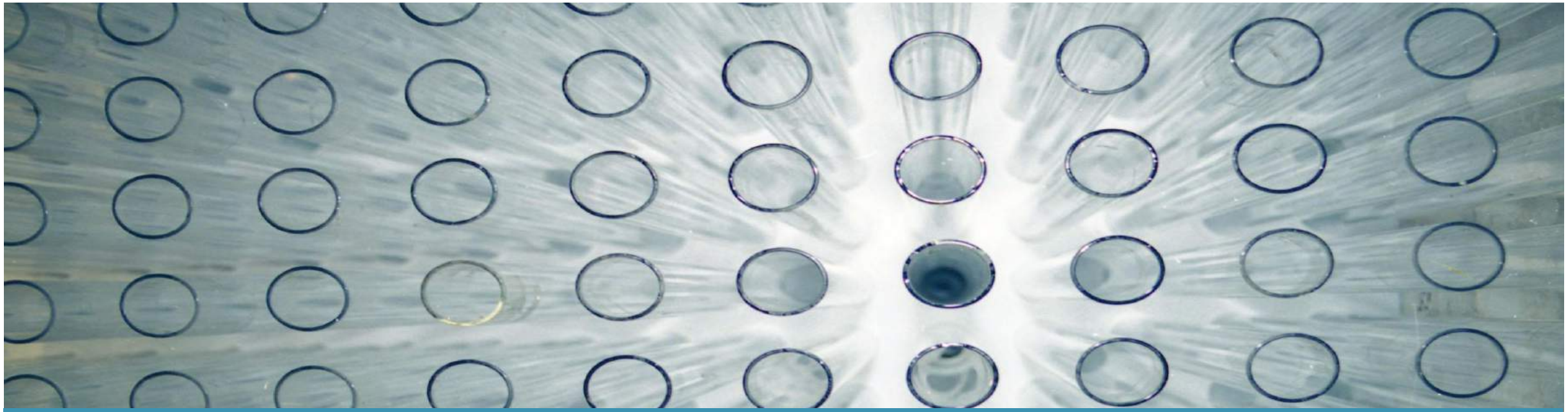

WSA Technology
a competitive solution for sulfur management

REFCOMM GALVESTON
MAY 7-11 2018

RESEARCH | TECHNOLOGY | CATALYSTS

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HALDOR TOPSØE

Agenda

- A few words about Haldor Topsoe
- Handling sulfurous streams
  - ✓ the traditional way
  - ✓ the WSA way
- Introduction to WSA technology
- WSA process and lay-outs
- References
- Summary

Haldor Topsoe Company

- Established in 1940 by Dr. Haldor Topsoe. Private 100% family owned company
- Global market leader in heterogeneous catalysis with a 75 year long track record
- ~2,700 employees in 11 countries across five continents.
- HQ in Lyngby, Denmark, HT Inc. located in Houston ~~250 employees
- Revenue about $1 billion.

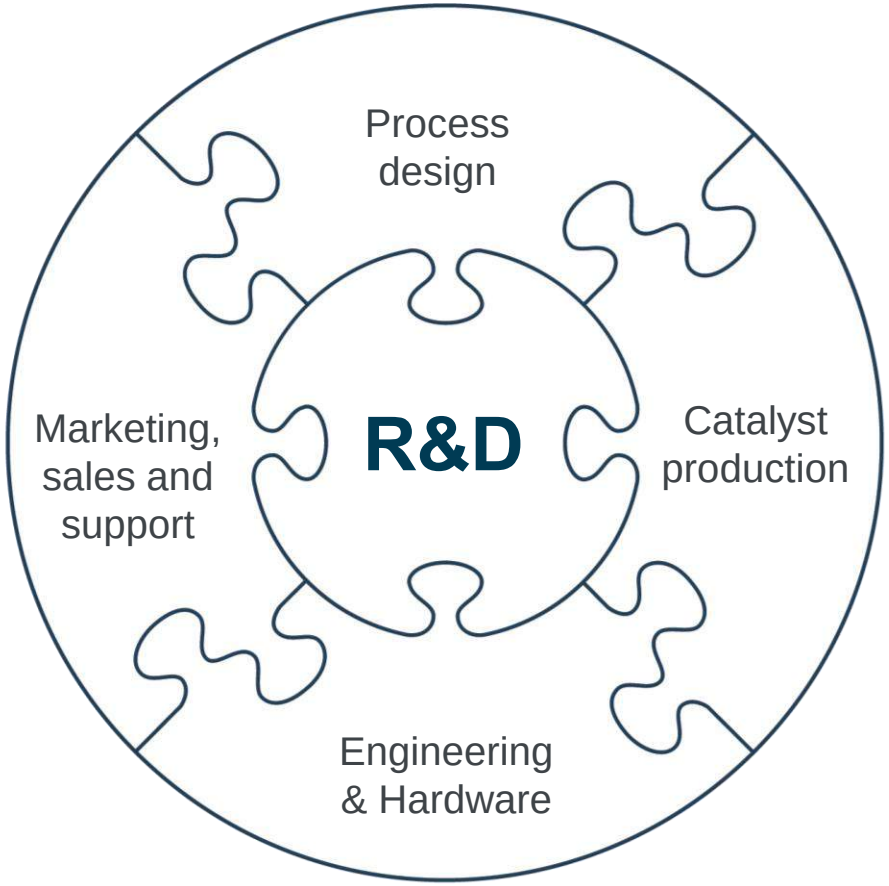
Services:

- Catalysts
- Technology/licensing
- Engineering
- Hardware
- Operation assistance

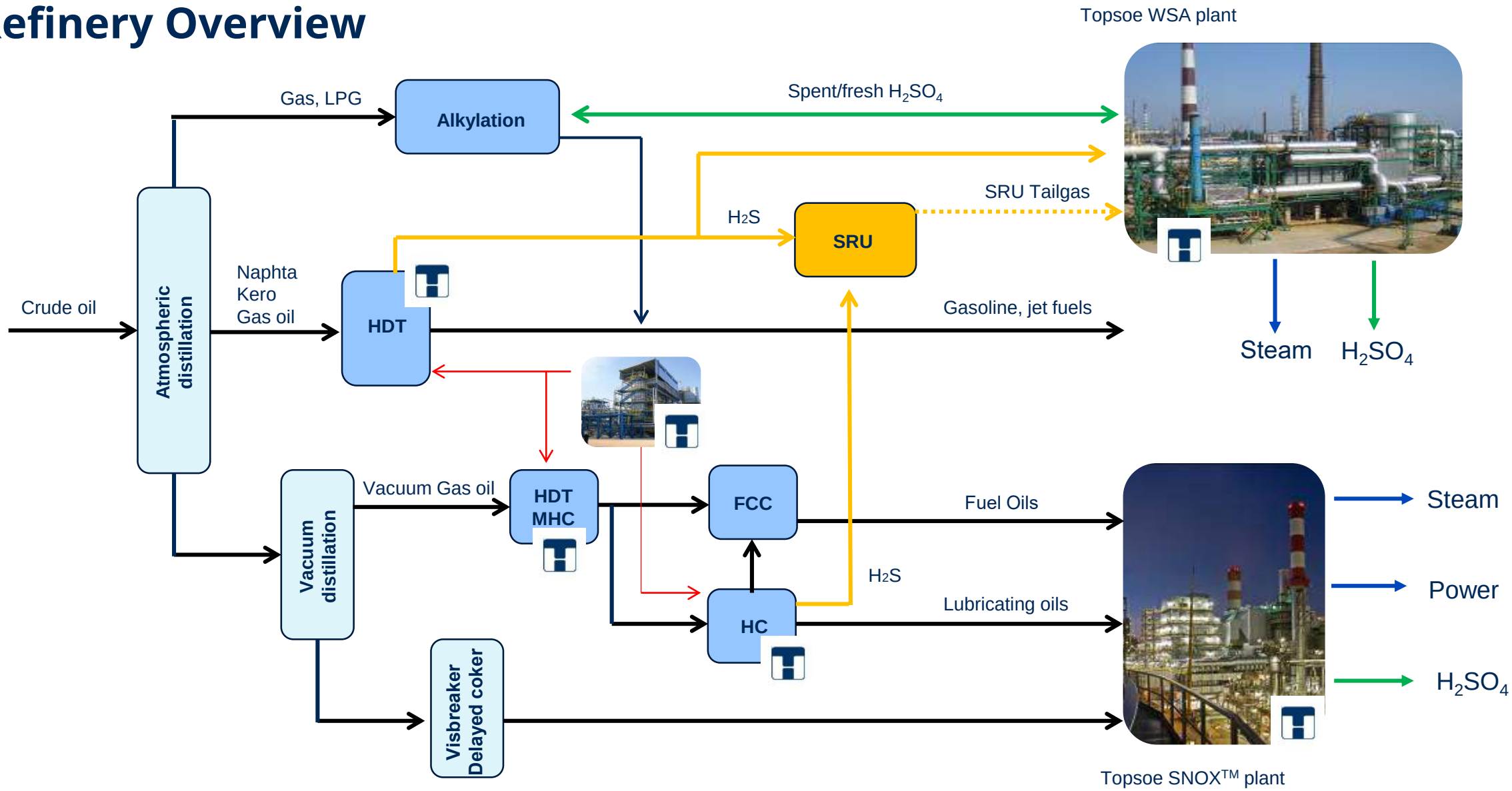
HALDOR TOPSOE

Synergies in the Topsoe business model

- Founded on the belief that applied fundamental research is key to build and retain a leading position in catalysis and technology supply
- Basic research and catalyst characterization done by 300+ world class scientists
- Approx. 10% of revenues annually applied to support R&D efforts
- Bringing science to the market
- Improving our products through costumer interaction



Refinery Overview



What to do with H_2S?

The traditional way

H_2S

Claus plant

Other uses
of sulfur
~ 10 %

~ 90 %
of all sulfur

Sulfuric acid plant

Sulfuric acid

What to do with H_2S?

The direct way

H_2S →

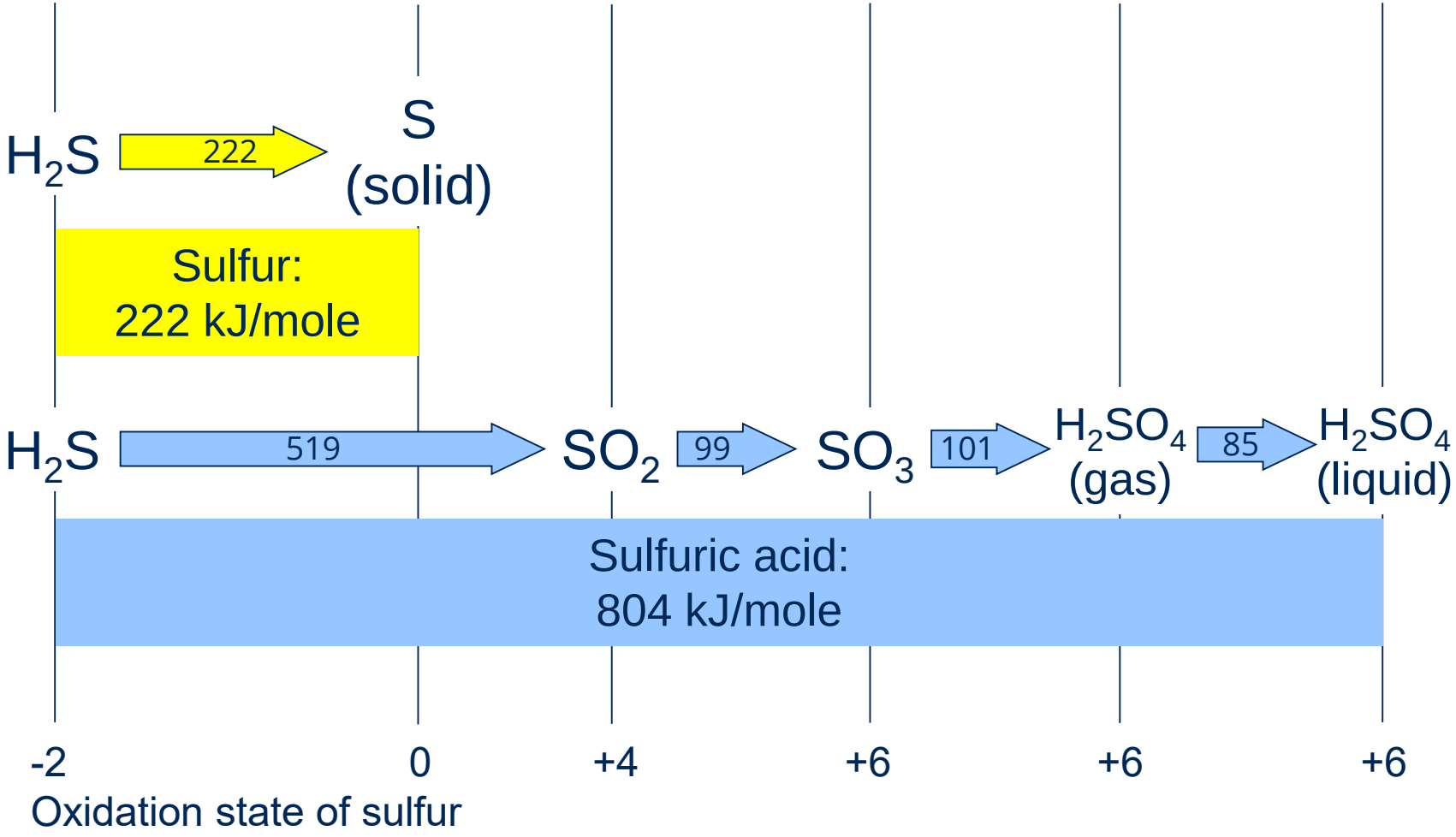
Sulfuric acid plant (WSA)

←

Sulfuric acid

Four times more energy

when producing sulfuric acid instead of sulfur



Limitations when producing sulfur in a Claus plant

- Minimum H_2S content in feed gas of 20 vol.-%
- Other combustibles than H_2S (like NH_3 and hydrocarbons) make air control more complex
- Ammonia requires very high furnace temperature
- Hydrocarbons give risk of carbon formation and catalyst deactivation
- COS and CS_2 require special design
- Sulfur solidifies below 120°C and gets viscous above 160°C.

Comparison WSA vs. Claus
Operating expenses (OPEX)

3 x more steam and better quality

Item	Unit price	Topsoe's WSA technology		Claus technology	
	USD	Production/day	USD/year	Production/day	USD/year
Sulfur, MT	80			100	2,640,000
Sulfuric acid, MT	40	306	4,040,000		
HP steam, MT	20	710	4,690,000		
MP steam, MT	12			225	891,000
Production revenues, USD/year			**8,730,000**		**3,530,000**
		Consumption/day	USD/year	Consumption/day	USD/year
Fuel gas, Nm^3	0.28			6,100	563,000
Cooling water, m^3	0.01	2,800	9,000		
Electric power, KWh	0.08	37,000	976,800	6,400	169,000
Waste water, MT	10			57	188,000
Production cost, USD/year			**985,800**		**920,000**
Net income, USD/year			**7,740,000**		**2,600,000**

Comparison WSA vs. Claus

Summary

- WSA offers larger revenues and less CAPEX
- WSA produces 3 times as much steam; this means saving in fuel consumption and CO_2 emissions
- WSA produces HP steam; Claus produces mostly MP steam
- WSA handles NH_3, COS and hydrocarbons
- DeNOx is conveniently included in the WSA process, when required
- Smaller plot area for WSA than for Claus
- Less equipment is required
- WSA is simple and easy to operate.

What is WSA - Wet gas Sulfuric Acid

A process for cleaning sulfur containing streams under production of concentrated sulfuric acid

Lean H_2S gas

Rich H_2S gas

SRU tail gas

SWS gas

SO_2

SO_3

Elemental sulfur

CS_2 / COS

Spent H_2SO_4

WSA

Clean gas

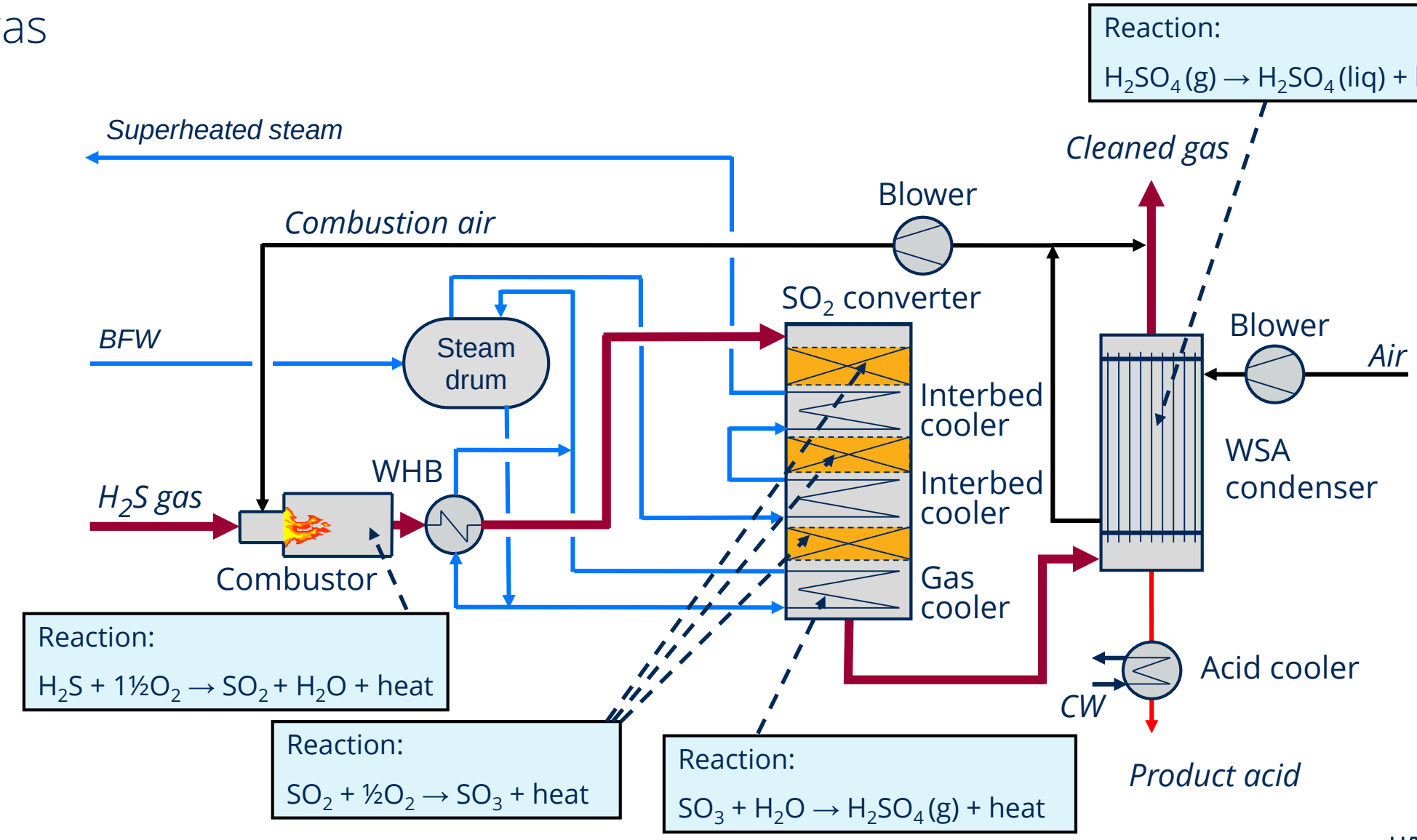
H_2SO_4

HP steam

- …No need to dry the gas
- …No water consumption
- …No need to use chemicals or other additives
- …No generation of waste products
- …With high energy efficiency.

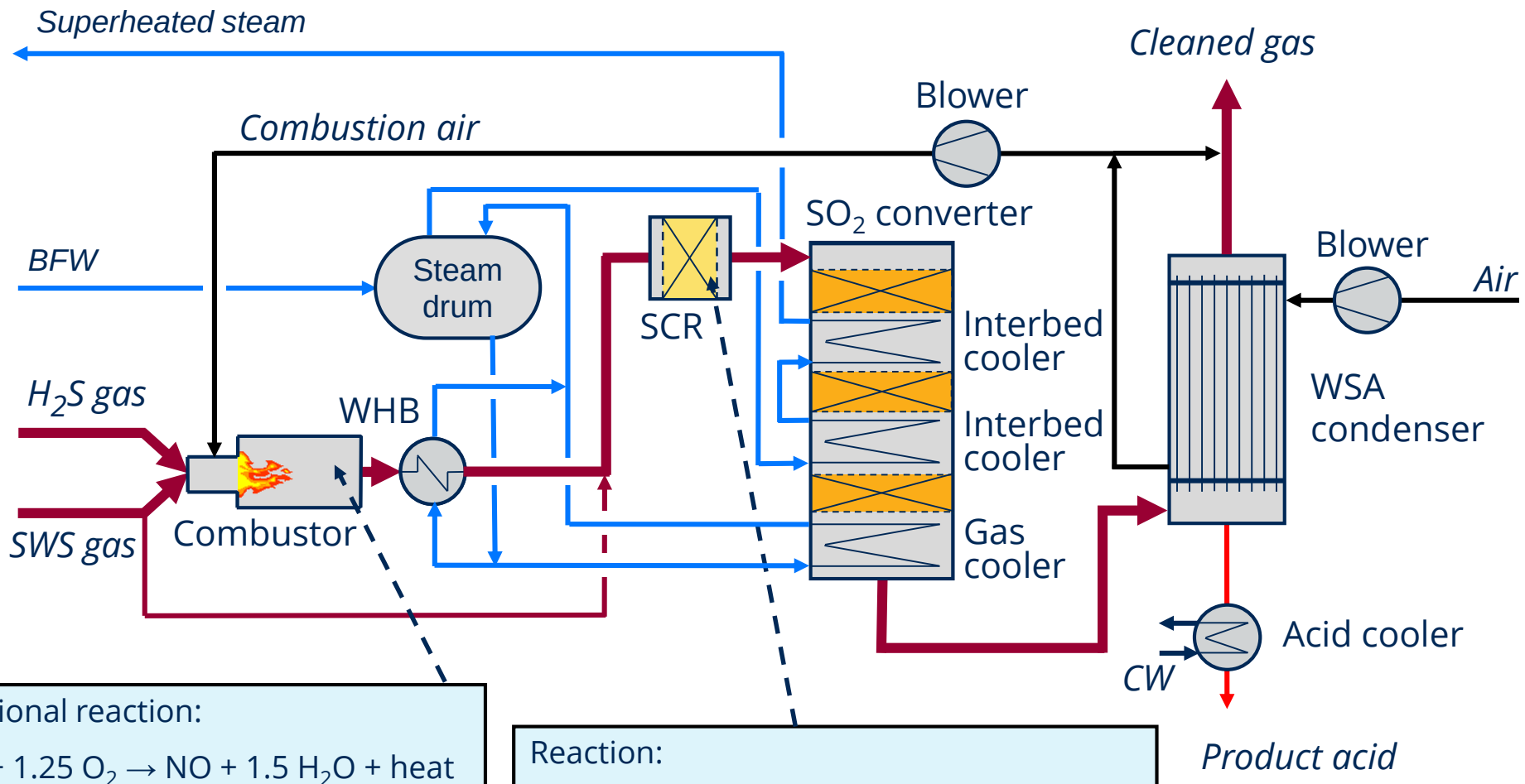
WSA process lay-out

H_2S gas

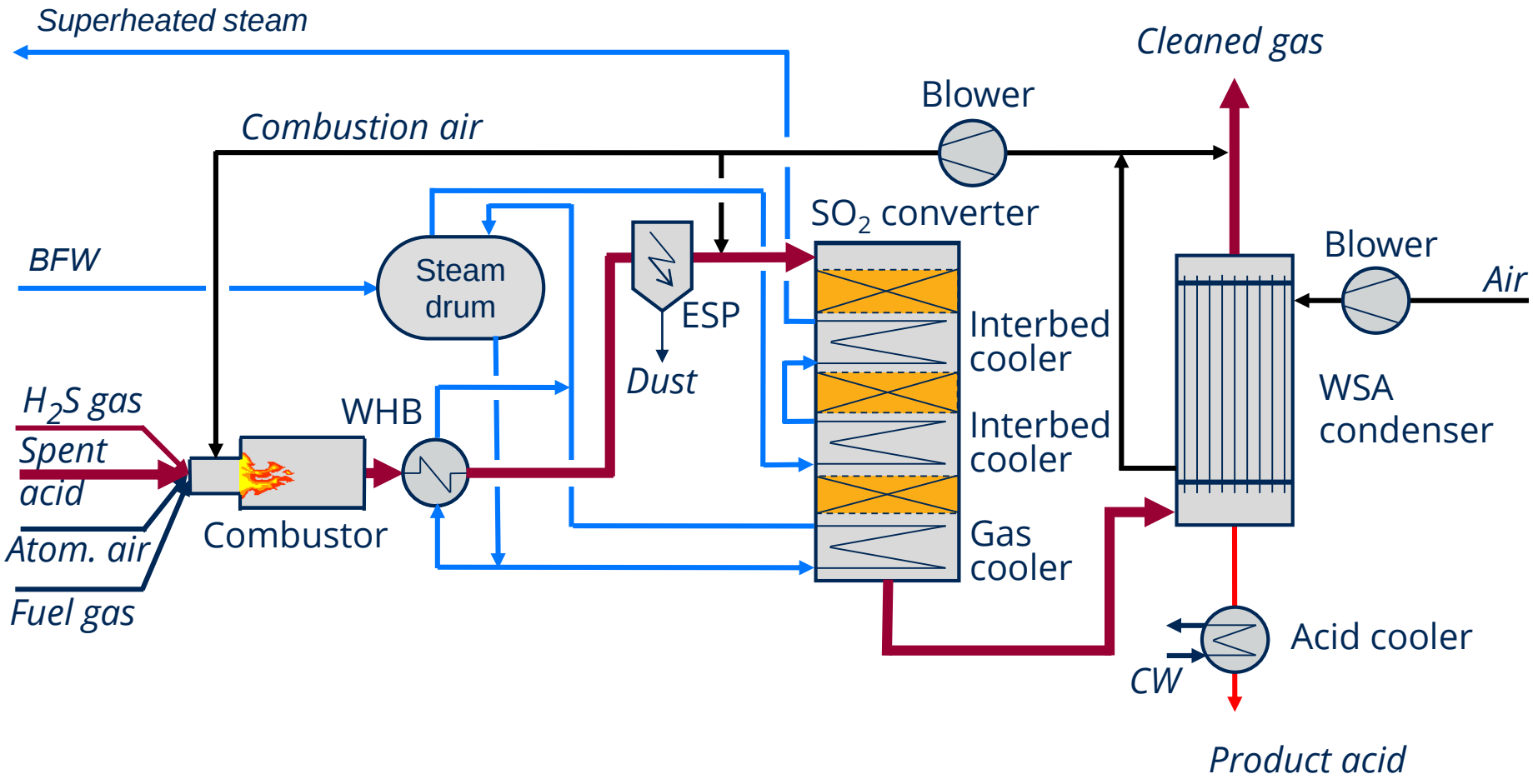


WSA process lay-out

H_2S gas + SWS gas



WSA process lay-out
Spent acid regeneration



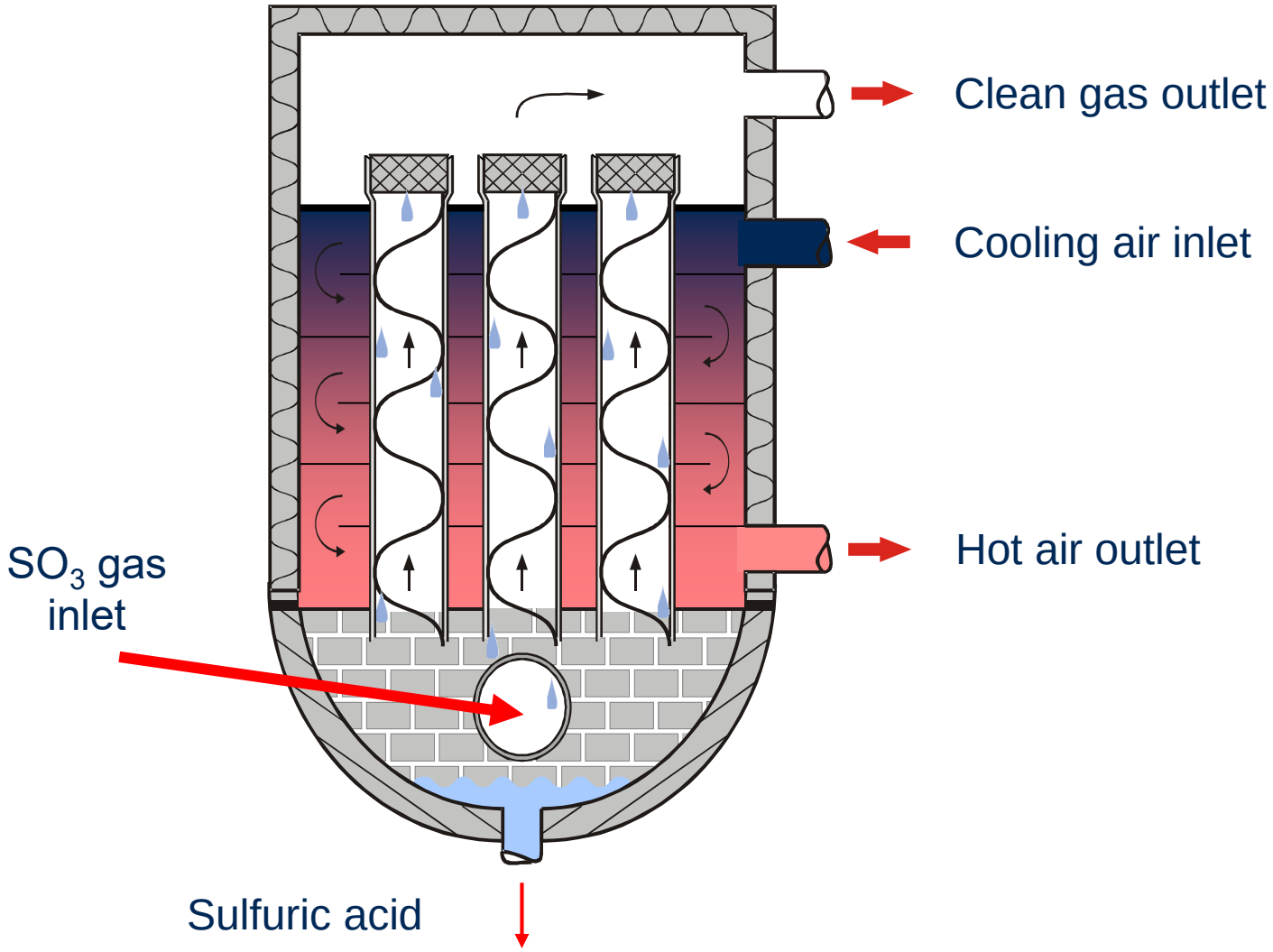
SO_2 conversion catalyst series VK-W

VK-WSX / VK-WL
9 mm Daisy

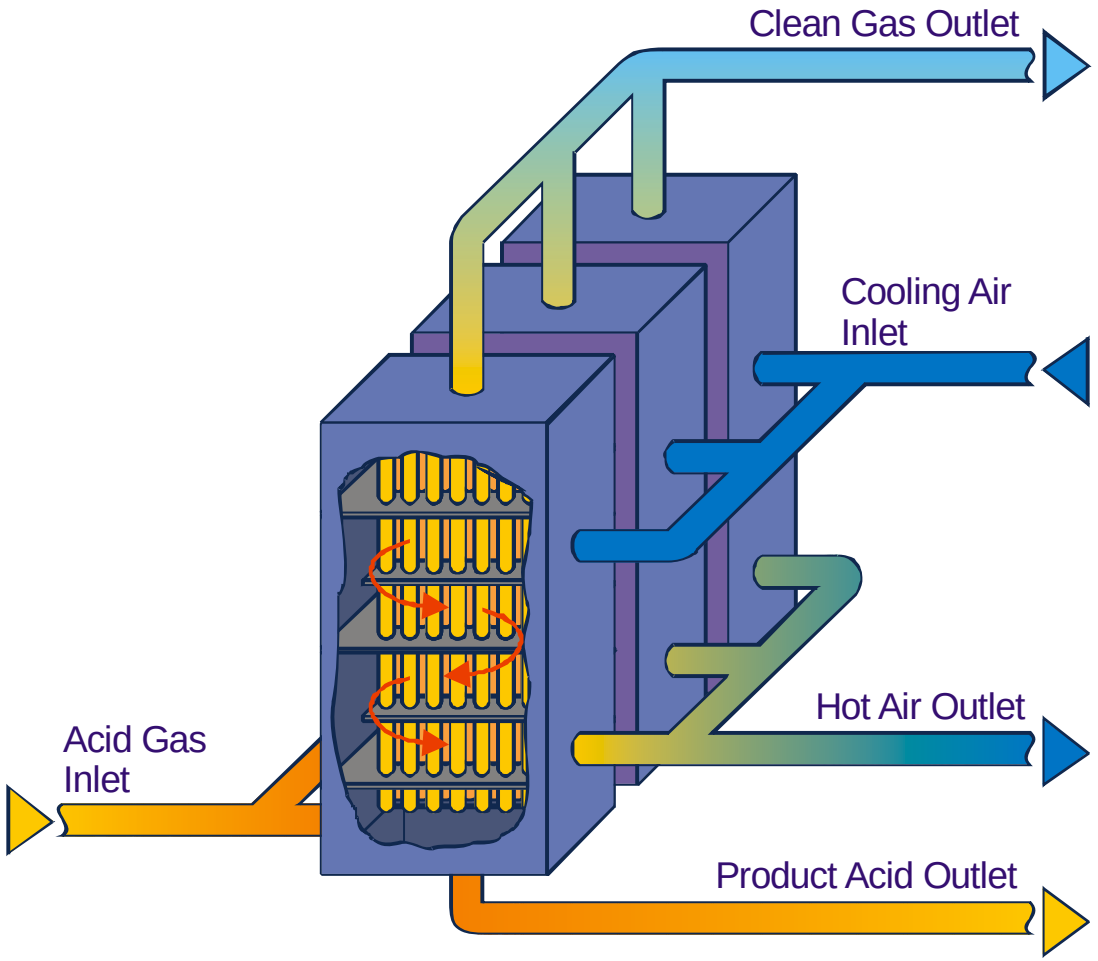
VK-WSA
25 mm Daisy

VK-WSA / VK-WH
12 mm Daisy

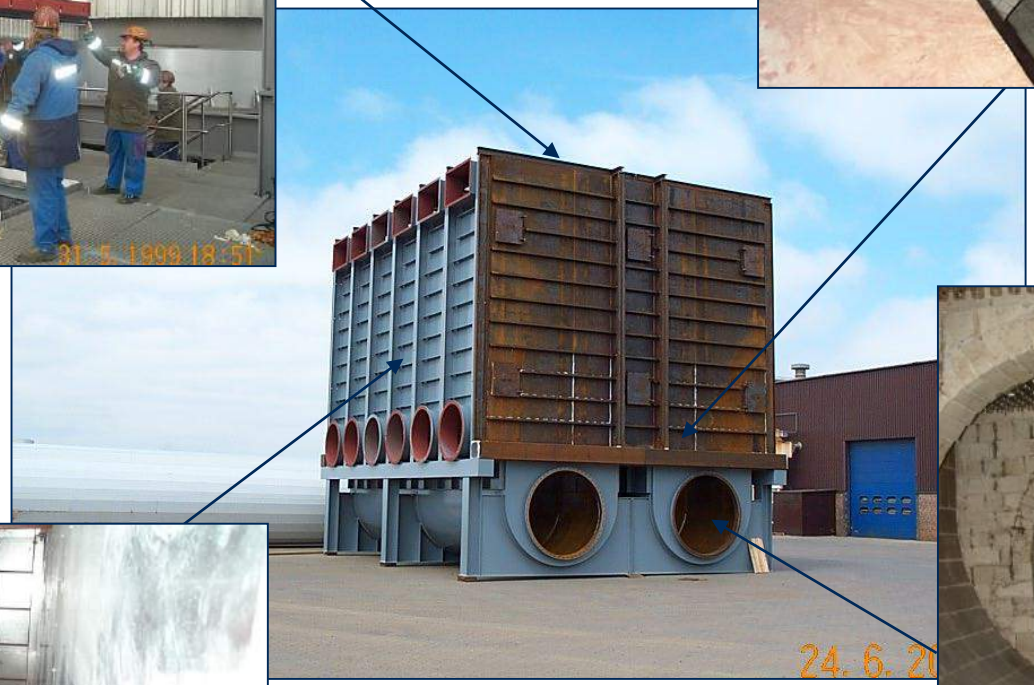
WSA condenser

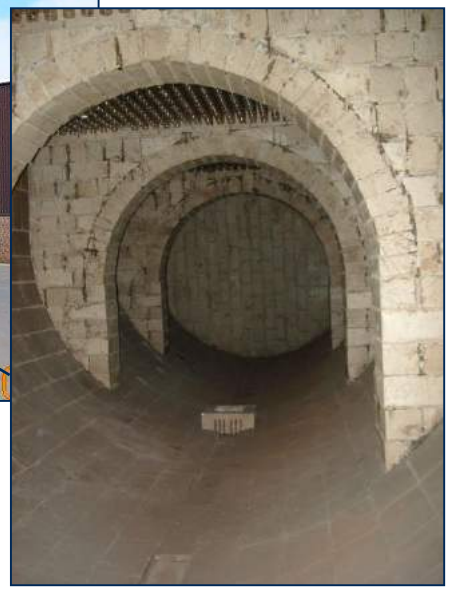


WSA condenser – modular construction



WSA condenser design

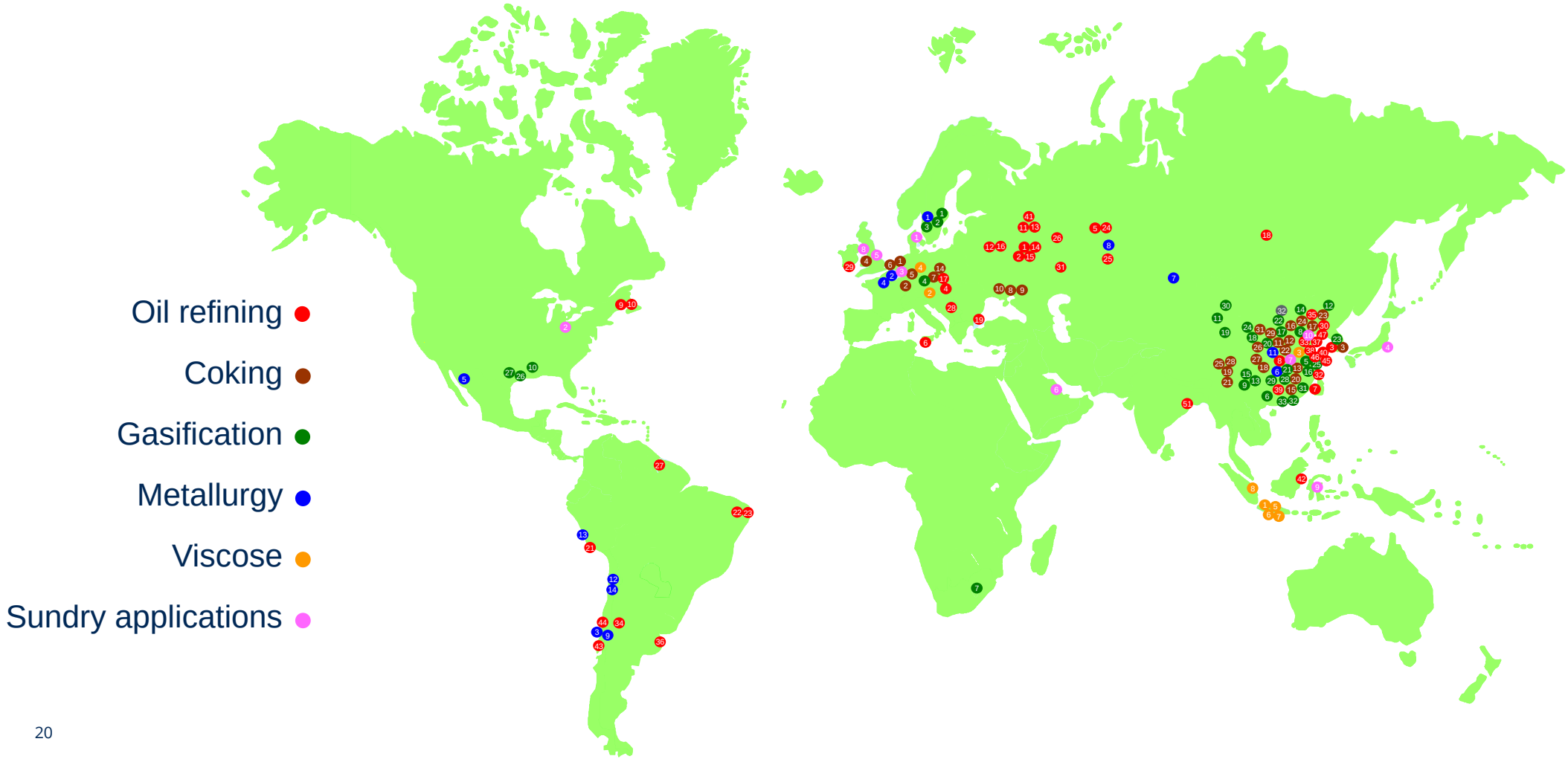




WSA/SNOX™ references

March 2018

Acid production: 4 – 1,140 MTPD
155+ references



HALDOR TOPSOE

Refinery WSA plants

Irving Oil Limited, NB, Canada

Claus plant
tail gas treatment

40 t/d sulfuric acid

OSC Slavneft (YaNOS)
Yaroslavl, Russia

Spent acid regeneration

260 t/d sulfuric acid

Too good to be true??
Conclusions

- Attractive OPEX and CAPEX
- Simple process and easy to operate
- Proven and reliable technology (155+ references)
- Low emissions and no waste materials
- No issues with NH_3 and hydrocarbons.