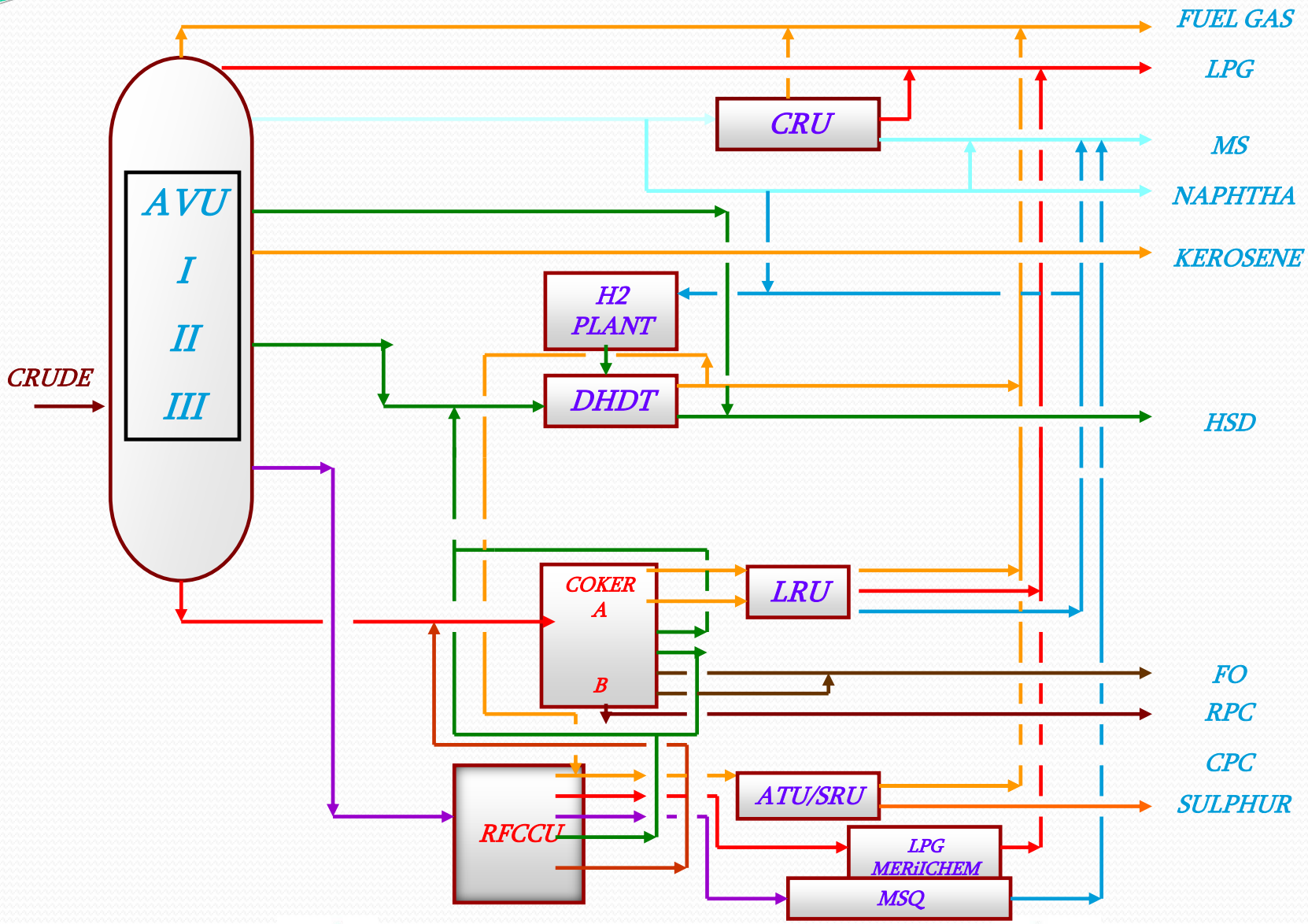
Lovraj Kumar Memorial Workshop
10th - 11th Mar'16

Barauni Refinery

OPERATIONAL EXPERIENCE OF RFCCU

Refinery Configuration



RFCC UNIT AT BARAUNI

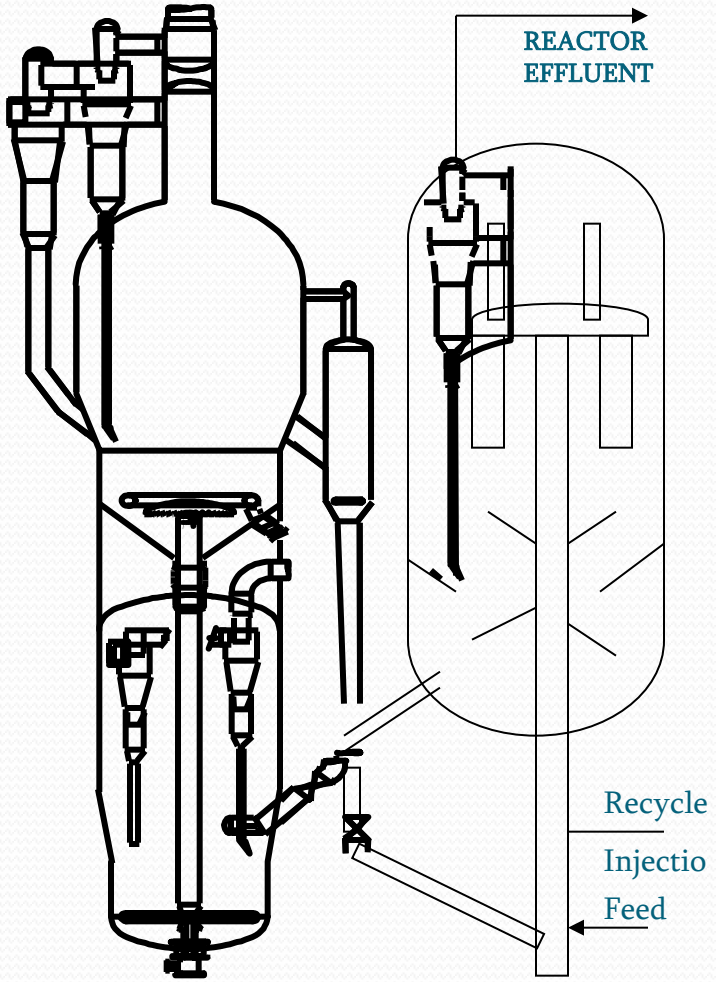
- CAPACITY : 1.37 MMTPA
  1.44 MMTPA
- LICENSOR : SWEC, USA.
- COMMISSIONED : AUG ' 02
- LAST M&I : AUG' 11
- NEXT M&I PLANNED : MAR'17
- MAX SUSTAINED OPERATION : 120 %

FEATURES OF RFCC UNIT AT BARAUNI

TWO-STAGE REGENERATION SPECIAL FEATURES

- Coke burnt in two regenerators
  - REGENERATOR-I : 70 WT%
  - REGENERATOR-II : 30 WT%

- Control on hydrothermal deactivation
- Control on catalyst circulation rate
- Higher flexibility in operation.
- Flue gas (Belco) scrubber.
- Total cold wall design.
- MTC (Mixed Temperature Control) facility for increasing cat/oil.



DESIGN BASIS OF RFCC UNIT

FEED QUALITY

S. NO	ATTRIBUTE	CASE-1	CASE-2	ACTUAL
1	FEED SP. GRAVITY	0.9444	0.9367	0.918-0.956
2	FEED, CCR	4.28	3.79	1.5 – 4.15
3	FEED, NICKEL (PPM)	9.5	7.1	12 – 14
4	FEED, VANADIUM (PPM)	32.6	24.2	6 - 7
5	Sulphur (wt%)	1.56	2.54	0.37 – 1.27

RFCC UNIT AT BARAUNI

TYPICAL OPERATING CONDITIONS

ATTRIBUTE	DESIGN	PRESENT VALUES
FEED RATE, MT/ HR	179.5	140 - 213
FEED PREHEAT TEMP, ^{O}C	204	188 - 205
RISER OUTLET TEMP, ^{O}C	510	505 - 514
CATALYST TO OIL RATIO	7.2	5.0 – 6.0
RG- I TEMP (dense Bed), ^{O}C	660	680 - 700
RG – II TEMP (dense Bed), ^{O}C	732	740 - 770

UNIT OPERATING PERFORMANCE

RFCC - Capacity

	Units	2014 (OCT-DEC)	2015 (JAN-MAR)	2015 (APR-JUN)	2015 (JUL-SEP)	2015 (OCT-DEC)
Unit designer	STONE & WEBSTER, USA					
Unit capacity	MMTPA	1.27	1.59	1.57	1.62	1.73
Design Feed rate	TPD	4308	4308	4308	4308	4308
Actual processed	TPD	3810	4770	4710	4866	5181
Feed processed	TMT	281.9	419.8	428.6	447.7	476.7
Capacity Utilization	%	88.2	110.4	109.0	112.9	120.3
No of On stream days		74	88	91	92	92

* T'put includes external naphtha

RFCC - Feed Properties

	Units	2014 (OCT-DEC)	2015 (JAN-MAR)	2015 (APR-JUN)	2015 (JUL-SEP)	2015 (OCT-DEC)
Density	gm/cc	0.925 – 0.954	0.923 – 0.944	0.924 – 0.939	0.928 – 0.952	0.925 – 0.944
Ni	ppm	12 – 14				
Vd	ppm	6 – 7				
CCR	Wt%	2.15 – 4.1	1.6– 3.5	1.85 - 3.63	1.55 – 3.3	1.5– 4.2
Sulphur	wt%	0.37 – 1.02	0.46 – 0.92	0.39 -0.79	0.52 – 0.85	0.37 – 0.89

Critical Operating Parameters

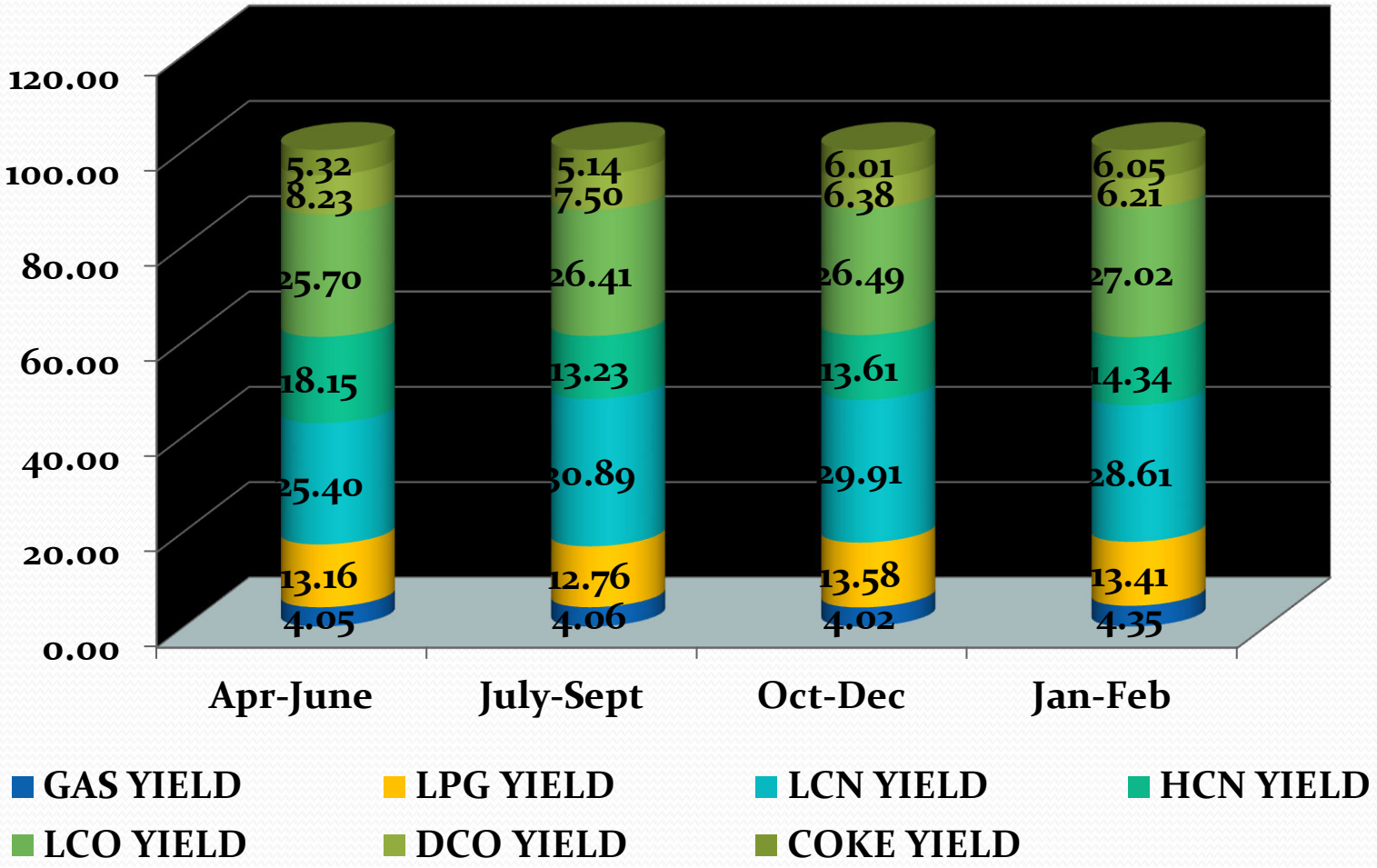
	Units	Design	2014 (OCT-DEC)	2015 (JAN-MAR)	2015 (APR-JUN)	2015 (JUL-SEP)	2015 (OCT-DEC)
Feed rate	m^3/hr	215	217	223	220	224.8	239.5
Rx temp	°C	510	509.8	509.8	510.9	510.8	510.3
Regen Temp	°C		698/763	681/754	684/752	681/751	682/757
Stripping steam	Kg/hr	3926	4160	5036	5469	5307	5003
Steam to Riser	MT/hr	9.6	10.6	10.8	10.8	10.9	11.6

Product Yields

PRODUCTS	Units	2014 (OCT-DEC)	2015 (JAN-MAR)	2015 (APR-JUN)	2015 (JUL-SEP)	2015 (OCT-DEC)
Gas	Wt%	4.8	4.1	3.9	3.9	3.9
LPG	Wt%	13	12.3	13.5	12.8	13.8
LCN	Wt%	24	25.8	23.7	24.1	25.3
HCN	Wt%	14.8	16.5	16.9	18.7	18.5
LCO	Wt%	26.8	26	26.1	25.9	24.3
CLO	Wt%	8.7	7.4	8.2	7.1	6.4
Coke+Loss	Wt%	7.9	7.9	7.7	7.7	7.7
Total	Wt%	100	100	100	100	100

Product Yields

ANNUAL PERFORMANCE : YIELD 2015-16



Catalysts and Additives

	Design	2014 (OCT-DEC)	2015 (JAN-MAR)	2015 (APR-JUN)	2015 (JUL-SEP)	2015 (OCT-DEC)
Catalyst used		Albemarle Upgrader R645 / Grace GENESIS® BR647-13	Grace GENESIS® BR647-13	Grace GENESIS® BR647-13	Grace GENESIS® BR647-13	Grace GENESIS® BR647-14 From Nov'15 onwards
Additive		ZSM-5	ZSM-5	-	ZSM-5	ZSM-5
Additive dosing rate, % Of F-Cat		0.70% (80 kg/day average)	3.78% (310 kg/day average)	-	2.7% (300 kg/day average)	2% (210 kg/day average)
Cat Make up rate, MTPD	18	11.6	8.2	11	10.8	10.4
Specific consumption Kg/MT of feed	4.17	2.35	1.73	1.96	2.12	1.77

** Ni Passivator Dosing at ~50 kg/day done continuously since 2014*

e-cat Properties

	2014 (OCT-DEC)	2015 (JAN-MAR)	2015 (APR-JUN)	2015 (JUL-SEP)	2015 (OCT-DEC)
MAT	67.6	74	75	75	75.3
Pore Volume, cc/g	0.32	0.36	0.34	0.34	0.37
SA, M2/g	124	147	134	133.7	139.3
ABD	0.84	0.85	0.85	0.85	0.83
APS	82.8	87	75	80	79
PSD < 40	3.4	2	7	6	5
CRC, WT %	0.02	0.08	0.06	0.08	0.06
Metals					
Sb, PPM	419	119	639	831	820
Ni, PPM	7037	5445	6761	5962	5137
V, PPM	3832	3175	2913	3200	2298
Fe, WT%	0.54	0.48	0.53	0.50	0.55
Na, WT%	0.3	0.29	0.31	0.32	0.31
Re, WT%	2.33	4.09*	5.31*	5.56*	5.04*
Al2O3, WT%	48.33	48.6	48.7	48.4	48

* Re_2O_3

Plant Modifications

PLANT MODIFICATIONS

Routing of WGC/MAB condensate thru DM water pre heat exchanger

➢DM water is pre-heated with LCO P/A stream before going to deareator

➢During Flue Gas Cooler bypass DM water consumption in unit use to reduce by 60%, hence LCO P/A stream was not cooled sufficiently.

➢To maintain LCO P/A return temp. DM water was drained through deareator to increase DM water flow through exchanger

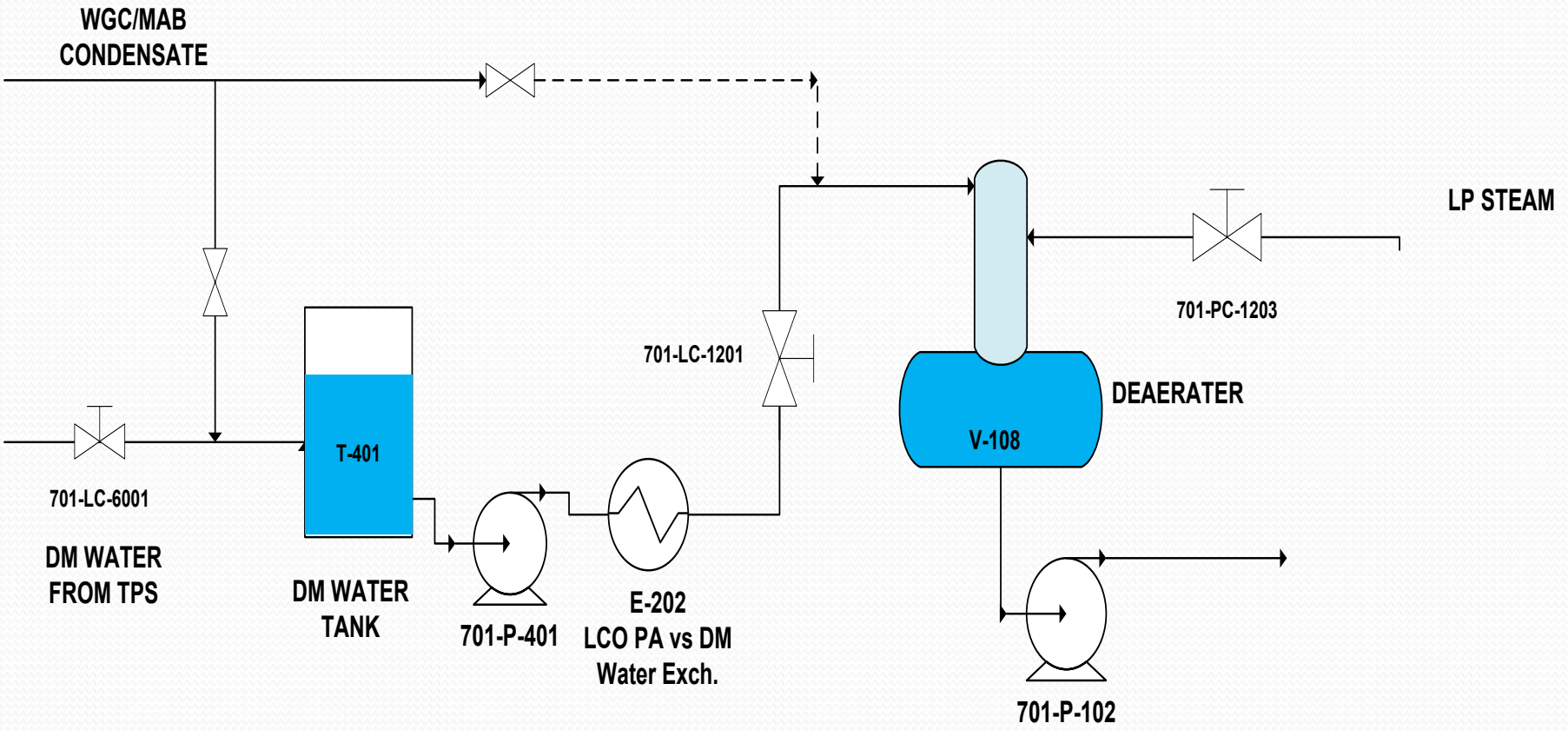
➢Scheme for routing WGC/MAB condensate through DM water preheat exchanger prior to going to Deareator was commissioned

BENEFITS:-

- LP steam consumption in deareator reduced from 4 MT/hr to 1 MT/hr
- DM water draining @15 m3/hr through deareator was stopped

PLANT MODIFICATIONS

Routing of WGC/MAB condensate thru DM water pre heat exchanger



PLANT MODIFICATIONS

Installation & Commisioning of 3rd Slurry HP Steam Generator E-209C

Two HP steam generator operation in the bottom slurry circuit instead of one resulting in,

- Increased slurry flow and lesser pressure drop in the circuit.
- Additional HP steam generation of around 8 MT/hr
- Better washing in flash zone resulting lower flash zone temperature & less coke formation in MF bottom
- Bottom circuit cleaning frequency reduced drastically (lower fouling of exchangers & strainers in slurry circuit)

Feed Management Scheme

Feed management system commissioned

- Dedicated line for routing high CCR material from OMS with control at RFCC B/L.
- Avoid upset in plant operation (RG temp fluctuation) and sustain maximization of high CCR feed. Effective control of feed CCR
- Regenerator temperature shoot up minimized
- High CCR material processing maximized and sustained.

PLANT MODIFICATIONS

Installation of Surge Drum to facilitate processing of External Naphtha(Coker MRN/SRN/LN) in feed riser

Installation of surge drum along with pump & control valves to facilitate processing of external naphtha in Feed Riser done .

- Enable processing of external naphtha at constant & controlled rate

Change in dosing point of Ni Passivator

- Dosing point was changed from injection with feed nozzles to lower LCN Recycle nozzles.
- Expected to improve lay down efficiency. Under observation.

Steam Letdown of HP to MP & MP to LP

- PRVs provided for letting down of HP to MP header & MP to LP Header during FGC bypass.

Closed Loop Sampling Systems

- Closed Loop Sampling Systems installed for all H2S bearing streams (Gas, LPG & Sour Water)

PLANT MODIFICATIONS

Provision of MP steam to NSU Reboiler

- Scheme implemented to use MP steam instead of HP steam in NSU Reboiler for revised operational reboiler load.

Pall filter:

- Old filter elements replaced with new elements
- Old & Spare elements maintained for periodic replacement after through cleaning by external agency by burning.

Provision of Back Pr Control Valve in Condensate line to TPS

- Back Pr control valve installed in condensate (MAB & WGC) line to TPS to avoid MAB/WGC trip due to high level while routing in case of blockage of condensate due to un foreseen reasons.

Provision of Pressure Transmitters in Bottom Slurry HE Circuit

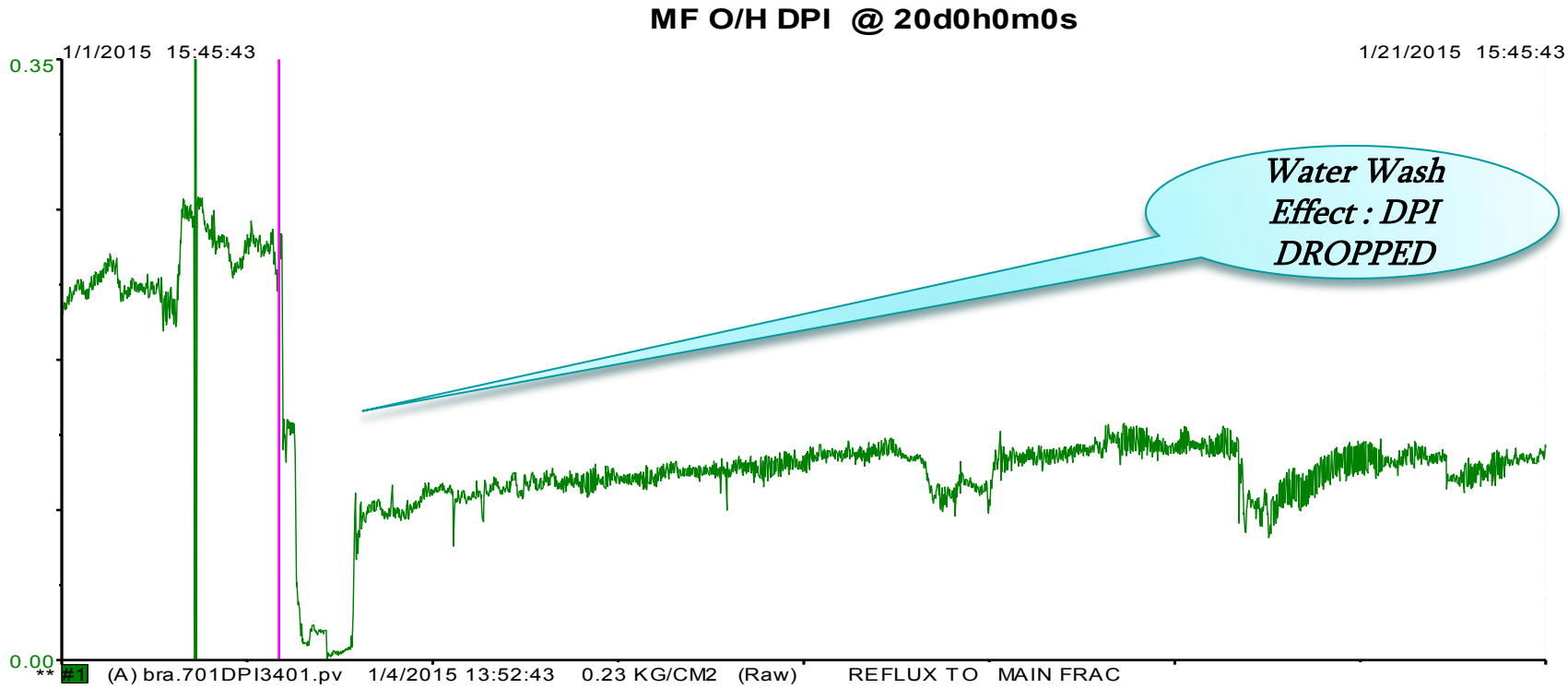
- Pr Transmitters installed in Bottom Slurry HE Circuit for online monitoring of exchanger fouling.

Trouble Shooting

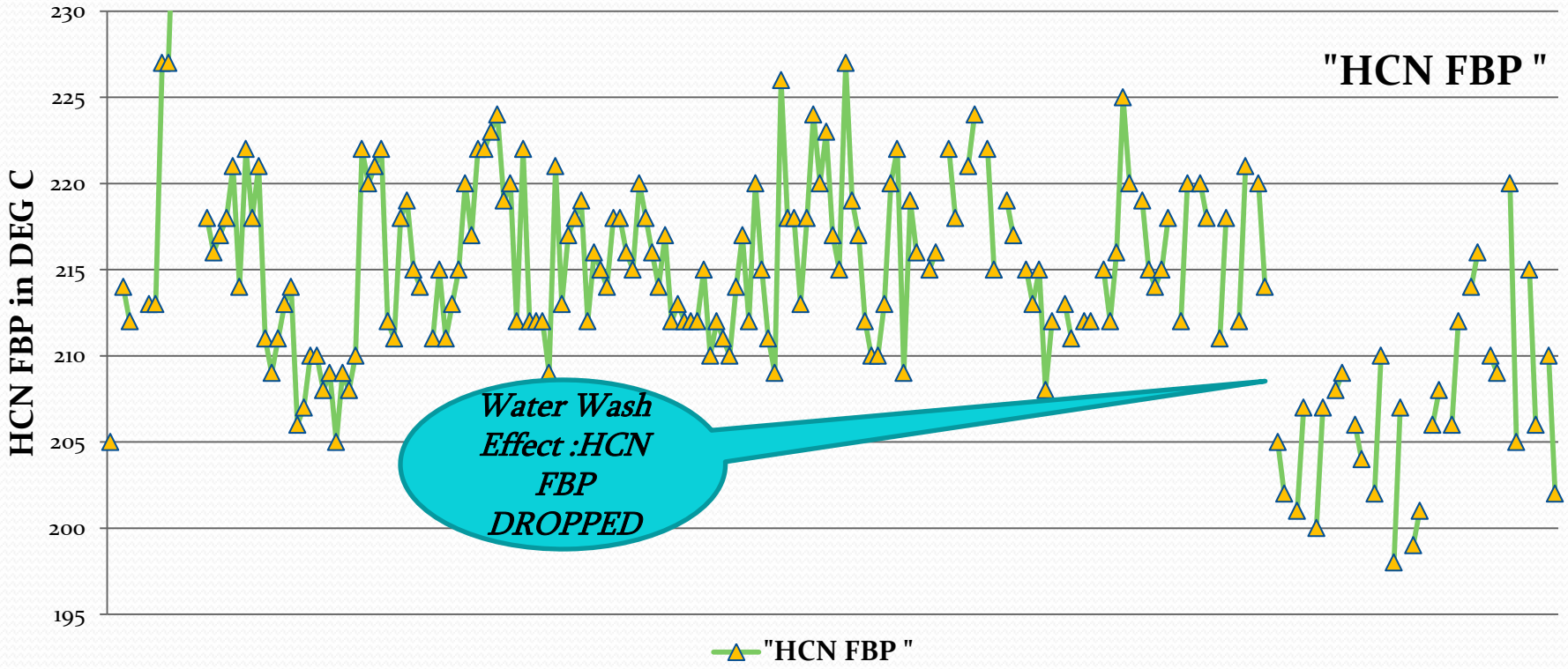
RFCCU MF Column Top Section Flooding Due To Salt Formation

- Flooding of MF Column top tray section was evident from the high ΔP across the top tray section as well as increase in FBP & Sulphur content of HCN product.
- Salt (NH_4CL) formation on the tray surface in the top section may be attributed to the following
  - Increase in N_2 content of feed (LS Crude VGO & VR)
  - Chlorides from Catalyst acid sites
- <u>Actions to overcome</u>
  - Water washing of top section
    - Offline water wash (Feed out required / outage of unit)
    - Online water wash thru reflux line (Slight decrease in T'put)
- Water samples tested showed the presence / formation of NH_4CL and ΔP back to normal after water wash.

RFCCU MF Column Top Section Flooding Due To Salt Formation



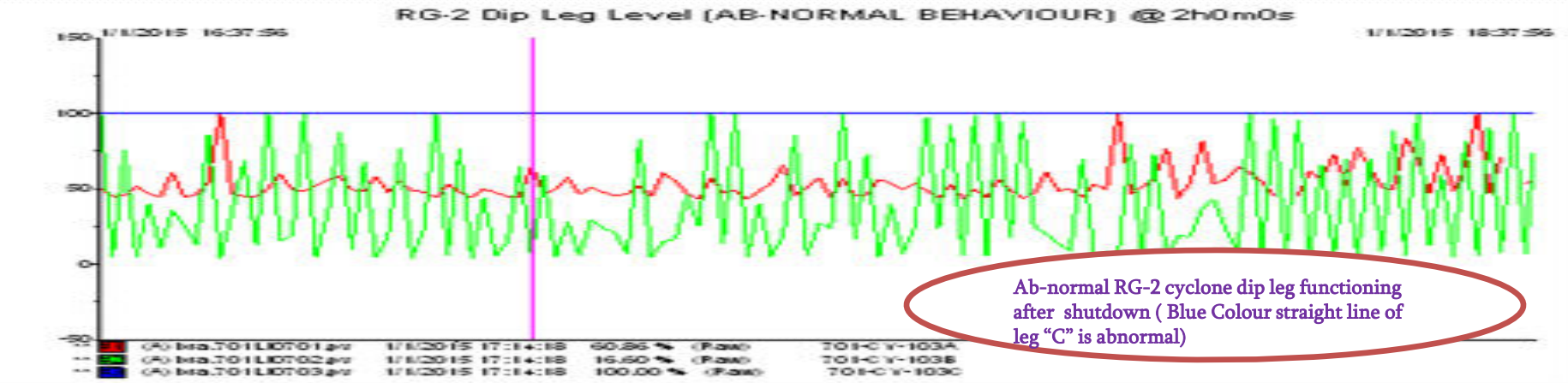
RFCCU MF Column Top Section Flooding Due To Salt Formation



TROUBLE SHOOTING

RG-2 Primary Cyclone Dipleg Chokage

- After start up post unit idling (phenomena experienced in previous start-ups too), huge catalyst loss was seen and consequences were
  - T'put restriction to 200 m3/hr (against normal of 230-240 m3/hr)
  - Belco Purge Treatment Unit was highly loaded and required to be bypassed, ETP load increased.
  - RG-2 flue gas to FGC remain bypassed as its inlet MOV was not operational due to pile-up of huge amount of catalyst upstream of MOV flapper.
- <u>Analysis of the problem of high cat loss</u>
  - One of the 3 primary cyclone dipleg LI showed constant high reading indicating a chokage.
  - External thermography too substantiated the chokage.

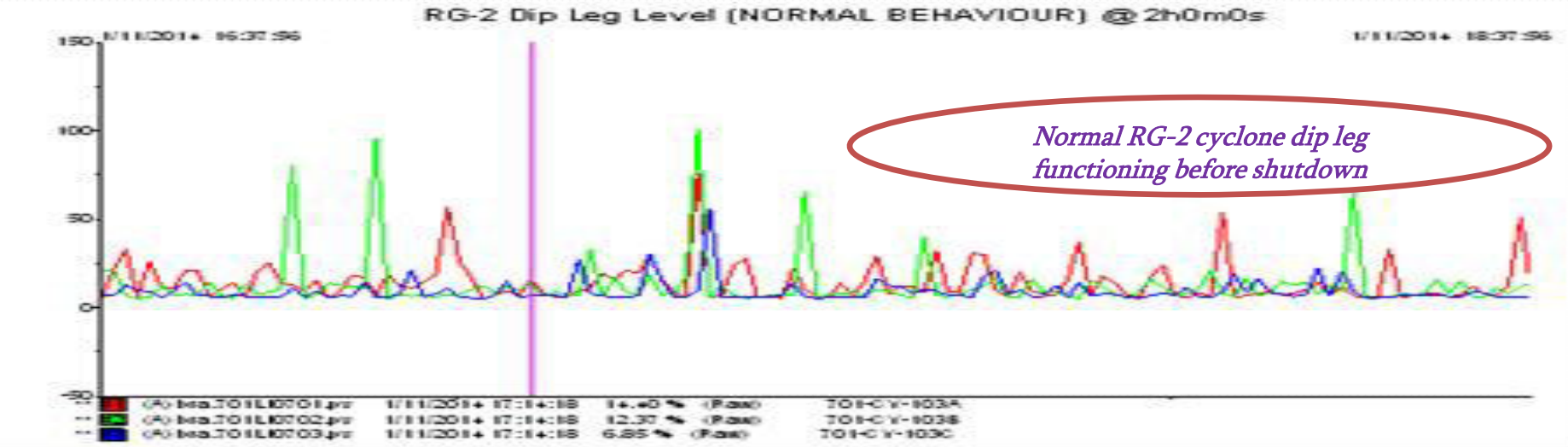


TROUBLE SHOOTING

Catalyst heap upstream of MOV restricting its operation

RG-2 Primary Cyclone Dipleg Chokage

- **Actions to overcome**
  - Cyclone dip leg aerations were adjusted & catalyst was blown out of RG-2 cyclone dip leg "C" in open under controlled condition with proper precautions.
  - E-cat addition was started after reviving e-cat loader
  - High pressure N_2 cylinder was attached to blow high pressure N2 inside dip leg duplex aeration point near bottom
  - RG-2 air was reduced to minimum to provide jerks, this was resulting in functioning of the dip leg "C"



TROUBLE SHOOTING

RG-1 Flue Gas DDSV problem

- On 8th of Aug, 2014 RG-1 DDSV both arms opening suddenly dropped to 0 % & pressure difference between RG-1 & 2 dropped to 0.25 kg/cm2 from normal operating of 0.70 kg/cm2. This led to
  - Restriction in catalyst circulation causing limitation in t'put increase

- <u>Analysis of the problem</u>
  - Pressure survey across RG-1 outlet flue gas circuit showed Low DP across RG-1 DDSV as compared to earlier pressure survey readings
  - Indications/suspection of DDSV-1 disc problem.

- <u>Actions taken to keep the unit running</u>
  - MAB air was maximised in RG-1 as far as possible to increase DP between RG-1 & RG-2
  - With limitation in further increasing MAB air due to low MAB vacuum additional 4500-5000 Nm3/hr of plant air was also given in RG-1 to increase RG-1 pressure and DP between RG-1 & RG-2. Additional air compressor was run to meet this requirement
  - Unit was run for almost 4 months with this operation strategy

TROUBLE SHOOTING

RG-1 Flue Gas DDSV problem

Finally in Nov'14 opportunity shutdown, DDSV-1 was inspected & found derailed from its position, which was replaced with help of M/M.

TROUBLE SHOOTING

Sponge Absorber Flooding

- Sponge absorber(C-206) is a 20 tray tower where essentially all of the C4's and C5's entrained in the absorber gas from the primary absorber are recovered.

- The lean oil (i.e. Heavy Naphtha from MF) used for absorption is cooled in E-203(Feed/Lean oil) & E-204(Lean oil/CW) and then routed to C-206 for absorption.

- The rich sponge oil leaves the bottom of the sponge absorber on level control and is routed back to the fractionator for recovery of the light ends (C4's and C5's).

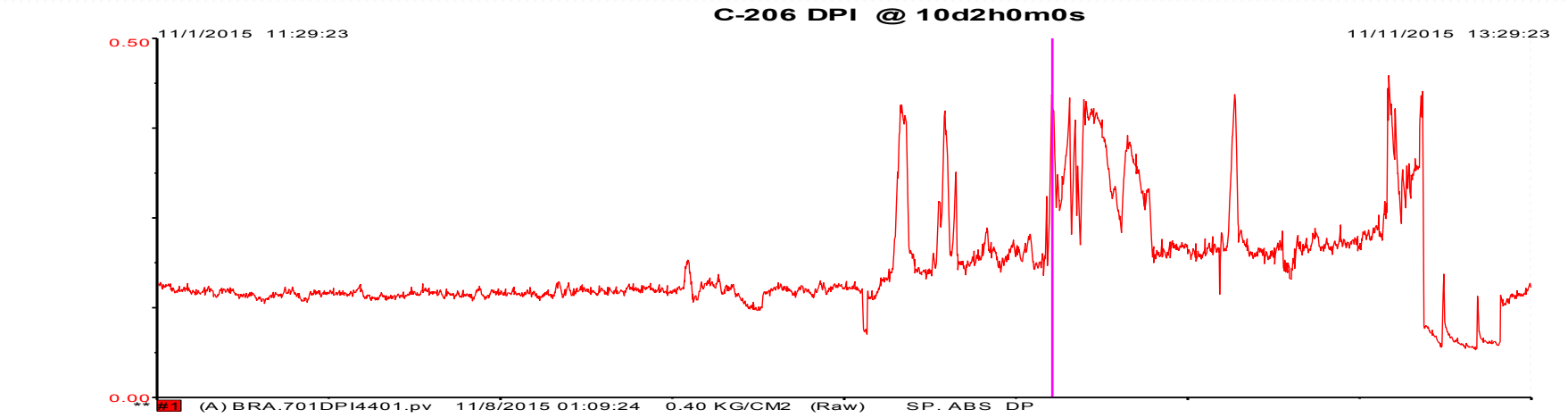
<u>Problem</u>

- High DP across C-206 was observed since 06.11.15. Normal DP is ~ 0.145 kg/cm2 which goes as high as 0.40 kg/cm2.

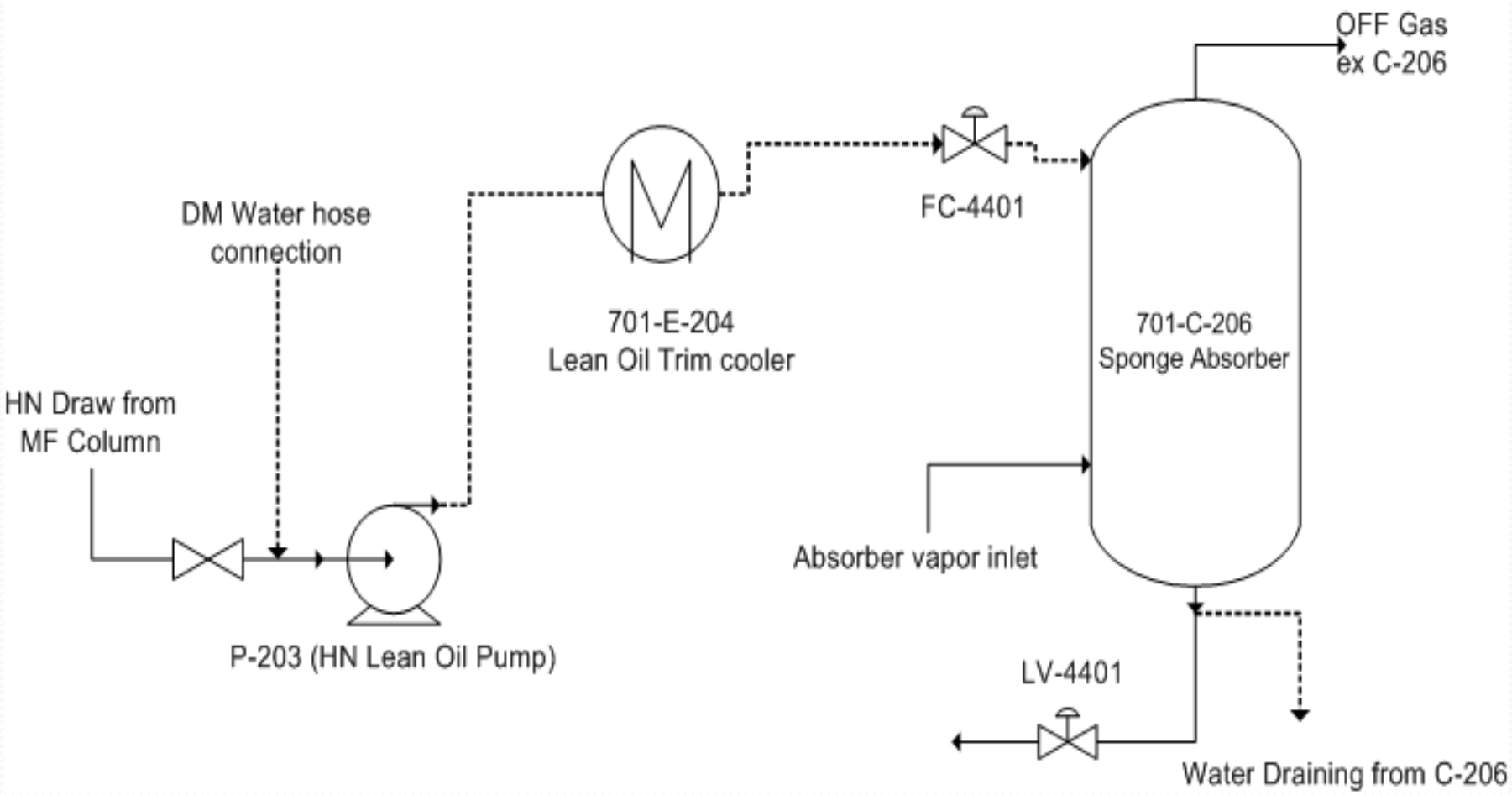
- High DP across C-206 causes flooding in column & liquid carry over to V-209 (Sour gas KOD) frequently.

Sponge Absorber Flooding

- Actions to overcome
  - Water washing was done on 10.11.2015 after t 'put was reduced to 225 m3/hr using DM water through hose connection in 701-P-203 suction for 40-45 minutes.
  - Wash water draining done from C-206 bottom drain & C-206 DP was normalized to 0.10 kg/cm2.
  - Lot of blackish water was observed which ensures presence of salt deposits inside HN circuit, which also causes MF overhead high DP issue.



Sponge Absorber Flooding- Schematic Diagram



Operational Improvements & Highlights

OPERATIONAL IMPROVEMENTS/HIGHLIGHTS

- **GRM Improvement :**

  RFCC Feed switch over from HS VR to LS VR resulting in

  - Higher VR processing (increase to ~18 wt% from 10 wt%)
  - Direct blending of LCN to MS pool due to lower S content
  - Better distillate as compared to VR processing in Coker

- **Naphtha Destruction: Injection of Light Naphtha in LCN recycle nozzle in RFCC riser**

  - Approx. 5 wt% Light naphtha (of total RFCCU t'put) ex CRU is injected in LCN recycle nozzles
  - 35 % conversion into LPG + Off gas & 65 % into LCN

- **Utilization of ZSM-5 to increase LPG production when prices are favorable i.e. higher than MS and also as Octane Booster.**

- **Utilization of Ni Passivator**

  - Continuous dosing to maintain Sb/Ni ratio at 0.2 in order to reduce dehydrogenation rxns. H_2/C_1 ratio maintained near to 1.

- **Utilization of BCA for bottom up-gradation whenever CLO yield is on higher side.**

OPERATIONAL IMPROVEMENTS/HIGHLIGHTS

➢ Sustained Operation of Pall Filter

Pall filter commissioned and & sustained operation of the same

- Routing of CLO to FO pool (extra margin of Rs 10000/MT)

➢ Reactor Stripper Performance Improvement

Stripper level was gradually increased from 15% to 35% and stripping steam was maximized

- H2 on coke was reduced to 8%
- RG temperature reduced giving scope for increasing feed CCR

➢ Reduction in Debutanizer column operating pressure

Due to fouling of debutanizer column reboiler, lighter components(C3 & C4) were carried into naphtha stream thus increasing its RVP.

- Debutanizer column pressure was reduced from 12.50 kg/cm2g to 10.75 kg/cm2g gradually to strip-off lighters from naphtha stream.

OPERATIONAL IMPROVEMENTS/HIGHLIGHTS

➢ VGO Feed Quality Improvement

VGO Feed (360° minus) trimmed down from ~12% to present value of 4-5%

- Freed up RFCC capacity by ~7%. This will help us push more crude T'put as BR was limited by FCC capacity
- Incremental DHDT feed production by 1.5% on crude due to this trimming

➢ New Portable online analyzer procured for fast & reliable measurement of RG Flue Gases

➢ Gasoline Splitter Optimization

GSU operation was optimized for energy conservation

- Column pressure reduced
- Stripper re-boiler load decreased (saving of ~ 5MT/hr of HP steam)
- GAP between LCN & HCN reduced from 13 deg C to 2 deg C

Last Shutdown Experience

Last Shutdown Experience

Huge coke deposit on Riser termination device

Last Shutdown Experience

RG-1 Cyclone welding cracks

Last Shutdown Experience

Reactor Pre-Stripping steam ring damaged

Major Upcoming Projects

Major Upcoming Projects

New Flue Gas Cooler (FGC)

- Job awarded to M/s Alstom (LSTK)
- Increased Capacity : 90 TPH net HP steam Production
- Provision of combusting Biturox off gases in COI
- Execution completion/Commissioning anticipated post M&I scheduled in Mar'17

Replacement of Reactor Stripper Internals

- Job awarded to M/s Technip SWEC
- New Main Stripping steam with newer design
- Execution completion/Commissioning anticipated post M&I scheduled in Mar'17

Benefits:

- Reduced H_2 on coke
- Reduction in RG temps by ~ 8 deg C
- Increase in equivalent feed CCR (more VR processing or increased T'put)
- Reduced stripping steam consumption

Major Jobs Planned in M&I Shutdown

Major Jobs planned in M&I s/d

- Replacement of damaged air grids of RG-1 & RG-2
- Replacement of RG-1 secondary cyclones
- Replacement of Reactor Cyclone diplegs
- Replacement of RG-2 secondary Cyclone diplegs
- Replacement of Rx Stripper internals with grid packing
- Required Hook ups for New Flue Gas Cooler (FGC)
- Installation of ROVs in MF Column Bottom Line
- Replacement of FFCs & Coalescer Pad in LPG Treater (Merichem)
- Debottlenecking of MF Overhead Distillate pump – New Pumps are planned to be installed.
- Retubing of MAB Surface Condenser

Best Practices

Best Practices being followed

- ✓ Regular monitoring of the performance of the slurry circuit heat exchangers. PTs have been installed in slurry side of the bottom circuit for online monitoring.
- ✓ Regular thermography of R-R Section to identify hot spots/refractory damage.
- ✓ Regular monitoring of catalyst losses-
  - ❖ By daily physical monitoring of Belco purge sample
  - ❖ By carrying out hopper dipping every 15 days and estimating catalyst loss based on catalyst addition.
- ✓ Continuous operation of RFCCU in RMPCT (Robust Multivariable Prediction Control Technology) i.e APC mode with an on-stream factor of 99%.
- ✓ Monitoring Gas oil component in VGO & VGO component in VR
- ✓ Flushing all RR tapings monthly
- ✓ Maximizing LS naphtha in FCC riser as a part of naphtha destruction strategy
- ✓ Continuous operation of pall filter.
- ✓ Quaterly pressure Survey across RR

Stream Sharing

Stream Sharing With Other Units

- Processing of off-spec LPG in gas con section.
- Processing of LPG rich off gases from other units i.e. DHDT Stabiliser off gas, NHDT off Gas & HDS Stabiliser off gas in gas con (routed to WGC Suction)
- Processing of coker MRN / excess LN of CRU in riser resulting in sulphur reduction, octane improvement & equivalent quantity of SRN destruction.
- Processing of RFO ex BGR & LVFO ex Digboi in RFCCU instead of processing in Cokers.

Thank You