FCC Flue Gas Treatment by implementing BELCO® Wet Scrubbing Technology

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Environmental Regulation

According to the EU Regulation it was mandatory for Petrotel-Lukoil Refinery to evaluate and implement the Best Available Technologies (BAT) in order to reduce the SOx, NOx and Particulate emissions generated in FCCU regenerator.

FCC Flue Gas Emissions	Flue Gas Emissions generated in FCC	Limits imposed by Environmental Regulation	Polutants Reduction %
SOx (mg/Nm3)	2700 – 3000*	550	81.6
NOx (mg/Nm3)	500-800*	300	62.5
Particulate (mg/Nm3)	500**	50	90.0

Note: * Caused by changing FCC Feed quality;
** Particulate emissions are influenced by regenerator cyclones efficiency.

FCC Feed Quality

No	Properties	Unit	Values
1	Density	Kg/m3	916 – 935
2	Sulphur	%	1.6 - 1.8
3	Nitrogen	ppm	1400 - 1900
4	IFB / FBP	ºC	320/575
5	K UOP Factor		11.6 - 11.8
6	Coke Conradson	%wt	0.4 – 1.2

The SOx, NOx and Particulate emissions generated are specific for this UOP FCC Unit, type Side-by-Side, which process a non-hydrotreated FCC feed with high nitrogen and sulfur content.

No	Operating Conditions		Unit	Values
1	Feed	Flow rate	m^3/h	90 – 130
		Feed Preheat Temperature	ºC	165 - 270
		Recicle Slurry	m^3/h	5 – 12
2	Reactor	Riser Outlet Temperature	ºC	520 – 530
3	Regenerator	Pressure	barg	1.52 – 2.21
		Air flow rate	Nm^3/h	max. 78000
		Dense Phase Temperature	ºC	~700

Flue Gas Treatment Options

No	SOx	NOx	Particulates
1	SOx reduction additives	Non-Pt CO Promoter	Improving cyclones efficiency
2	Flue Gas Scrubbing	Flue Gas Scrubbing / LoTOx™ System	Flue Gas Scrubbing
3	FCC Feed desulfurization	NOx reduction additives	Electrostatic Precipitation
4		Selective Catalytic Reduction	Third Stage Separation
5		Selective Non-Catalytic Reduction	

Flue Gas Treatment Options

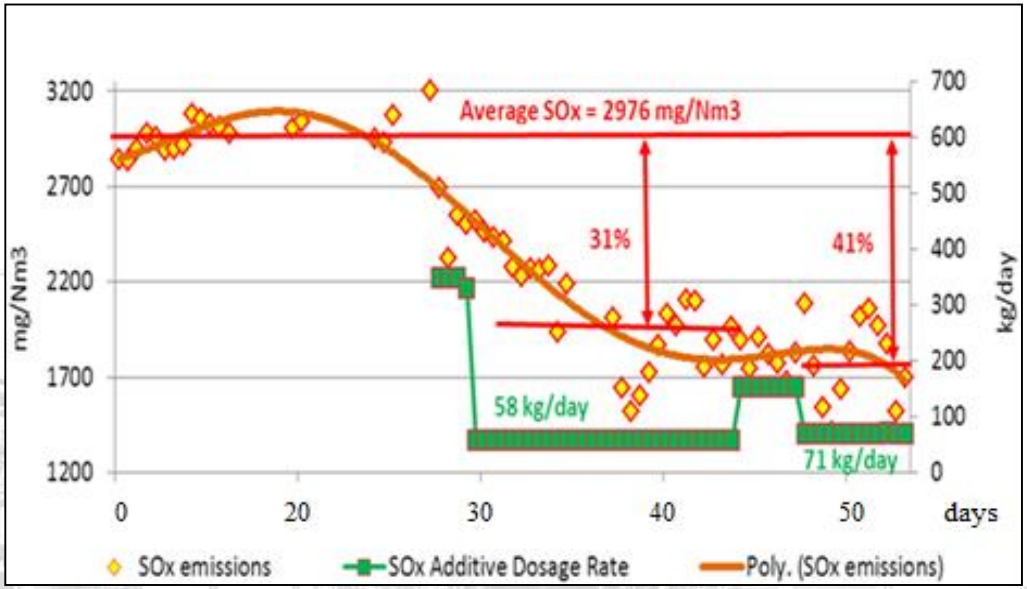
Petrotel-Lukoil conducted a systematic analysis of available SOx, NOx and particulates abatement techniques. The conclusion taken are the following:

- **BELCO® Wet Scrubbing/LoTOx™ System** was considered to be the most efficient technology and can reduce all three types of emissions: SOx, NOx and particulates.
  - Disadvantage: higher CAPEX and OPEX required for implementation and operation.
- **SOx and NOx reduction additives** does not required any investment costs.
  - Disadvantage:
  - Higher dosages can dilute the FCCU e-cat inventory.
  - Concerns regarding their capacity to reduce the SOx and NOx below the limits imposed by Environmental at high contamination with S and N of the FCC Feed.
- **Feed pre-treatment (VGO Hydrofining) and Post-Regenerator Treatment Technologies** (3rd Stage Separators, Electrostatic Separators, SCR and SNCR) are considered to be not suitable for the refinery (higher CAPEX/OPEX, associated costs for work, operation, safety and continuous monitoring in order to improve the process).

FCC Industrial Testing

SOx reduction additives

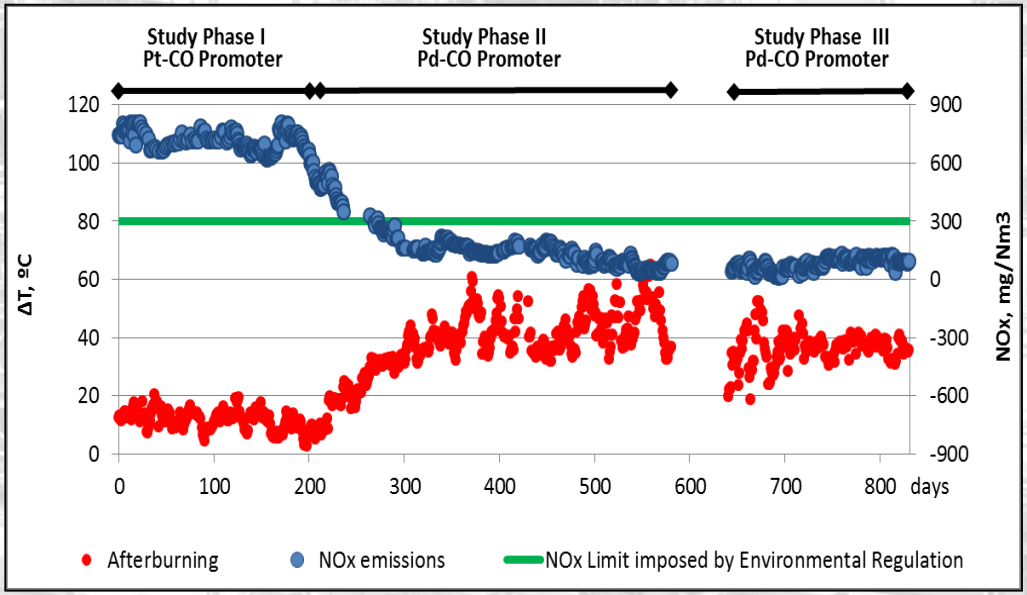
By industrial testing the SOx reduction additives it was concluded that, in our FCC conditions, SOx emissions can be reduced up to 41% by dosing 71 kg/day additive (which correspond to a consumption norm of 0.053 kg/kg fresh catalyst).



Non-Pt CO promoters

Replacing the Pt-CO promoters with Pd based additive can reduce the NOx emissions but can increase the afterburning phenomenon.

Therefore Pd-CO promoter are not recommended to be implemented in FCCU confronted with high afterburning in regenerator.



BELCO® Wet Scrubbing System

Decision taken to implement BELCO® Wet Scrubbing System

BELCO® Wet Scrubbing System

Design Philosophy of DuPont for FCCU Scrubbing

- FCCU (refinery process units) makes $$$ - gasoline, diesel and other valuable products

- Always keep the FCCU running
  - Match FCCU – typically 3-7 years
  - Handle Upset – no outages

- Always control flue gas emissions

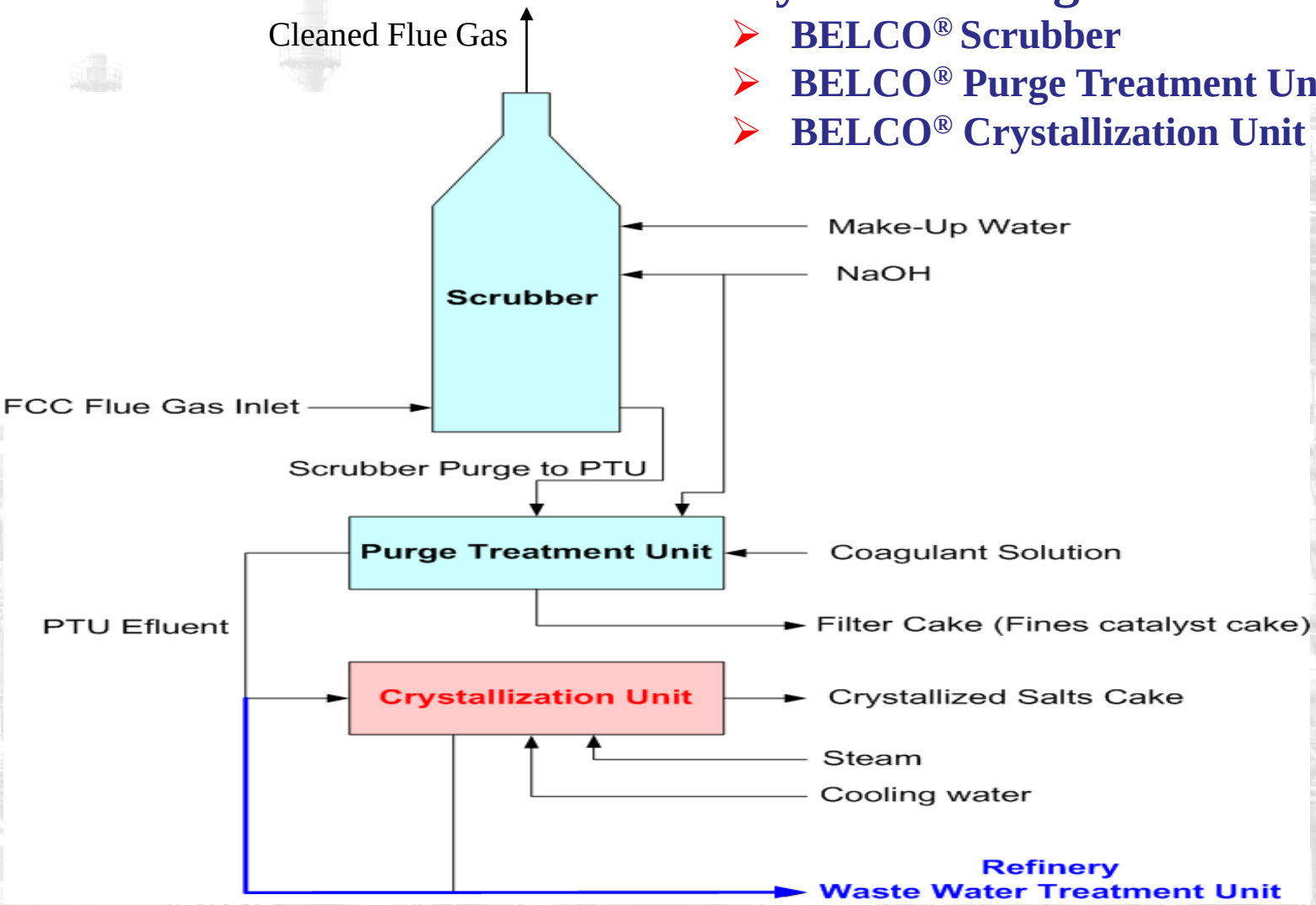
- Always keep emissions control costs as low as possible

- Always understand that controlling emissions does not typically make $$$, but costs $$$

BELCO® Wet Scrubbing System

Basic System Configuration Considered

- BELCO® Scrubber
- BELCO® Purge Treatment Unit (PTU)
- BELCO® Crystallization Unit (CU)



BELCO® Wet Scrubber

Quick Overview

- Low Energy Wet Scrubbing
  - Staged Scrubbing
  - Quench/Saturation - water sprays
  - Absorption - water sprays
  - Condensation by compression/expansion
  - Filtration - water sprays
  - Separation – remove droplets

BELCO® Wet Scrubber

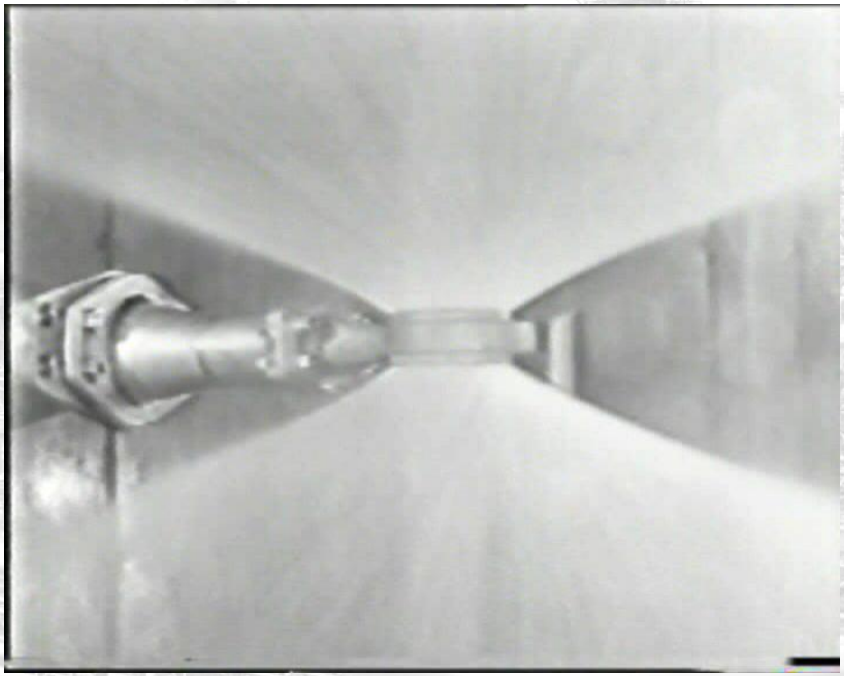
Step A

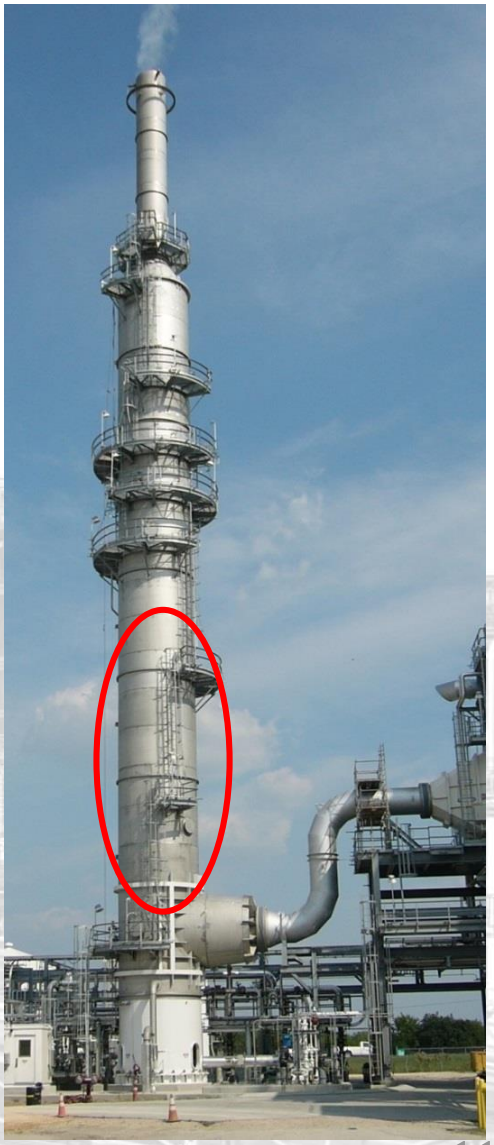
- Hot dirty flue
- Quenched to saturation with water sprays
- From 220° – 750° C hot gas
- To 40° – 70° C (adiabatic saturation)

BELCO® Wet Scrubber

Step B

- Multiple levels of buffered water sprays provide intense liquid-gas contact for cleaning
- SO_2 + SO_3 Removed
- Large Size Particulate Removed

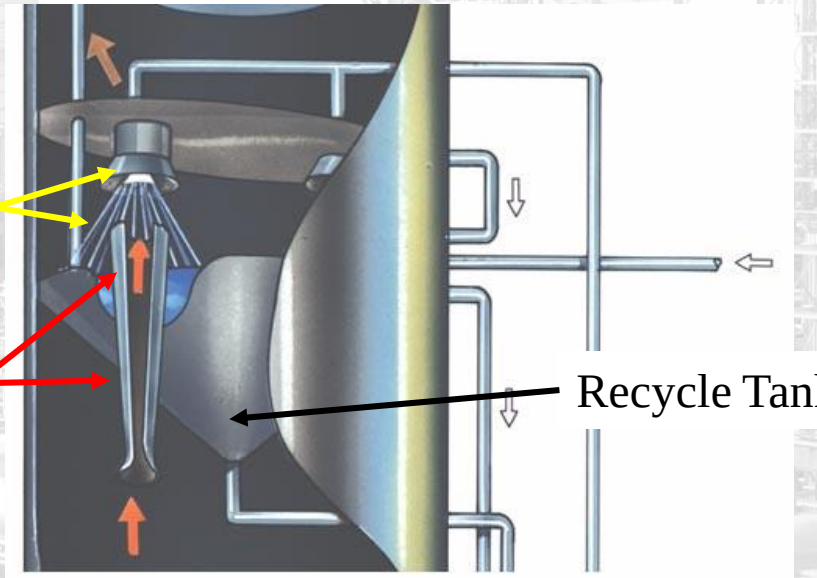




BELCO® Wet Scrubber

Step C

- Flue gas pressure drop energy and buffered water sprays
- Fine Particulate removed
  - Growth in particulate
  - Particulate agglomeration
  - Particulate filtered by water sprays

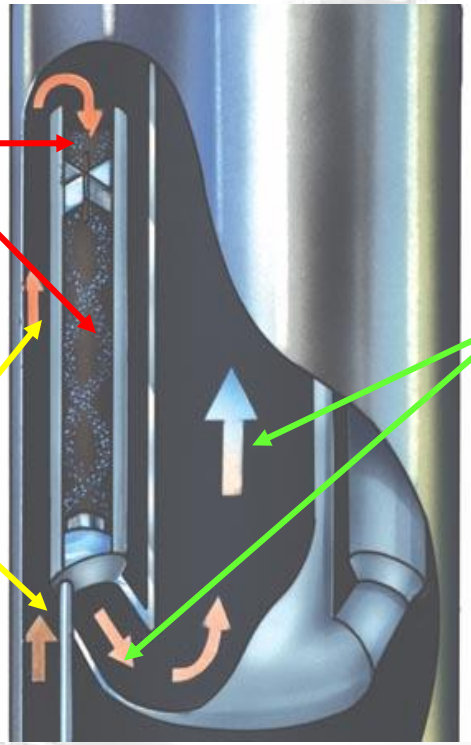


BELCO® Wet Scrubber

Step D

- Free water droplets removed with cyclonic separation

2. Gas flows down through the droplet separator tubes



1. Gas flows up around outside of droplet separators tubes

3. Gas flow out bottom of droplet separator tubes and into bottom of stack and up stack

BELCO® Wet Scrubber

Step F

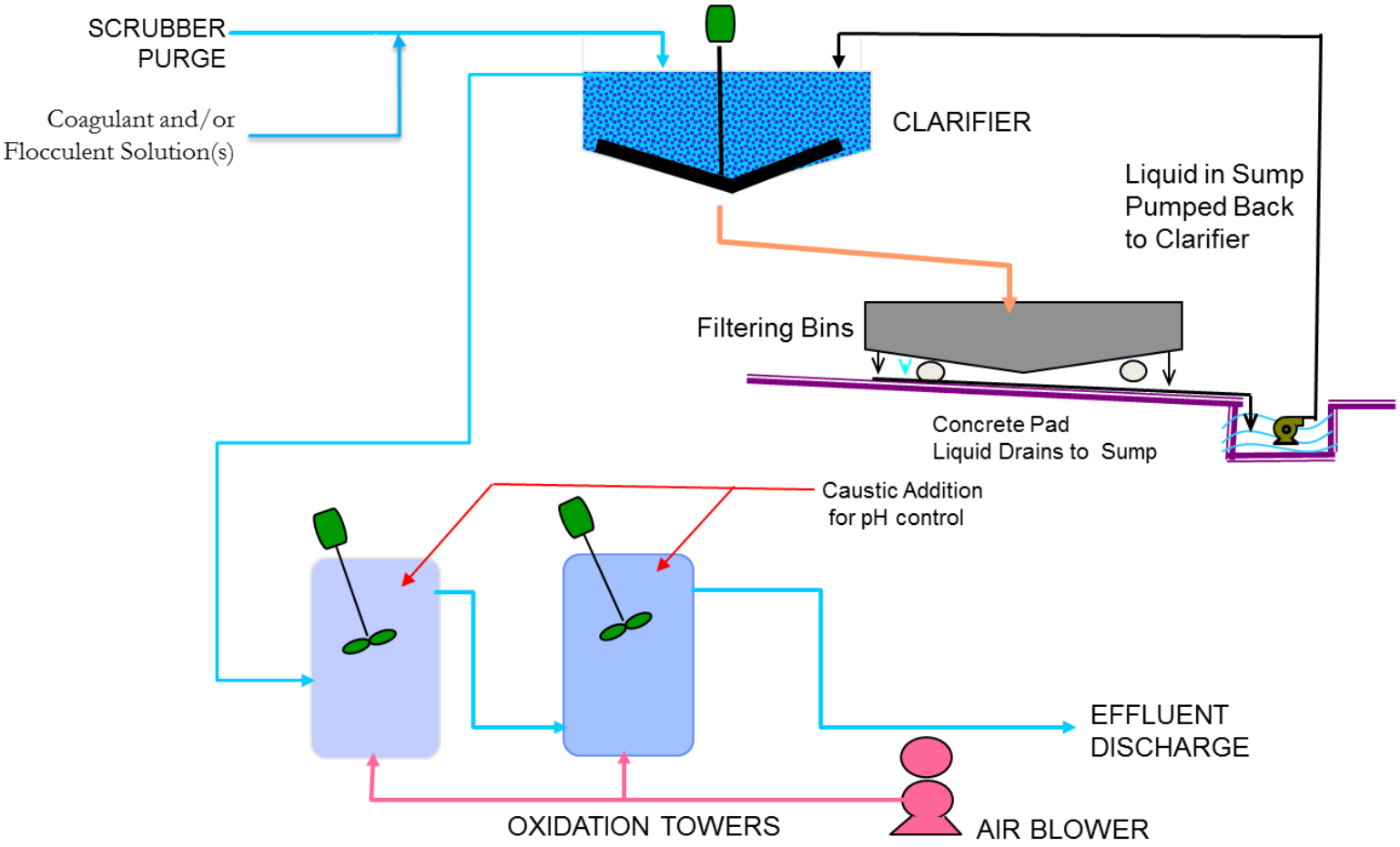
- Discharge to atmosphere
- Meet regulatory requirements
- No rain of free water
- Good plume distribution

Caputured Emissions Discharged from Scrubber for Treatment

- Single liquid stream
- Water
- Dissolved SO2 and SO3
- Neutralized with NaOH
- Suspended catalyst fines

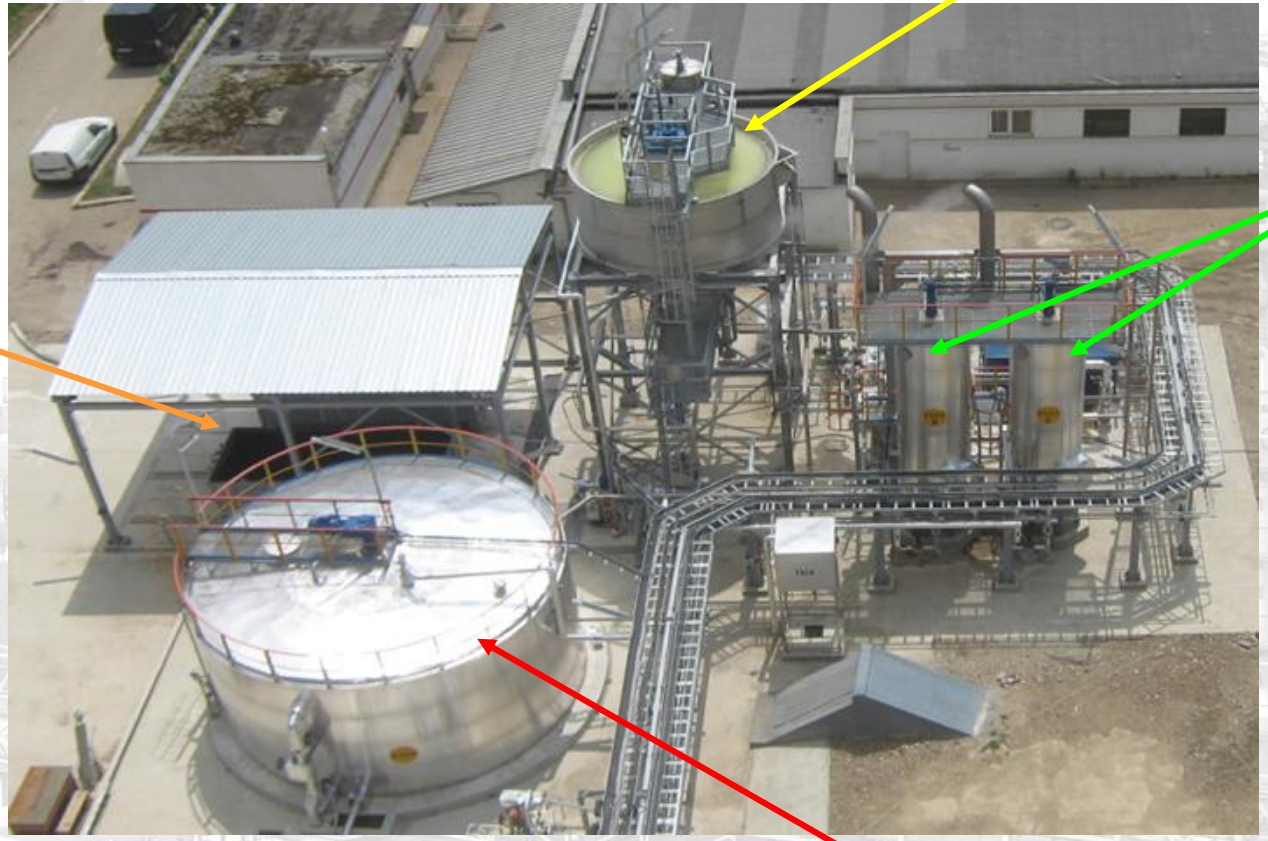
BELCO® Purge Treament Unit

- Treats liquid discharge from scrubber
- Removes catalyst fines - produces de-water cake for disposal
- Oxidizes sulfites (COD) – produces stable salty water for disposal



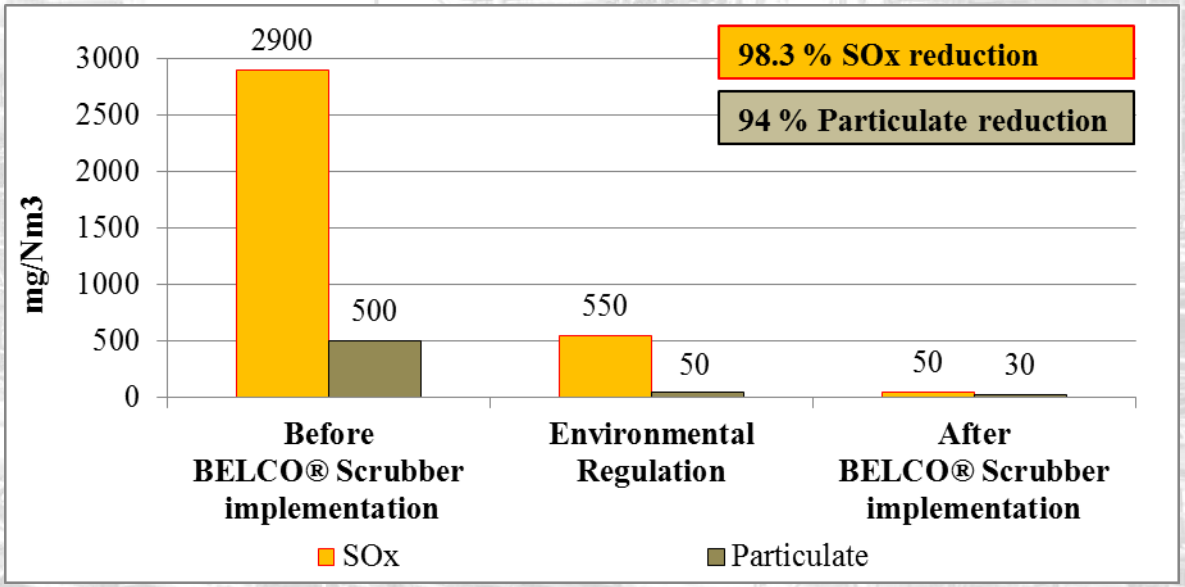
BELCO® Purge Treament Unit

System installed at refinery



BELCO® Wet Scrubbing System

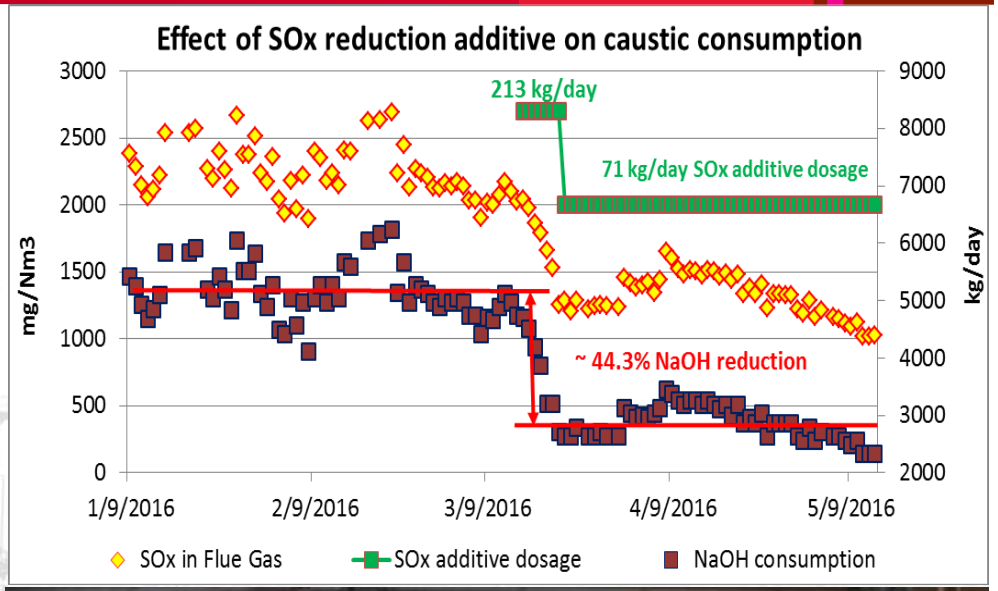
BELCO® Wet Scrubbing System was put in operation in May 2015 and the immediate results consisted in removal of SOx and particulates from FCC flue gas below the limits imposed by environmental regulations.



Integrating Wet Scrubbing System with SOx/NOx reduction additives

SOx reduction additives

Petrotel-Lukoil explored the possibility to integrate SOx reduction additives and Wet Gas Scrubbing technologies the main target being to minimize the caustic consumption required for scrubber operation.

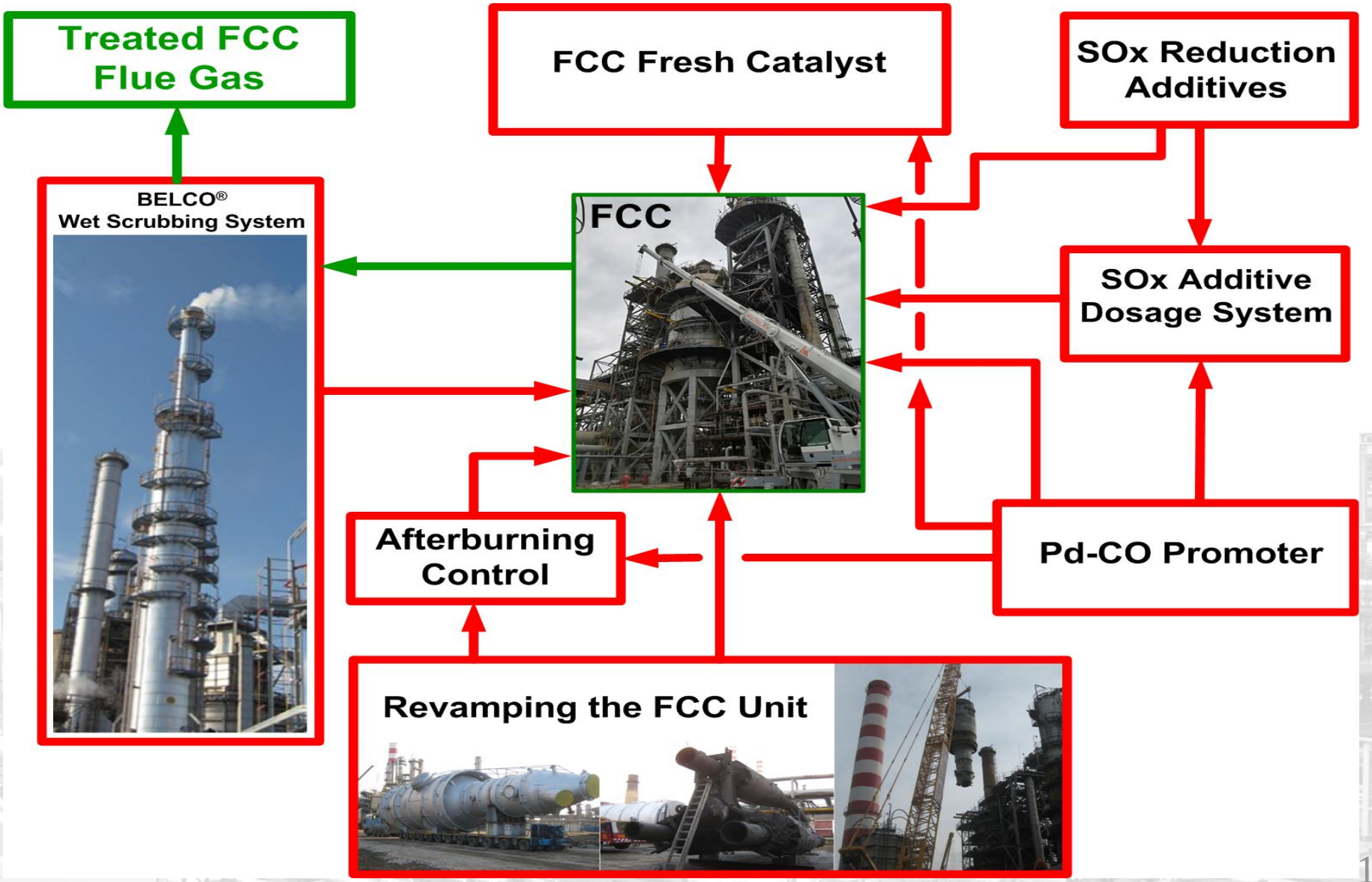


Pd-CO Promoter

Petrotel-Lukoil performed and extensive revamping of FCC regenerator in order to control the afterburning (by replacing the old ineffective cyclones/plenum chamber and changing their layout).

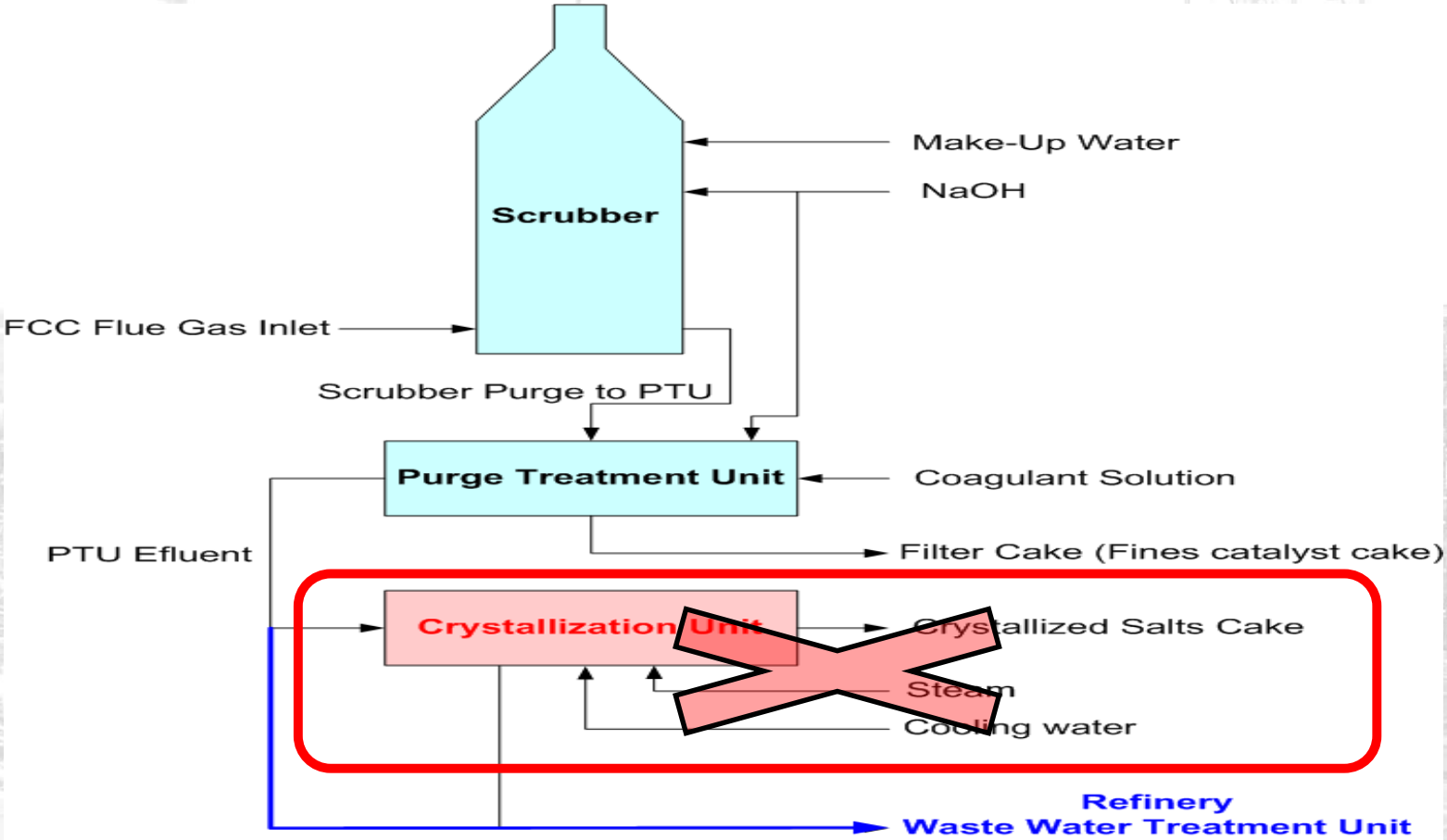
Since the afterburning was eliminated it was possible to replace Pt with Pd-CO Promoter to reduce NOx emissions.

Integrating Wet Scrubbing System with SOx/NOx reduction additives



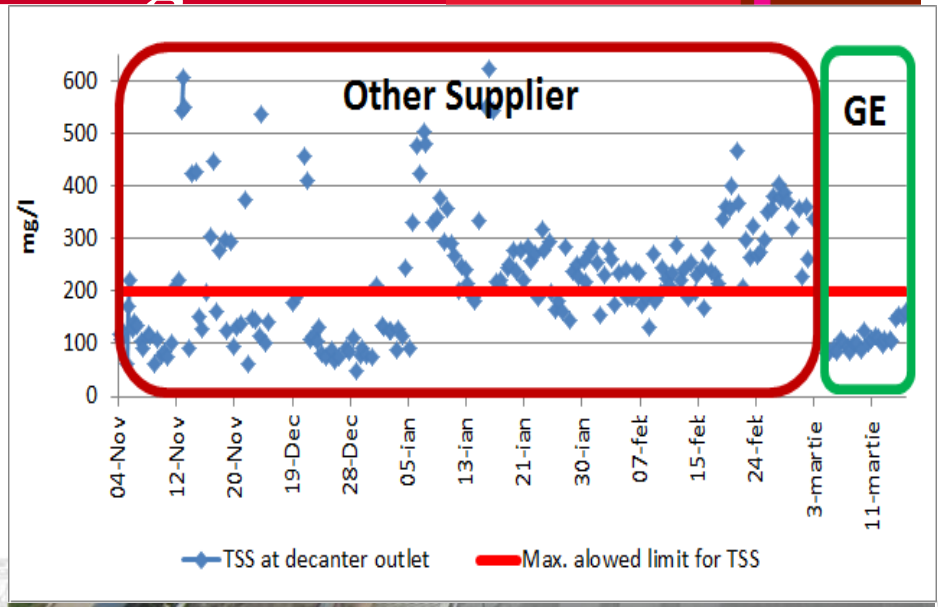
Integrating Wet Scrubbing System with Waste Water Treatment Unit

The refinery considered to exclude the Crystalization Unit and direct the PTU Efluent to Waste Water Treatment Unit in order to reduce CAPEX and OPEX for FCC Flue Gas Treatment but also to eliminate the environmental issues associated with the disposal of sulfate wastes.



Industrial testing and selecting the most efficient PTU coagulant

To optimize BELCO® PTU and to avoid the contamination of waste waters with suspended solids were performed a series of industrial tests to select the most efficient coagulant. In our case, it was concluded that by using GE Klaraid coagulant it was possible to reduce the dosage rate from 3 kg/h to 0.8 kg/h and assure maximum 200mg/l TSS in PTU Effluent.



Wet Scrubbing System optimization

Adapting the PTU filter cake platform for winter operation in order to avoid freezing.

Conclusions

- All European refineries face a challenge to reduce atmospheric emissions below the limits imposed by European Environmental Regulation;
- Analyzing the efficiency of all available technologies for FCC Flue Gas Treatment it was concluded that BELCO® Wet Scrubbing System is the most efficient and can reduce SOx, NOx and particulate below the limits imposed by Environmental Regulation;
- Petrotel-Lukoil evaluate the possibility to integrate Wet Scrubbing System technologies with other technologies in order to reduce CAPEX & OPEX associated with FCC Flue Gas Treatment Project;
- The caustic consumption required for Wet Scrubbing System operation can be reduced by dosing SOx reduction additives in FCCU. The economic effect achieved depend on the market price for both additive and caustic;
- Replacing the Pt-CO promoters with Pd based additive can reduce the NOx emissions but can increase the regenerator afterburning. Therefore Pd-CO promoters are not recommended to be implemented in a FCCU confronted with a high afterburning phenomenon in regenerator;

Conclusions

- Petrotel-Lukoil eliminate the environmental issues associated with the disposal of sulfate wastes by directing the PTU Effluent to Waste Water Treatment and therefore excluding the Crystallization Unit included in the initial Project;
- To optimize the PTU and to avoid the contamination of waste waters with suspended solids is recommended to perform a series of industrial tests for evaluate the efficiency of different coagulant types/different suppliers. The test results showed that, by selecting and using the most efficient coagulant, we were able to reduce the suspended solids in PTU Effluent at maximum 200 mg/l in the conditions of reducing dosage rate from 3 kg/h to 0.8 kg/h;
- Petrotel-Lukoil improved and optimized the Wet Scrubbing System in order to adapt it at the refinery operation conditions (winter operation);
- The refinery estimated that the economic effect achieved by implementing and integrating the most efficient FCC flue gas treatment technologies consist in reduction of investment cost by 4.6 million $ and operating expenses by 2.5 million $.

Thank you for your attention!