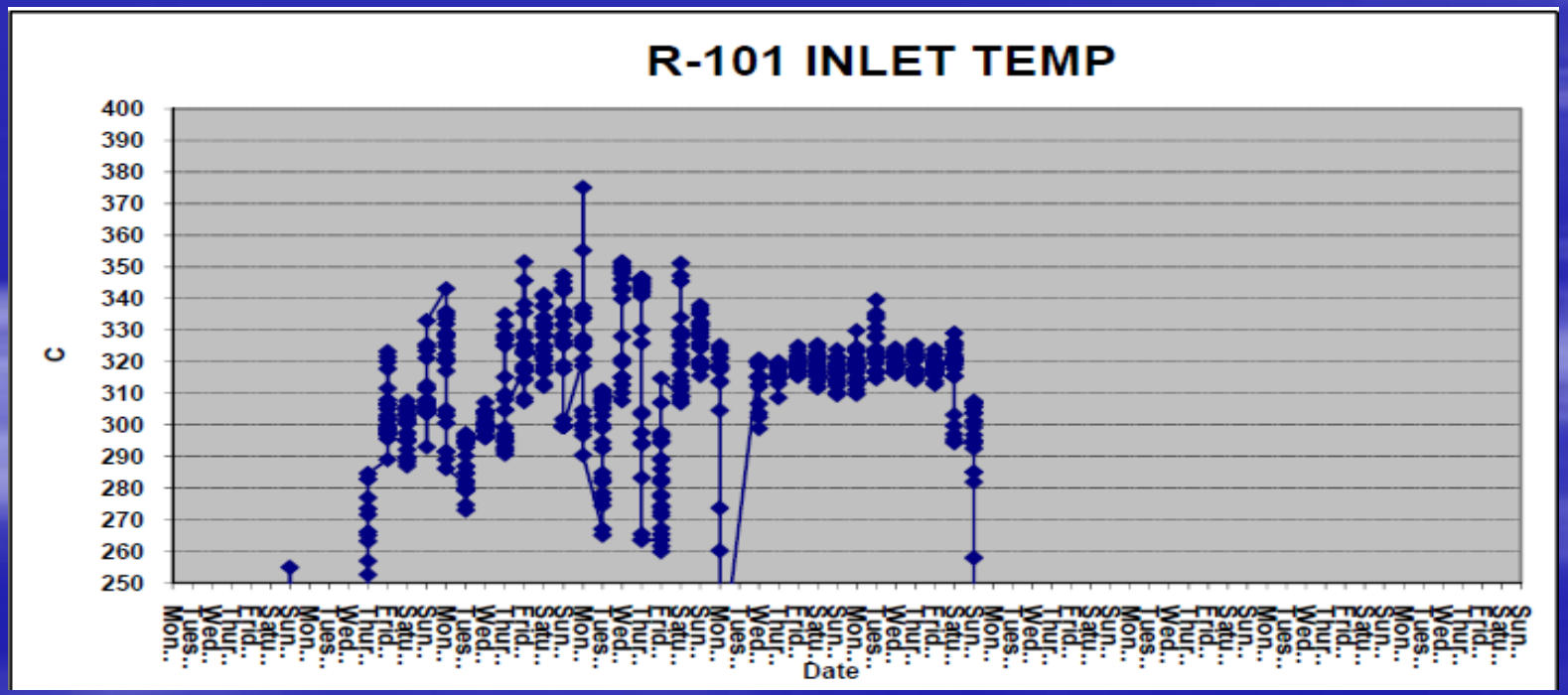


Changes of inlet temperature of first reactor R-101

Because of hand control of TIT:

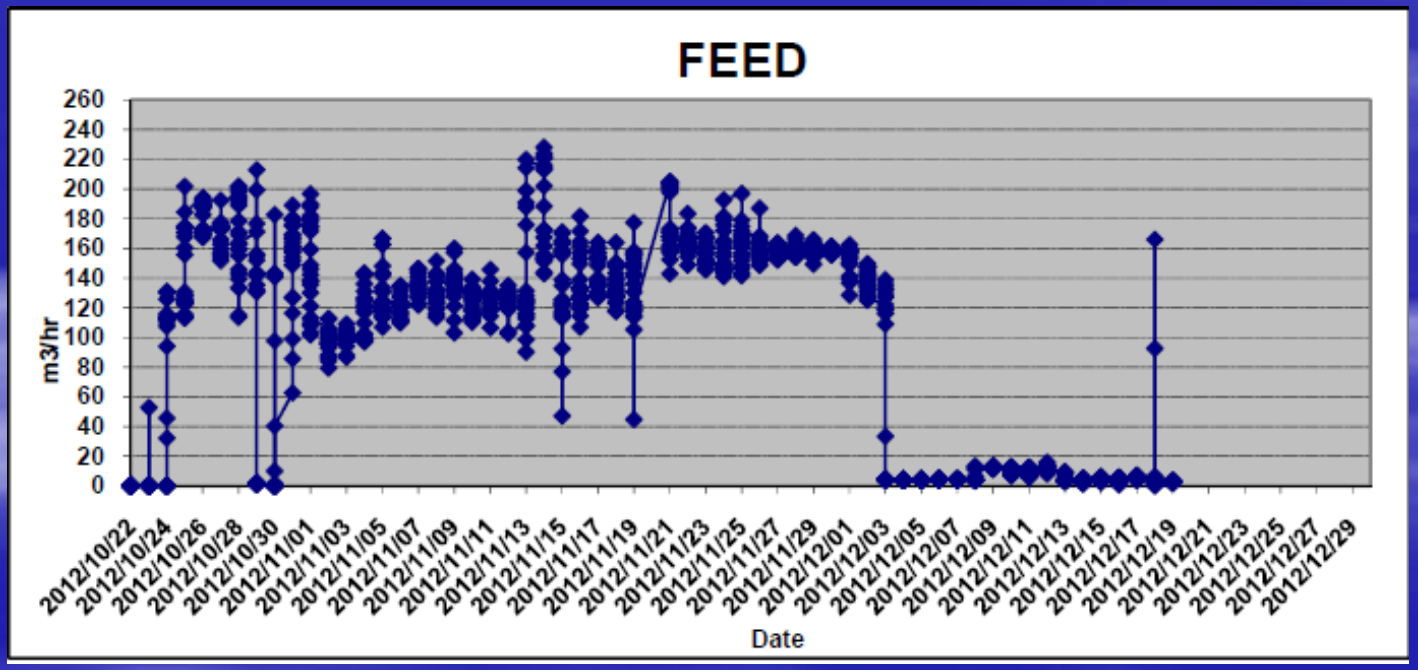
you could see so many fluctuation

VB was not injected when this story happen, so they should not increase the temperature up to 370C



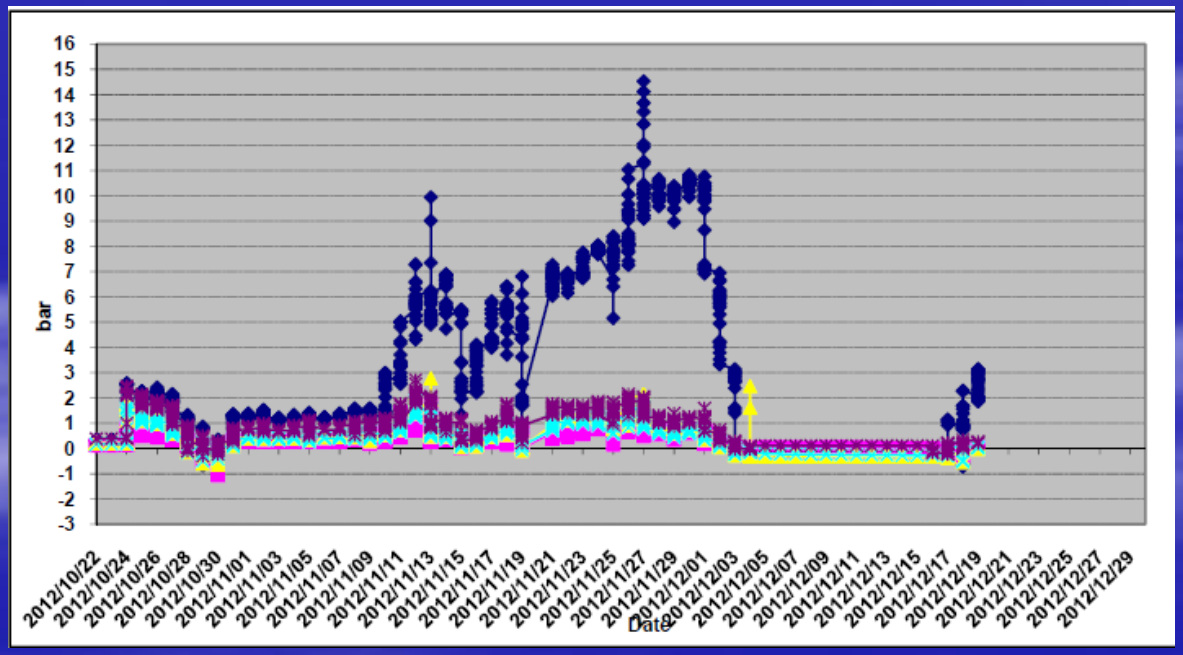
Changes of feed amount

- You could see large range for feed (100 to 240m3/hr) , so it cause damage of catalyst .
- Change of feed shall be adjust with reactor temperature , but in one day , the flow rate changed many times.

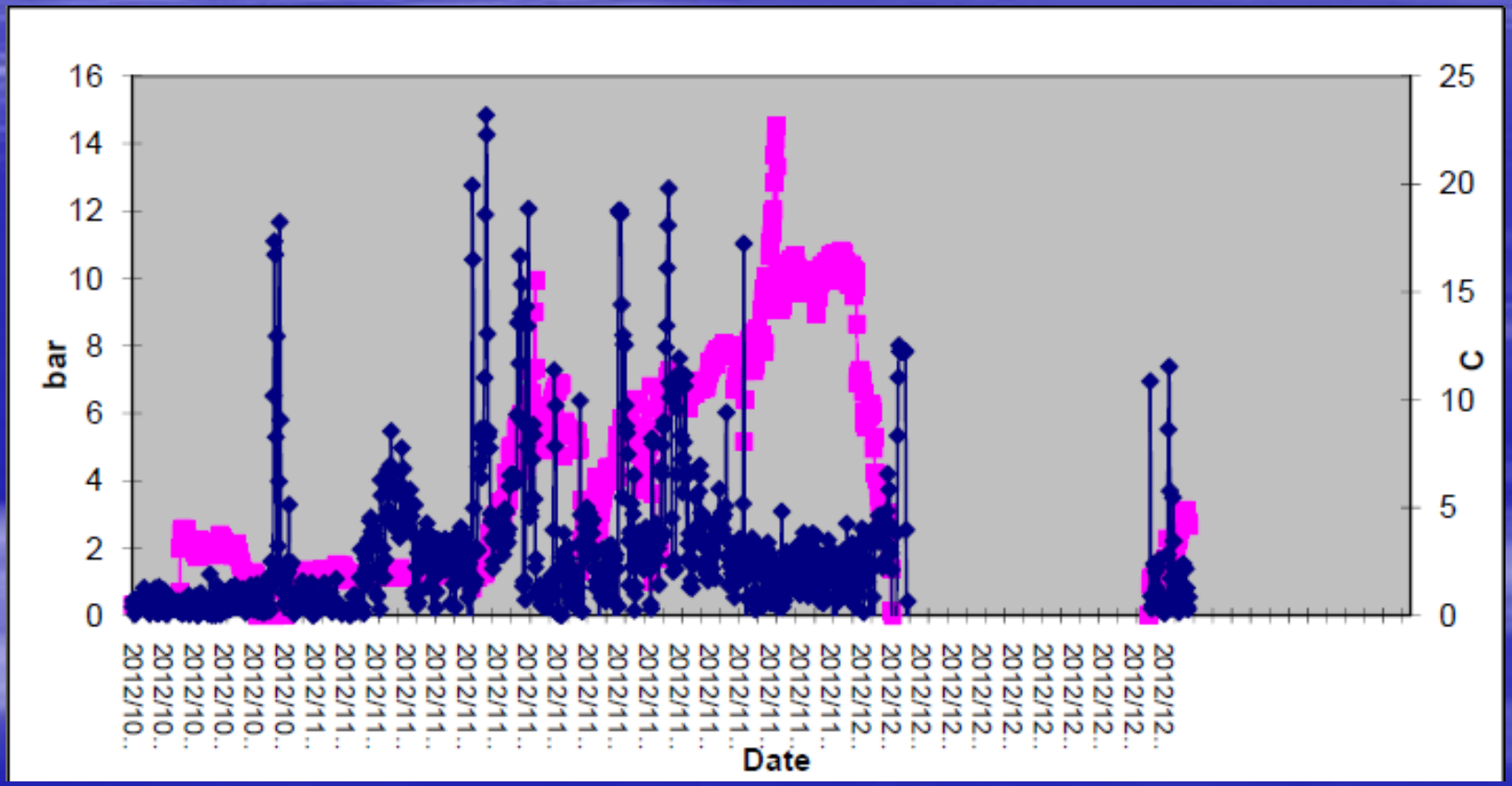


Changes of pressure drop of the reactors

- Shown strongly DP in the 1st reactor with comparison the other reactors because of feed flow rate and reactor temperature changed many times.



Changes of pressure drop and inlet temperature in the first reactor



In conclusion

- 1- In case of recycle gas compressor stopped as emergency , the unit shall be Feed cut and compressor back to work as Full Spillback
- Regarding to DP , speed shall be increased very slowly till spillback closed
- Feed injected shall not been done till hold up liquid goes out.
- Feed could be increased gradually.

- If the unit feed cut normally , recycle compressor shall be in service till all hold up liquid goes out from reactors.

- Temperature shall be establish over reactor inlet

THANK YOU FOR YOUR KIND ATTENTION