REACTION RESISTANCES IN THE SO_2 OXIDATION – AND THEIR IMPLICATIONS FOR CATALYST DESIGN AND SELECTION

(TO MEET DEMANDS IN THE INDUSTRY)

TOPSOE

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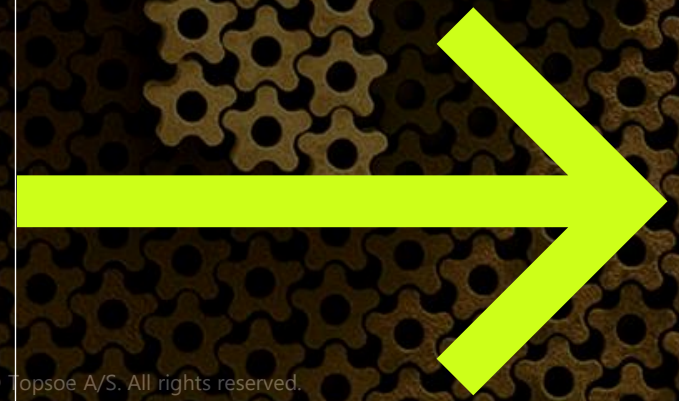
SAIMM Sulphur & Sulphuric Acid Conference , Cape Town

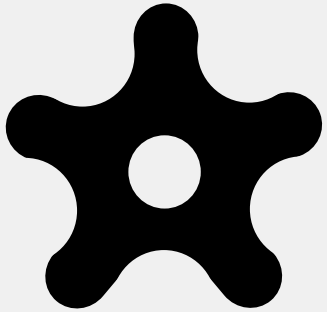
May 2025



THE SULFURIC ACID CATALYST REACTION RESISTANCES
TODAY'S AGENDA

Reaction resistances

Under what conditions is the reaction kinetic, pore, and film limited?



Changes in catalyst size and shape

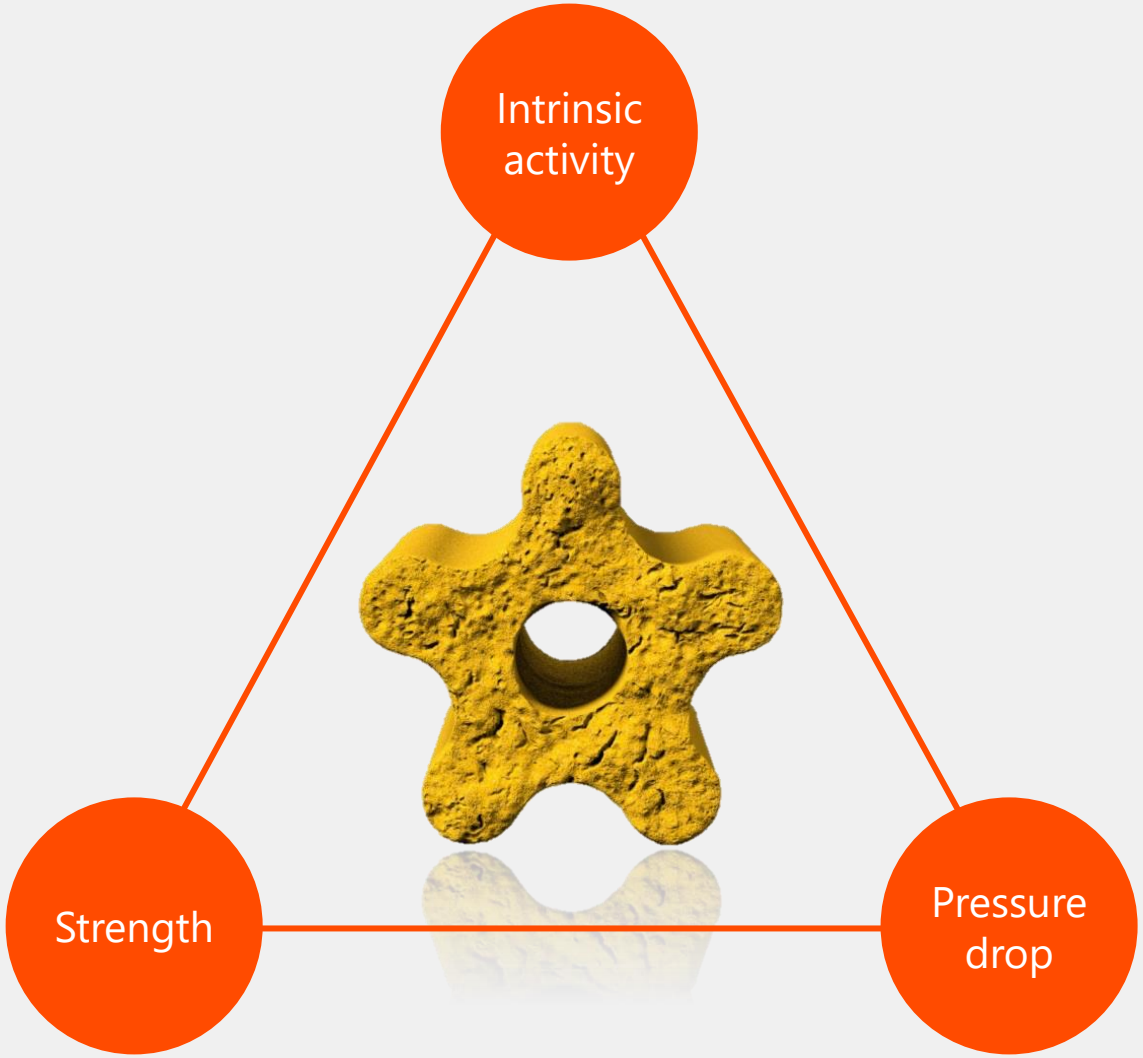
How do size and shape affect performance?

Process conditions

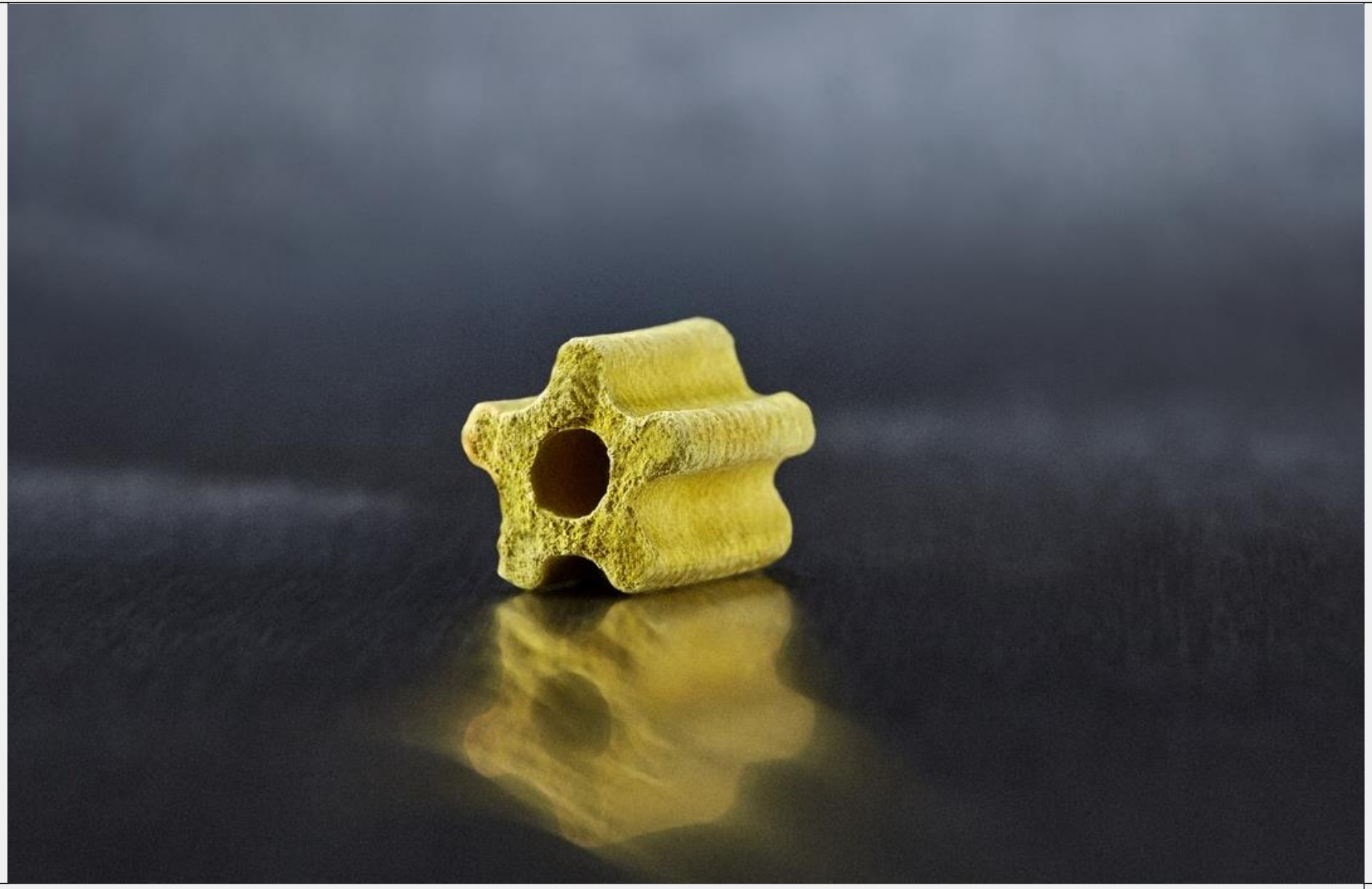
How do the process conditions affect the different resistances?

DESIGNING A CATALYST IS NORMALLY A COMPROMISE

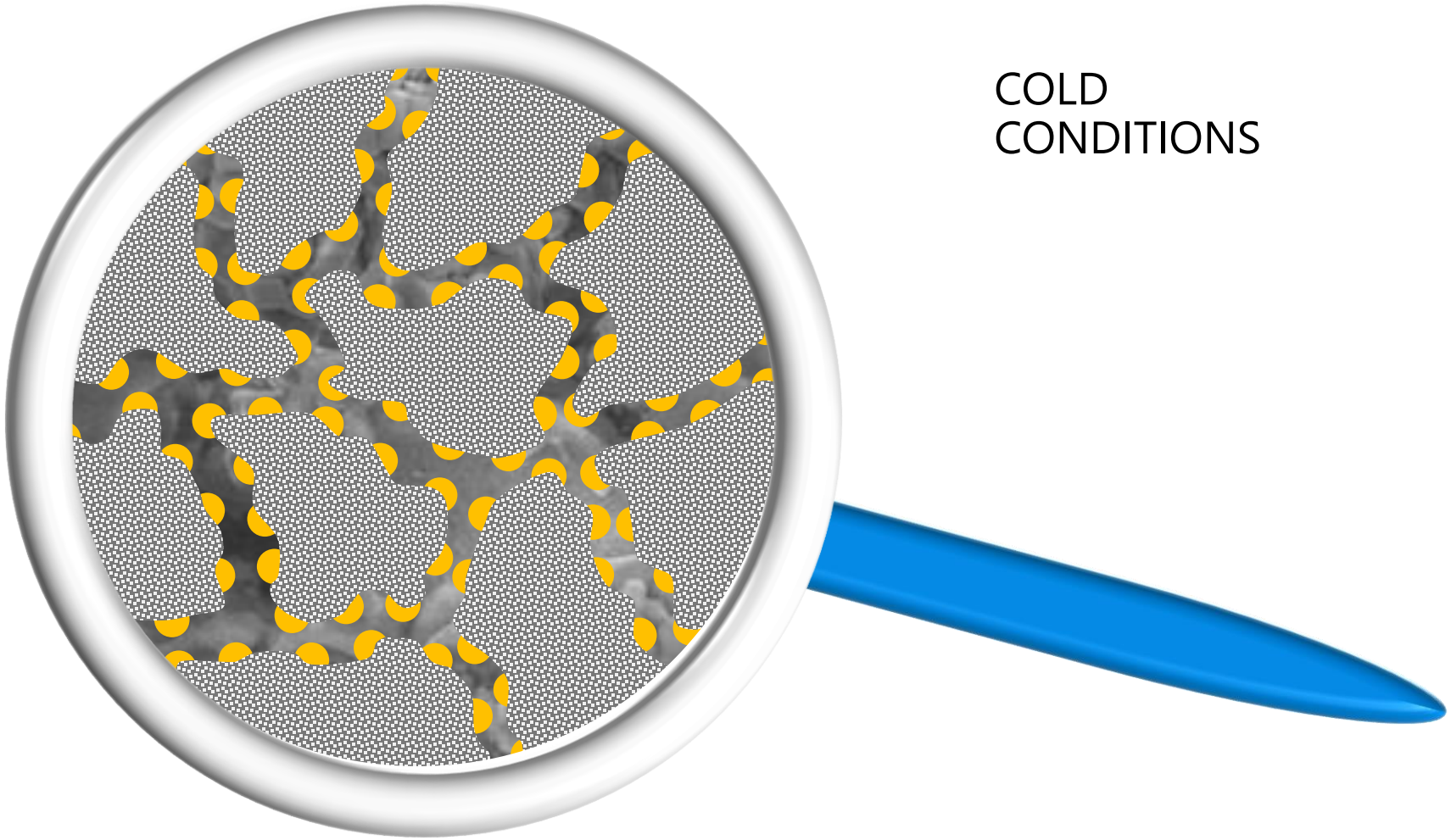
WITH NEWLY DESIGNED MATERIAL COMES NEW POSSIBILITIES



VK - CATALYST

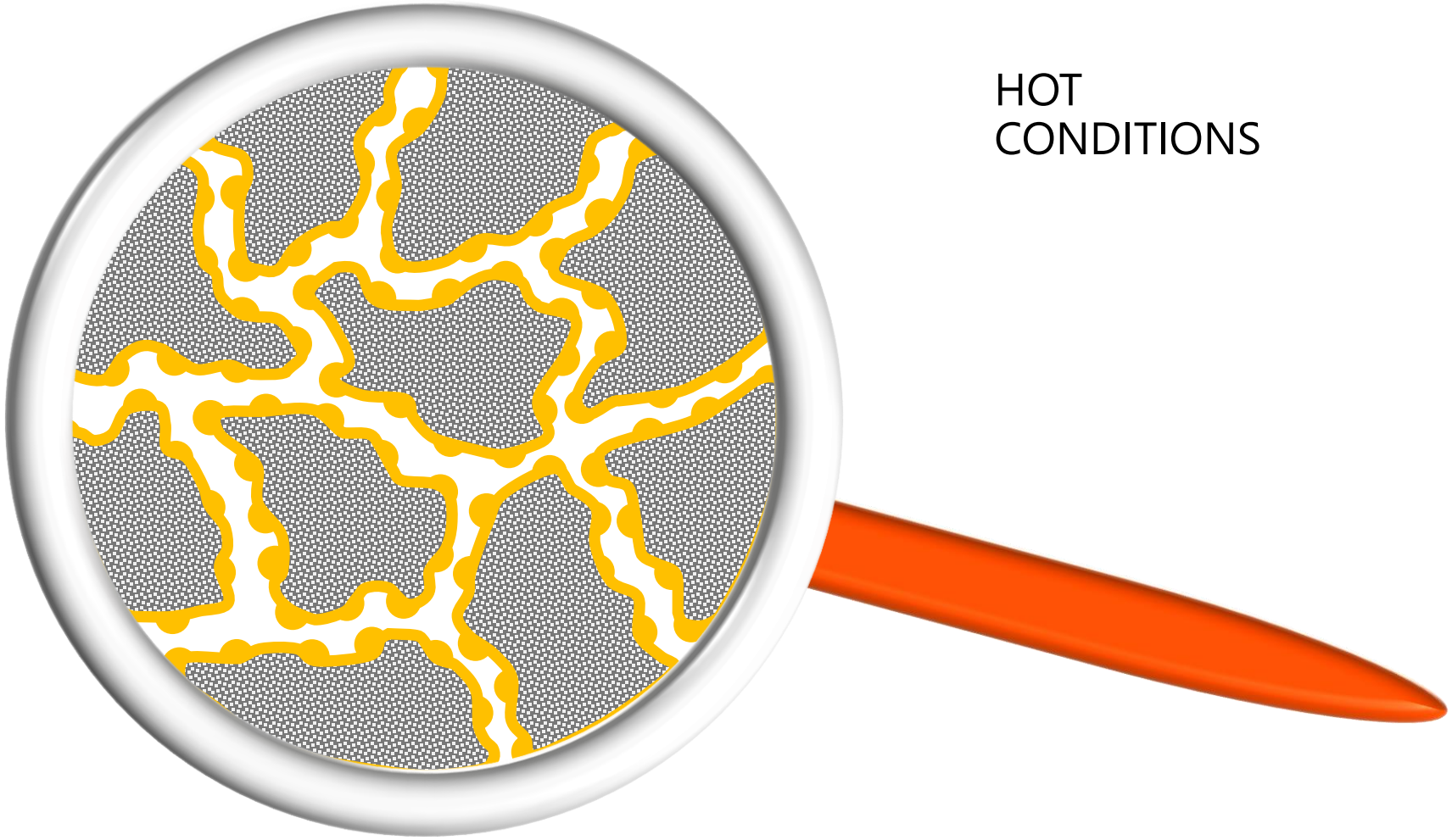


VK-CATALYST



COLD CONDITIONS

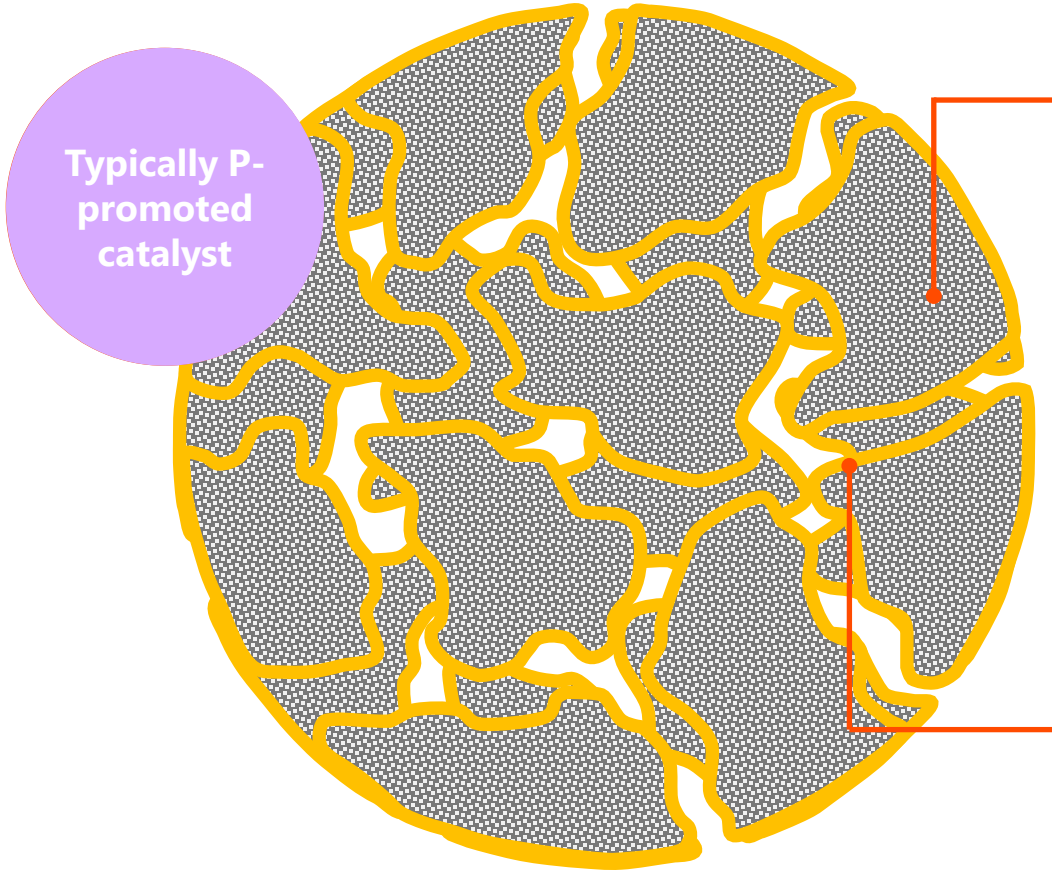
VK - CATALYST



HOT
CONDITIONS

VK38+

HIGH
INTRINSIC
ACTIVITY
CATALYST



Modified support

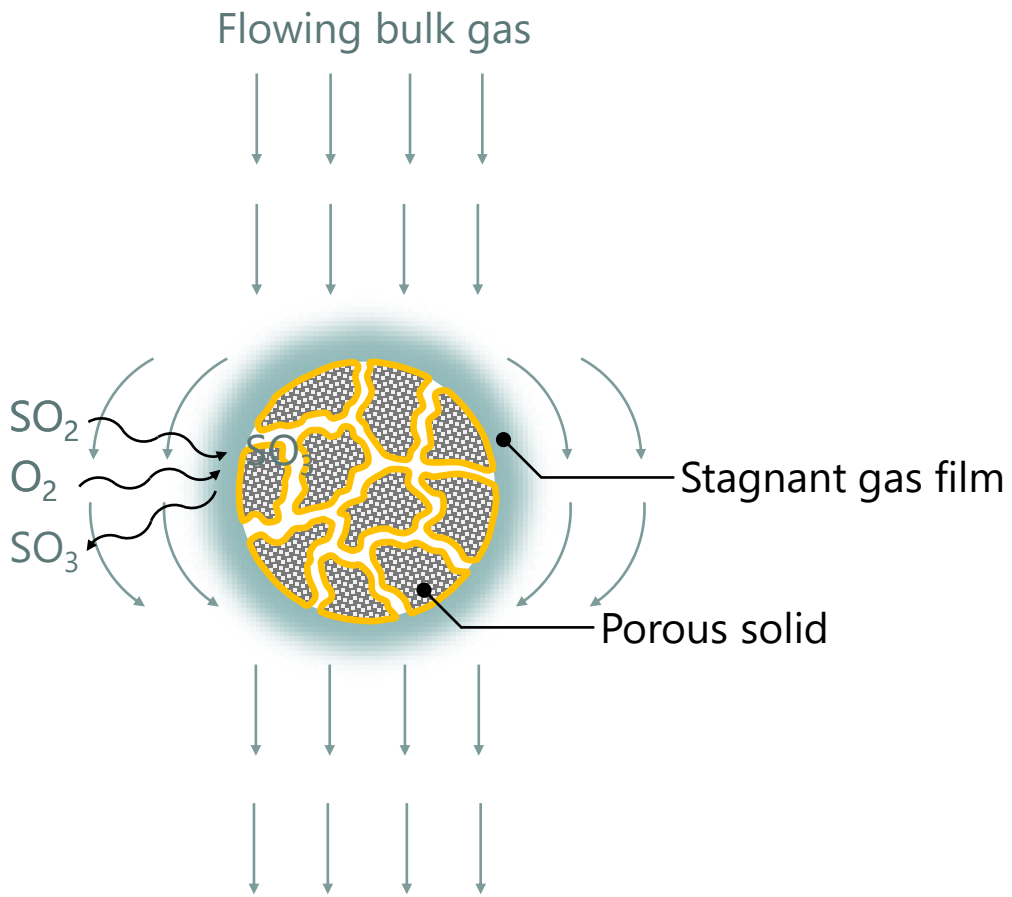
Changes to how the support is designed and produced with the improved intrinsic material gives better utilization of internal pore volume

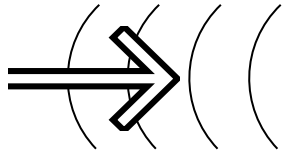
Optimised active melt formulation

The active melt has been optimized for maximum performance with the new support

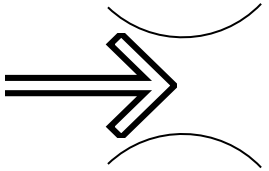
… without compromising the strength

RESISTANCES
DIFFUSION AND REACTION IN POROUS CATALYST

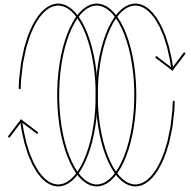




Film diffusion resistance

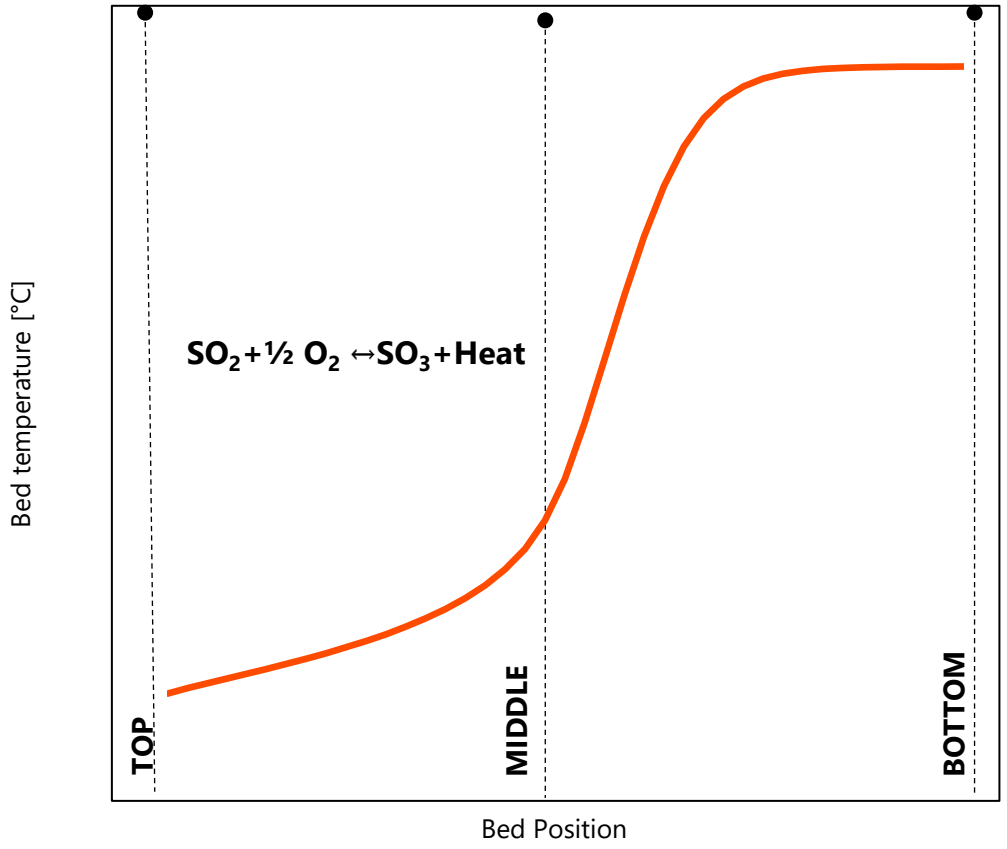


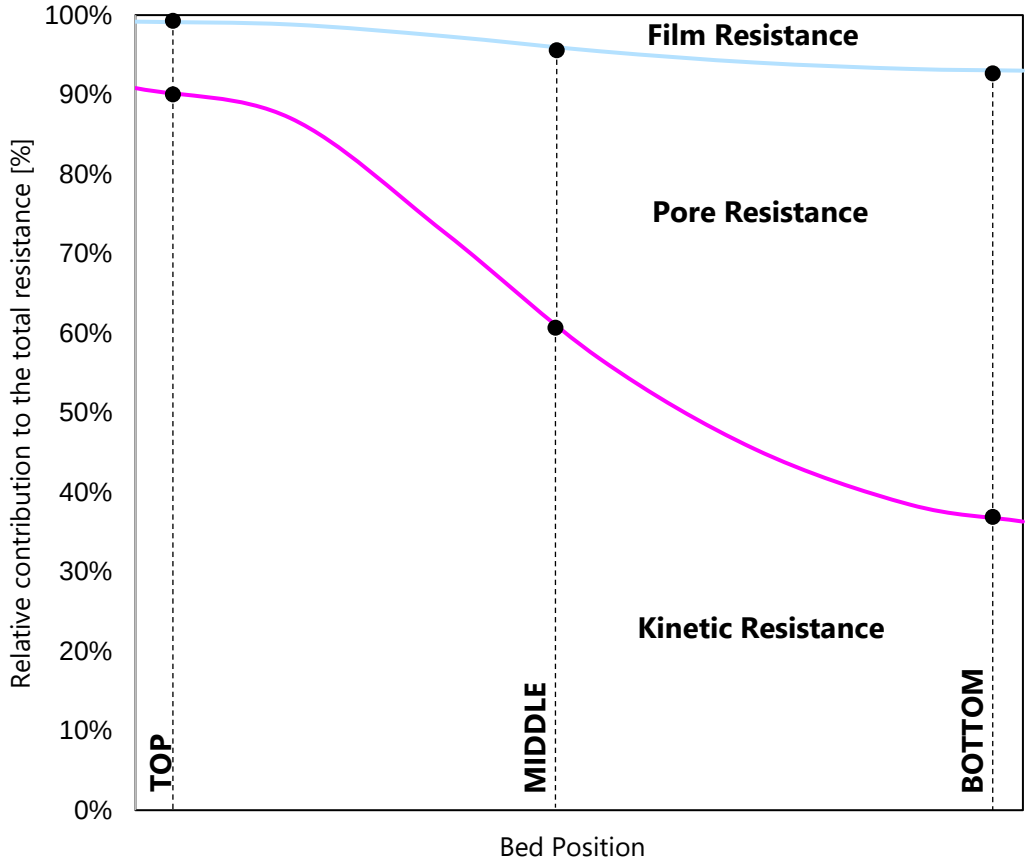
Pore diffusion resistance



Kinetic resistance

PROFILES OF CATALYST BEDS
CONTRIBUTION OF DIFFERENT RESISTANCE IN A FIRST PASS





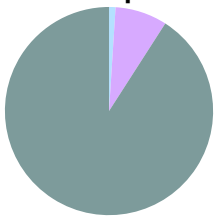
CATALYST BED RESISTANCE DISTRIBUTION

THE RESULT FOR AN INDUSTRIAL 1ST BED

First bed – Standard catalyst

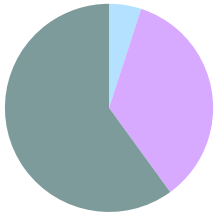
Top
Middle
Bottom

Top



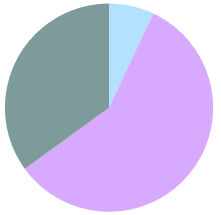
Lower temperature predominantly kinetically limited

Middle



Mainly kinetical, but pore diffusion becomes more important as the temperature increase

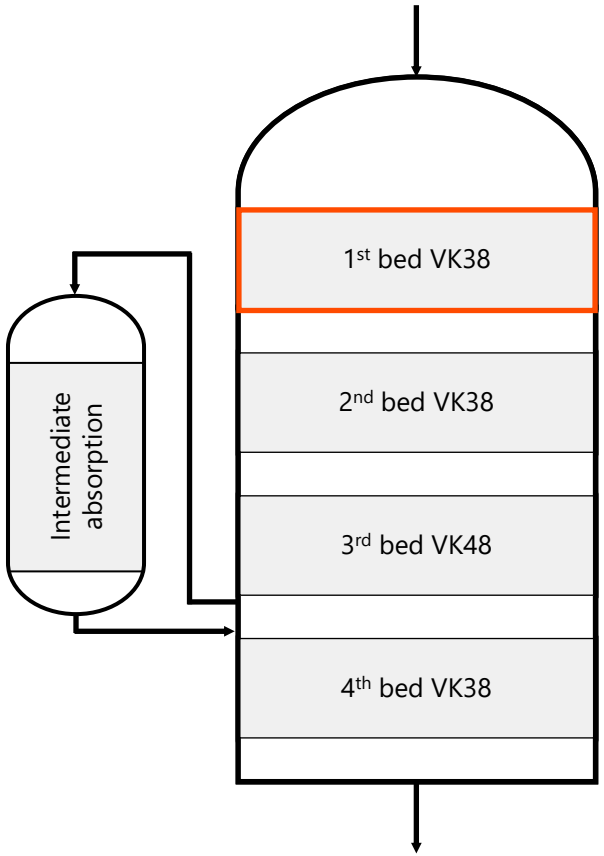
Bottom

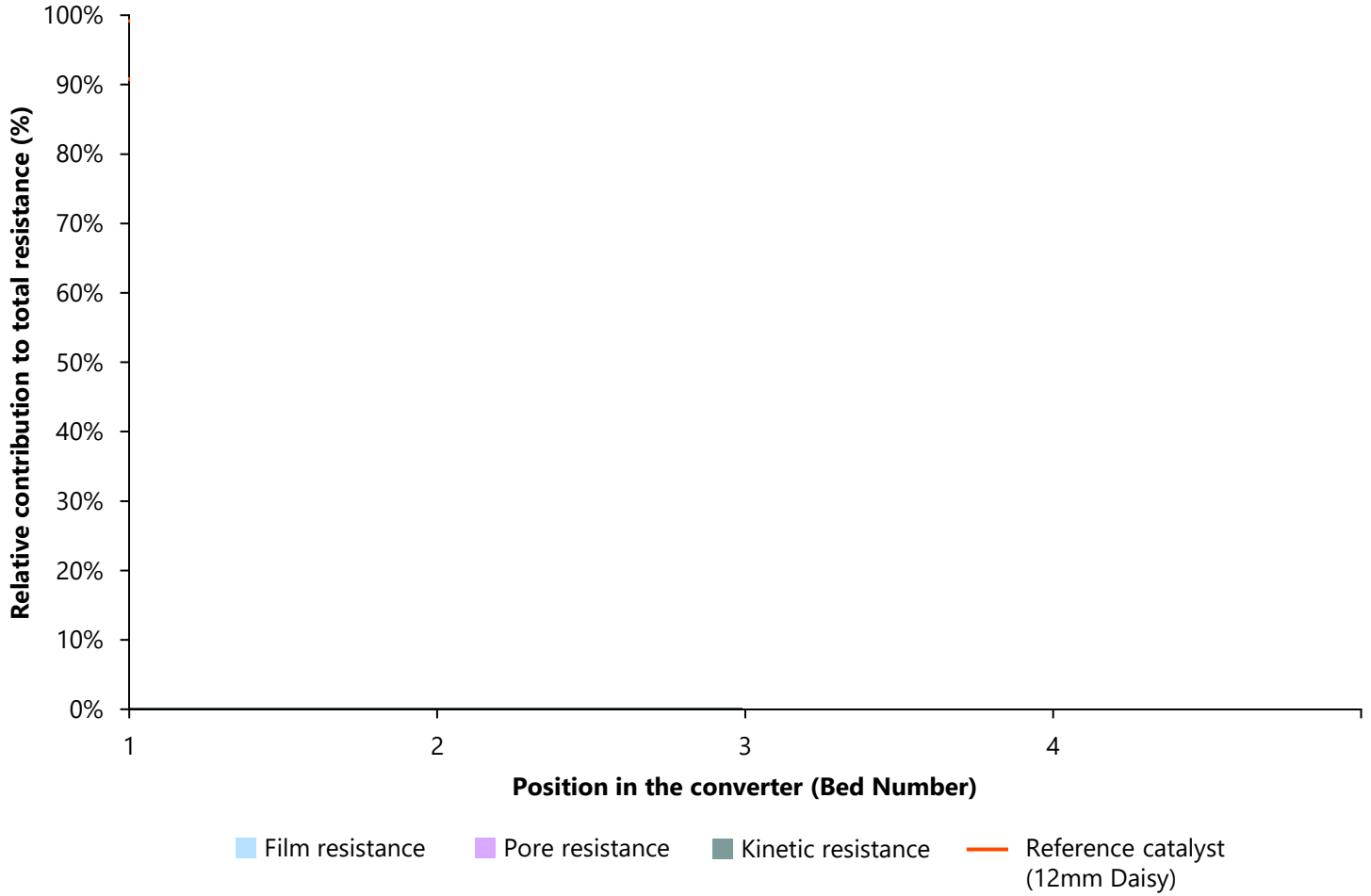


High temperature results in high reaction rate and diffusion resistance plays the most important role

FULL CONVERTER RESISTANCE DISTRIBUTION

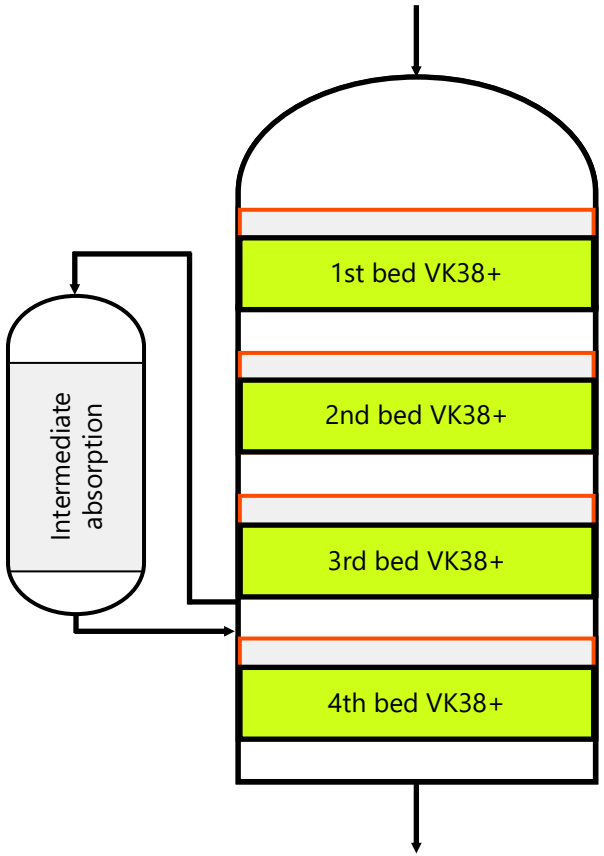
KINETIC RESISTANCE IS THE MAIN BOTTLENECK – FILM RESISTANCE NEGLIGIBLE

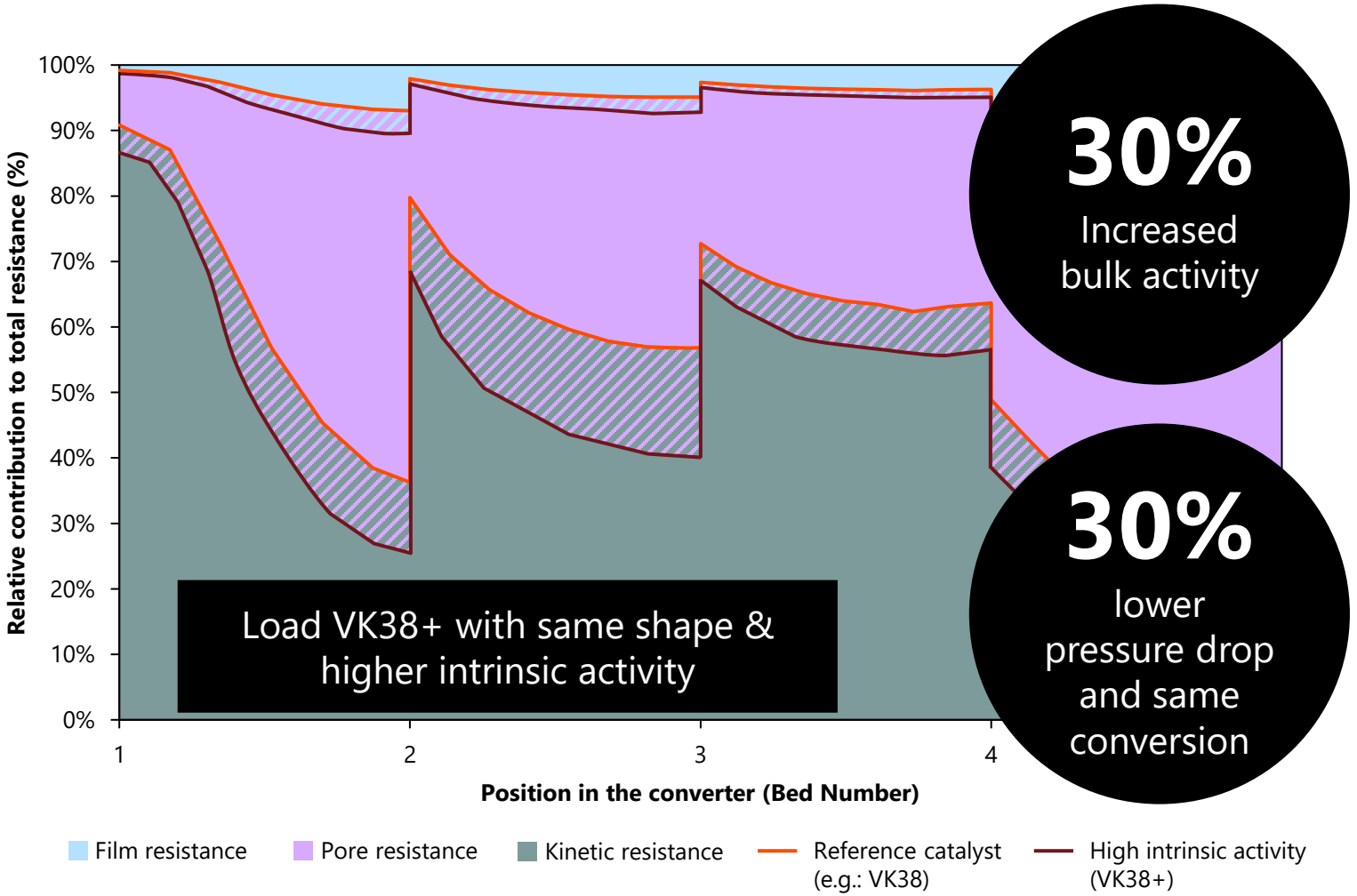




THE EFFECT OF A HIGHER INTRINSIC ACTIVITY WITH VK38+

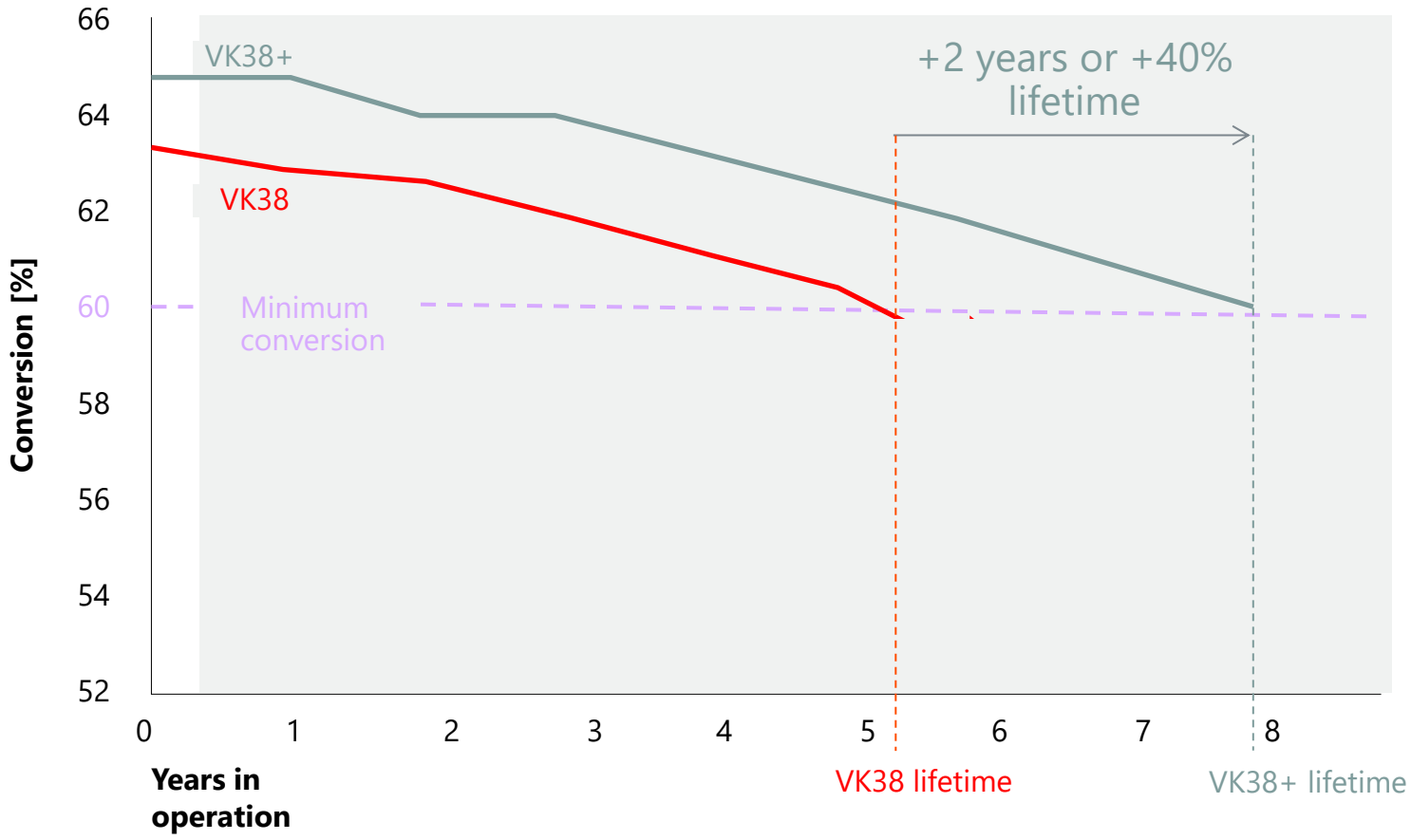
REDUCED KINETIC RESISTANCE GIVES HIGHER BULK ACTIVITY





UTILIZING HIGHER INTRINSIC ACTIVITY

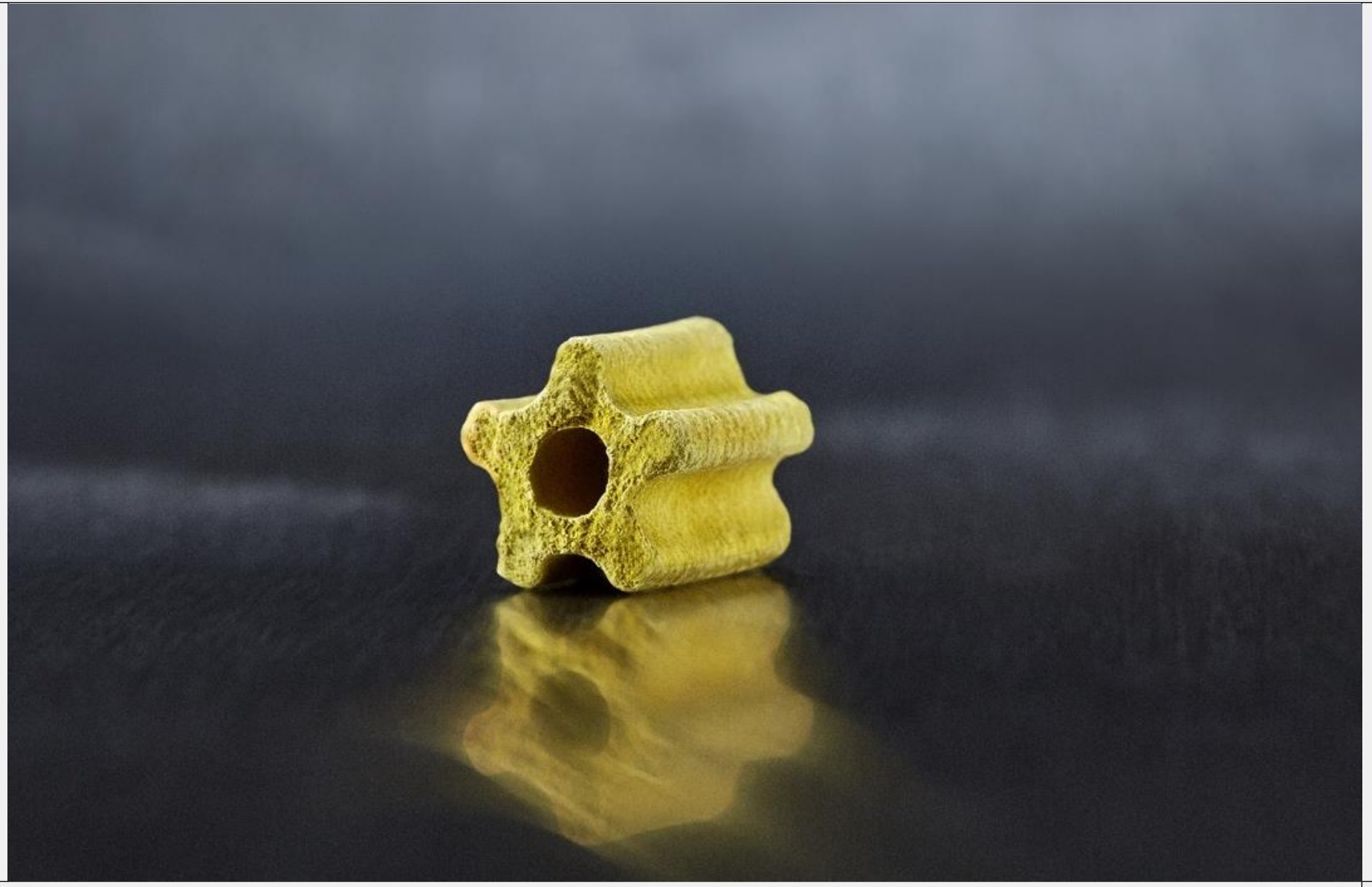
HIGHER START-OFF-RUN (SOR) ACTIVITY TO INCREASE LIFE-TIME



- Increase catalyst lifetime
- Extent the time between turnarounds with catalyst work
- Reduced catalyst consumptions
- Reduction of spent catalyst generated.

VK-CATALYST

OPTIMAL SHAPE FOR INDUSTRIAL USE



THE EFFECT OF DIFFERENT SHAPES AND SIZES
ADRESSING THE EXTERNAL SURFACE AREA

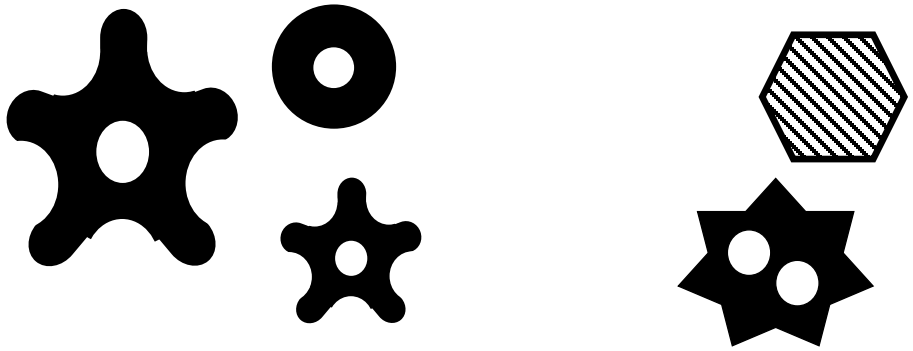
$$(1)\ \deg = 6 \cdot \frac{V_{pellet}}{A_{extenal\ surface\ area\ of\ the\ pellet}}$$

$$(2)\ \Delta p = f(v, \rho, \mu) \cdot \frac{1}{d_{eg}} \cdot \frac{1 - \varepsilon}{\varepsilon^3}$$

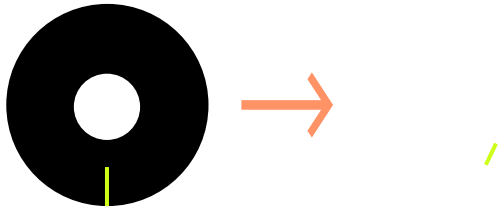
$\varepsilon = void\ fraction\ of\ the\ packed\ bed$

- Not for free to increase the external surface area per pellet , the d_{eq} will be reduced and pressure drop will increase.
- Can be compensated by higher catalyst intrinsic activity of the pellet by lowering catalyst volume to meet same performance.

Catalyst size	Void fraction ε	d_{eq} (mm)
6 mm cylinder	0.38	6.5
10 mm ring	0.50	7.1
12 mm daisy	0.55	6.2
20 mm ring	0.50	13
25 mm daisy	0.55	12
Other shapes	?	?



THE EFFECT OF DIFFERENT SHAPES AND SIZES
ADDRESSING PORE DIFFUSION DISTANCE

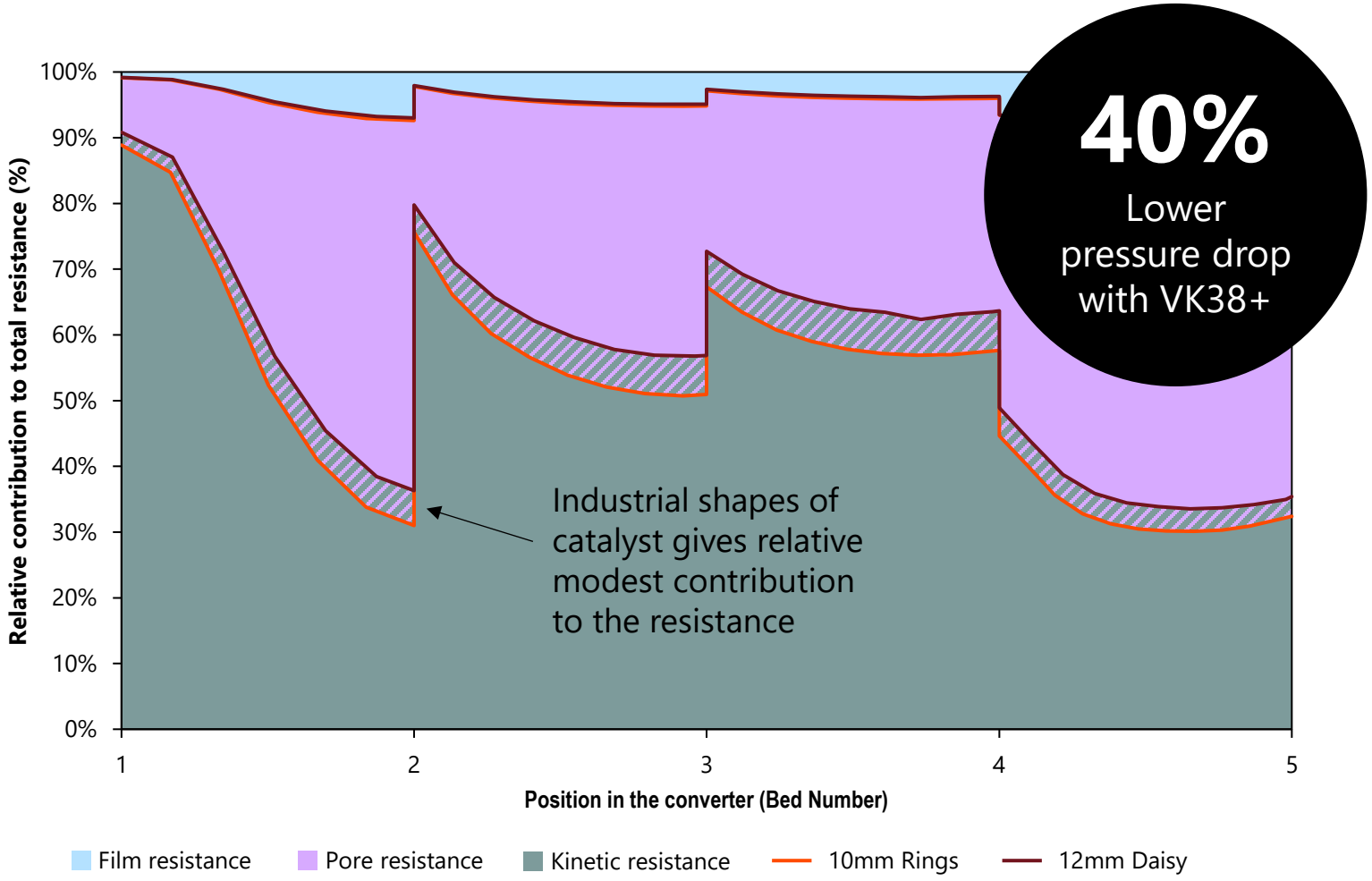


10mm Rings

Smaller pellets or higher surface area reduce the length of diffusion - reduction of pore diffusion resistance

Higher external surface area of the pellet per volume or lower d_{eq} give shorter length of diffusion L_C

Combination of optimal shape with **higher void** and **increased intrinsic activity** by far the most important to improve bulk activity and reduce the pressure drop.



CONCLUSION

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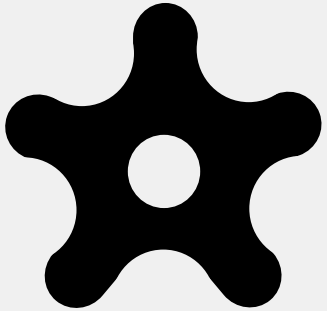
THE SULFURIC ACID CATALYST REACTION RESISTANCES
DESIGNING A CATALYST

Reaction resistances

Film resistance is insignificant and reducing the **kinetic resistance** is by far the most effective way to improve the bulk activity



Changes in catalyst size and shape

A reduction in the length of diffusion (by changes in size or shape) reduces the **pore diffusion resistance**, but comes at the expense of higher pressure drop

Process conditions

Except for lean gases and very high temperatures, improving the **intrinsic activity** is what matters the most

TOPSOE

VK Catalyst

New types of VK catalyst to increase the **intrinsic activity** is the path going forward for improving the performance - VK38+ and other new catalysts to be launched

MEETING DEMANDS IN THE SULPHURIC ACID PLANTS
WITH CATALYST WITH HIGHER INTRINSIC ACTIVITY

Cut Emissions

Reducing SO_2 emissions to comply with new legislation

Boost Production

Maximize Acid production

Avoid Scrubbers

Reduce (or avoid) chemical consumption in tail gas scrubbers

Save Energy

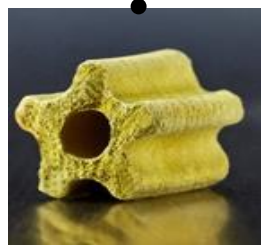
Reduce pressure-drop or produce more steam

Debottlenecking

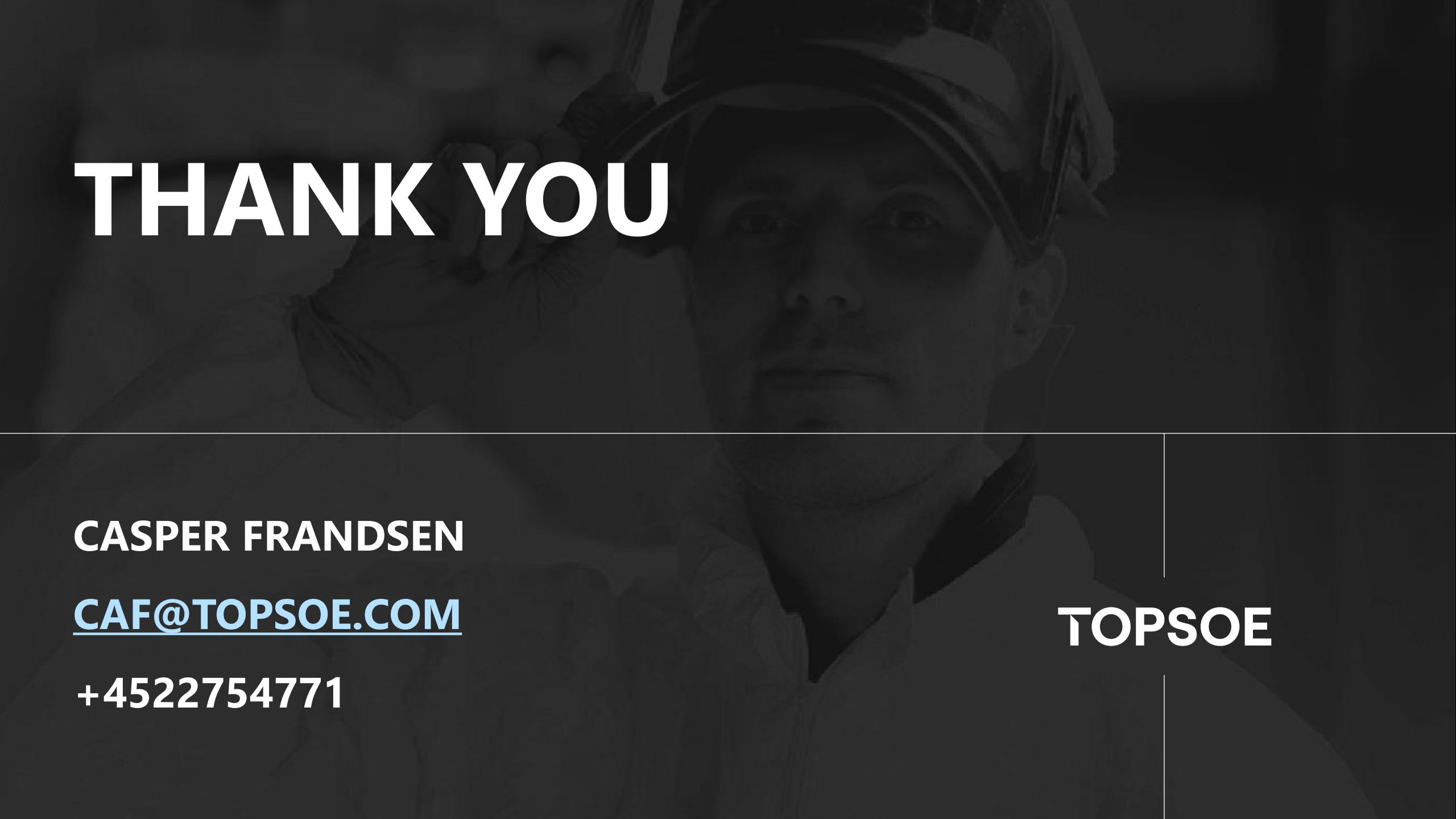
Use the extra activity to overcome bottlenecks in the unit

Lifetime

Longer lifetime, reduction of catalyst consumption and waste



VK38+
an alternative to expensive Cs-catalyst



THANK YOU

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