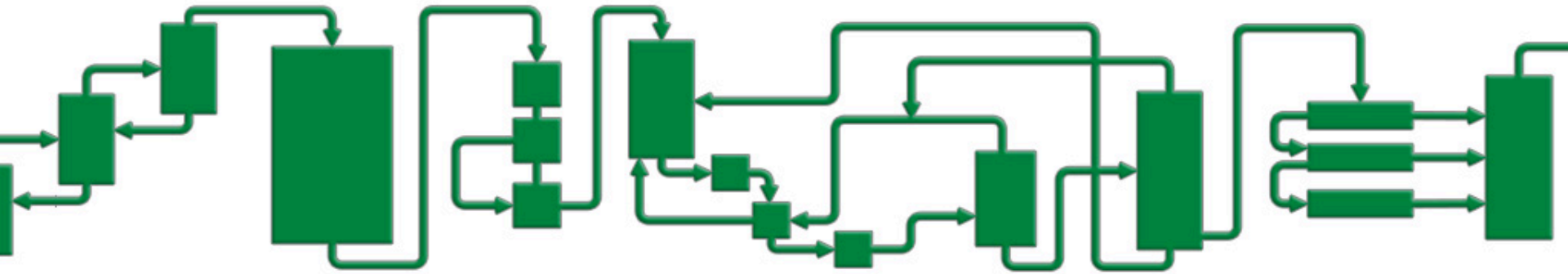
Catacel



Redefining Steam Methane Reformer Performance in Hydrogen Production

Diane Dierking
Johnson Matthey Process Technologies
Oakbrook Terrace, Illinois

JM
Johnson Matthey
Process Technologies

Heat Transfer – Tubular Reactors

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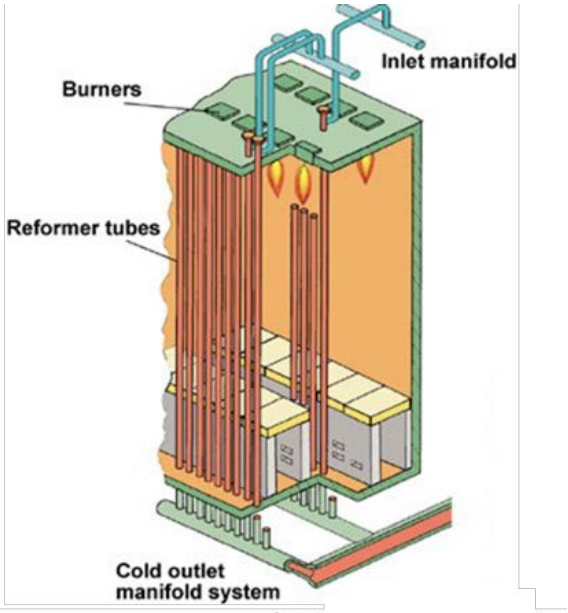

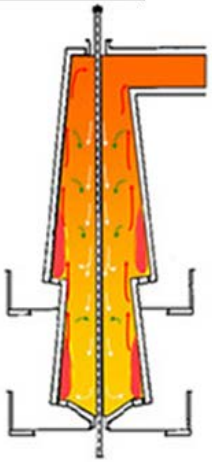

Catacel SSR

What is **CATACEL$_{JM}$** Technology?

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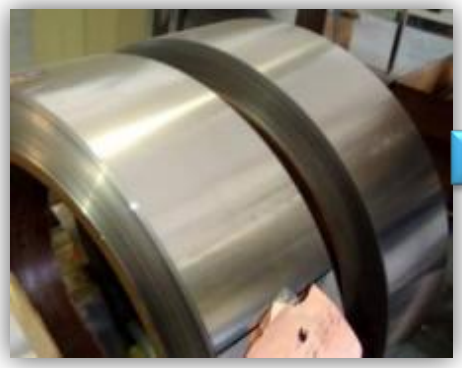
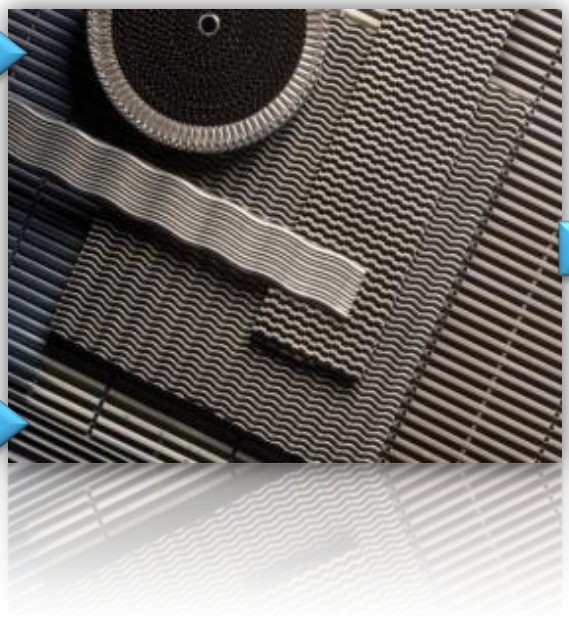
Catalysts & absorbents



Foils



Hydrogen & Syngas

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CATACEL$_{JM}$ SSR Technology
Controlled Gas Flow and Wall Impingement

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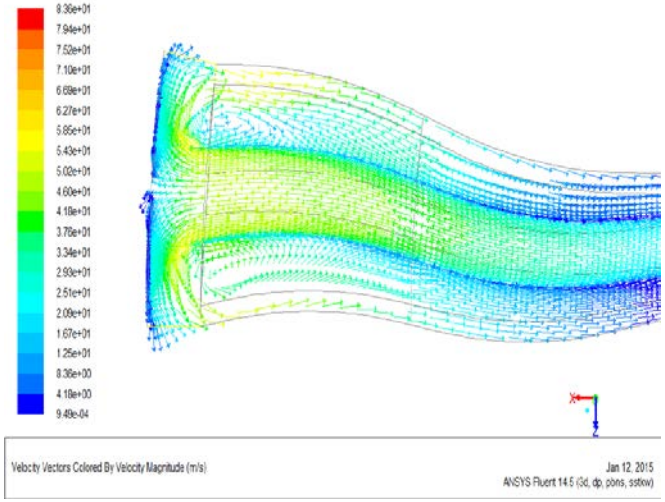
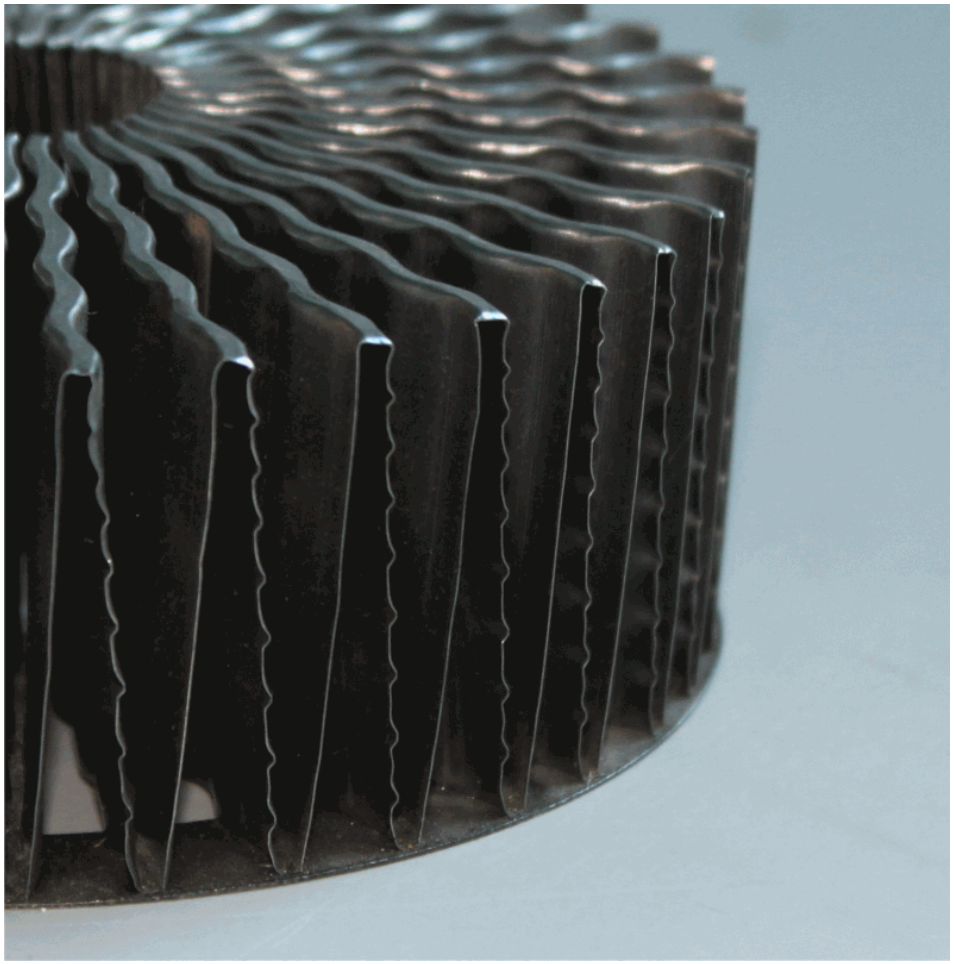
Process Technologies





Catacel SSR JM

Novel Technology

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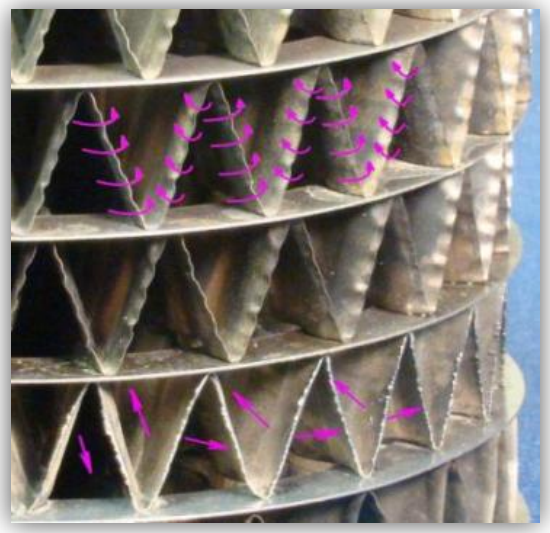
Process Technologies

- **CATACEL$_{JM}$ SSR** is a novel, patent-protected steam methane reforming technology that provides leading-edge performance
- This technology delivers step-out increases in heat transfer, pressure drop and activity, which give a range of plant-specific operational benefits



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CATACEL$_{JM}$ SSR Technology
Enhanced Heat Transfer

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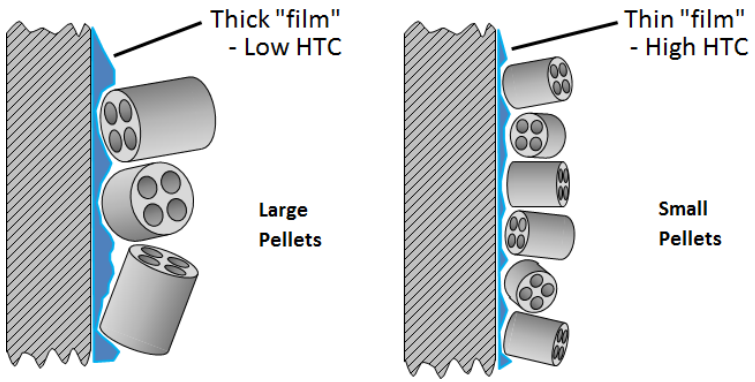
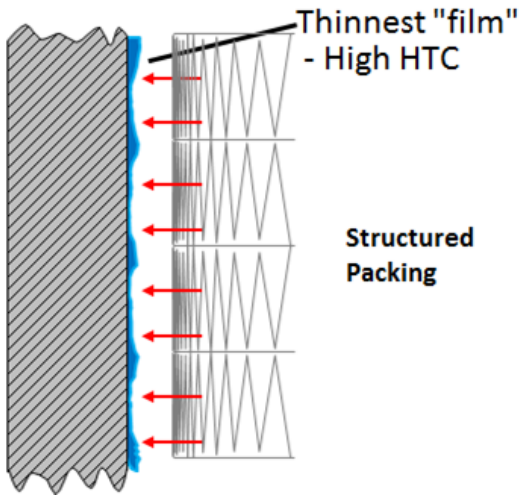
Process Technologies

- Heat transfer, traditional pellets
  - Limited by static gas film at tube wall
  - Smaller pellets will help break up the gas film, but increase dP



- Highest heat transfer ensures heat is available where it is needed to drive reactions
  - 20% to 30% increase in heat transfer



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CATACEL$_{JM}$ SSR Technology
Step-Change in Performance Characteristics

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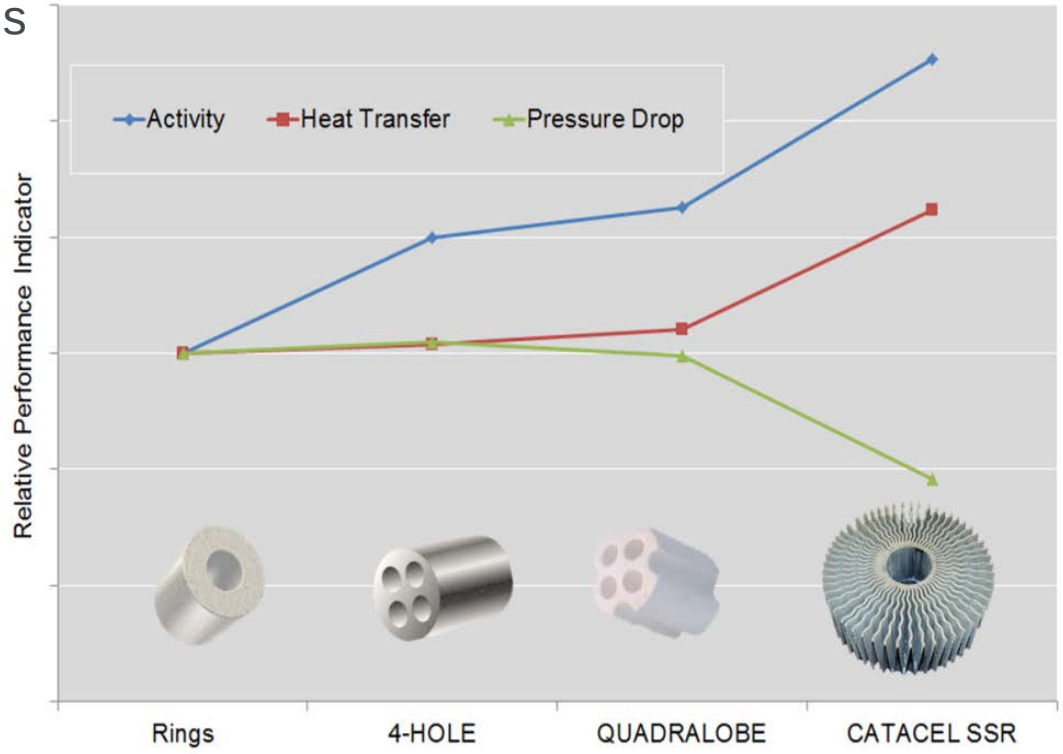
Process Technologies

- Higher geometric surface area
  - 40% more surface area means more activity
  - Resilient to upsets
  - Higher conversion or more throughput at same fuel rate
- Increased void space with **CATACEL$_{JM}$ SSR**
  - Pressure drop 10% to 20% lower
  - Lowers cost of compression and higher throughput for same pressure drop



Catacel SSR

CATACEL$_{JM}$ **SSR** Technology Different Than Pellets

Johnson Matthey
Process Technologies

- **CATACEL**$_{JM}$ **SSR** design is tuneable to generate maximum value
  - Fan dimensions provide a number of degrees of freedom
  - Easy to adjust design, enhancing desired key performance characteristics
    - Heat Transfer
    - Geometric Surface Area (Activity)
    - Voidage (Pressure drop)

Catacel SSR

Revamp – Increased Throughput

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Process Technologies

- Hydrogen plant switched from naphtha to natural gas feed
- Operation on natural gas has moved the plant to a TWT limit
- 15% more H_2 now required
- **CATACEL$_{JM}$ SSR** heat transfer and activity deployed to minimize TWT
- Lower dP of **CATACEL$_{JM}$ SSR** allows operation at 115% rate with same pressure drop as pellets at 100% rate

Case	Units	Base	1	2
Catalyst		Pellets	CATACEL$_{JM}$ SSR	CATACEL$_{JM}$ 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 comb'n air flow	%	100.0	99.4	105.0
Excess air	%	15.0	15.0	7.5
Exit temperature	°F	1580	1580	1582
Methane slip	mol%dry	2.80	2.75	2.80
Max TWT	°F	1634	1625	**1636**
Pressure drop	psi	18.7	14.6	**18.6**
Fluegas exit temperature	°F	1827	1816	1854
Relative hydrogen make	%	100.0	100.2	115.0

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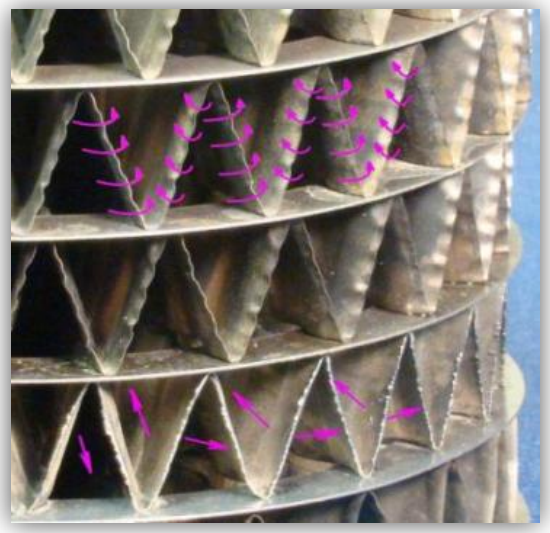
Benefit Summary – Revamp/Throughput

Johnson Matthey
Process Technologies

- **CATACEL$_{JM}$ SSR** is a novel, patent-protected steam methane reforming technology that provides leading-edge performance
- This technology delivers step-out increases in heat transfer, pressure drop and activity, which give a range of plant-specific operational benefits



- **For revamps and plant uprates**:
  - ✓ 10% - 20% throughput increase with no change in tube wall temperature margin
  - ✓ Tubes can be replaced with those having thinner walls (lower cost per tube)

Catacel SSR

Operating Units – Fuel Savings

Johnson Matthey
Process Technologies

- **CATACEL$_{JM}$ SSR** deployed as direct replacement for pellets
- Same feed rate and unchanged plant operating conditions
- Enhanced heat transfer performance of **CATACEL$_{JM}$ SSR** allows less fuel to be consumed to achieve the same TWT
- Savings taken via a reduction in the natural gas fuel rate
- Considerable savings – maximized in high gas cost regions

	Units	Top Fired Reformer	
Catalyst Type		Pellets	**CATACEL$_{JM}$ SSR**
Nat Gas price $/MBtu		9.48	9.48
Hydrogen Product	MMSCFD	127.2	127.2
Nat Gas Feed Rate	MSCFH	2,071	2,071
Nat Gas Fuel to Burners	MSCFH	**88.0**	**81.1**
Off-Gas to Burners	MSCFH	2,602	2,602
Catalyst volume	ft^3	1990	1990
Nat Gas Feed	$M/year	178.0	178.0
Nat Gas Fuel	$M/year	7.6	6.9
Saving on Nat Gas Fuel	$/yr		**$ 697,001**
	%		7.9

Catacel SSR JM

Reference – Increased Flow Rate

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Process Technologies

- 20-25% increase in achievable production rates
  - Highest sustained production rate with pellets was 71,000 SCFH (1,902 Nm^3/hr)
  - Maximum rate with **CATACEL$_{JM}$ SSR** is 90,000 SCFH (2,411 Nm^3/hr)
    - Several campaigns > 85,000 SCFH (2,277 Nm^3/hr)

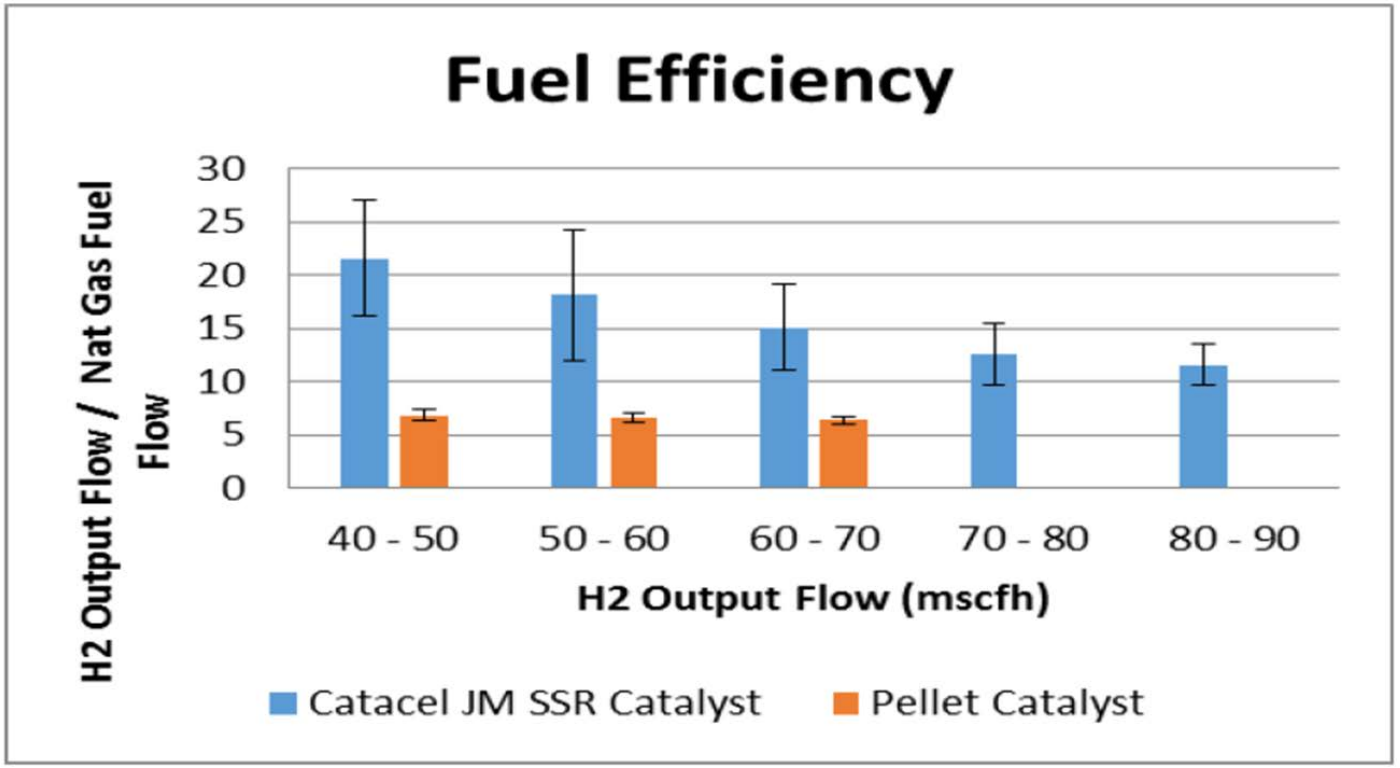
H_2 Production Rate (scfh)	Pellet (% of Operating Time)	CATACEL$_{JM}$ SSR (% of Operating Time
40,000 – 50,000	24%	8%
50,000 – 60,000	31%	26%
60,000 – 70,000	34%	27%
70,000 – 80,000	N/A	21%
80,000 – 90,000	N/A	11%

Catacel SSR JM

Reference – Fuel Savings

Johnson Matthey
Process Technologies

- Fuel savings of 57%
  - Pellet: 6.6 SCFH H_2 / SCFH NG consumed as fuel
  - SSR: 15.5 SCFH H_2 / SCFH NG consumed as fuel



Catacel SSR

Operating Units – Remove Process Constraints

Johnson Matthey
Process Technologies

- **CATACEL$_{JM}$ SSR** deployed as direct replacement for pellets
- Same feed rate and unchanged plant operating conditions
- Enhanced heat transfer performance of **CATACEL$_{JM}$ SSR**
  - Less fuel consumed
  - Lower TWT and higher TWT margins
- Enhanced activity of **CATACEL$_{JM}$ SSR**
  - Operation outside carbon forming zone without the use of alkalized catalyst

	Units	57-4Q: 57-4XQ	CATACEL$_{JM}$ SSR
Feed Flow Rate	MSCFH	315.4	315.4
Steam to Carbon Ratio	mol/mol	2.8	2.8
Inlet Temperature	°F	842	842
Off-Gas	MSCFH	157.7	157.7
Nat Gas Fuel	MSCFH	158.5	**156.4**
	%		**1.3**
Exit Temperature	°F	1592	1589
Exit Pressure	psig	346.7	346.7
Catalyst Pressure Drop	psi	17.7	20.7
Flue Gas Temperature	°F	1813	1795
Max Tube Wall Temperature	°F	1637	1623
	Δ °F		**-14**
Peak Heat Flux	Btu/hr/ft^2	42326	43153
Approach to Equilibrium	°F	4.7	**2.0**
Minimum Carbon Margin	°F	-38	**37**

Catacel SSR JM

Operating Units – Steam:Carbon Ratio

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Process Technologies

- **CATACEL$_{JM}$ SSR** deployed as direct replacement for pellets
- Equivalent hydrogen production
- Enhanced activity of **CATACEL$_{JM}$ SSR**
  - Maintains comfortable carbon margin
- Enhanced heat transfer properties of **CATACEL$_{JM}$ SSR**
  - Impact of additional firing on TWT is minimized

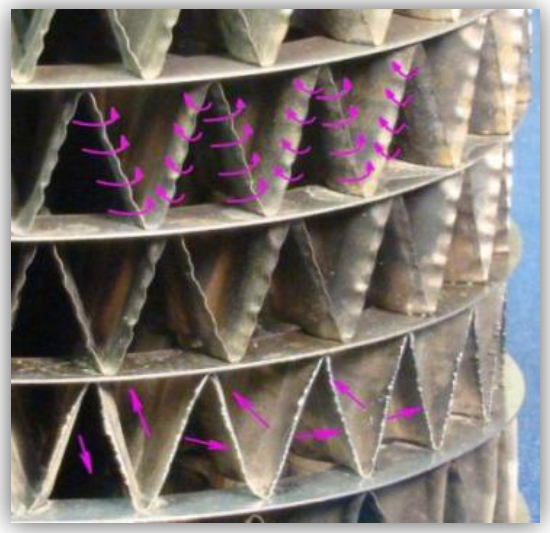
	Units	QUADRALOBE	CATACEL$_{JM}$ SSR	
Steam to Carbon Ratio	mol/mol	2.9	2.9	**2.7**
Feed Flow Rate	%	Base	99.9	102.4
Fuel Flow Rate	%	Base	98.9	91.5
Total NG Flow Rate	%	Base	99.6	99.4
Exit Temperature	°F	1521	1521	1521
Max Tube Wall Temperature	°F	1593	1582	1582
Carbon Margin	°F	Base	+36	+23
Catalyst Pressure Drop	psi	38.4	38.4	37.0
Process Heat Duty	%	Base	99.8	96.2
Hydrogen Production	%	Base	Base	Base

Catacel SSR JM

Benefit Summary – Existing Plants

Johnson Matthey
Process Technologies

- **CATACEL$_{JM}$ SSR** is a novel, patent-protected steam methane reforming technology that provides leading-edge performance
- This technology delivers step-out increases in heat transfer, pressure drop and activity, which give a range of plant-specific operational benefits



- **For existing plants**:
  - ✓ 1% - 2% throughput increases (at same trim fuel rate) when **CATACEL$_{JM}$ SSR** used as direct replacement for standard pellets
  - ✓ 2% - 10% trim fuel savings when **CATACEL$_{JM}$ SSR** used as direct replacement for standard pellets
  - ✓ 20% decrease in pressure drop compared to standard pellets
  - ✓ Steam to Carbon decrease of 0.5 units (mol/mol) when replacing standard non-alkalized pellets

Catacel SSR JM

Case Study – New Hydrogen Plant

Johnson Matthey
Process Technologies

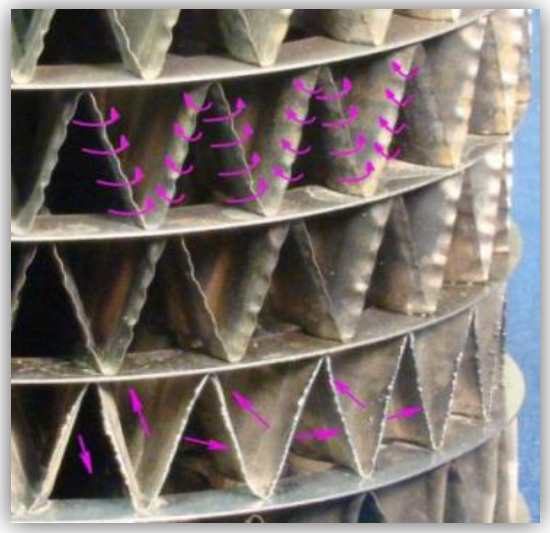
Top-Fired	Units	Pellets	CATACEL$_{JM}$ SSR
Number tubes	–	460	**385**
Tube ID	in	4.50	**4.61**
Tube heated length	ft	41.8	**46.4**
Furnace length	ft	48.0	**50.0**
Furnace width	ft	76.5	**61.5**
Pressure drop	psig	29.9	30.4
Peak TWT	–	Base	Base

Catacel SSR

Benefit Summary – New Plants

Johnson Matthey
Process Technologies

- **CATACEL$_{JM}$ SSR** is a novel, patent-protected steam methane reforming technology that provides leading-edge performance
- This technology delivers step-out increases in heat transfer, pressure drop and activity, which give a range of plant-specific operational benefits



- **For new build projects**:
  - ✓ Decrease tube count by 10% - 20%
  - ✓ Decrease tube wall thickness, longer tubes
  - ✓ 5% - 20% lower capital cost of the radiant box

Catacel SSR

Conclusions

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Process Technologies

- Novel steam reforming technology, **CATACEL$_{JM}$ SSR**
  - Provides improvement in heat transfer (overcomes limitations), activity, and pressure drop
  - Carbon-free operation over wider range of operating conditions
  - Tolerates upset conditions that would normally lead to unscheduled change-out, whether low S:C or poisoning
  - Allows increase in throughput up to limitations of burners and convection section
  - OPEX savings on fuel
  - Unique properties allow for CAPEX reduction in new plant designs through optimized furnace designs

Catacel SSR

Thank you!

Johnson Matthey
Process Technologies

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