

REINHOLD ENVIRONMENTAL Ltd.



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Catalyst Regeneration for the Long Haul

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February 11, 2014

steag

Catalyst regeneration for the long haul



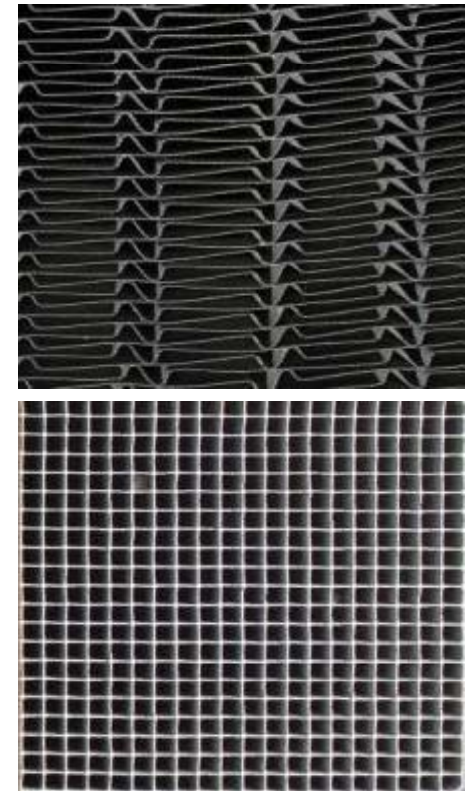
- **The new catalyst purchase**
- **The SCR reactor operation**
- **The Catalyst Regeneration Process**



The New Catalyst Purchase



- **New Catalyst Purchase – Purchasing for Catalyst Longevity**
 - **The catalyst type**
 - **The catalyst pitch**
 - **The catalyst wall thickness**
 - **The catalyst structural consideration**
 - **The catalyst module design**



Catalyst is and Asset and should be treated as one!

The New CatalystThe Catalyst Type



**Extruded Honeycomb
Ceram, Cormetech, Johnson Matthey**



**Corrugated Honeycomb
Haldor Topsoe**



**Wire Mesh Supported Plate
Ceram, Hitachi, Johnson Matthey**



**Corrugated Plate
Hitachi Zosen**



The New Catalyst Purchase The Catalyst Pitch



- **Honeycomb Catalyst**

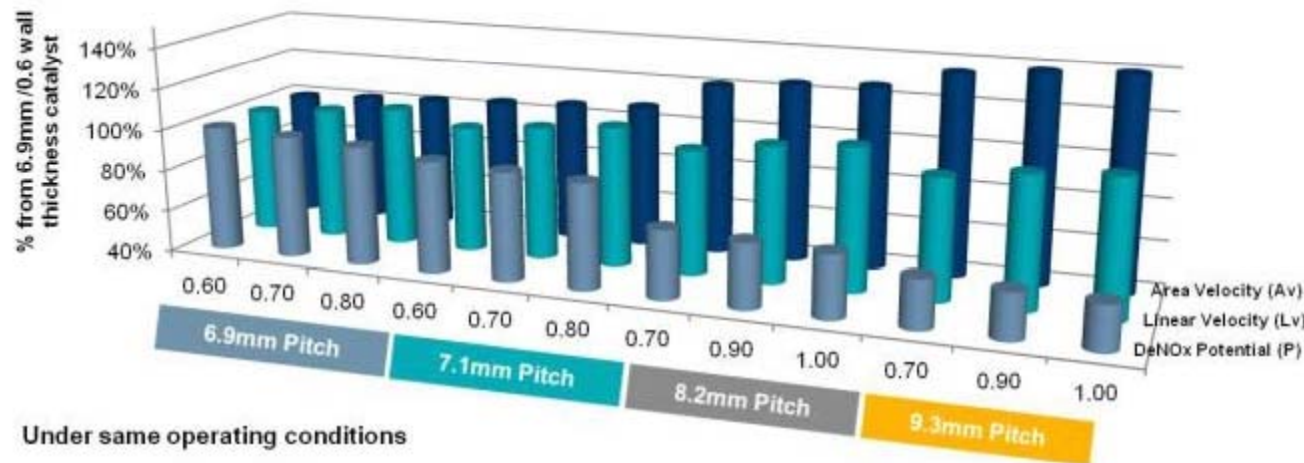
- The tendency is to move to larger catalyst pitches.

- Bituminous Fuel

6.9mm / 7.1mm → 7.4mm / 8.2mm

- PRB Fuels

6.9mm → 8.2mm / 9.3mm



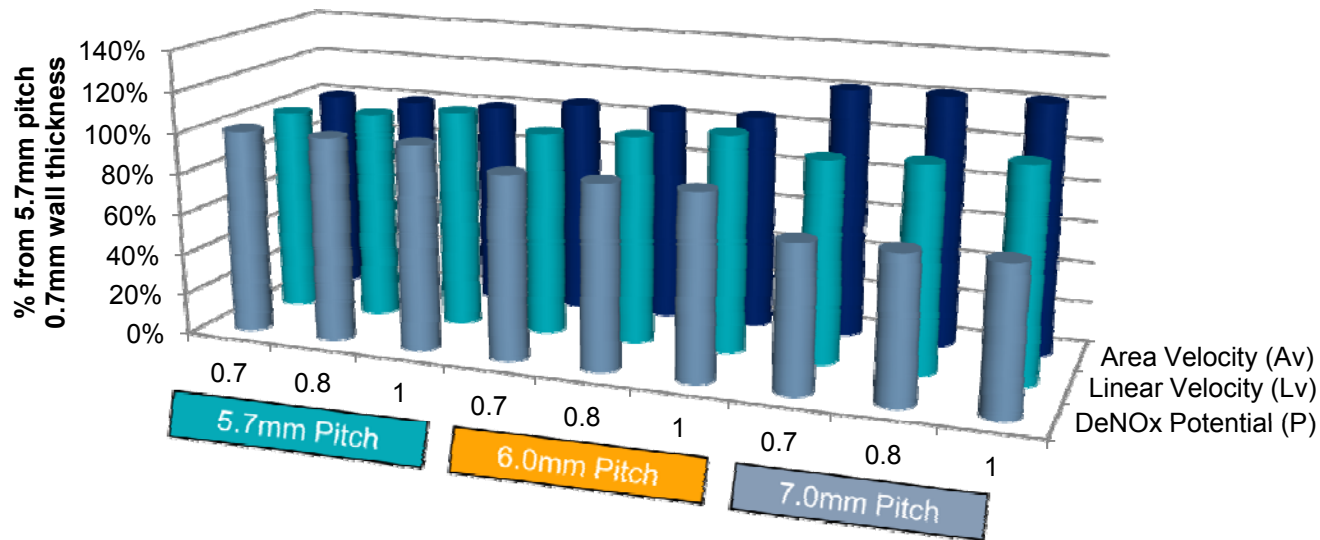
Under same operating conditions

The New Catalyst Purchase The Catalyst Pitch



- **Plate Type Catalyst**

- The tendency is to move somewhat larger size catalyst near the front wall of the reactor.
- The catalyst pitch is in one direction allowing more assistance in moving ash into the module.
- The ash normally begins to plug between the catalyst cassettes.



The New Catalyst Purchase The Catalyst Pitch



- **Haldor Topsoe**
 - Need to keep the pitch larger.
 - Need to minimize the amount of fiber hairs in the channel. Particularly for the smaller particles.
 - Need to obtain the Specific Surface Area from the vendor.
 - Need to understand the ash loading of the fuel.
 - For future regenerations it is recommended that the modules not be tack welded but placed in a module.
 - The metal impregnation process is very similar to regeneration impregnation process.
 - Make sure that you require modules have 6" X 6" X catalyst height sample sleeves.




The New Catalyst Purchase The Wall Thickness



- **Honeycomb Type Catalyst**

- The wall thickness have been getting thinner.

0.8mm to 1.2mm  0.6mm

The primary reason is SO_2/SO_3 conversion rate.

On STEAG units - STEAG will purchase (for catalyst longevity):

- 6.9mm – 7.4mm Not less than 0.8mm
- 8.2mm – 9.3mm..... Not less than 1.0mm

- **Plate Type Catalyst**

- The wall thickness have been getting thinner.

0.9mm / 1.0mm  0.7mm / 0.5mm

On STEAG units - STEAG will purchase (for catalyst longevity):

- Not less than 0.8mm



The New Catalyst Purchase Catalyst Structural Consideration



- **The Structural metal in the catalyst:**

- Honeycomb – Tungsten
- Plate – Molybdenum or Tungsten

The metal content

- Normally about 8 to 9%
- Seen as low as 3%
- Reason – lower cost!

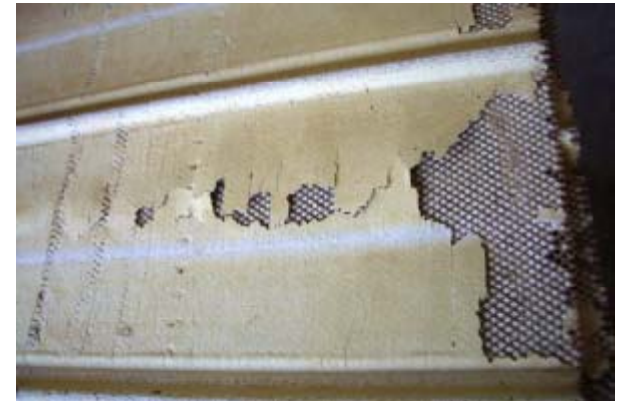
Recommendation for catalyst longevity

- Require the 8 – 9% content.

- **Plate Catalyst wire mesh**

- Austenitic stainless steel
- Reduction in Quality has been noticed
 - Ferritic Stainless steel
 - Additives (spray coating or into the metal compound)

Recommendation for catalyst longevity – Keep Austenitic Stainless!



The SCR Reactor Operation Fluegas Flow Distributions



- **Maintaining a reactor with minimum ash free area:**
 - The pressure drop is less which reducing auxillary power thus reducing operating cost.
 - Less pluggage provides for more catalyst surface thus extended catalyst Potential thus extended catalyst operation.
 - Less pluggage maintains lower flue gas velocity thus minimizes catalyst erosion.
- **Ash pluggage during SCR operation:**
 - Reduces the amount of surface area thereby reduces the amount of NO_x reduction potential.



The SCR reactor

Soot Blowers or Sonic Horns



- **Fuel Determination is Key!**
- **Sonic Horns Effective to about 20 – 25 foot depth to opposite wall. If greater than 20 – 25 feet, should considered sonic horns on both sides.**
- **For Catalyst with excess ash should consider Soot Blowers. To protect the catalyst from erosion, the height above the catalyst is critical! Combination of nozzle selection, air pressure and volume / type of ash to determine the correct height.**
- **Cleaning mechanism on the front wall should be considered if there is ash pile-up.**
- **Combination of sonic horns (with possible addition of air cannons and sootblower may be required.**



The SCR Reactor The Outage!



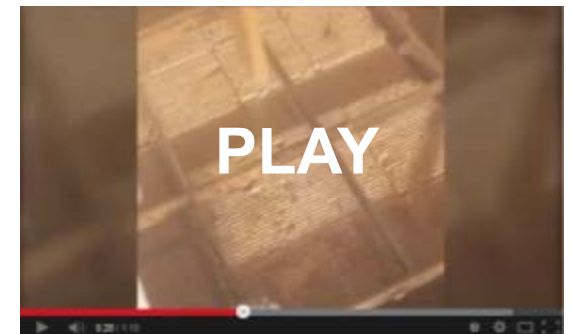
- **The catalyst should be vacuumed during the outage.**
 - **The catalyst module screens should be removed.**
 - **All the layers should be vacuumed.**
 - **The catalyst channels should be removed of pluggage, if possible.**
 - Restores the catalyst Potential - extended life of the catalyst. Fewer catalyst replacements.
 - Reduces the pressure drop – saves operating cost.
 - Reduces ammonia consumption.



STEAG Patented - Dry Ice Blasting



- **What is it?**
 - In the reactor process for removing pluggage.
 - Performed after the layers are vacuumed.
 - A reactor can easily be cleaned in the outage.
 - Can be used on both plate and honeycomb.
- **Why does the process work?**
 - There is compressed air force which will push the channel ash plug out of the catalyst.
 - The Dry Ice temperature acts to contract the plug assisting the air force.
- **What is Dry Ice?**
 - Dry ice is the solid form of carbon dioxide Dry ice sublimates at $-78.5\text{ }^{\circ}\text{C}$ ($-109.3\text{ }^{\circ}\text{F}$) at atmospheric pressures.



STEAG US Patent # 8,268,743

STEAG Patented - Dry Ice Blasting



- **Is it Safe?**
 - Air Monitoring of reactors showed no increase in CO₂ from the dry ice.
 - Appropriate PPE equipment is worn for protection from the flyash entrainment.
- **What about damage to the catalyst?**
 - STEAG has been developing for nearly 3 years this process.
 - Catalyst samples have been removed and analyzed to detect any damage of the catalyst. No damage has been seen from the ice blasting process.
 - The pluggage and blinding layers are removed.



STEAG US Patent # 8,268,743

The Regeneration Process

Receiving / Warehouse



STEAG's Regeneration Process Steps



- **Receiving and warehousing:**
 - **The Q/A process upon receipt of modules:**
 - Primary inspection of the catalyst modules – As-received inspection report submitted
 - All modules labeled with tag for module tracking
- **Dry mechanical fly ash removal:**
 - Require complete disassembly of plate type catalyst.
 - This should be done quickly!
 - **STEAG can Ice Blast honeycomb catalyst – PRB catalyst cleaning is critical.**



The Regeneration Process Chemical Treatment



STEAG's Regeneration Process Steps



- **Multi-stage wet chemical treatment for poison removal:**
 - **Complex combinations of treatment time, pH, surfactants, chemical types, concentrations and temperature.**
 - **Very precise process control to maintain stable process conditions including continuous removal of solids and replacement of spent solution.**
 - **Tailored to avoid unwanted activation of metal ions (i.e. $\alpha\text{-Fe}_2\text{O}_3$ to $\gamma\text{-Fe}_2\text{O}_3$) while maximizing their removal.**
 - **Minimization of unwanted removal of active compounds (i.e. V_2O_5 , WO_3) and damage to glass fibers.**



The Regeneration Process

Ultrasonic Treatment



STEAG's Regeneration Process Steps



- **Ultrasonic treatment:**
 - Minimize the amount of time in the solution
 - Very precise process control to maintain stable process conditions.
 - Significant damage can occur to catalyst from ultrasonic energy, therefore ultrasound is only used when really needed
- **Ion mobilization and elimination:**
 - More advanced, complex compounds but fewer chemicals used for cation mobilization.
 - Highly effective cation elimination
 - Initial Step for preparation for *Selective Impregnation*[®]



The Regeneration Process

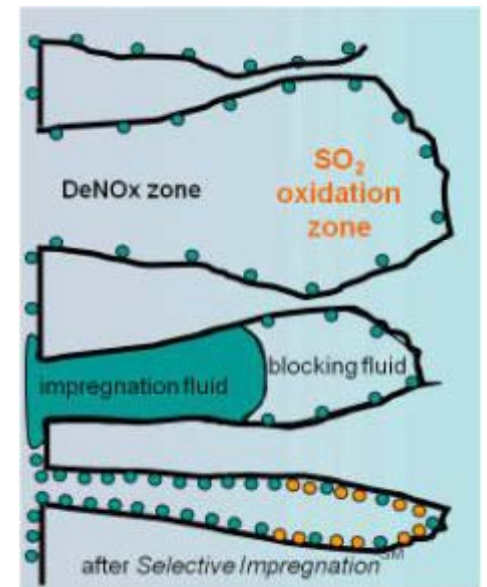
Preconditioning for Impregnation



STEAG's Regeneration Process Steps



- **Pre-conditioning for *Selective Impregnation*[®] :**
 - Effective removal of all cleaning reagents and residual chemicals from the prior treatment.
 - Controlled drying to a defined residual moisture content
- ***Selective Impregnation*[®] of catalytic activity:**
 - Patented one-step process for the replenishment of V_2O_5 and WO_3 or V_2O_5 and MoO_3 depending on catalyst type.
 - *Selective Impregnation*[®] – the local distribution of active V_2O_5 on the catalyst surface is extremely critical for the effective reduction of the SO_2/SO_3 conversion rate.
 - A one solution fits all is what reduces the strength metals. Tailored solutions are better.



The Regeneration Process

Preconditioning for Impregnation

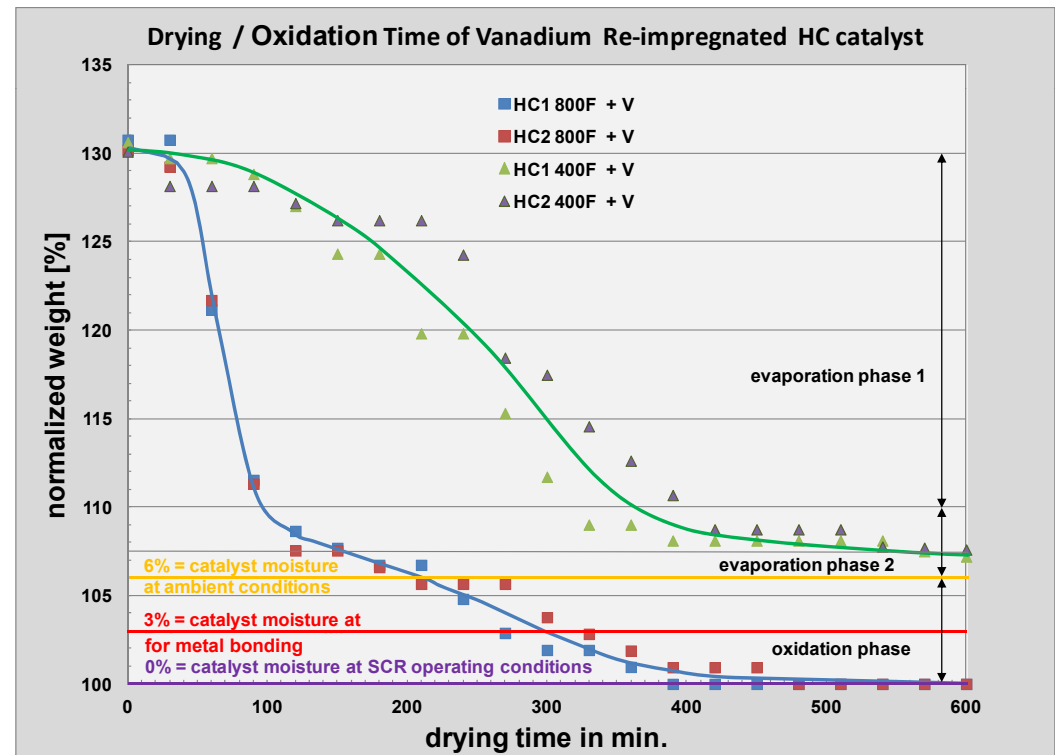


STEAG's Regeneration Process Steps



- **Final drying and Heat Treating (Re-calcination):**

- Precise high temperature treatment process to regain the mechanical strength (i.e. WO_3 crystallization).
- Activation of ingredients added during impregnation (i.e. vanadium oxalate to V_2O_5).
- Removal of captured crystalline water from crystalline TiO_2 structure.



Quality Assurance and Quality Control



STEAG's Regeneration Process Steps



- **Quality Assurance / Quality Control:**
 - Inspection and verification of cleaned channels.
 - XRF throughout the process is critical during the process. This provides the important information.
 - Full Bench Testing to verify the Catalyst under operating conditions.
 - Select random “internal” samples.
- **Strength Metal Addition**
 - Bring it back to the original “as-received” conditions.
 - In addition to the EPRI or VGB tests, validate the amount of metal replacement with XRF analysis.



Conclusions



- **Decide the path of the catalyst layer early – disposal or multiple regenerations.**
- **Fuels constituents determine the “life” of the catalyst. The most important are Phosphorus and arsenic deposition.**
- **Catalyst can be regenerated for multiple regenerations. STEAG is now on our 6th regeneration with a layer of catalyst.**
- **The initial purchase of the catalyst is critical for the longevity of the catalyst layer operation.**
- **Understanding “What your buying’ is critical.**
 - **Get the initial test data.**
 - **Do independent testing to insure what you are buying.**
 - **Specify the minimum requirements (i.e. wall thickness, pitch, wire mesh material, etc.)**



The New Catalyst Purchase



	Plate	Honeycomb	Corrugated
Ash Pluggage	Occurs normally between the bottom and top layers	Normal at the top of the module	Occurs between the bottom and top layer
Dry Cleaning Capability	This is easily done with good inspection ability.	There is now a method to dry clean the modules	This can be a difficult process and
LPA resistance	Excellent as it can be cleaned	If passing through screen can get caught in channels. Can not normally be cleaned.	If passing through screen can get caught in channels. Can not normally be cleaned.
Potential	Least performance per volume.	Very Good performance per volume	Greatest performance per volume
Ruggedness	Very good – can be cleaned in reactor	A little less than Plate – can be cleaned in reactor	Least – cannot be cleaned in reactor
Regeneration	Can be successfully regenerated numerous times	Can be successfully regenerated numerous times	Very dependant on the fuel. Much weaker structure



Catalyst is an asset and can be installed for many years. STEAG is at 28yrs with a layer of catalyst!

Questions?

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