SulfoMax® Catalysts and three-dimensional **Technical Services** ensures your sulfuric acid plant stay efficient

M. Shanmuga Sundaram
BU-Catalysts/Syngas
Oct 23, 2018

SÜD-CHEMIE
CREATING PERFORMANCE TECHNOLOGY
A Clariant group company

Agenda

- Our company at a Glance
- SulfoMax Catalyst profile
- 3D Technical services
- Few Case studies

Clariant at a glance

CLARIANT

Public

Corporate Presentation
14.02.2018

what is precious to you?

CLARIANT

Clariant at a glance

A GLOBALLY LEADING COMPANY IN SPECIALTY CHEMICALS

6377
Sales 2017 (CHF m)
from continuing operations

302
Net result 2017 (CHF m)
from continuing operations

4
Business Areas

974
EBITDA 2017 (CHF m)
before exceptionals

15.3%
EBITDA margin 2017
before exceptionals

156 in companies **52** countries

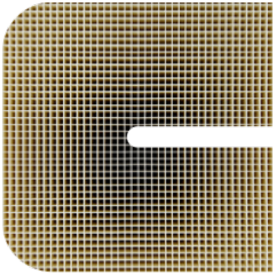
18135
Employees 2017

CLARIANT

Four Business Areas – the right portfolio for future growth

Care Chemicals

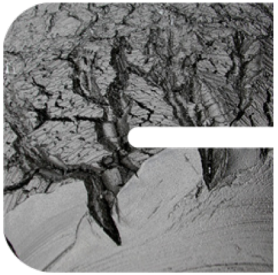
SALES (CHF m)	**1 575**
EBITDA (CHF m)	**290**
EBITDA margin	**18.4 %**



Catalysis

SALES (CHF m)	**767**
EBITDA (CHF m)	**198**
EBITDA margin	**25.8 %**

Süd-Chemie India



Natural Resources

SALES (CHF m)	**1 357**
EBITDA (CHF m)	**207**
EBITDA margin	**15.3 %**

Plastics & Coatings

SALES (CHF m)	**2 678**
EBITDA (CHF m)	**388**
EBITDA margin	**14.5 %**

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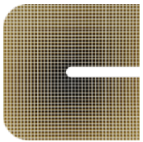
Business Area – Catalysis

APPLICATIONS



CATALYSTS

- Ammonia
- Sulfuric Acid
- Custom Catalysts
- Ethylene and derivatives
- Fischer-Tropsch
- Fuel cell
- Fuel upgrading
- Gasoline desulfurization
- Gas processing
- Hydrogenation
- Methanol
- Off-gas treatment for chemical plants and stationary engines
- On-purpose propylene
- Oxidation
- Polypropylene
- Refinery hydrogen
- Refinery stream purification
- Sour gas shift
- Steam cracker / Olefin purification
- Styrene and BTX, MTP
- Synthetic natural gas
- Zeolite powders

BIOTECHNOLOGY

- Bioethanol and alternative fuels
- Bio-based specialties and enzymes

KEY FINANCIAL FIGURES 2017

* Over the cycle

767
Sales in million CHF

25.8%
EBITDA margin
before exceptional items

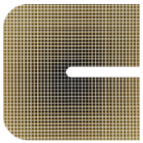
24 - 26%
EBITDA margin potential*
before exceptional items

6 - 7%
Growth ambition per annum*

CLARIANT

Business Area – Catalysis

APPLICATIONS



CATALYSTS

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- **Sulfuric Acid**
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CREATING PERFORMANCE TECHNOLOGY
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Süd-Chemie India – A Clariant group company

- Established in 1969 in collaboration with SCI of USA. (CCIWA » UCIL » SCIL)
- Market leaders in India for **Syngas** and **Sulfuric Acid** catalysts
- Catalytic Converters for two, three, four wheelers as OEM suppliers
- Recognized exporter of catalysts to USA, Uruguay, Germany, Netherlands, Japan, CIS Countries, South Korea
- Manufacturing facilities in India at Kochi (Kerala) and Vadodara (Gujarat)
- Well equipped ISO-9001 certified R&D units recognized by the DSIR, Govt. of India.
- ISO-14001,9001:2000,OHSAS-18001 and TS-16949 accredited by BVQI
- "Dream Company to work for" Award winner in manufacturing sector

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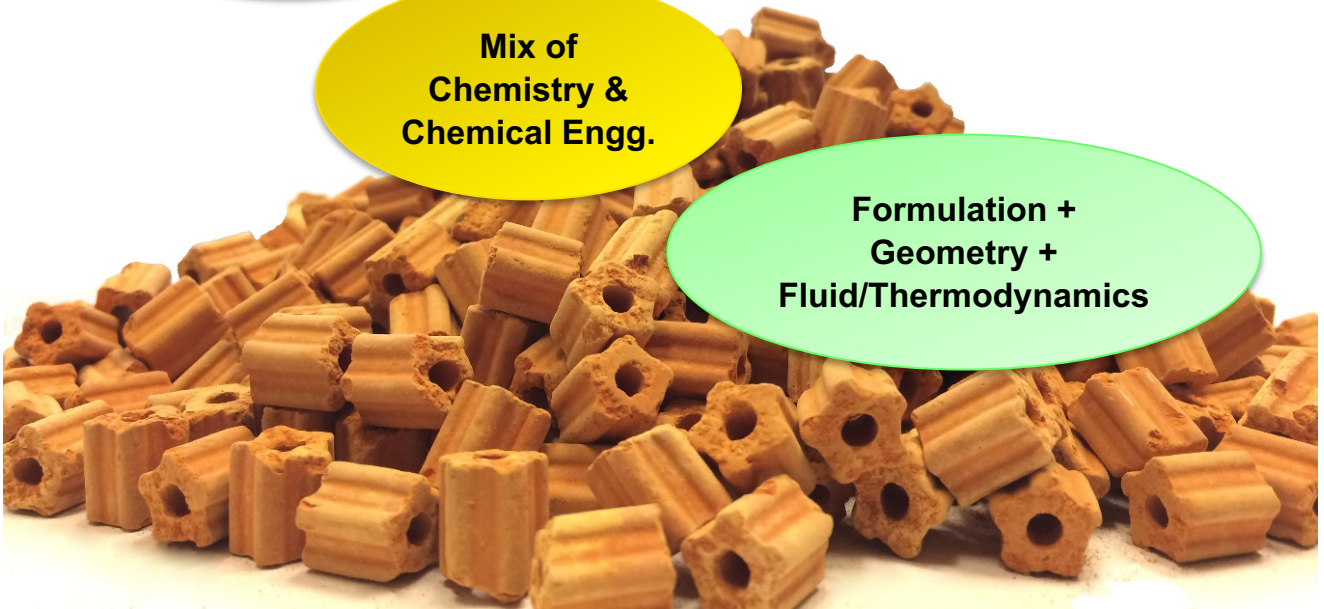
We are Catalyst people …

150+ years of expertise in Catalysis

Mix of Chemistry & Chemical Engg.

Formulation + Geometry + Fluid/Thermodynamics



SulfoMax® Catalysts

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Süd-Chemie first manufactured its Sulfuric Acid catalyst in **1964**

- CCE, Belgium, a Süd-Chemie Group company manufactured and supplied SulfoMax catalysts from 1964 till early 90's.
- As part of consolidation, CCE operations from Belgium had been moved to various locations.
- SulfoMax technology was transferred to India and now being made in Cochin, India for global supply since last 15 years
- SulfoMax has proven its performance in 130 sulfuric acid plants across the globe, ranging in capacity from 30 – 3500 MTPD
  - **India** **60 plants**
  - **Japan** **26 plants**
  - **Rest of world** **44 plants**
- The customer profile includes Sulfur burning, metallurgical Off-gas, pyrite smelting and wet gas applications.

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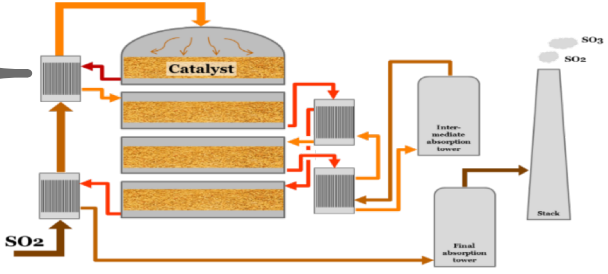
Feed stock and plant technologies
Sulfuric acid production process

Metallurgical off-gas

Sulfur burning

Spent acid regeneration; Wet sulfuric acid process
(Humid gas applications)

Contact process:
- Single absorption
- Double contact double absorption (DC/DA)



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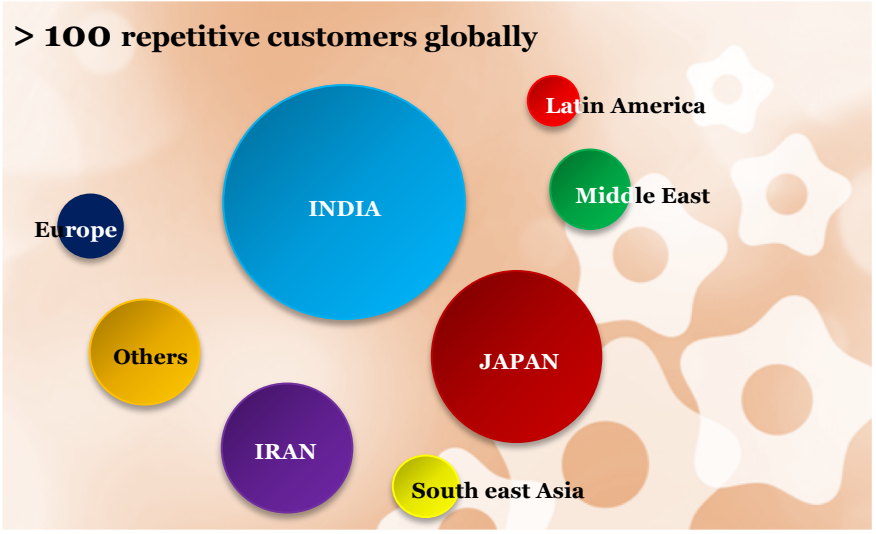
SulfoMax Global presence



Includes:

- Fertilizer plants / S burning
- Metallurgical Off-gas plants
- Spent Acid Regeneration plants
- Wet sulfuric acid plants
- Iron pyrite roasting plants

SulfoMax®

VARIANTS – SOLUTION TO DIFFERENT NEEDS OF ACID PLANT

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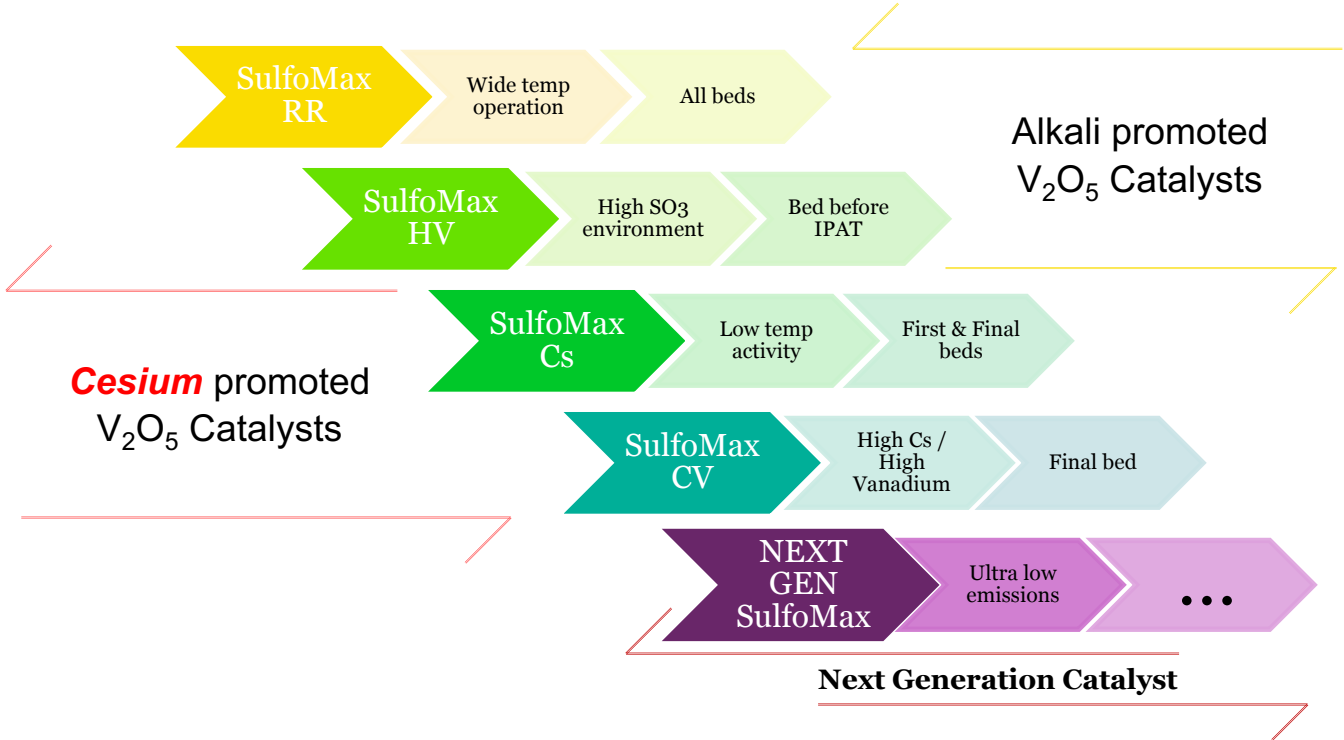
Our Products – result of continuous research – to meet industry needs



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Various Forms of SulfoMax®

Ribbed Rings

12x4, 9x3 mm

Pellets
6 mm

25x7 mm

Rings

20x7, 12x4, 9x3 mm

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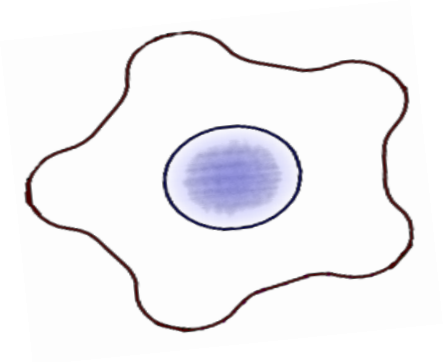
Ribbed ring is Unique!



- Interlocking of pellets is avoided unlike with ‘gear’ profiles
- No interlocking → Unrestricted gas flow
- Good gas flow → **less DP**

Catalyst Chemistry

A CENTURY OLD FORMULATION…

…MAKING IS BOTH SCIENCE AND ART

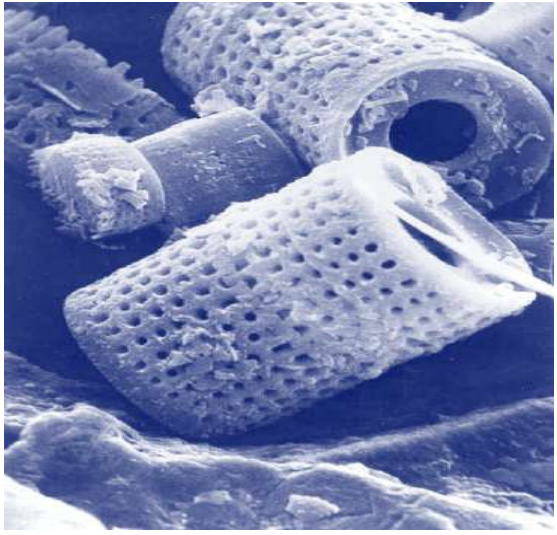
What builds up SulfoMax® Catalysts

	Ingredients	*Function*
Promoters	**Potassium** **Sodium**	To lower melting temp of active catalytic complex
Active ingredient	**Vanadium Salts**	Catalytic activity
Carrier	**Diatomaceous earth**	Porous support to house active melt

$K_wV_xS_yO_z$

Diatomaceous Earth – What and Why ??

- Also known as Diatomaceous Earth (DE) or Kieselguhr
- Skeletons of plankton (diatoms) deposited on lake and ocean beds millions of years ago
- Nearly pure silica – very much inert
- Complex natural structures
- Highly porous (85% air)
- High surface area
- Around 5 - 15 microns in size
- Can be thermally fused into larger, more complex structures
- An economical source of inert surface area and controlled porosity for a myriad of applications.



Courtesy: EP Minerals

Catalyst Performance

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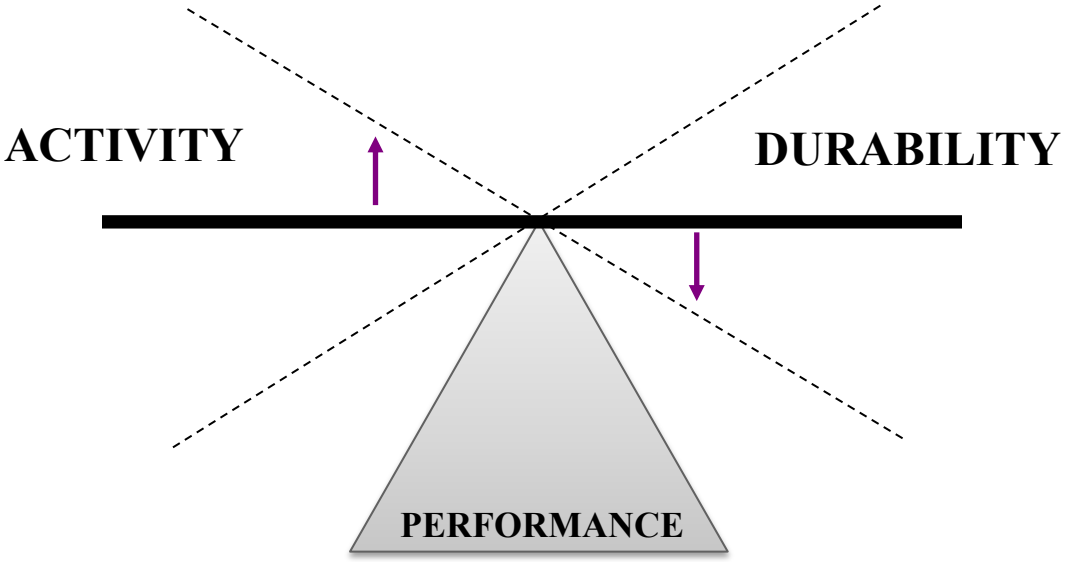

It's a Balancing Act !!

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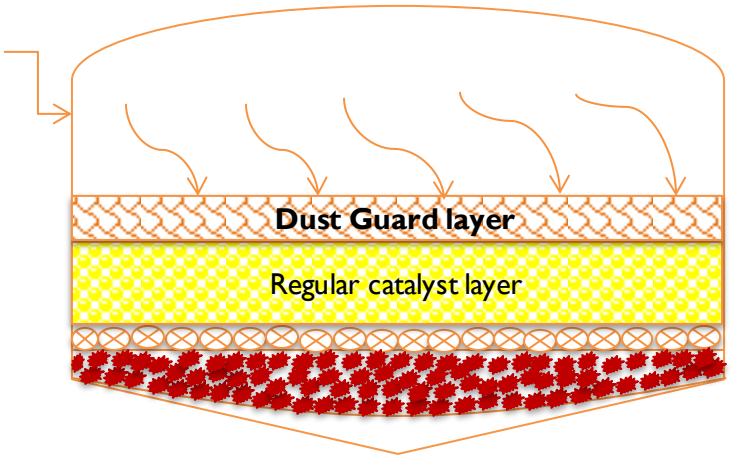
SulfoMax® GRR Special Purpose Catalysts:

Dust Guard catalyst



Fact:
Catalyst, in general, adsorbs dust from the process gas stream

Problem:
Dust deposition blocks the gas path leading to higher pressure drop, deactivates catalyst

Principle:
Dust is to be adsorbed and gas path should not be restricted

Solution:
SulfoMax® GRR effectively adsorbs dust and yet maintaining proper gas flow distribution

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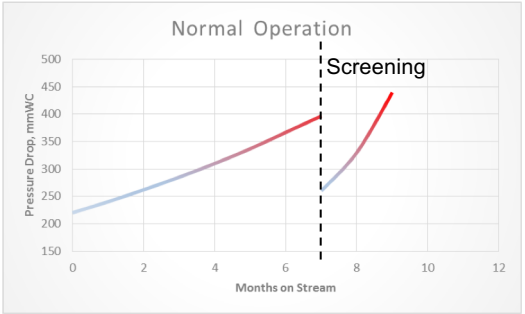
Real life Case Study – Dust Guard catalyst

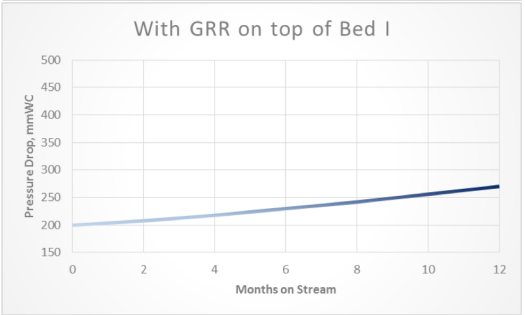
Plant information

Capacity: 3500 MTPD
Feed: Sulfur Burning
Type: 3x1 DCDA
Catalyst quantity in Bed I:
120 cu. m

Concern:
Historical issue of pressure drop rise in bed I
Reason:
Dust carryover from filtration section

Design Details:
Design Pressure drop:
190 mmWC
Shutdown taken at DP:
> 400 mmWC





Study & Recommendation

Normal Operation:
DP rise: 30 mmWC/month

After a screening,
DP rise: 90 mmWC/month

Recommendation:
SulfoMax® GRR was installed on top of bed I
(to a depth of 10%)

Results:
Run with no stoppage
DP rise: ~ 6 mmWC/month

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SulfoMax® Special Purpose Catalysts:

SulfoMax® WRR – Humid gas application

In Plants other than sulfur burning ones, the gas stream is generally moisture-laden. Moisture is offensive to vanadium pentoxide catalysts.

SulfoMax WRR is developed and supplied globally for wet gas applications. This catalyst is available in all shapes. In specific cases, this catalyst is also promoted with Cesium for low temperature activity.

W series catalysts are available in

- Cesium promoted forms
- Ribbed/raschig rings
- Big rings
- Pellets/Ribbed extrusions

Next Generation Catalyst

SULFOMAX® EV (PATENT PENDING)

To handle Challenges of Future, Today !!

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R&D leads to the evolution of a new catalyst

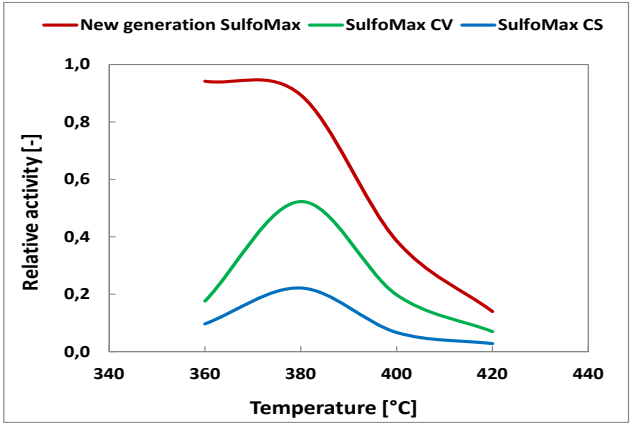
"SulfoMax® EV"
New generation SulfoMax® catalyst

SulfoMax EV, **A Unique** Catalyst that operates at much lower temperatures than current catalysts

New formulation takes conversion efficiency to much higher levels and has potential to reduce emissions greatly

Suitable for passes after intermediate absorption, due to peak performance at low SO2 concentrations

Relative activity of SulfoMax EV in comparison with existing SulfoMax catalysts



Laboratory results confirm superior activity at significantly lower temperature

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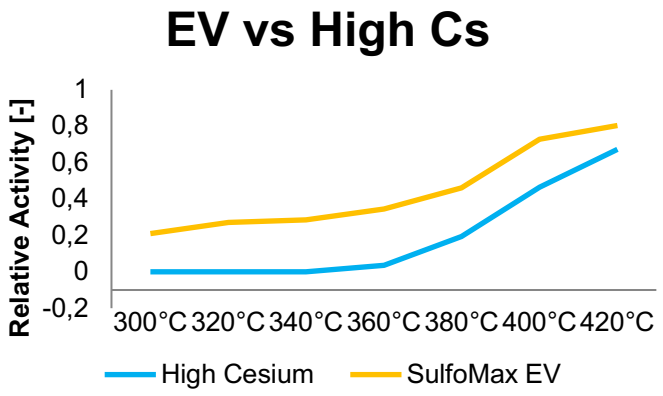
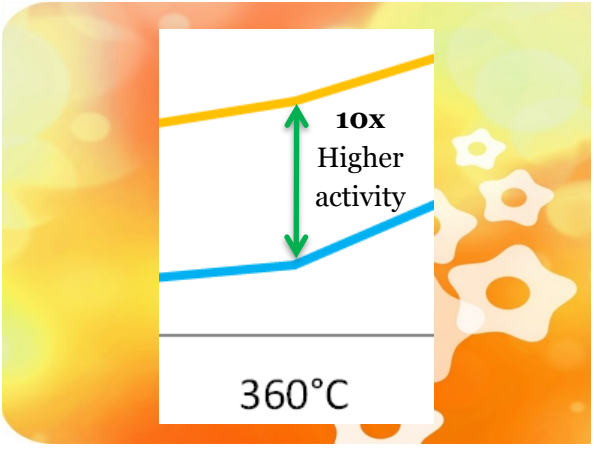
Comparison - SulfoMax®EV vs. Cesium catalysts



Relative activity of EV over existing high cesium catalysts at 1% SO2 (v/v), enriched with SO3



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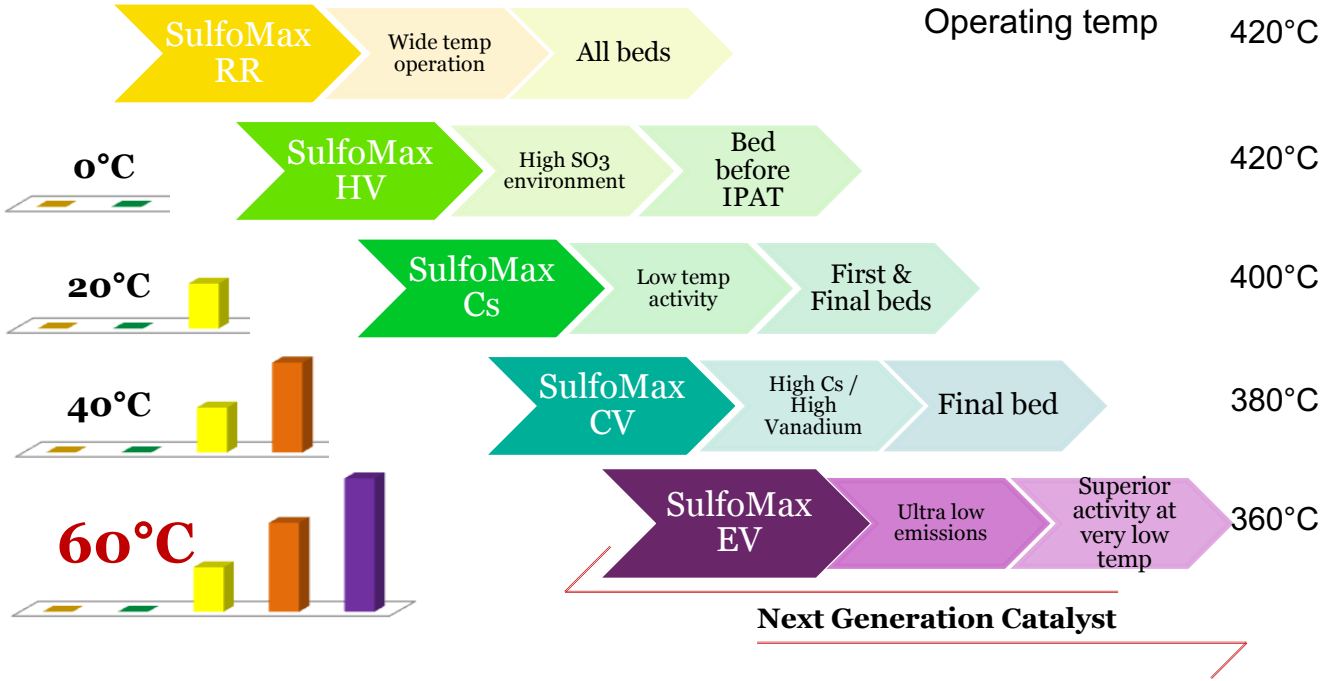
Energy recovery Benefits Over Conventional catalysts



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Benefits and opportunities SulfoMax® EV

Value creation through innovation

LOWER
SO_2 EMISSIONS

Higher catalyst activity, especially at low SO2 concentrations, allows higher conversion rates and thus reduced SO_2 emissions.

- **SulfoMax EV** helps you meet stringent environmental norms

IMPROVED ENERGY RECOVERY

Higher catalyst activity allows reduction of inlet temperatures to the final pass after intermediate absorption and thus reduces the energy requirement for heating.

- **SulfoMax EV** helps increase energy efficiency in sulfuric acid plants
- Lower operating temperatures can help influence new plant designs

SulfoMax® Market Position

MARKET LEADERS IN INDIA AND JAPAN

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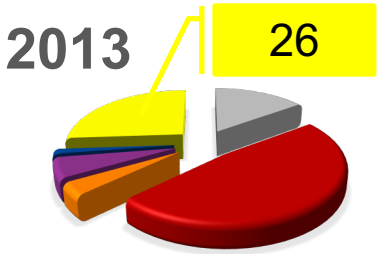
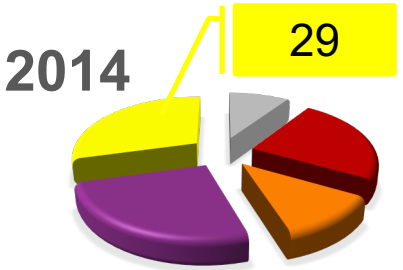
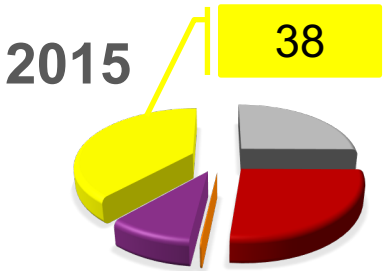
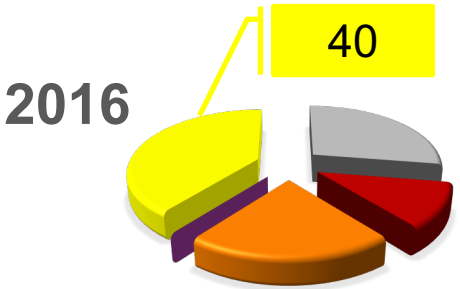
SulfoMax in Indian Market









2017 — 42 Share of SulfoMax

SulfoMax in Japanese Market

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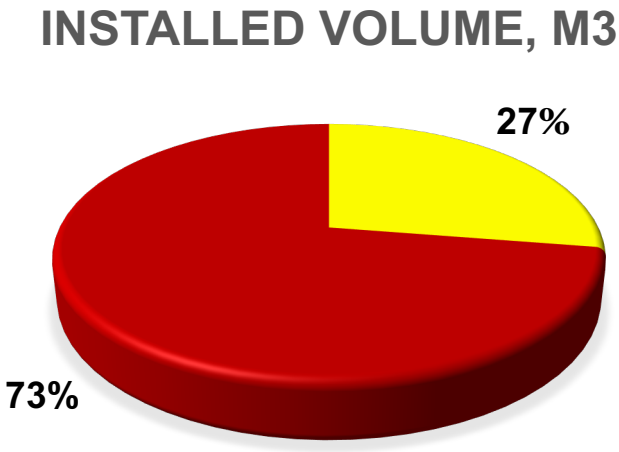

- Preferred product in Japanese market
- More than **25** customer references in Japan
- Replaced competition: HTAS/BASF

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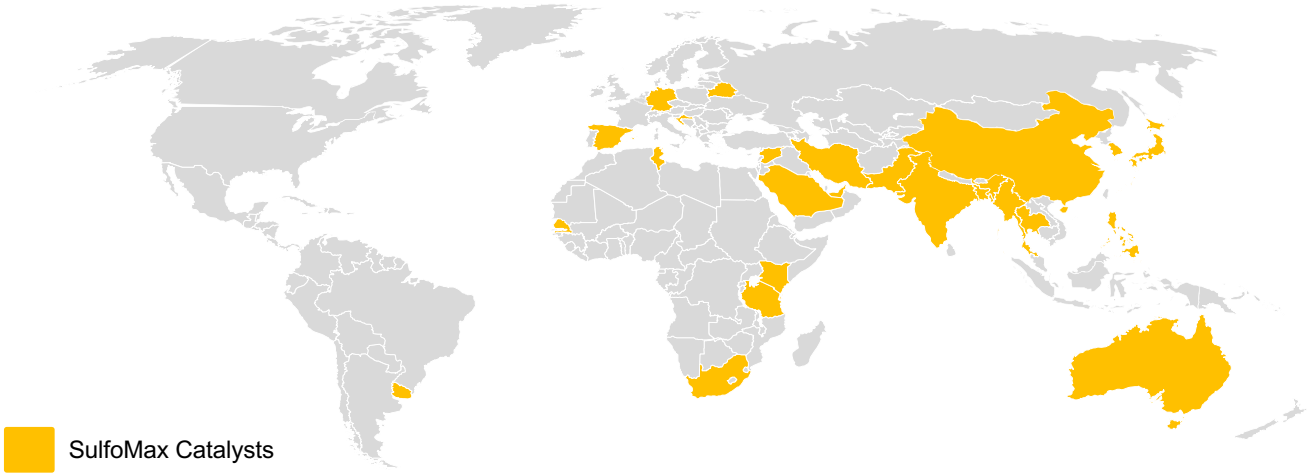
SulfoMax Global presence



More than **130** references globally

Production and R&D in INDIA

Produced and supplied Globally

New Greenfield Projects with SulfoMax

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Customers	Location	Capacity	Stack SO2	Year
Delivered				
Wata Chemicals	Bangladesh	44 kTPA	0.59 kg SO2/MT acid	2016
Sebasic	Oman	33 kTPA	0.52 kg SO2/MT acid	2017
WgSA	China	55 kTPA	Wet gas Sulfuric Acid	2017
Panoli Intermediates	India	220 kTPA	0.52 kg SO2/MT acid	2017
Kutch Chemicals	India	110 kTPA	0.52 kg SO2/MT acid	2018
Kisan Phosphates	India	37 kTPA	0.98 kg SO2/MT acid	2018
WgSA	China	180 kTPA	Wet gas Sulfuric Acid	2018
Projects in pipeline				
Several projects totaling to ~440 kTPA in pipeline				2018 - 22

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Partial list of S Burning references – SulfoMax

- IFFCO Paradip, India - **3500** MTPD x 2 trains
- ICS, Senegal – **3000** MTPD
- FACT, India – **2000** MTPD
- Paradeep Phosphates,India – **1200** MTPD
- GSFC, India – **1750** MTPD
- Philphos, Philippines – **1000** MTPD
- Nippon, Japan – **1000** MTPD
- GFC, Syria – **850** MTPD
- GCT, Tunisia – **750** MTPD
- Tata Chemicals, India – **750** MTPD
- ISUSA, Uruguay – **500** MTPD
- Mangalore Chemicals, India – **400** MTPD
- Rama Group, India – **450** MTPD

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Partial List of Smelter references for SulfoMax

- Incitec Pivot (Australia),
- Pan Pacific Copper (Japan),
- Birla Copper (India),
- Sterlite Copper (India)
- Hindustan Copper (India)
- Akita (Japan),
- Hachinohe smelting (Japan),
- Hindustan Zinc (India)
- PASAR (Philippines),
- Hibi Kyodo (Japan)
- Toho Zinc (Japan)
- Kamioka smelting (Japan)

Technical Services

YOUR FRIEND TO RELY ON…

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3D - Technical Services

Computer Simulation

- Thermodynamic equilibrium study
- Bed-wise conversion analysis
- Process optimisation
- Troubleshooting
- Designing of new plants

Spent Catalyst

- Activity Evaluation
- Physical strength
- Chemical composition
- Life projection
- Catalyst top-up planning

Inter-bed gas analysis

- Catalyst performance assessment
- Bed-wise conversion analysis
- Heat Exchanger healthiness
- Stack emission reassurance
- Catalyst turnaround planning

… To monitor the pulse of the plant

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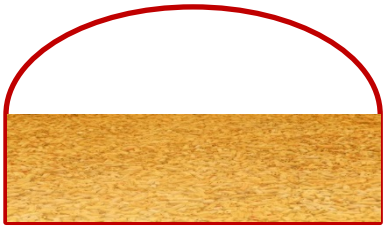
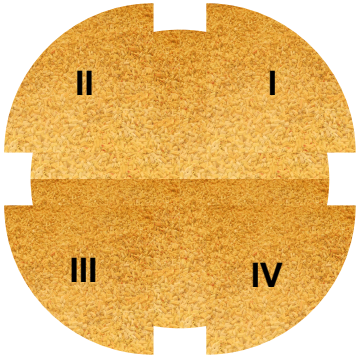
Effective Catalyst sampling





Representative sample

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3D - Technical Services – Simulation studies

Spent Catalyst

- Activity Evaluation
- Physical strength
- Chemical composition
- Life projection
- Catalyst top-up planning

Computer Simulation

- Thermodynamic equilibrium study
- Bed-wise conversion analysis
- Process optimisation
- Troubleshooting
- Designing of new plants

Inter-bed gas analysis

- Catalyst performance assessment
- Bed-wise conversion analysis
- Heat Exchanger healthiness
- Stack emission reassurance
- Catalyst turnaround planning

… To monitor the pulse of the plant

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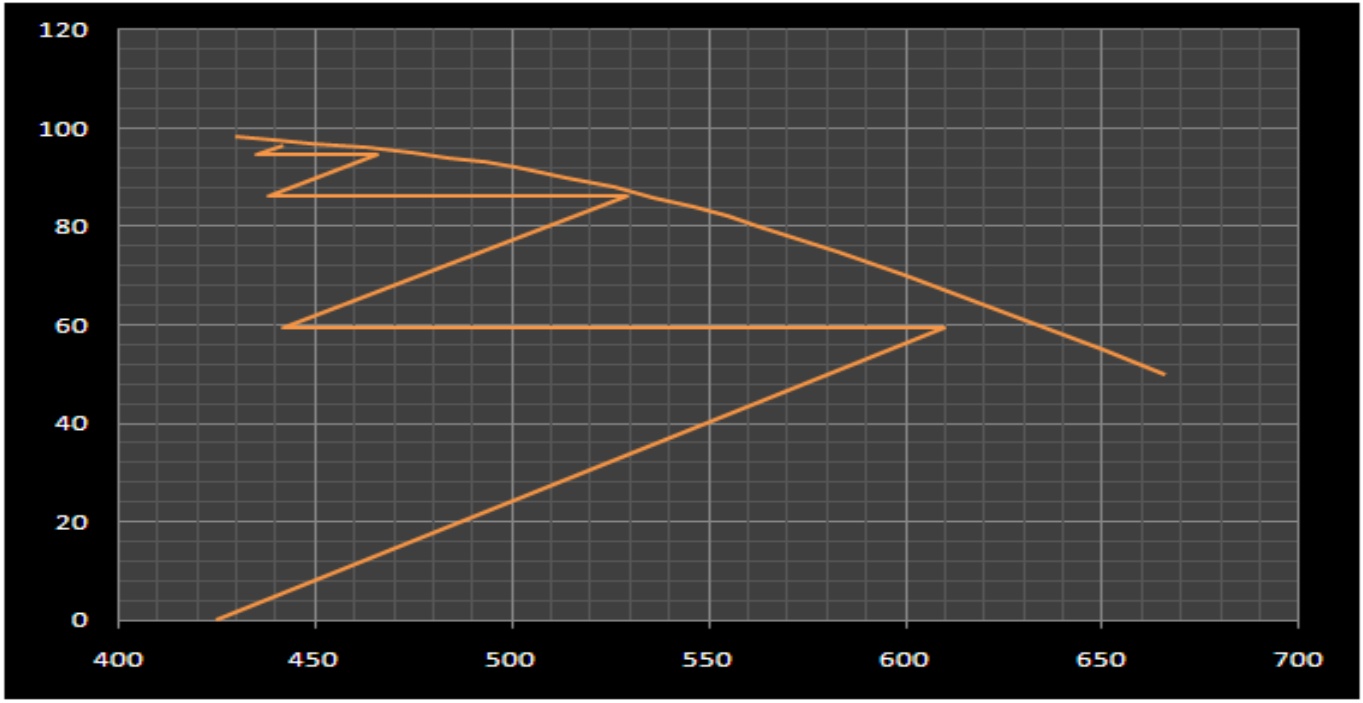
Computer simulation & Optimization studies



Better the Equilibrium approach, higher is the conversion efficiency

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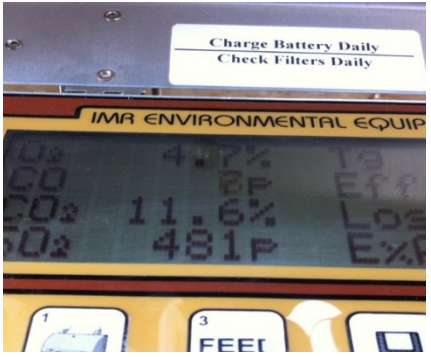
3D - Technical Services – Gas Analysis

Spent Catalyst

- Activity Evaluation
- Physical strength
- Chemical composition
- Life projection
- Catalyst top-up planning

Computer Simulation

- Thermodynamic equilibrium study
- Bed-wise conversion analysis
- Process optimisation
- Troubleshooting
- Designing of new plants



Inter-bed gas analysis

- Catalyst performance assessment
- Bed-wise conversion analysis
- Heat Exchanger healthiness
- Stack emission reassurance
- Catalyst turnaround planning

… To monitor the pulse of the plant

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3D - Technical Services – iGAS®

SO3 interference free

Inter-bed Gas Analysis
Bed-wise performance assessment

Case Studies

- **TROUBLESHOOTING**
- **CONVERSION IMPROVEMENT**
- **LONGER CAMPAIGNS**
- **PRODUCTIVITY IMPROVEMENT**

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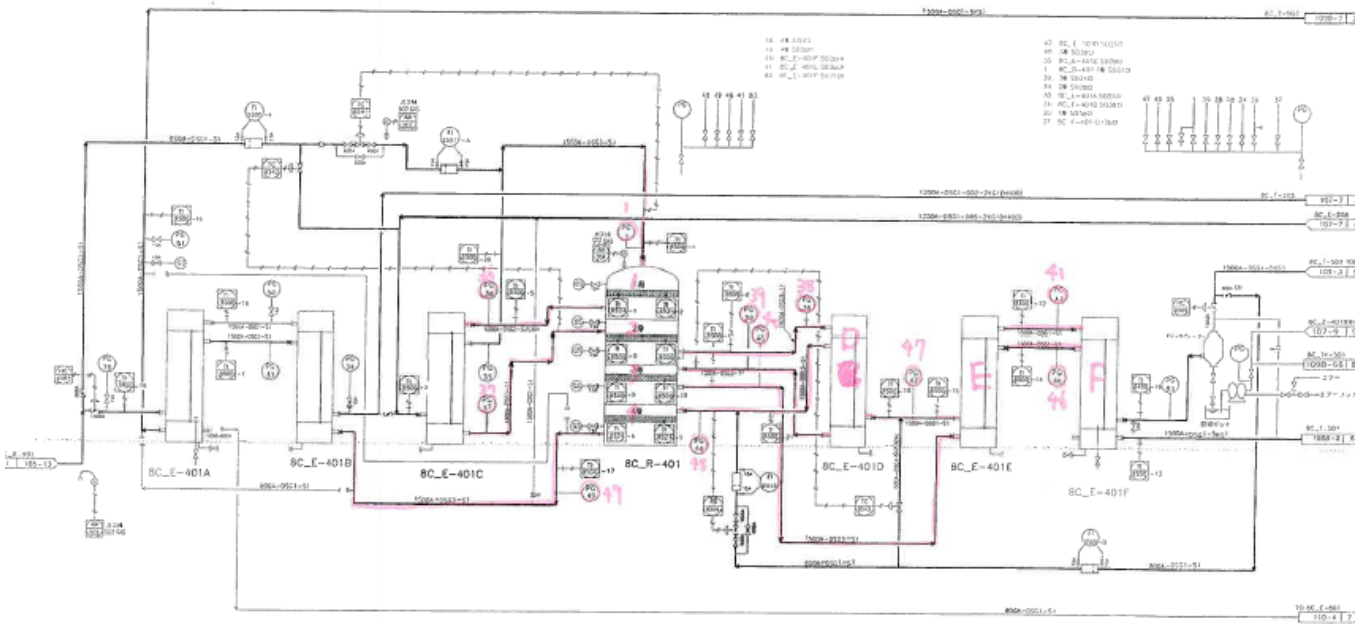
Case Study – I



Case Study – I

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Customer in Japan

Plant Capacity	620 MTPD
Feed type	Sulfur burning
Config	3 x 1 DCDA
Catalyst type	Non-Cesium
Catalyst loading	< 170 lit/MTPD
SO2 load	10.5 – 11%v/v

Recommendations

- Bed I – Partial replacement
- Bed II & III – screening and top up
- Beds IV - Partial replacement

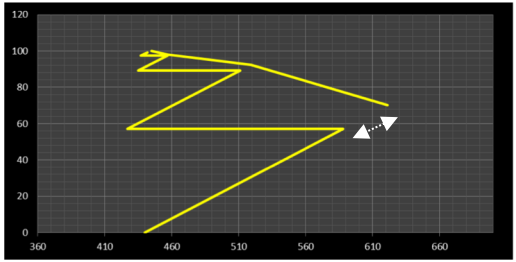
Results

- Overall conversion efficiency – **99.82%**
- Bed I ATE improved as below
- Pressure drop reduced to 60 mmWC – **lower than the design**

Jul 2013 — *Study & Recommendation* — *Implementation & Results* — **Nov 2013**

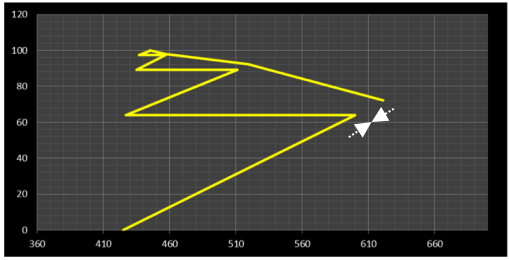
Simulation results

- Overall conversion efficiency - 99.26%
- Bed I was operating quite far from equilibrium (> 2x, x is desired)
- Pressure drop across bed I > 2x
- Plant throughput reduced due to higher pressure drop across bed I



Targets from Customer

- Overall conversion above 99.8%
- Higher throughput with DP reduction



Equilibrium performance after implementation of recommendations

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Case Study – I *(Continued)*

Situation during Jul 2016

Catalyst service life (as of Jul 2016):

Beds	Catalyst installed	Service life in years
I	SulfoMax RR 9x3	3
II	SulfoMax RR 9x3	3
III	SulfoMax HV 9x3	> 7
IV	SulfoMax RR 9x3	> 7

Turnaround during Dec 2017

- Screening & top up of screening losses

Run Continued — **Jul 2016** — *Run Continued* — **Dec 2017** — ***... 2020***

Simulation results

- Overall conversion efficiency – **99.8%**
- NO screening in 3 years
- NO top-up in 3 years
- NO pressure drop issue
- NO catalyst turnaround in 3 yrs

Conclusion

- One of the **LONGEST CAMPAIGN** using SulfoMax® catalysts – **4.5 yrs**
- Next catalyst screening planned during 2020

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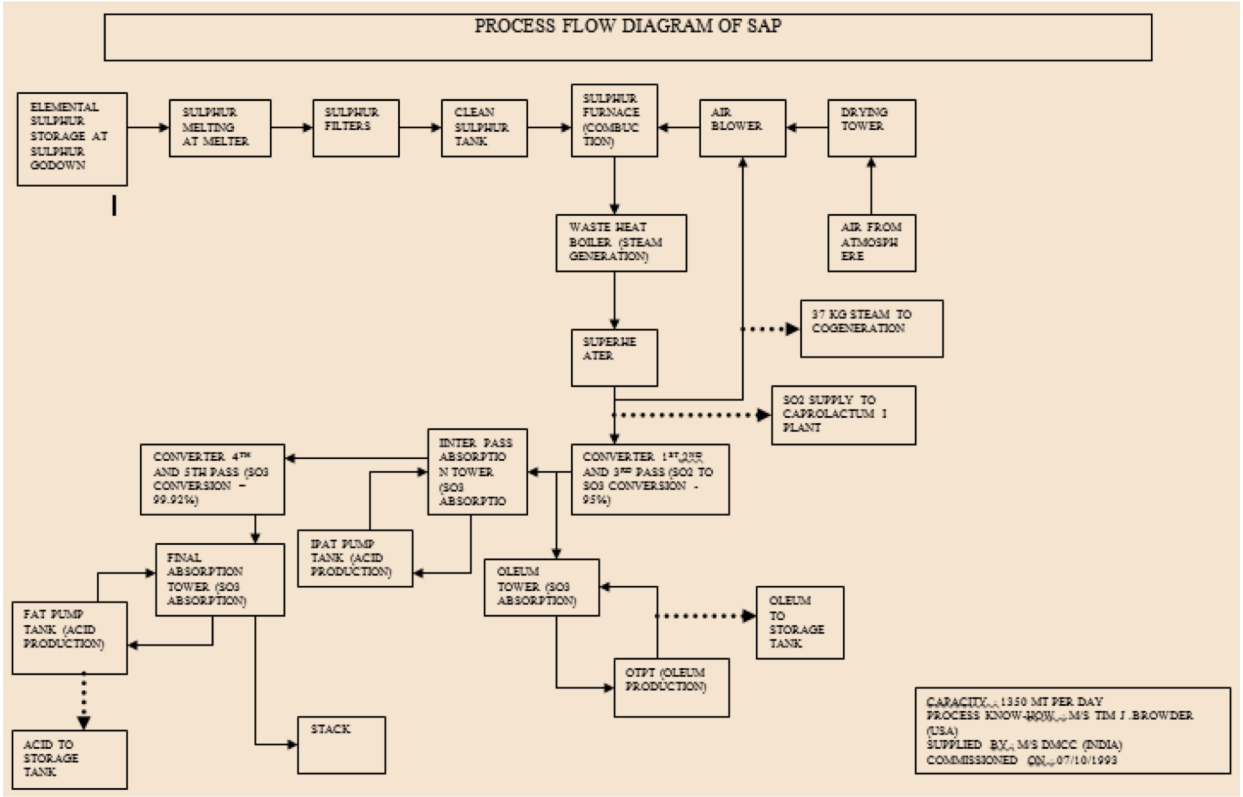
Case Study – II



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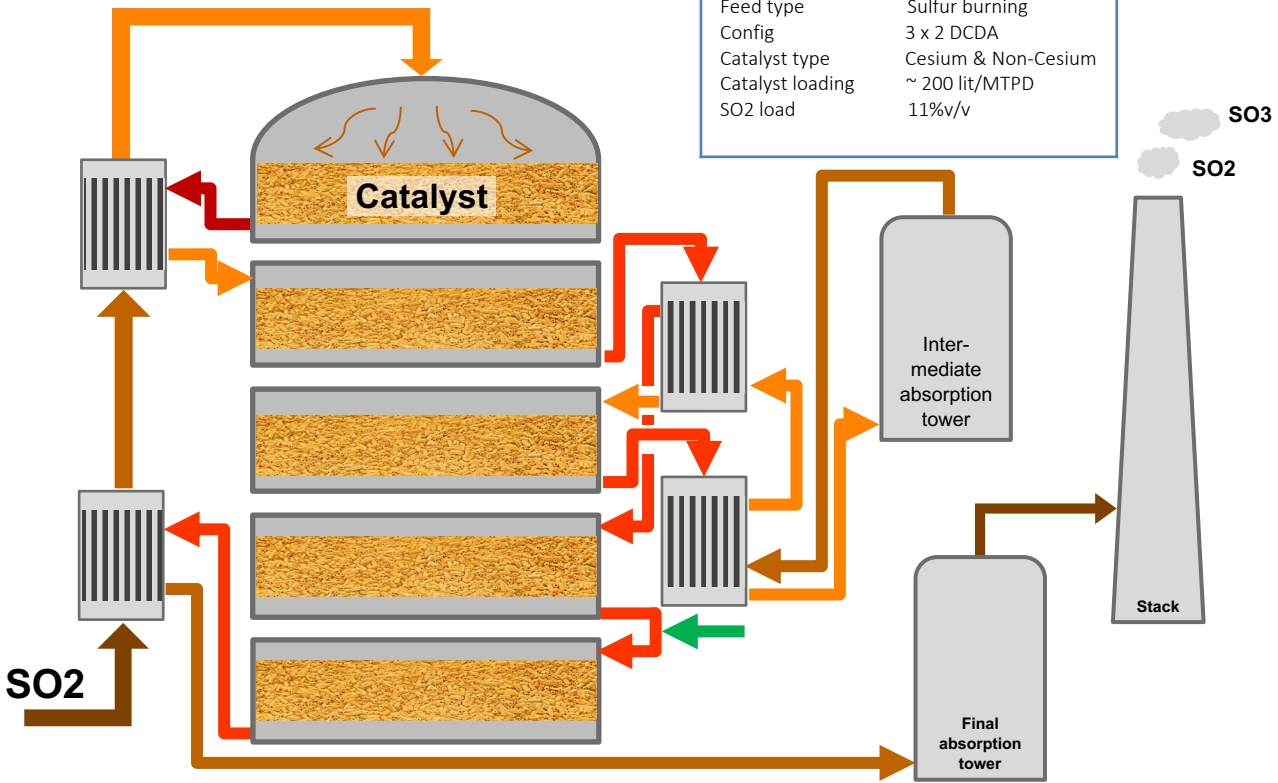
Case Study – II *Continued*

Customer in India	
Plant Capacity	1350 MTPD
Feed type	Sulfur burning
Config	3 x 2 DCDA
Catalyst type	Cesium & Non-Cesium
Catalyst loading	~ 200 lit/MTPD
SO2 load	11%v/v



Case Study – II *Continued*

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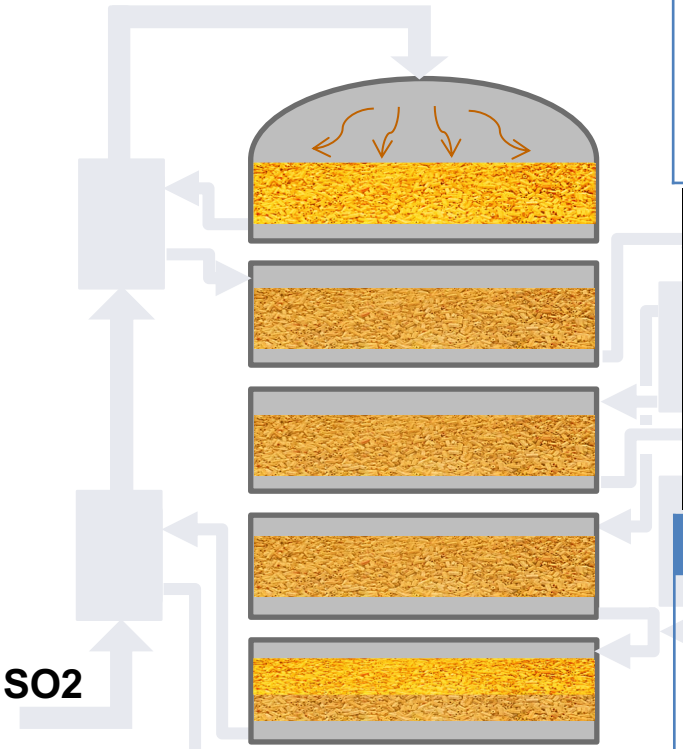
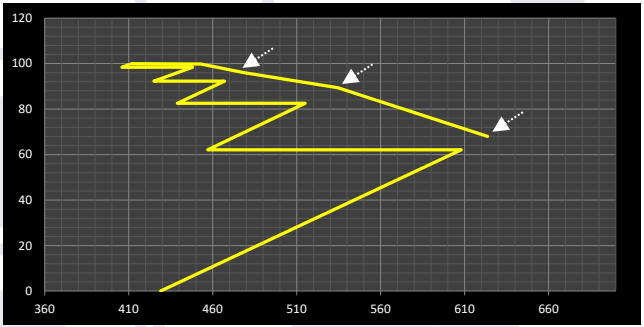


Simulation study revealed

- Beds I, II, III operating far from equilibrium
- Exit emission - 3.0 kg SO2/MT (470 ppm)
- Overall conversion – 99.55%
- SO2 at converter inlet was 10% (Design – **10.5%**)



Recommendations

- Bed I replacement with SulfoMax RR
- Half of bed V with SulfoMax Cs
- Reduce inlet temperature to beds I & V

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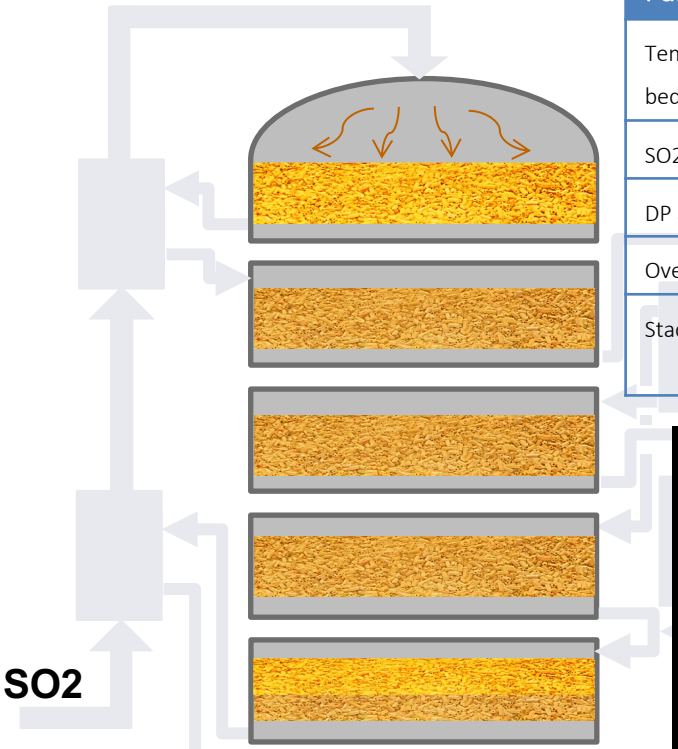
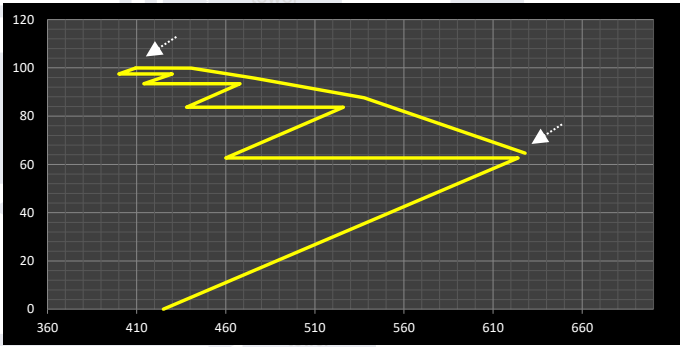
Case Study – II *Continued*

Post implementation Results		
Parameters	**Before**	**After**
Temperature diff in bed I	175 – 180 °C	199 – 200 °C
SO2 load	10.3%	11.05%
DP across bed I	200 mmWC	50 mmWC
Overall Conversion	99.55%	99.8%
Stack Emission	3.0 kg SO2/MT 470 ppm	1.4 kg SO2/MT 258 ppm





Case Study – II *Continued*

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Bonus Benefits

The Customer realized following benefits using Cesium promoted Catalysts in bed V

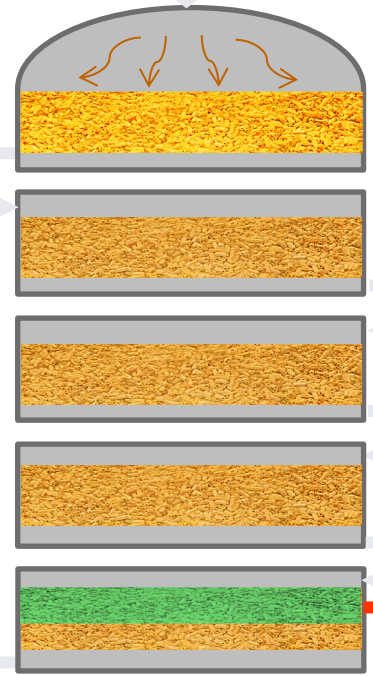
On an average, **80 mins** saving during every plant start up (which otherwise is spent on ramp up to full load)

When savings only during scheduled stoppages are accounted,

- **900 MT** of additional acid produced p.a.
- ~ **1050 MT** of additional steam production

Besides,

- **No deviation of emission norms** during start up
- **Longer catalyst lifetime** in final bed (low temperature operation
- **Sustained lower emission**



SO2

HIGHER EQUILIBRIUM YIELDS

REDUCED EMISSIONS

MAXIMUM ENERGY RECOVERY

EXTENDED CATALYST LIFETIME

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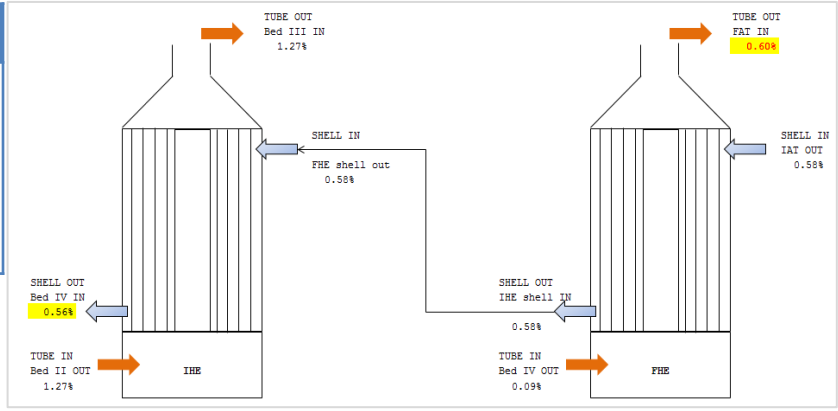
Case Study – III

Problem definition

In a 400 MTPD S burning sulfuric acid plant in India with 3 x 1 DCDA configuration,

- Higher emission despite satisfactory converter temperature/performance



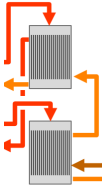
Troubleshooting

Converter

Simulation – satisfactory conversion until B IV

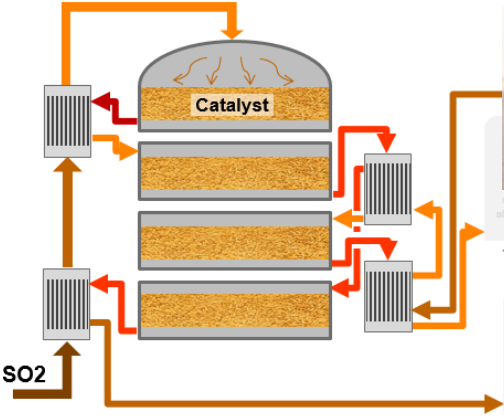
iGAS® - conforming Simulation study

Heat Exchanger System



Visual checks – no visible / identifiable leaks

iGAS® - identified significant leak of SO2 into FAT, leading to higher stack emission



iGAS® technique:

- Catalyst performance assessment
- Stack emission reassurance
- Heat Exchanger system Healthiness

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Conclusion

- SulfoMax Catalysts – Technical proven and is in use in 130 SA plants satisfactorily
- Three-dimensional Technical services help customer
  - Optimize the operation
  - Achieve higher efficiency
  - Improve energy recovery
  - Lower Stack emissions
- Partner with us !!

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