



We create
chemistry
that makes
individual
refiners love
fueling the
world.



BoroCat™ – An Innovative Solution from Boron-Based Technology Platform for FCC Unit Performance Improvement

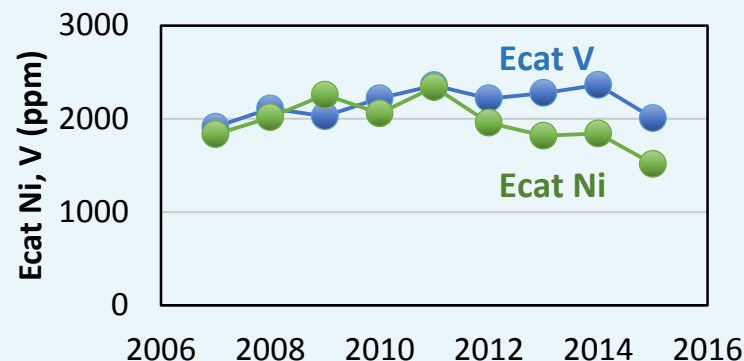
Alexis Shackelford

Technical Marketing Specialist, BASF Refining Catalysts

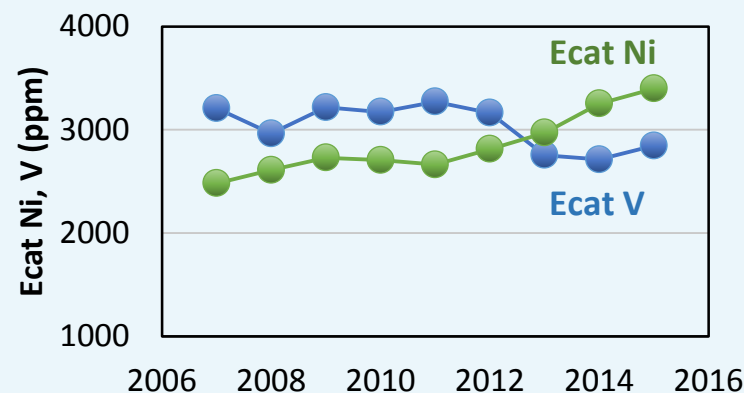
Trends in Global Resid Operations

- Ecat nickel and vanadium decreased in the US
- Ecat nickel increased significantly in the rest of the world by 37% since 2006
- The nickel challenge:
 - ▶ Dehydrogenation reactions lead to increased hydrogen and delta coke

Units with >2000 ppm Ni+V in US



Units Outside US



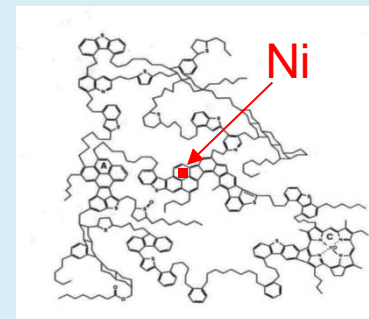
* From BASF benchmarking database. Represents 54% of all FCC units (ex. China)

Improving Dry Gas and Coke Selectivity is a Key Objective for Resid Cracking Operations

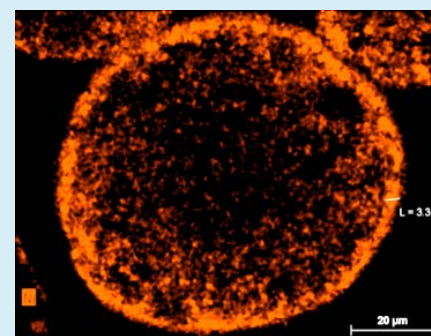
Improve Nickel Passivation for Resid Operations

Technology Objectives

- Create a new resid catalyst to minimize impact of contaminant Ni
- Improve conventional Ni passivation technologies
 - ▶ Specialty alumina incorporated into the catalyst
 - **Immobility**
 - ▶ Antimony Feed Injection
 - **Environmental and safe handling concerns**



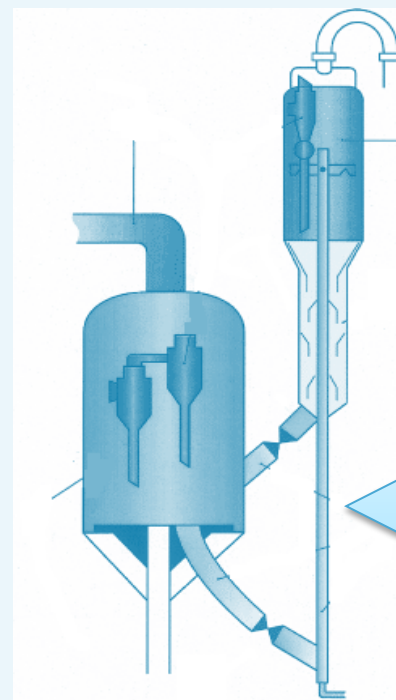
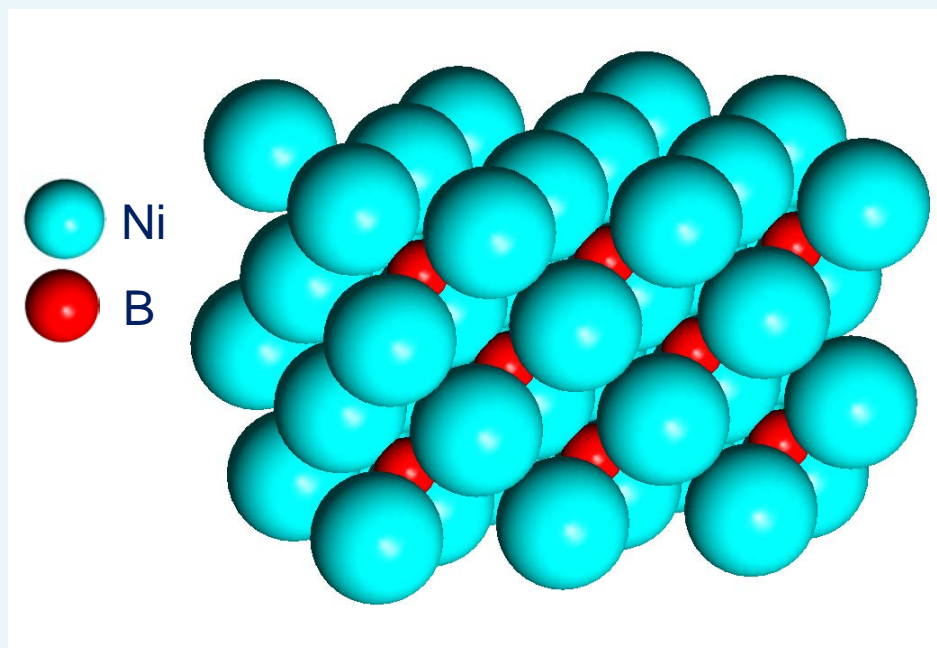
Typical metal-containing feed porphyrin



Elemental map of Ni on Ecat

A Novel Solution for FCC Refiners

Boron, Mobile under FCC Conditions, Migrates to Ni on the Catalyst



B deters Ni from being reduced to a more detrimental state in the riser

Introducing Boron-Based Technology (BBT)

BBT utilizes a novel chemistry for improved Ni passivation versus traditional technologies

- Boron migrates within the catalyst by solid state diffusion to passivate Ni
- Passivation of Ni confirmed by multiple spectroscopy studies

Performance Benefits

- Reduction in H₂ and delta coke

Nickel Passivation with BBT Confirmed in Multiple Lab Studies

BBT versus Base Resid Catalyst: Relative Yield Shift Percentage @ 75% Conversion

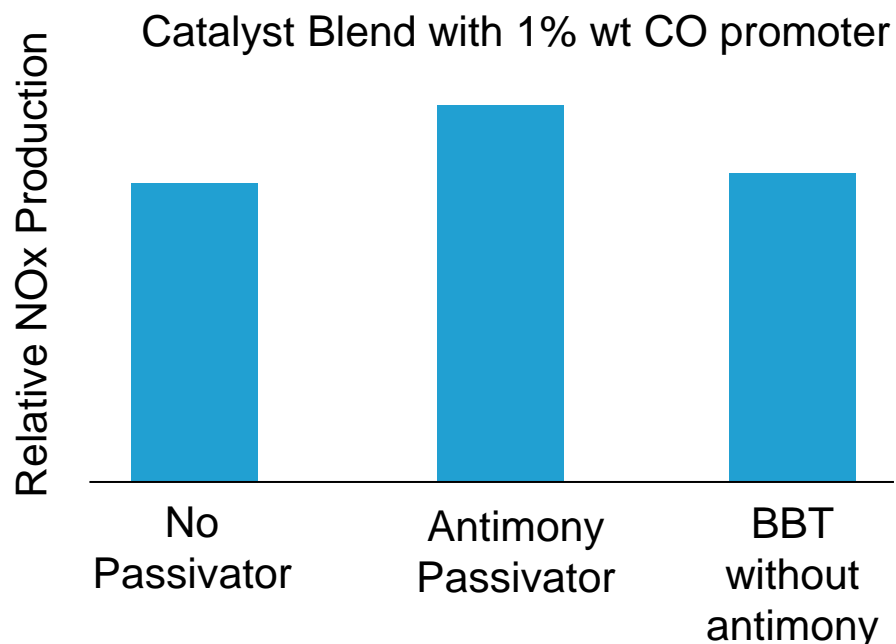
		CPS (3000 ppm Ni; 3000 ppm V)	CMDU (3000 ppm Ni; 3000 ppm V)	Conventional Steam Deactivation (3000 ppm Ni)
H₂	%	-27	-27	-25
Gasoline + LCO	%	+0.8	+2.0	+4.0
Coke	%	-22	-13	-35%

BBT Passivates Nickel without Increasing NOx

Antimony use is not always possible in locations under strict NOx regulations.

Unlike antimony, BBT achieves Ni passivation without any increase in NOx

Third Party Lab Testing Results



BoroCat™ – First FCC Catalyst based on BBT Platform for Resid FCC

- Pore architecture that minimizes diffusional limitations of heavy feed molecules
- Reduced H₂ and delta coke
- Improved yield selectivity
- Provided operational flexibility

List of BoroCat Users with Average Feed API and Ecat Ni/V

Refinery	Location	Feed API	Ecat Ni	Ecat V
A	N America	23	2000	4000
B	N America	25	1100	2900
C	N America	31	2700	1100
D	Europe	19	3500	3200
E	Europe	23	3500	2500
F	Europe	19	2300	3500
G	Europe	21	5600	6100
H	Europe	26	2800	1600

Successful Commercialization

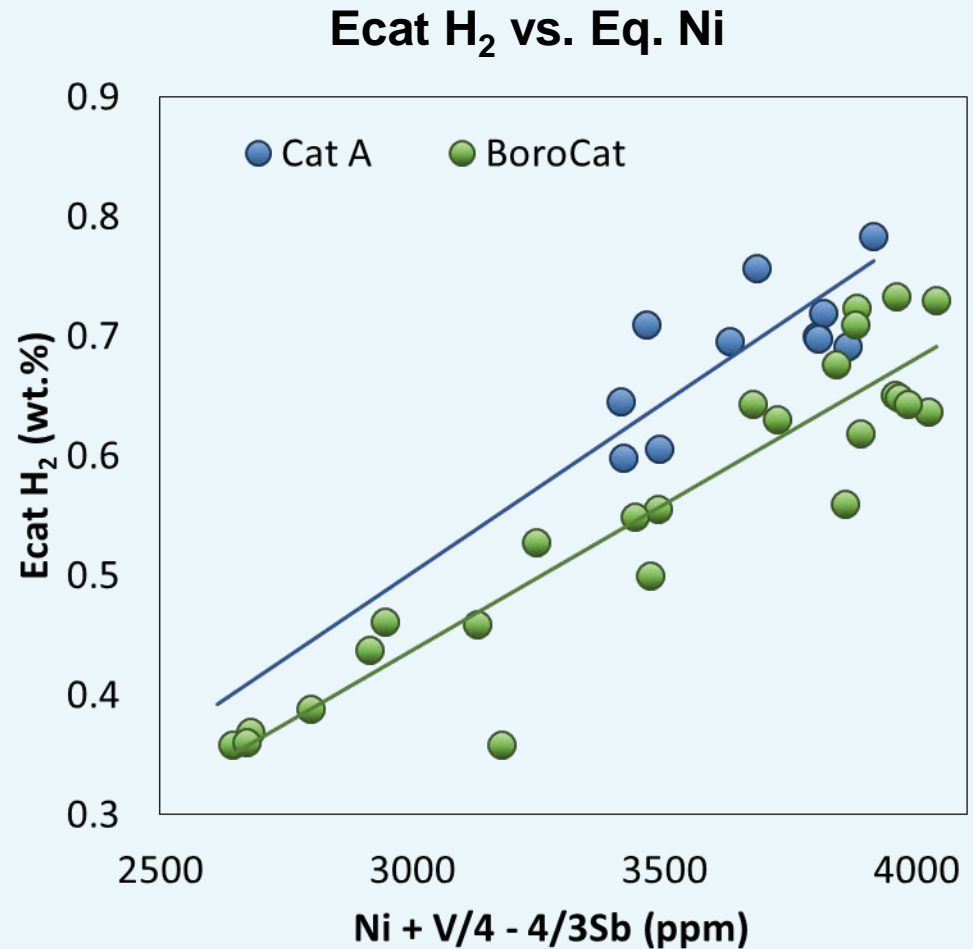
BoroCat Commercial FCC Trial #1

- Resid unit in Europe
 - ▶ API gravity: 24 – 27
 - ▶ Ecat Ni: 2700 – 3300 ppm
 - ▶ Ecat V: 1500 – 2000 ppm
- Switched to BoroCat for max gasoline yield

Result: Improved yield selectivity with lower H₂ and delta coke

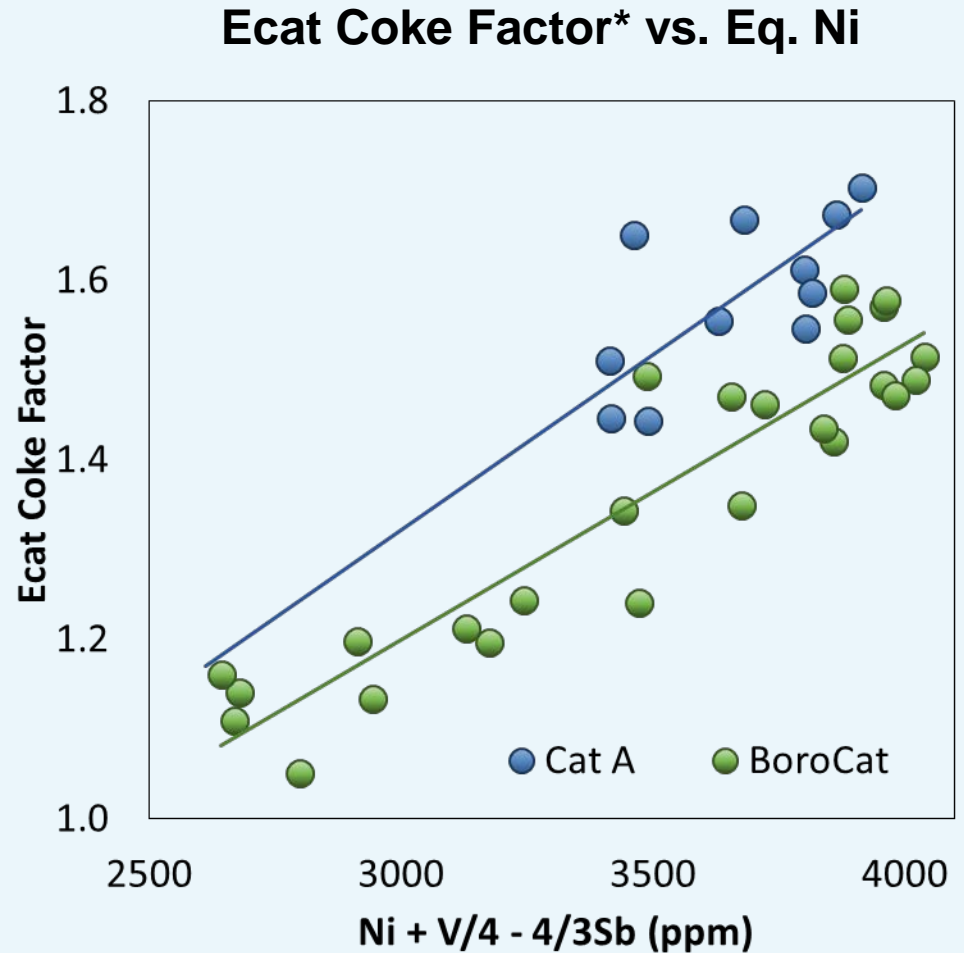
Ecat Hydrogen Reduction with BoroCat

- Ecat H₂ decreased at constant equivalent Ni level with BoroCat
- Mobility of boron resulted in more effective Ni passivation



Ecat Delta Coke Reduction with BoroCat

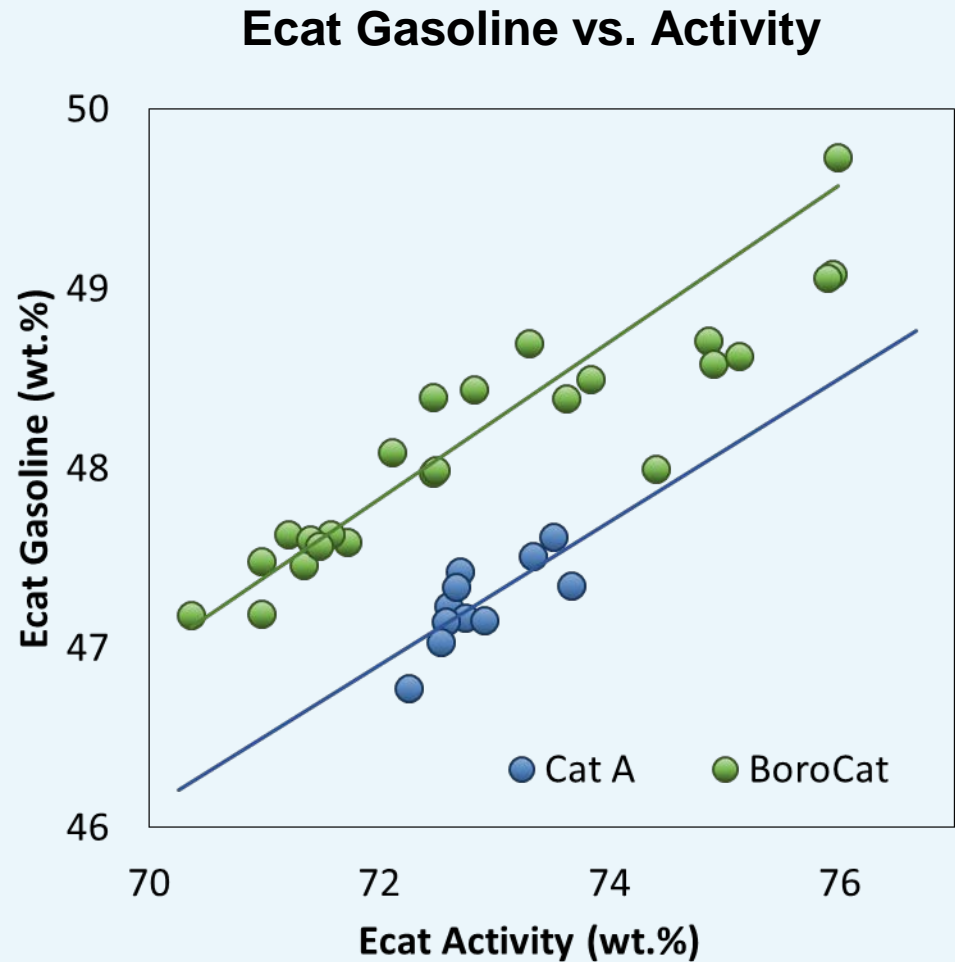
- Ecat coke factor indicates coke generating tendency of Ecat
- Coke factor decreased with BoroCat at constant equivalent Ni



*ACE coke yield normalized by catalyst activity, a measure of coke selectivity

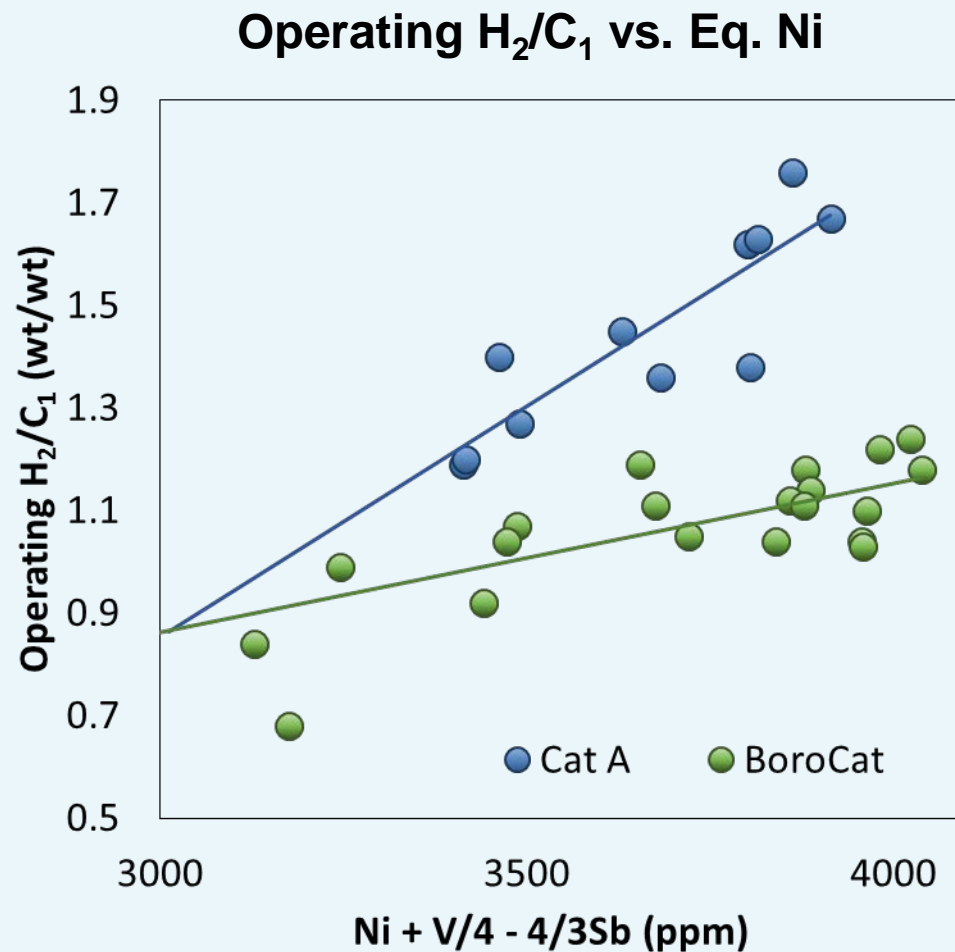
Improvement of Ecat Gasoline Selectivity with BoroCat

- Gasoline yield increased at constant Ecat activity with BoroCat



Operating Hydrogen Reduction with BoroCat

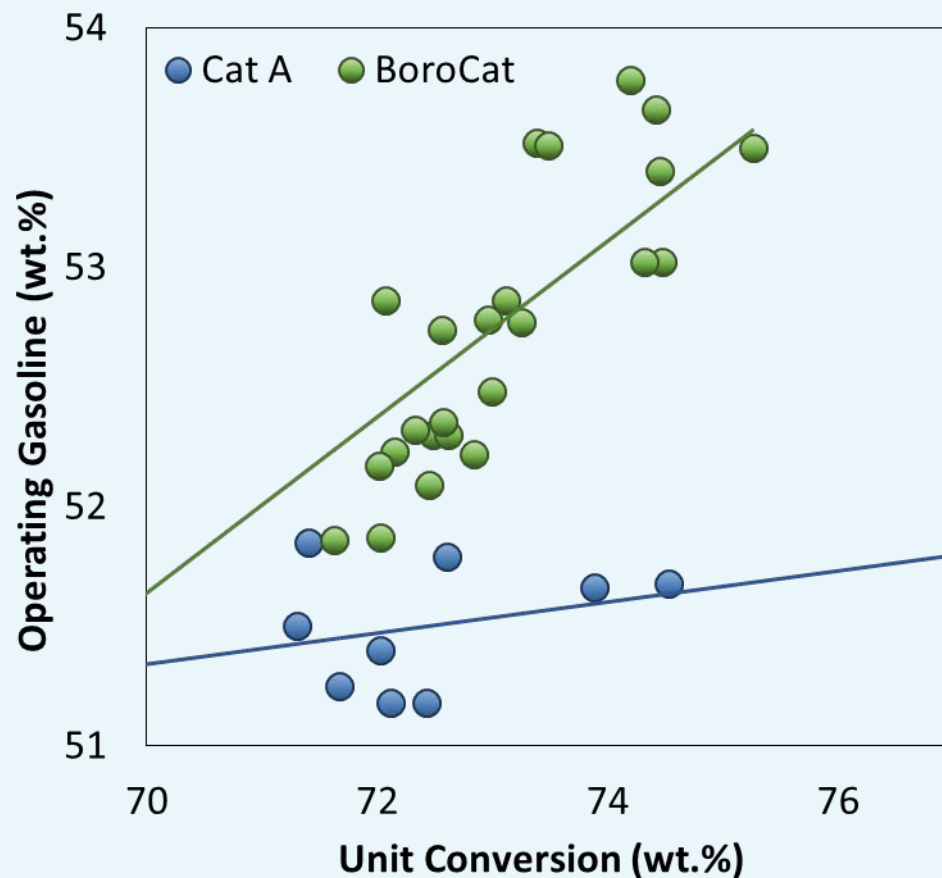
- Operating H_2/CH_4 decreased with BoroCat at constant equivalent Ni



Operating Gasoline Selectivity Improvement with BoroCat

- Increase in operating gasoline yield with BoroCat at constant conversion

Operating Gasoline vs. Conversion



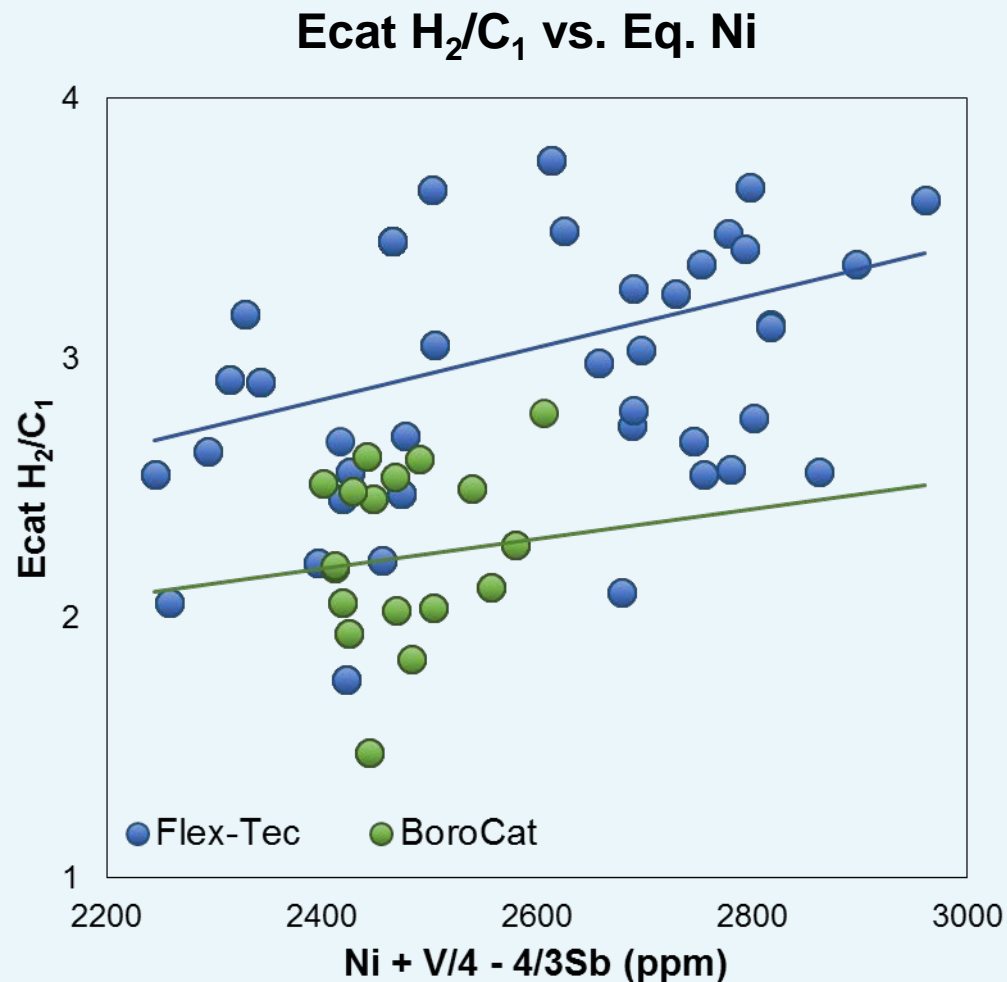
BoroCat Commercial FCC Trial #2

- Moderate resid unit in North America
 - ▶ API gravity: 20 - 22
 - ▶ CCR: 1 - 2%
 - ▶ Ecat Ni: 1900 – 2100 ppm
 - ▶ Ecat V: 3200 – 4000 ppm
- User of BASF Flex-Tec resid technology with antimony addition for max conversion

Result: Improved conversion with lower H₂ and delta coke

BoroCat Reduced Ecat Hydrogen

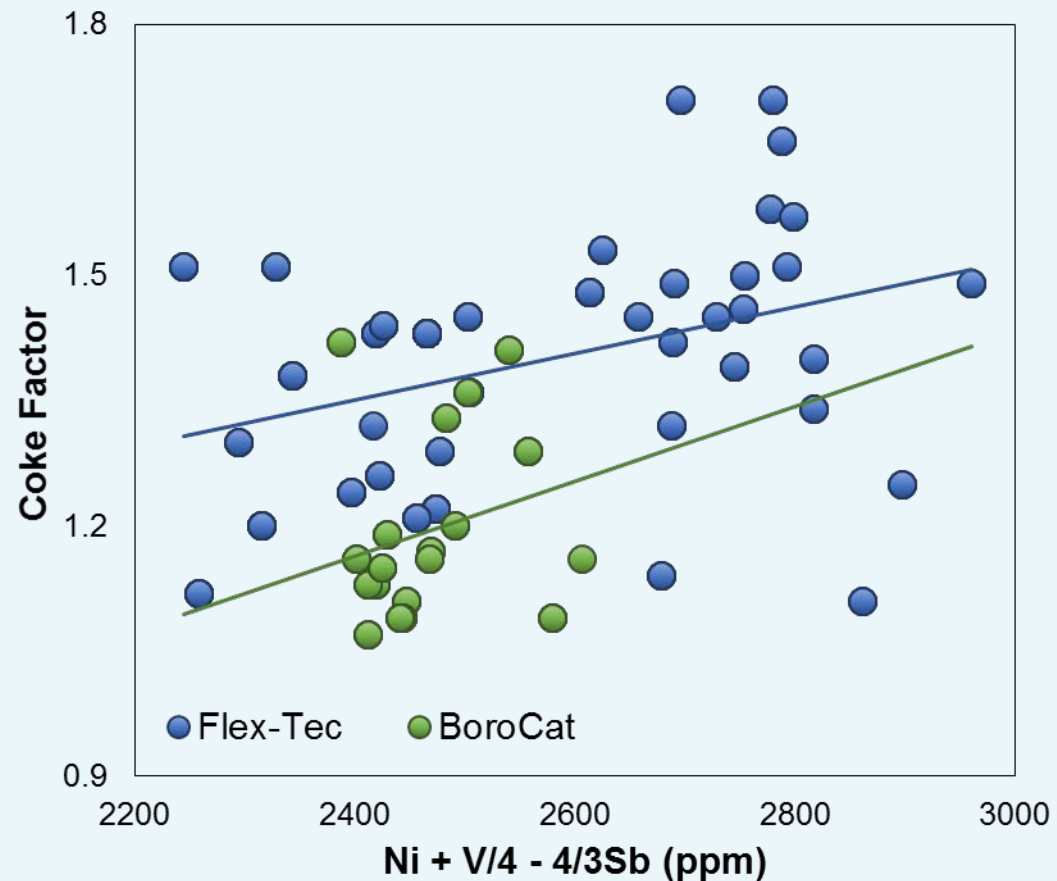
- Ecat H_2/C_1 ratio was lower at constant equivalent Ni
- Reduction in H_2 selectivity as expected with BBT



BoroCat Improved Coke Selectivity

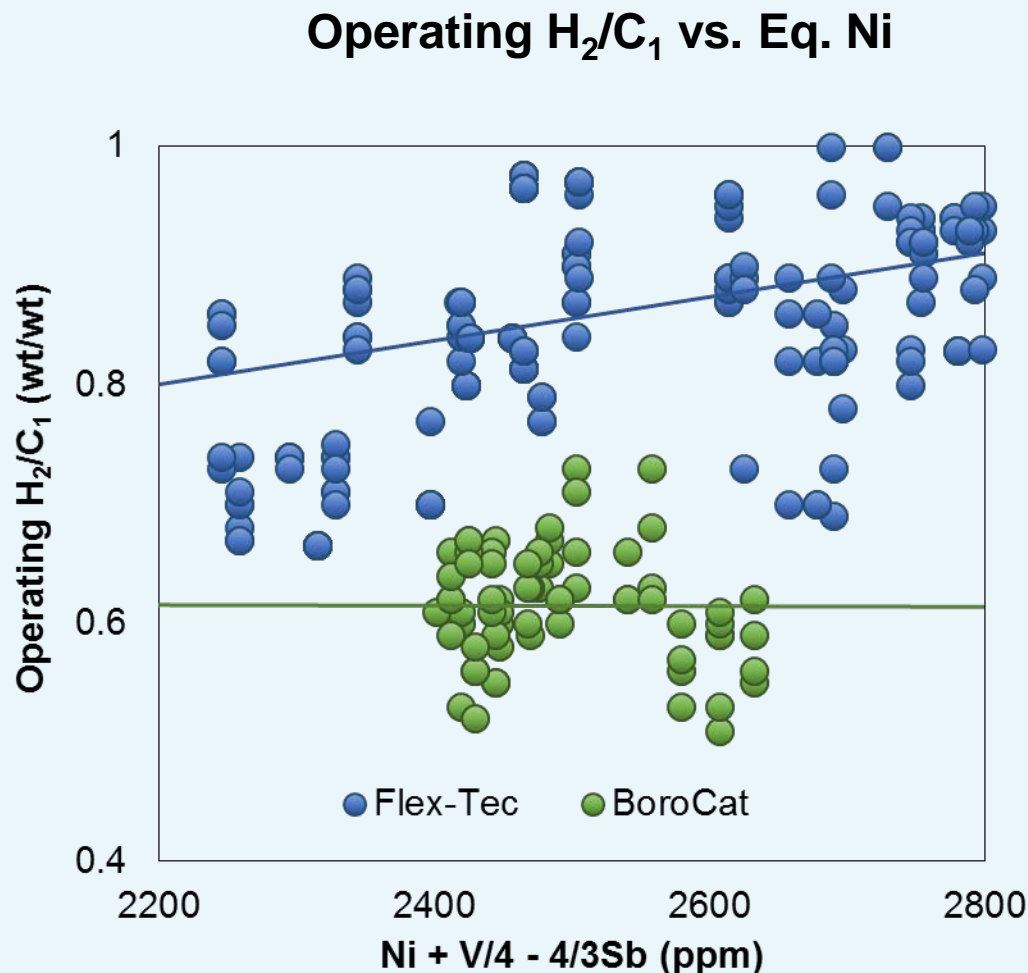
- Ecat coke factor decreased at constant equivalent Ni with BoroCat
- Improvement in coke selectivity as expected with BBT

Ecat Coke Factor vs. Eq. Ni



BoroCat Reduced Operating Hydrogen by ~ 25%

- ~25% reduction in unit H_2/C_1 ratio at constant equivalent Ni was in line with Ecat H_2/C_1 reduction



Commercial Yield Improvements with BoroCat

Profitability Improvement of \$0.32-0.38/bbl

- Higher conversion, LPG and gasoline
- Lower H₂ and bottoms
- Profitability improvement in-line with refinery's internal evaluation
- Gain in operational flexibility provides opportunities to further increase profitability

At Constant Operating Conditions

	Flex-Tec	BoroCat	Delta
Conversion, vol.%	84.9	86.0	+1.1
H ₂ , SCF/BBL	87.1	53.4	-33.7
LPG, vol.%	27.8	28.7	+0.9
Gasoline, vol.%	52.5	53.0	+0.5
LCO, vol.%	12.1	12.0	-0.1
Bottoms, vol.%	7.7	7.4	-0.3

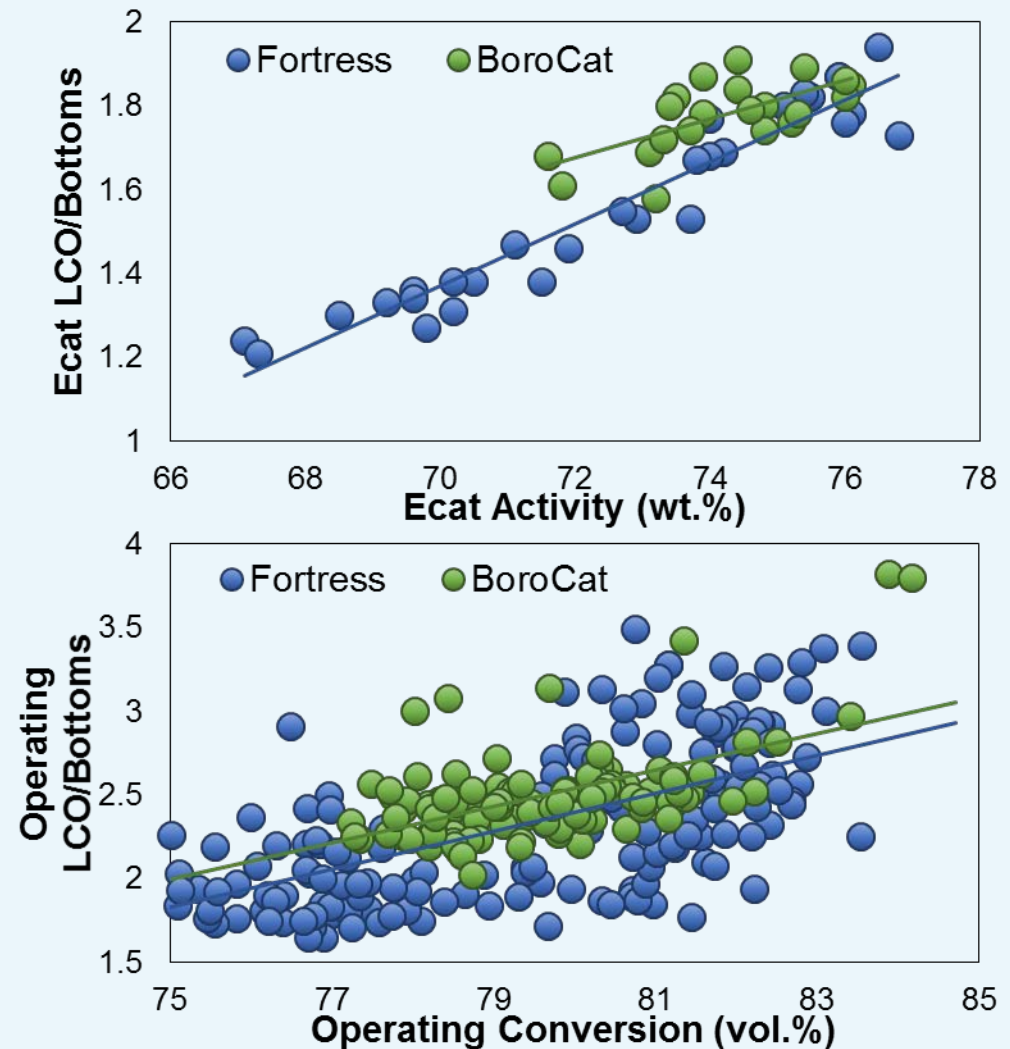
BoroCat Commercial FCC Trial #3

- Mild resid unit in North America
 - ▶ API gravity: 23 – 27
 - ▶ CCR: 0.4 – 1.5
 - ▶ Ecat Ni: 300 – 1400 ppm
 - ▶ Ecat V: 1300 – 3000 ppm
- User of BASF Fortress resid technology with antimony addition for Max Conversion

Result: Improved Bottoms Upgrading with No Additional NOx Emissions

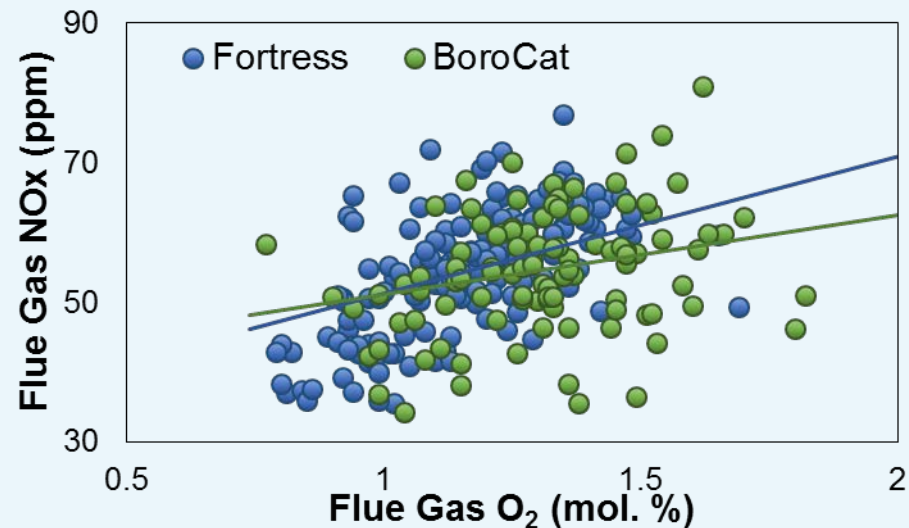
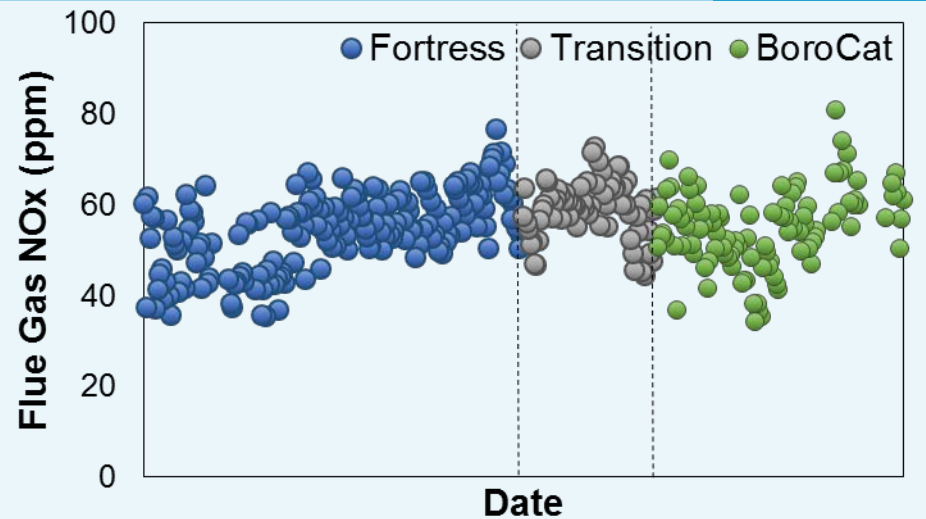
BoroCat Improved Ecat and Operating Bottoms Upgrading

- Higher LCO/Bottoms in Ecat data
- \$0.19/bbl improvement in unit profitability



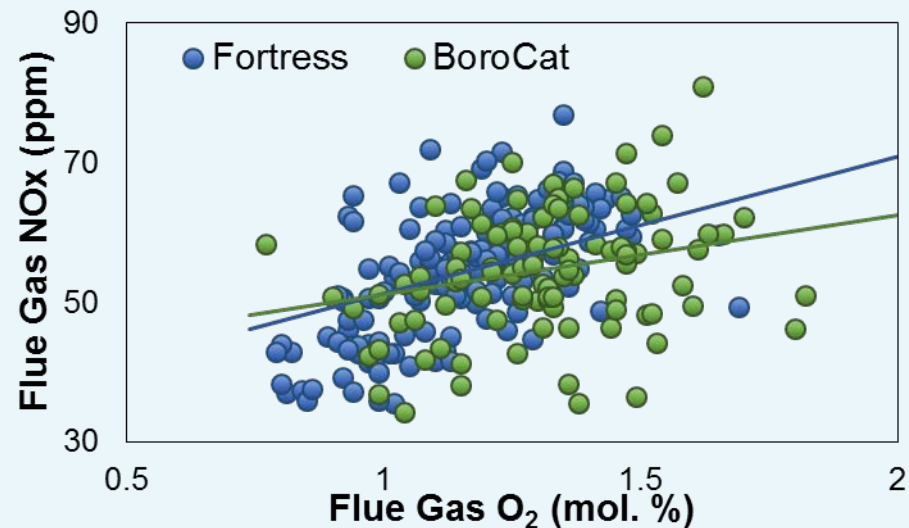
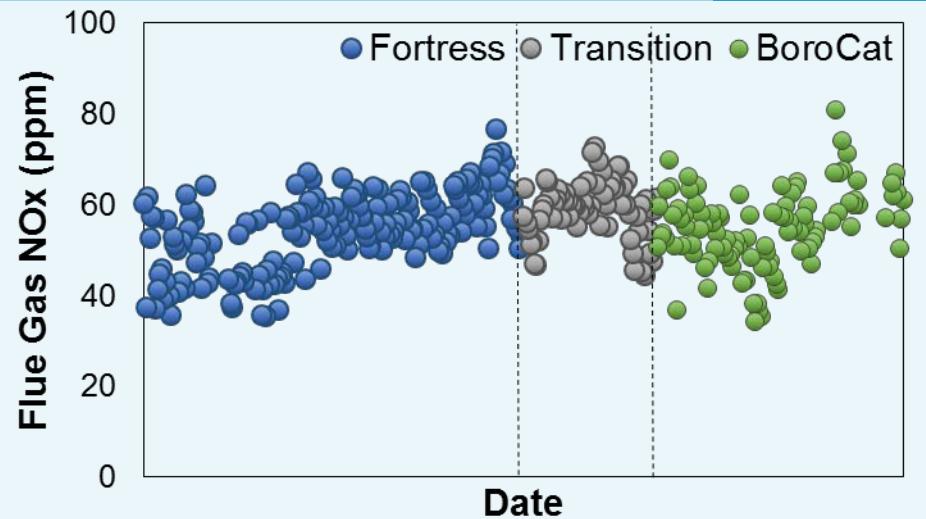
No Change in Unit NO_x Emissions with BoroCat

- No increase in NO_x emission at constant excess oxygen



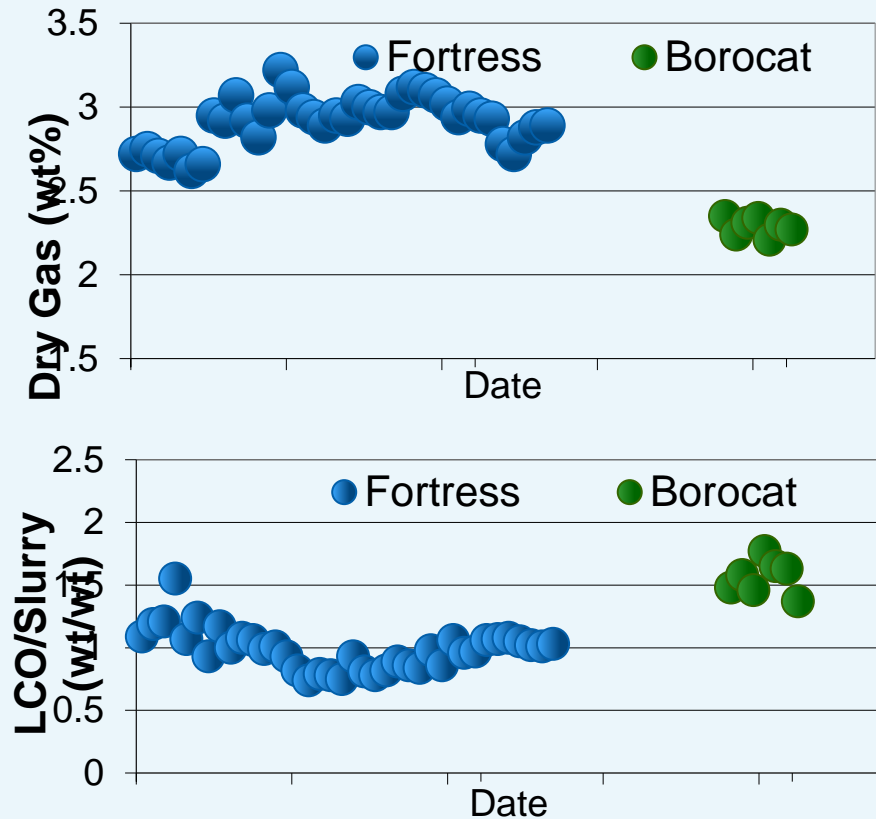
No Change in Unit NO_x Emissions with BoroCat

- No increase in NO_x emission at constant excess oxygen



BoroCat Trial #4 Tamoil Collombey

- R2R Design
- 100% Atmospheric Resid
- 21 API gravity
- 4-6 wt% Conradson
- Ni + V ranges 5,000-10,000ppm
- Uses Sb and ZSM-5



Conclusions and Path Forward

- BoroCat is the latest innovation based on BBT platform designed to further enhance the passivation of contaminant Ni

- BoroCat has been successfully proven in multiple refineries:
 - ▶ Improved metals passivation and lowered hydrogen and delta coke
 - ▶ Improved yield selectivity
 - ▶ Increased FCC unit profitability
 - ▶ No increase in unit NOx emission

- BoroCat unloads common unit constraints, giving flexibility to optimize unit operations.

Thank you



We create chemistry