Johnson Matthey
Inspiring science, enhancing life

Americas hydrogen and syngas technical training seminar

Unlocking potential : Navigating existing hydrogen plant constraints

Ken Chlapik

Agenda

- Summary CATACEL™ SSR™
- Common Hydrogen Plant Constraints
- Addressing These Constraints
- Random to Targeted Performance
- Examples of Performance Impact
- Review of SSR Performance Progress

JM

Agenda

- **Summary CATACEL SSR**
- Common Hydrogen Plant Constraints
- Addressing These Constraints
- Random to Targeted Performance
- Examples of Performance Impact
- Review of SSR Performance Progress

JM

CATACEL SSR - Iterative technology development, optimization, and industry experience

CATACEL – catalyst coated thin metal foil substrate technology

SSR – industrial scale steam methane reforming product using CATACEL technology – removes traditional barriers from pelleted reforming catalyst

Agenda

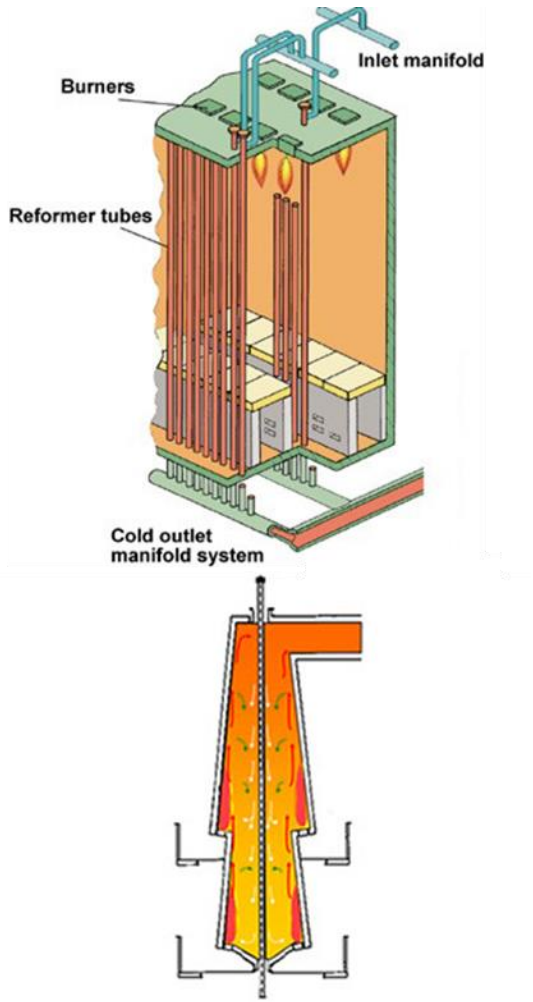
- Summary CATACEL SSR
- **Common Hydrogen Plant Constraints**
- Addressing These Constraints
- Random to Targeted Performance
- Examples of Performance Impact
- Review of SSR Performance Progress

JM

Common Hydrogen Plant Constraints

Process

- S/C
- Pressure Drop
- Plant Efficiency



Furnace

- TWT
- Flue Gas Crossover
- Stack O2 Content

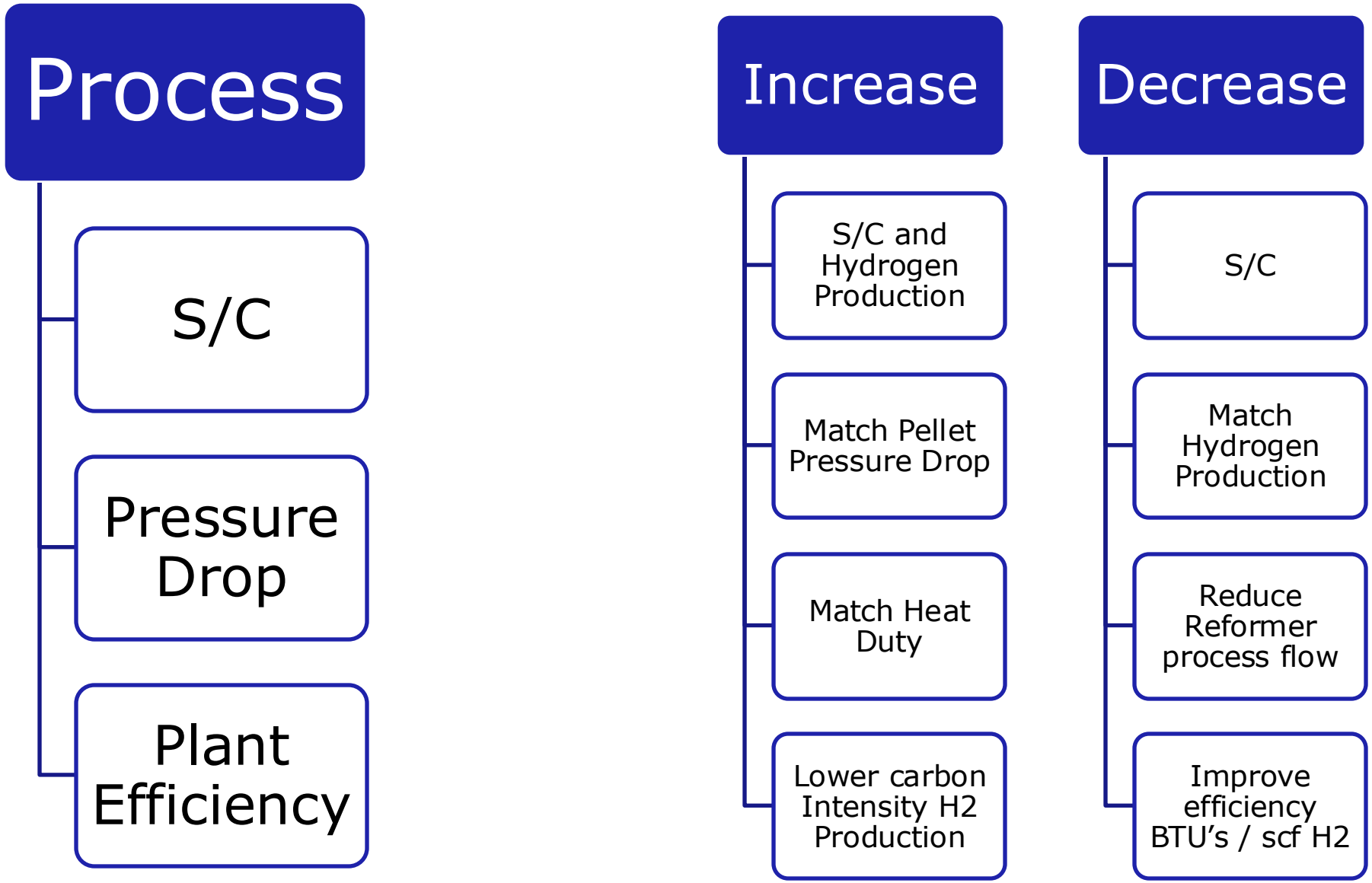
JM

Agenda

- Summary CATACEL SSR
- Common Hydrogen Plant Constraints
- **Addressing These Constraints**
- Random to Targeted Performance
- Examples of Performance Impact
- Review of SSR Performance Progress

JM

Addressing Process Side Constraints

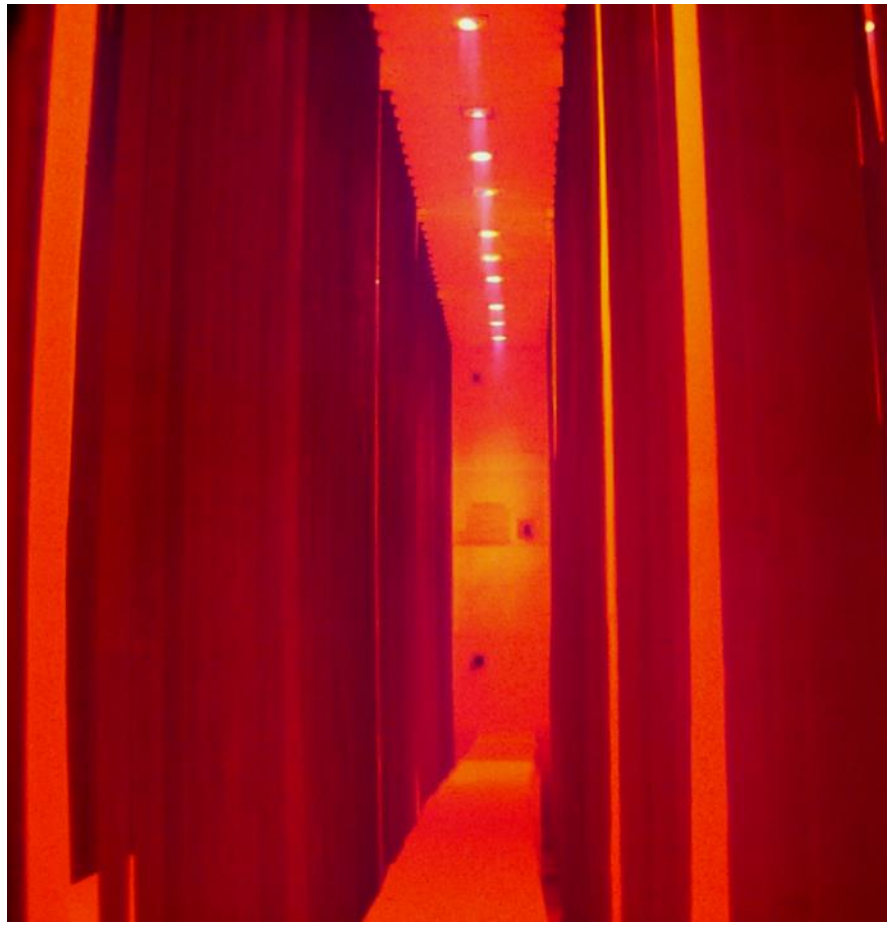


JM

Addressing Furnace Side Constraints

Furnace

- TWT
- Flue Gas Crossover
- Stack O2 Content



Impact

- S/C and Hydrogen Production
- Match Pellet Pressure Drop
- Match Heat Duty
- Lower carbon Intensity H2 Production
- Reduce reformer tube and flowsheet stress
- More uniform reformer profile

JM

Agenda

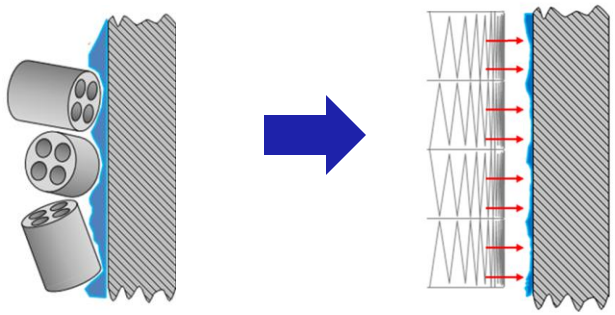
- Summary CATACEL SSR
- Common Hydrogen Plant Constraints
- Addressing These Constraints
- **Random to Targeted Performance**
- Examples of Performance Impact
- Review of SSR Performance Progress

JM

CATACEL SSR technology

SSR is a disruptive technology that creates valued solutions for existing hydrogen plants beyond what pellets can achieve

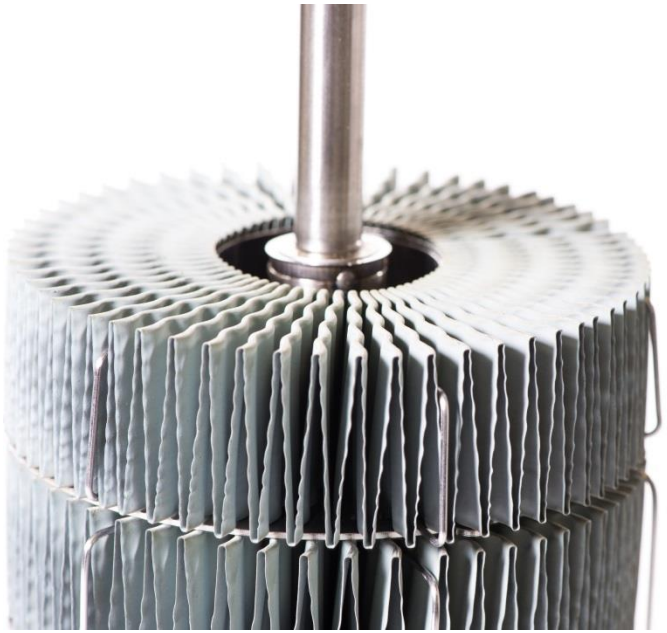
- SSR addresses fundamental science that is limiting further improvement in pellet use

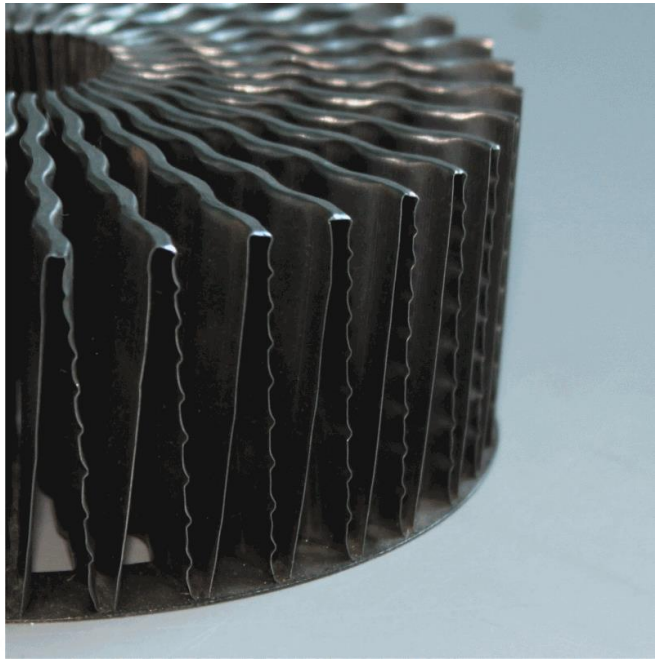


Random

Targeted

- Actively disrupting the boundary layer increases the heat transfer coefficient
- High voidage structure reduces pressure drop
- Efficient contact and use of active sites
- Step change performance compared to pelleted catalysts

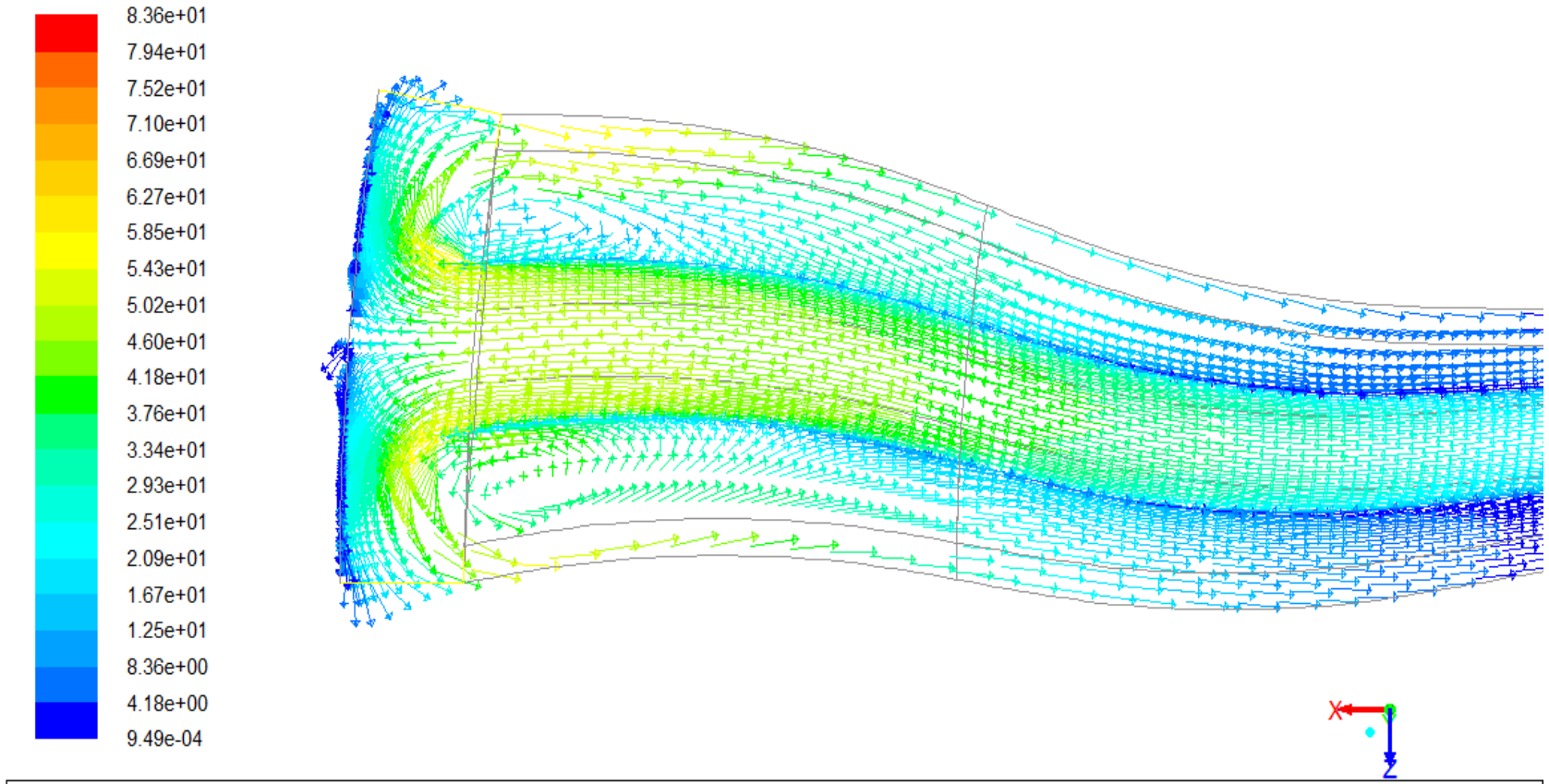




Controlled gas jetting & wall impingement

JM

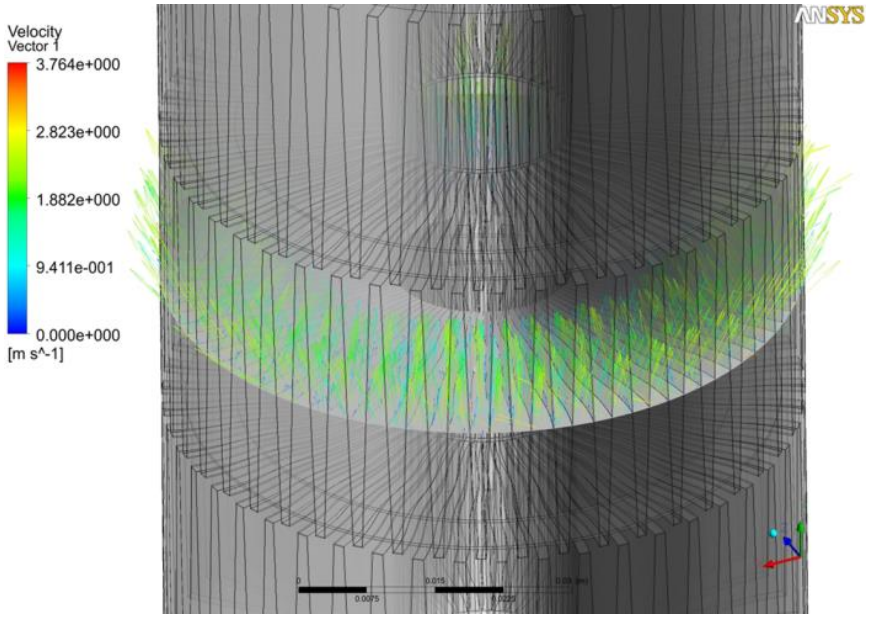
CATACEL SSR - Gas Jetting

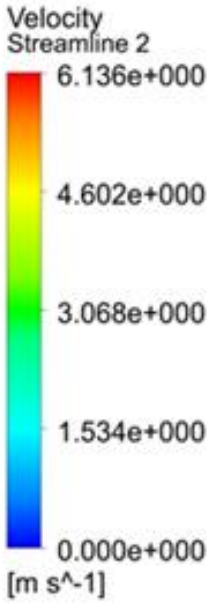


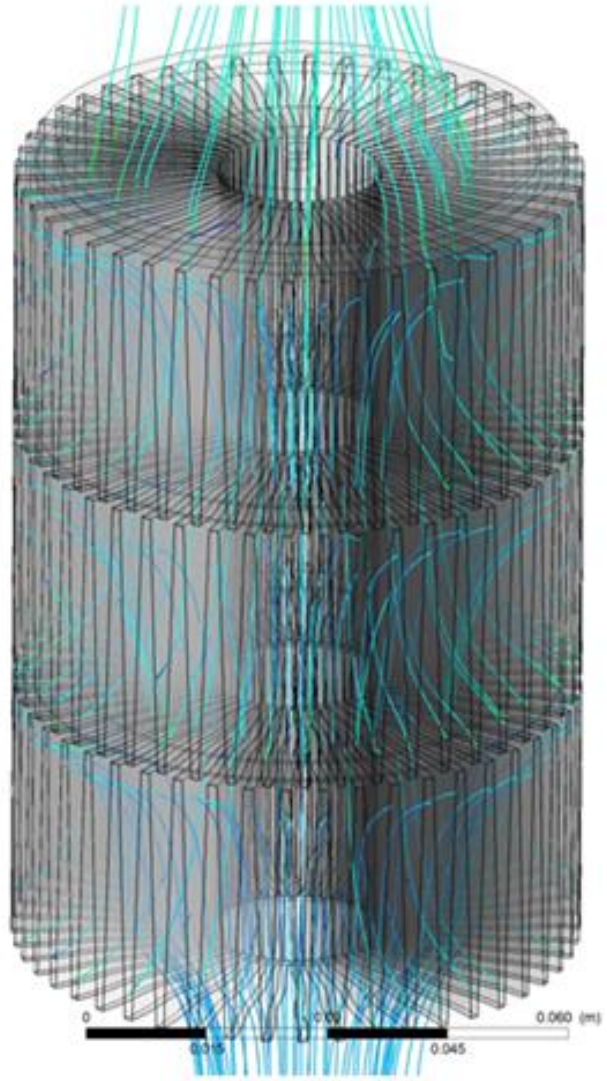
JM

CATACEL SSR - CFD

- **CATACEL SSR** generates high velocity gas jetting
  - Mechanism drives improved heat transfer at modest pressure drop
  - Coated fan structures produce a large reactive surface area







Agenda

- Summary CATACEL SSR
- Common Hydrogen Plant Constraints
- Addressing These Constraints
- Random to Targeted Performance
- **Examples of Performance Impact**
- Review of SSR Performance Progress

JM

Example Overcoming Steam/Carbon Ratio Limitations

CATACEL SSR deployed as direct replacement for pellets

Same feed rate but with reduced S/C ratio

- Enhanced activity of **CATACEL SSR**
  - Maintains comfortable carbon margins
- Enhanced heat transfer performance of **CATACEL SSR**
  - More fuel, higher flue gas to deliver close approach
  - Impact of additional firing on TWT is minimised by heat transfer capability of **CATACEL SSR**

	Units	Pellets	CATACEL SSR
Feed Flow Rate	Nm^3/h	217477.1	**182939.6**
Thoughput	%	100.0	**84.1**
Steam to Carbon Ratio	mol/mol	2.878	**2.260**
Inlet Temperature	°C	557.1	557.1
Inlet Pressure	barg	37.1	36.2
Off-Gas	Nm3/h	69712.0	69712.0
Nat Gas Fuel	Nm3/h	2358.7	**2894.2**
Exit Temperature	°C	849.1	**880.5**
Exit Pressure	barg	35.2	35.2
Catalyst Pressure Drop	bar	2.0	**1.0**
Flue Gas Temperature	°C	999.7	**1016.3**
Max Tube Wall Temperature	°C	881.4	903.8
Peak Heat Flux	kW/m2	123.8	126.7
Minimum TWT margin	°C	40.5	22.8
Approach to Equilibrium	°C	2.2	0.6
Minimum Carbon Margin	°C	39.4	**39.4**
Position	m	2.575	1.781

JM

Example Overcoming Process Limitations

CATACEL SSR deployed as direct replacement for pellets

Same feed rate and unchanged plant operating conditions

- Enhanced heat transfer performance of **CATACEL SSR**
  - Less fuel consumed
  - Lower TWT and higher TWT margins
- Enhanced activity of **CATACEL SSR**
  - Operation at positive carbon margins without the use of alkalised catalyst

	Units	Pellets	CATACEL SSR
Feed Flow Rate	Nm^3/hr	33025	33025
Steam to Carbon Ratio	mol/mol	2.8	2.8
Inlet Temperature	°C	450	450
Off-Gas	Nm^3/hr	4225.5	4225.5
Nat Gas Fuel	Nm^3/hr	4247.7	**4190.5**
	%		**1.4**
Exit Temperature	°C	866.4	864.8
Exit Pressure	barg	23.9	23.9
Catalyst Pressure Drop	bar	2.1	**1.4**
Flue Gas Temperature	°C	989.5	**979.2**
Max Tube Wall Temperature	°C	891.6	**883.8**
Peak Heat Flux	kW/m2	133.5	136.1
Minimum TWT margin	°C	5.7	**12.6**
Approach to Equilibrium	°C	2.6	**1.1**
Minimum Carbon Margin	°C	-21.1	**20.5**
Position	m	2.467	2.467

JM

Example Increasing Incremental Hydrogen Production

- Hydrogen plant changed from naphtha to natural gas feed
- Operation on natural gas has moved the plant onto a TWT limit

- 15% more H_2 now required
- **CATACEL SSR** heat transfer and activity deployed to minimise TWT
- Lower DP of **CATACEL SSR** allows operation at 115% rate with same pressure drop as pellets at 100% rate

Case		Base	1	2
Catalyst		Pellets	CATACEL SSR	CATACEL SSR
Description		Base	Same feed Lower firing	More feed Extra firing
Relative feed flow	%	100.0	100.0	**115.0**
Relative fuel flow	%	100.0	99.5	**112.5**
Relative combustion air flow	%	100.0	99.4	**105.0**
Excess air	%	15.0	15.0	**7.5**
Exit temperature	°C	860	860	861
Methane slip	mol%dry	2.80	2.75	2.80
Max TWT	°C	890	**885**	**891**
Pressure drop	bar	1.29	**1.01**	**1.28**
Fluegas exit temperature	°C	997	**991**	1012
Relative hydrogen make	%	100.0	100.2	**115.0**

JM

Agenda

- Summary CATACEL SSR
- Common Hydrogen Plant Constraints
- Addressing These Constraints
- Random to Targeted Performance
- Examples of Performance Impact
- **Review of SSR Performance Progress**

JM

Improved efficiency and intensification of existing SMR based hydrogen plants

Mid and large-scale hydrogen lifecycle performance validation

- **Fuel saving**
  - >10% fuel savings achieved with European refiner and US petrochemical syngas plant against pellets
  - 15% reduction in natural gas usage per scf hydrogen achieved by US refiner

- **CO_2 emissions**
  - European refiner reduced CO_2 emissions >15%
  - US refiner maintaining CO_2 emissions with 15% uprate enabled by SSR

- **Increased production**
  - US refiner has achieved 15% increased production

Established lifecycle operation in multiple small can, mid and large hydrogen plants

Multiple charges of catalyst produced to date; charge to charge consistency; over 480,000 hrs of operation

Drop in solution - no tube changeout needed for performance benefits

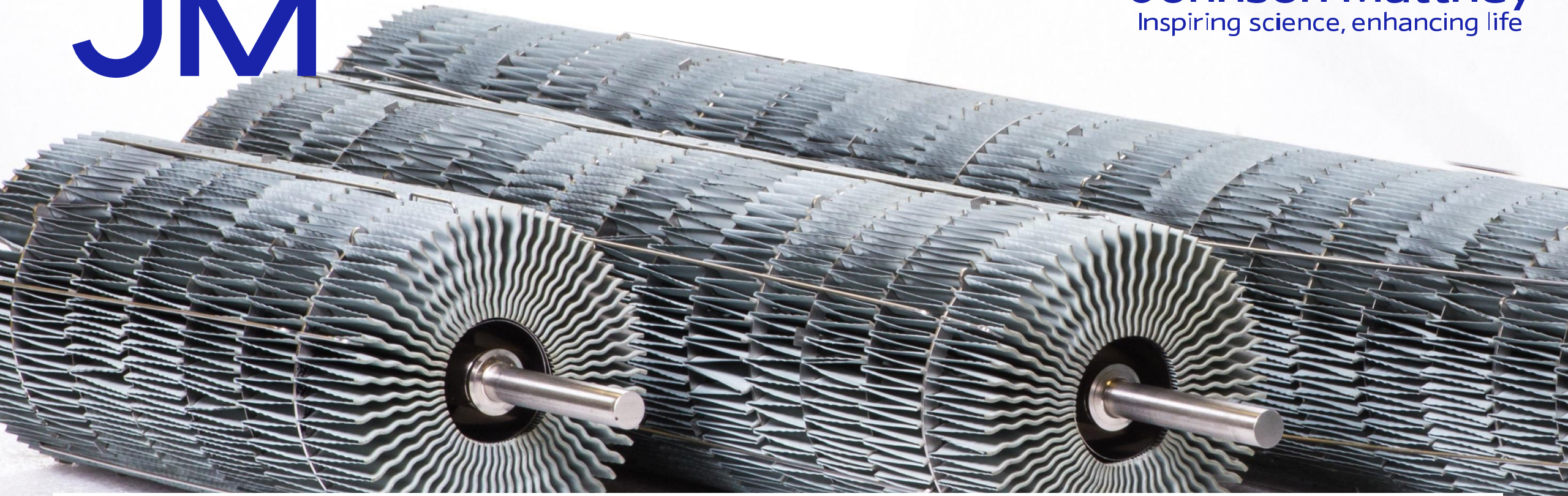
Renowned support and performance of reforming catalyst in existing hydrogen plants

Combines JM's expertise in syngas with our core capability in **precision coating** with JM Clean Air automotive and stationary emission control

JM

JM

Johnson Matthey
Inspiring science, enhancing life



Send us a message to ask for our advice and review your operation to show you how **CATACEL SSR** can meet your energy, emissions, and uprate needs. We'd welcome providing a valued solution to your existing hydrogen plant.

ken.chlapik@matthey.com


JM
Johnson Matthey
Inspiring science, enhancing life