VK-701 LEAP5™ Update
Sulfuric Acid Roundtable 2013

RESEARCH | TECHNOLOGY | CATALYSTS

Patrick Polk – Haldor Topsoe, Inc.

HALDOR TOPSØE

VK-701 LEAP**5**™

- Designed for high SO_3 environments
  - 4th bed of single absorption plants
  - 3rd bed of double absorption plants
- Introduced at Sulfur Conference in 2010
- Presentation at Sulfuric Acid Roundtable in 2011

How to reduce SO_2 emissions

- 1. Process changes
- 2. Catalyst – more liters/STPD – aka more horsepower
- 3. Optimized catalyst – VK69 & VK-701

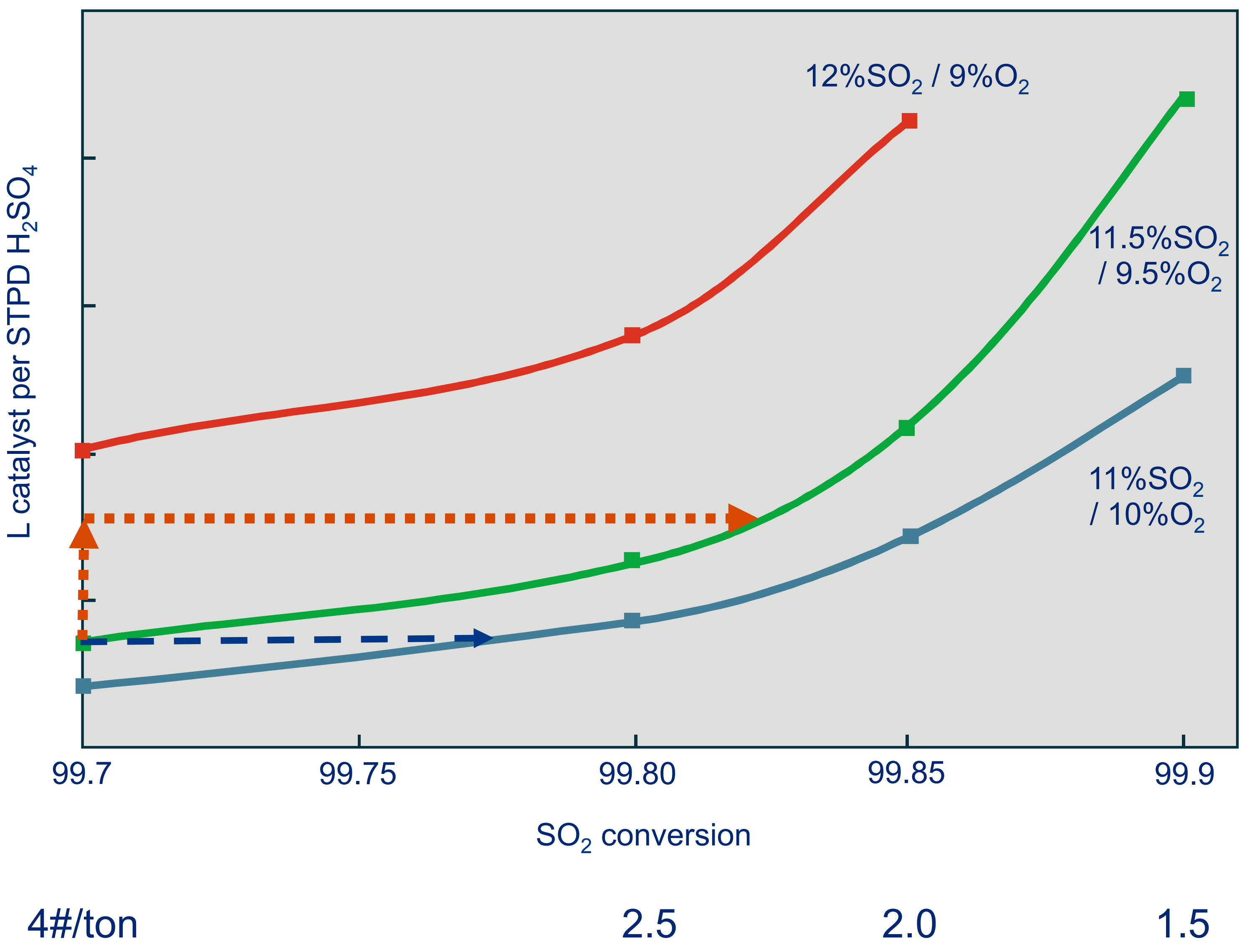
Process Options

- Reduce rate
- Reduce gas strength
- Single absorption convert to double absorption
- Install a scrubber - $$$$, annual O&M costs, possible waste disposal issues

Catalyst – increase liters/STPD

- Add more catalyst if there is room
- Add additional satellite bed & operate 2 existing beds in parallel
- Build a new converter & add more catalyst – space requirements and $$$$

Liters/STPD


12%SO2 / 9%O2
11.5%SO2
/ 9.5%O2
11%SO2
/ 10%O2
L catalyst per STPD H2SO4
99.7
99.75
99.80
99.85
99.9
SO2 conversion
4#/ton
2.5
2.0
1.5

Optimized Catalyst

- Catalyst optimized for specific gas compositions
  - Low SO_2
  - Low O_2
  - High SO_3

Catalyst Refresher

RESEARCH | TECHNOLOGY | CATALYSTS

HALDOR TOPSØE

Sulfuric Acid Catalyst Composition

- Vanadium
- Sodium
- Potassium
- Diatomaceous earth
- Binders

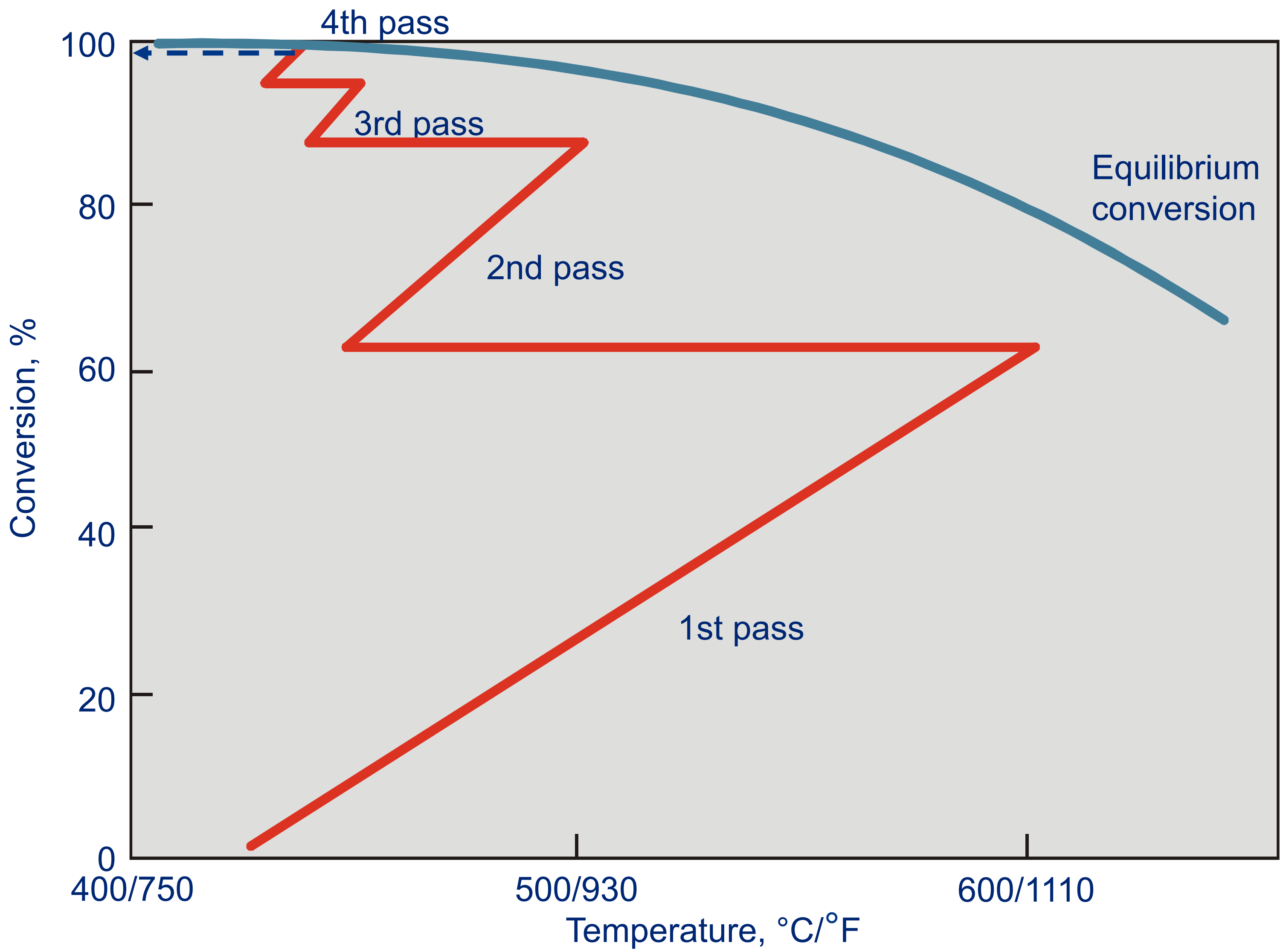
Supported Liquid Phase Catalyst

- Vanadium salts are liquid at operating temperature
- DE substrate provides physical structure
- Liquid melt coats the surface and pores of the DE

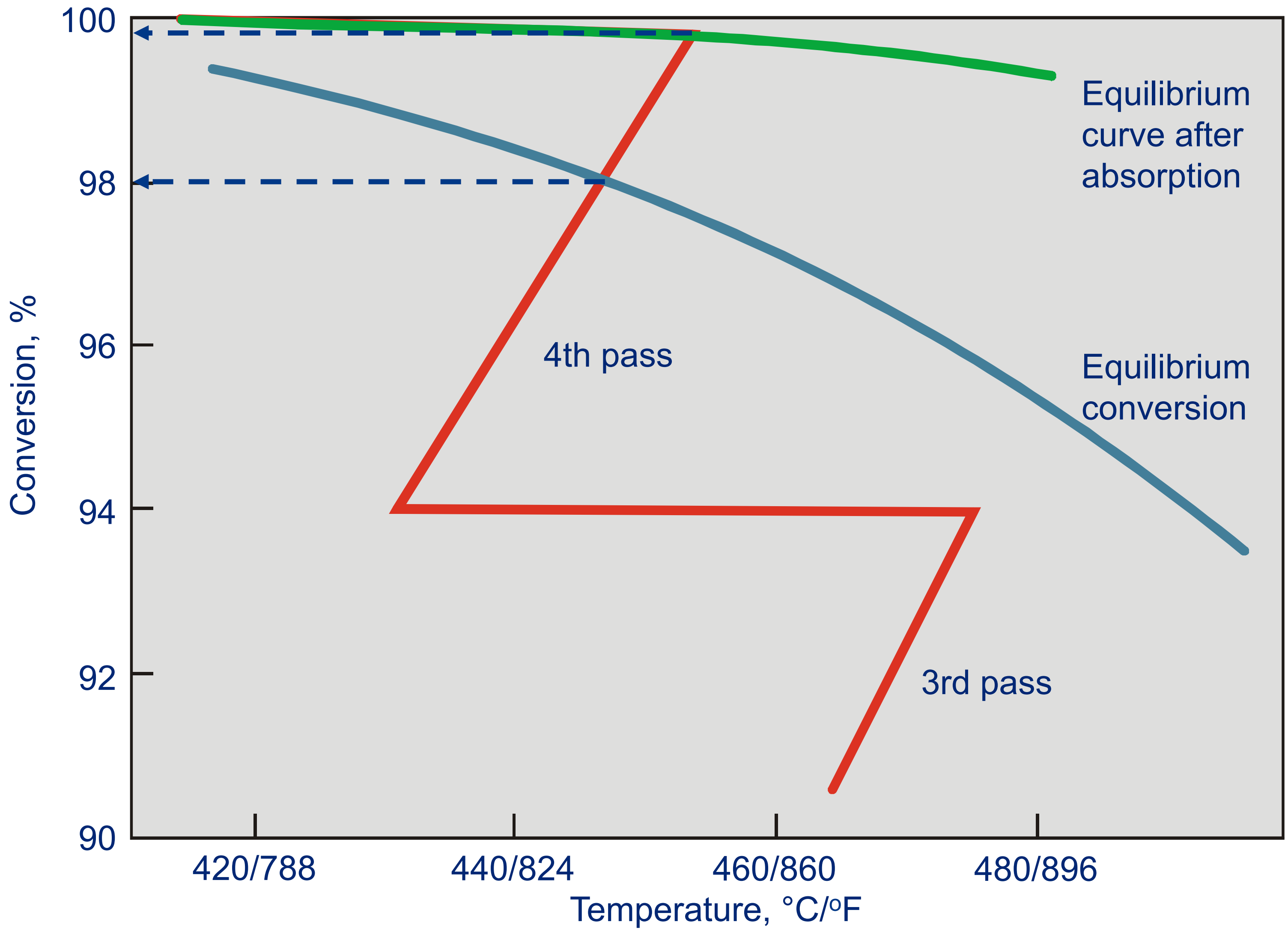
Conversion of SO_2 toSO_3

- Reversible reaction
- $SO_2 + ½O_2 \leftrightarrow SO_3$
  - Temperature
  - Pressure
  - Concentration
- Equilibrium – rate of forward reaction equals the rate of the reverse reaction
- Reaction rate slows down as approach equilibrium

Equilibrium and conversion



Equilibrium and Double Absorption



Optimized Catalyst

RESEARCH | TECHNOLOGY | CATALYSTS

HALDOR TOPSØE

Basis - 3x1 DA 11.5% SO_2 sulfur burner with150 liters/STPD catalyst loading

Bed	SO_2	O_2	SO_3	N_2
1	11.5	9.45	0	79.05
2	4.77	6.22	7.14	81.87
3	1.78	4.78	10.31	83.13
4	1.00	4.90	0.01	94.09

Bed Specific catalyst

- The gas composition at the inlet to each catalyst bed varies significantly.
- For maximum conversion and minimum SO_2 emissions one size fits all catalyst is not sufficient
- In the future, plants may utilize a different catalyst in each bed to maximize conversion and reduce emissions

VK69

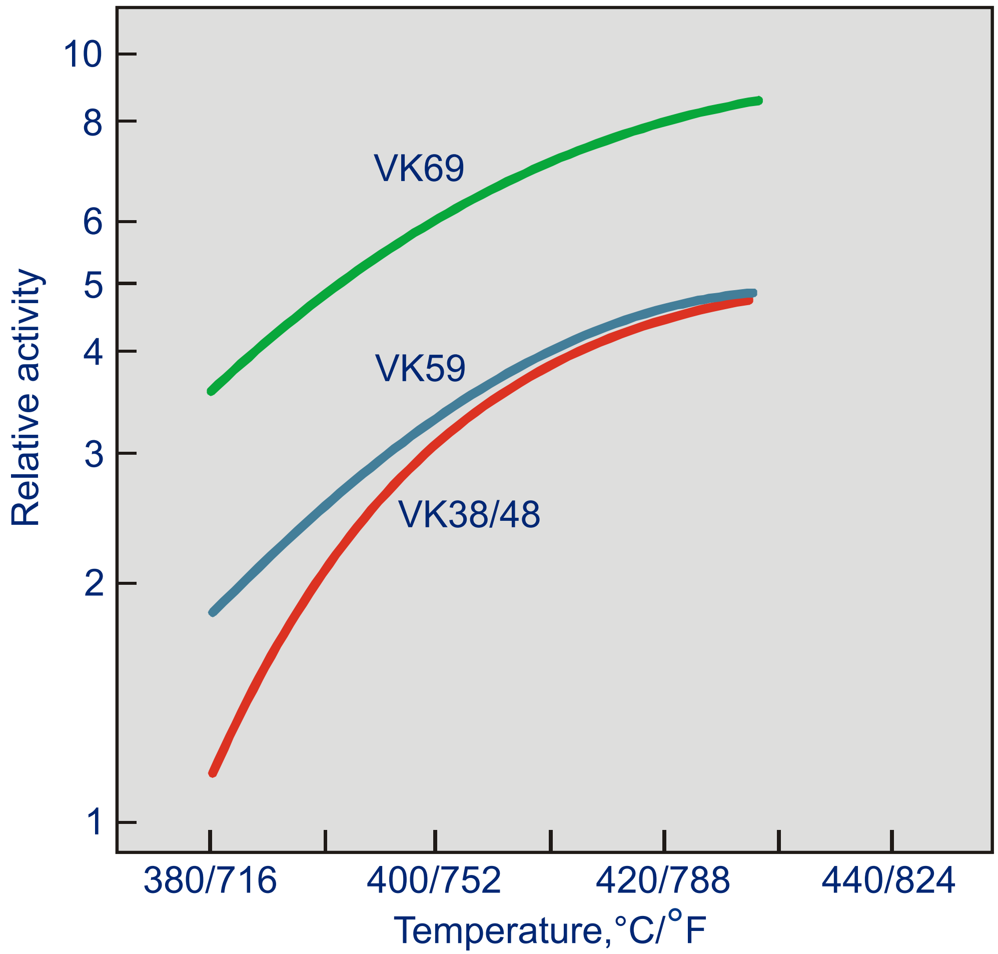
RESEARCH | TECHNOLOGY | CATALYSTS

HALDOR TOPSØE

VK69 cesium promoted catalyst

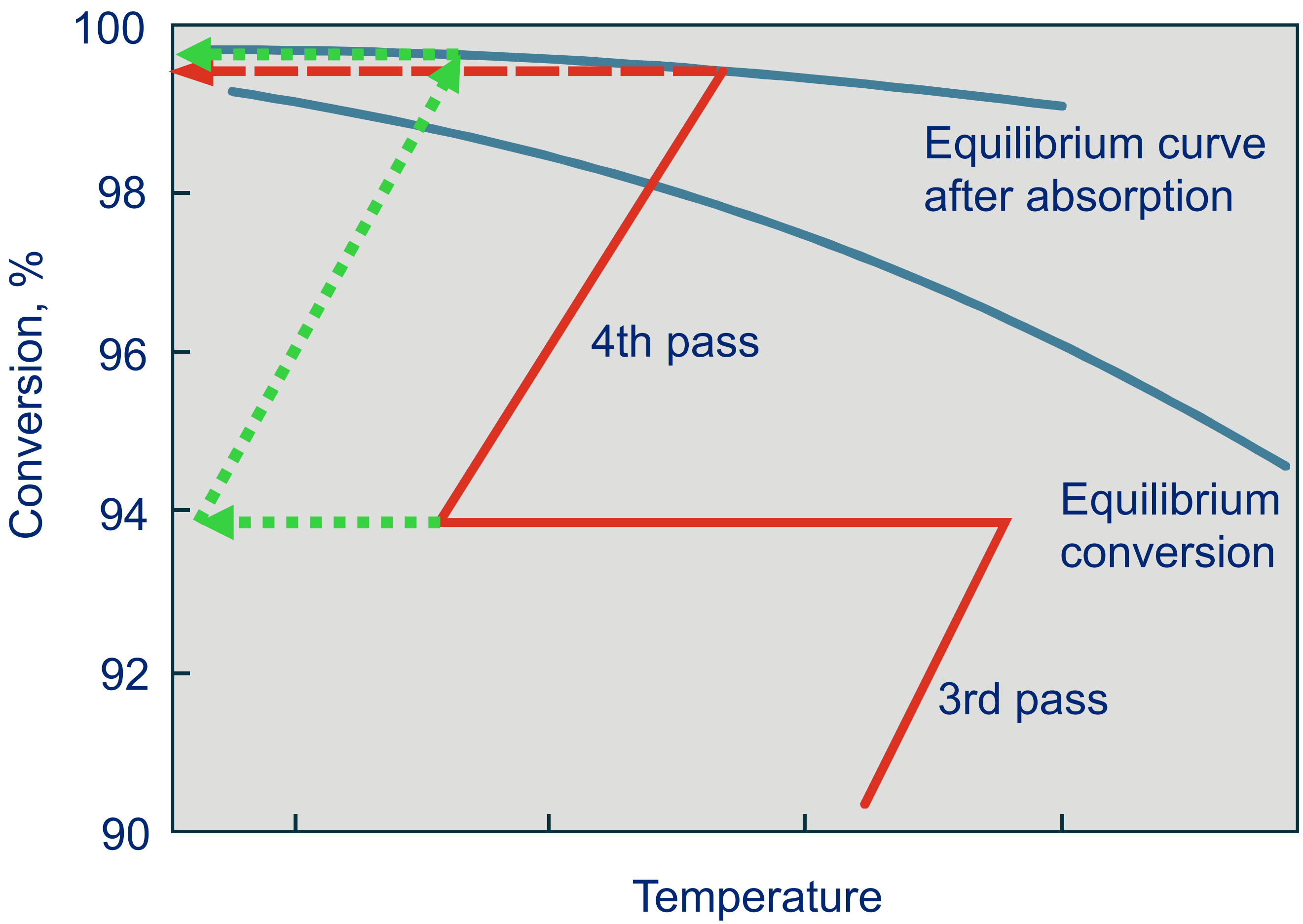
- Introduced in 1996 – 110+ references
- Designed specifically for double absorption plants in the bed after the intermediate absorption tower.
- Much higher activity at low temperatures
- Reduces emissions up to 50%

Activity in low SO_2 & O_2 gasses



Sulphur dioxide oxidation

Effect of interstage absorption on equilibrium conversion



VK 701 LEAP5™

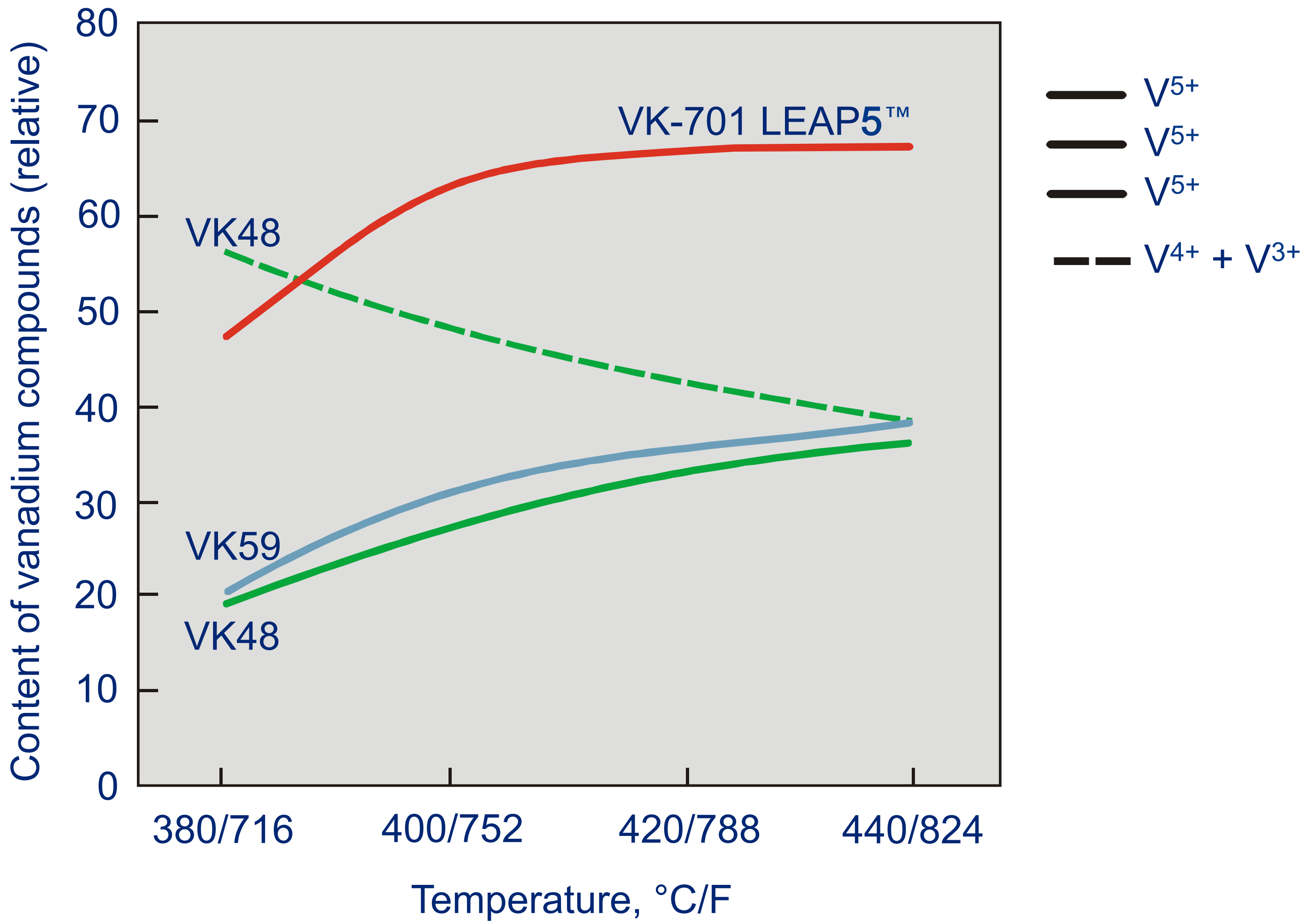
RESEARCH | TECHNOLOGY | CATALYSTS

HALDOR TOPSØE

VK-701 LEAP**5**™

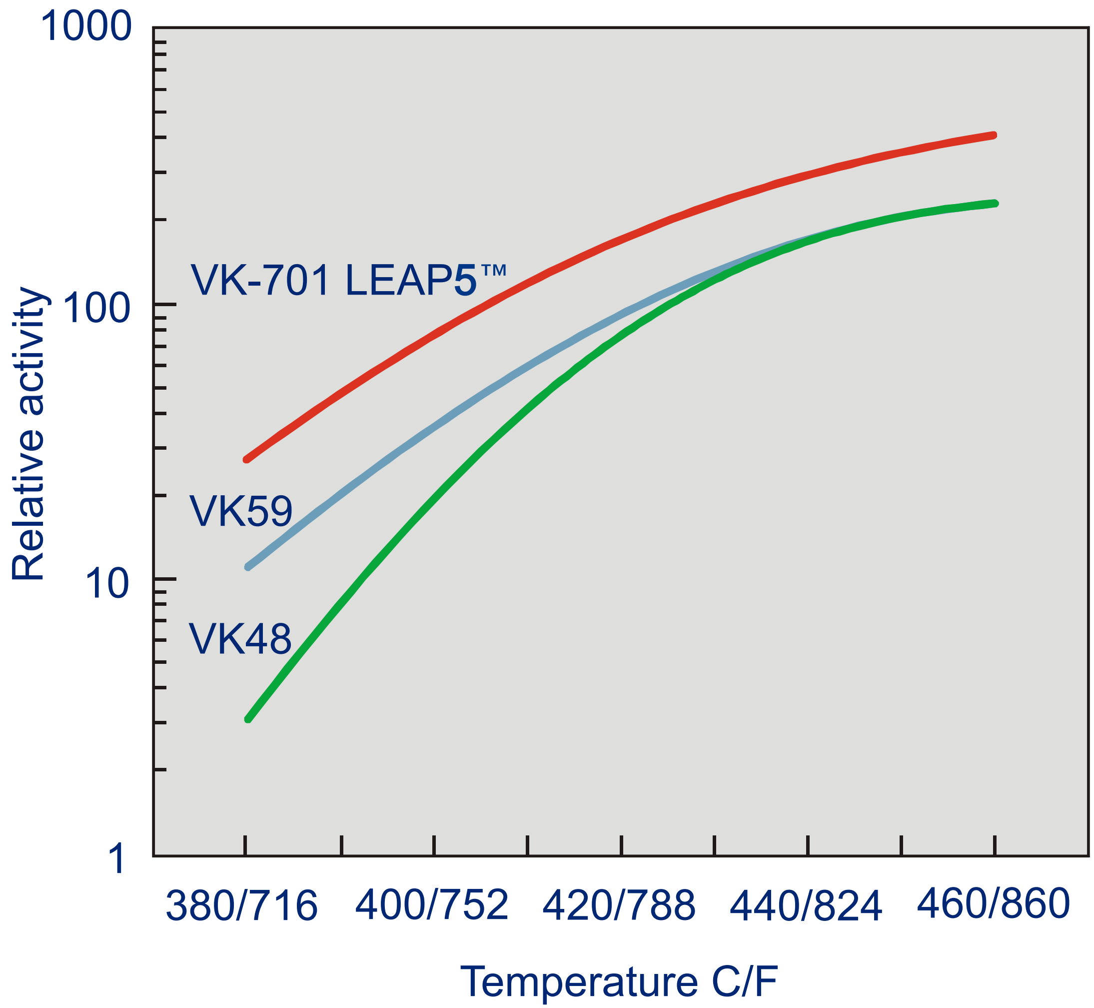
- Changed intrinsic morphology and surface properties of the carrier
- Optimized active phase for high SO_3 concentration
- Developed a new unique production technology
- Reduces emissions up to 40%

Vanadium oxidation states in 3rd bed catalysts

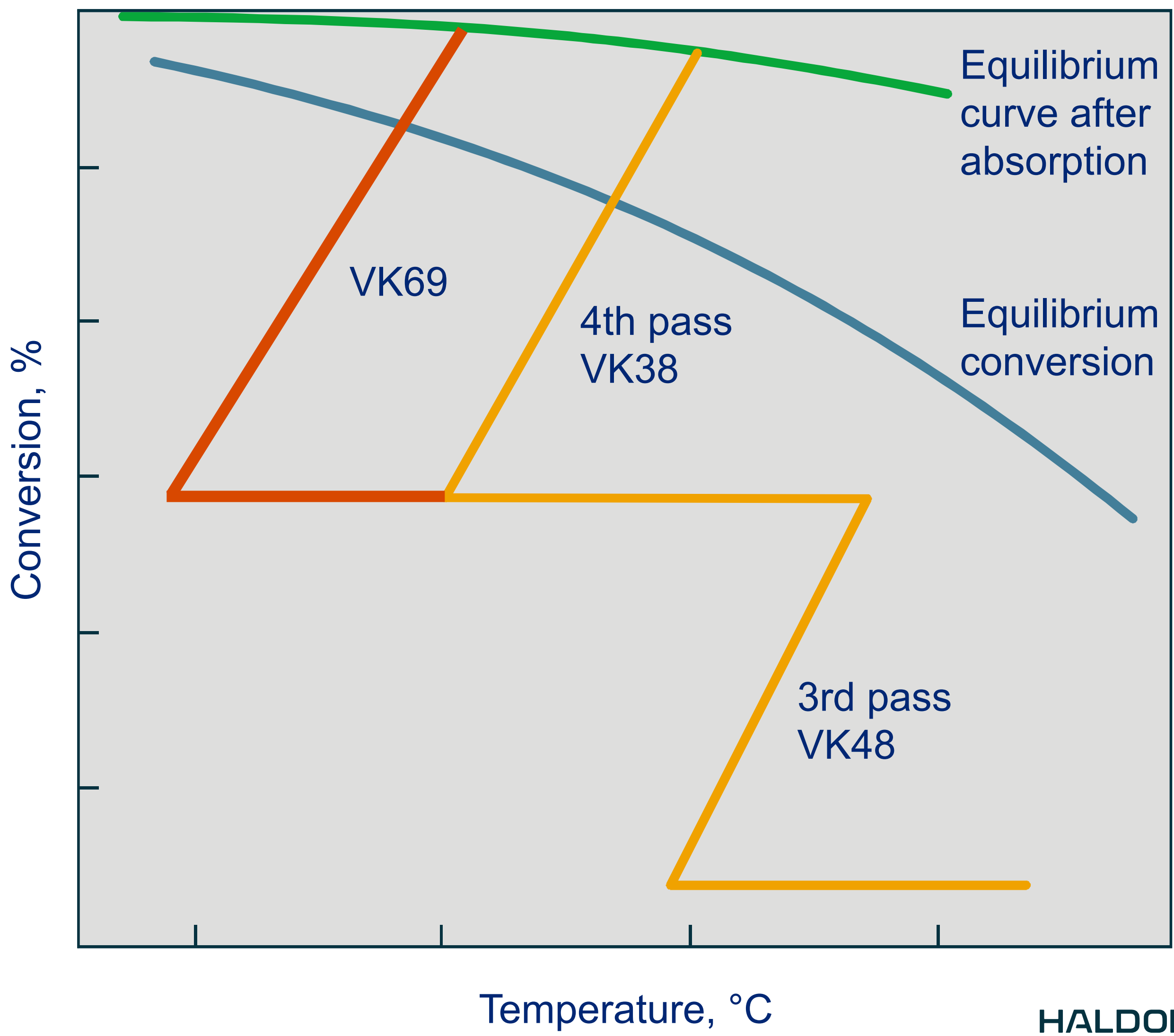


HALDOR TOPSØE

Activity of VK-701 LEAP**5**™ in SO_3 rich gas

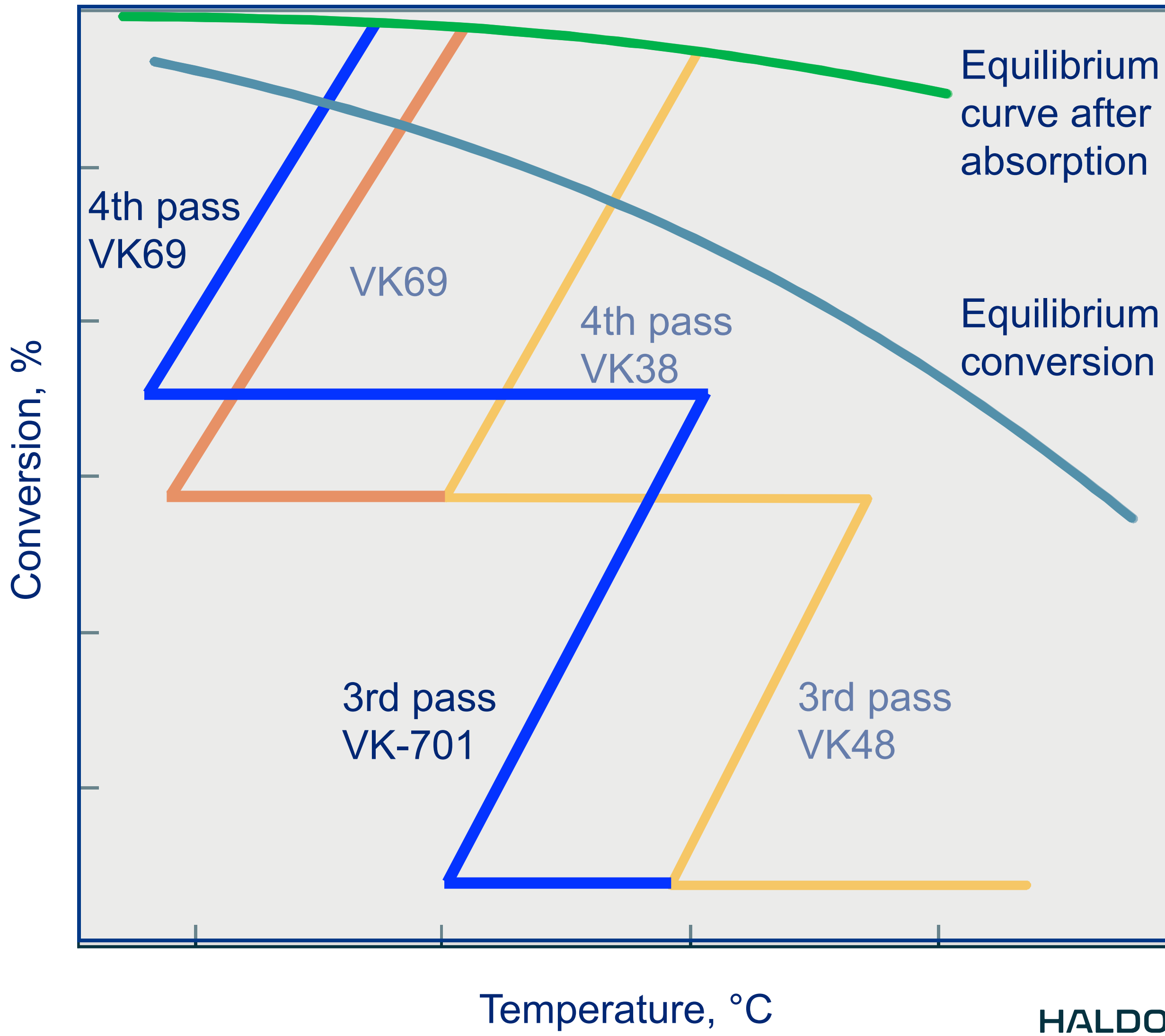


Equilibrium conversion
- VK69 application



HALDOR TOPSØE

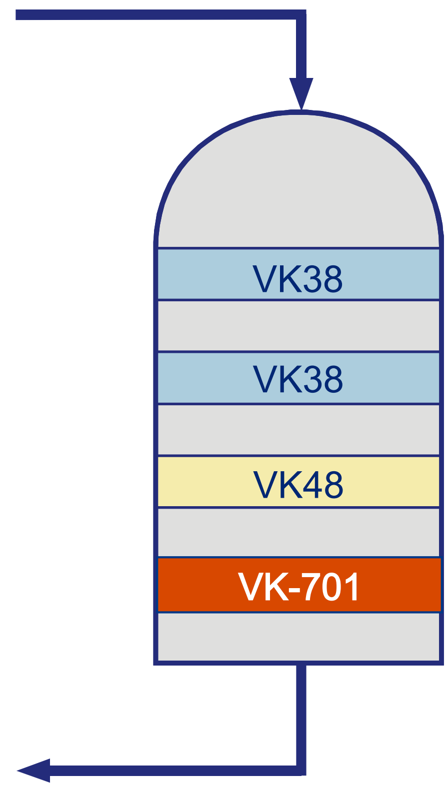
Equilibrium conversion
- VK69 & VK701 LEAP5™ applications



HALDOR TOPSØE

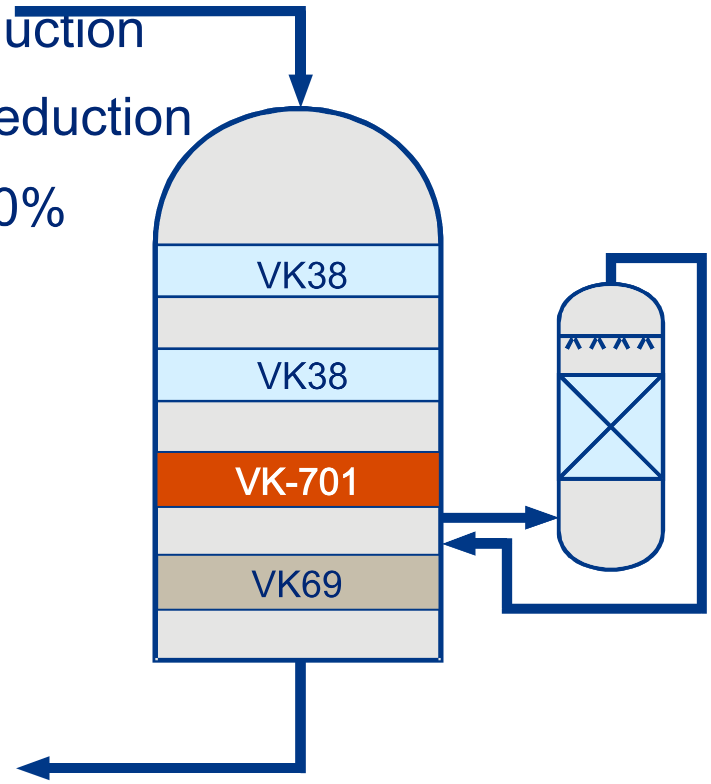
Single Absorption Example

Layout	: 4-pass single-absorption
SO_2 source	: Metallurgical off-gas
Catalysts in beds 1/2/3	: VK38 / VK38 / VK48
Catalyst in bed 4	: VK-701
Emissions reduction	: Approximately 40%



Double Absorption Example

Layout	: 3+1 double-absorption plant
SO_2 source	: S-burning in air
Catalysts in beds 1/2	: VK38 / VK38
Catalyst in bed 4	: VK69 ~ 50% reduction
Catalyst in bed 3	: VK-701 ~ 40% reduction
Net reduction	: approximately 70%



HALDOR TOPSØE

References

RESEARCH | TECHNOLOGY | CATALYSTS

HALDOR TOPSØE

VK-701 LEAP5™ References

- Single absorption sulfur burning
- Single absorption smelter off-gas
- Double absorption sulfur burning

Lessons Learned

RESEARCH | TECHNOLOGY | CATALYSTS

HALDOR TOPSØE

Lessons Learned

- No heat exchanger modifications have been required.
- Optimum inlet temperature only 25 to 30F lower for existing plants.
- VK-701 was “very hard” after being in service for a turnaround cycle.

Conclusion

- Demand to decrease emissions will continue
- Use of optimized catalysts will result in lower emissions
- No heat exchanger modifications required to date.

Conclusion (cont)

- Emission reductions through catalysis
  - Does not require additional energy consumption
  - Does not create any waste - the only byproduct is additional sulfuric acid production
  - Has the potential for additional energy recovery
  - Cost effective

Conclusion (cont)

- Potential emissions reduction
  - Single absorption
    - VK701 – approximately 40%
  - Double absorption
    - VK69 – approximately 50%
    - VK69 and VK701 – approximately 70%

Thank you

Any questions?