Catacel Corporation CASE STUDY: Borcelik SSR Installation

Novel SMR Catalyst for Lower-Cost Hydrogen Production Achieves 17,500 Hour Benchmark

Substitution of traditional ceramic media with catalyst-coated metal foil structure equates to reduced furnace fuel consumption, fewer catalyst change-outs

Figure 1 – Novel catalyst-coated metal foil structure

Figure 2 – Conventional ceramic catalyst media

A NEW CATALYST

In 2008, a 250-m3/hr-hydrogen plant was constructed in Europe to supply a Borcelik steel facility with H2 for annealer and coating line operations. Unique was the plant's utilization of a novel catalyst-coated metal foil structure – the Stackable Structural Reactor (*SSR®; Figure 1*) – developed by Catacel Corporation in place of catalyst-impregnated ceramic pellets (*Figure 2*) to sustain Steam Methane Reforming (SMR) processes. Expected performance was achieved at startup on July 24, 2008, with minimal correction; reactions were observed to operate at exact equilibrium. As anticipated, furnace temperatures registered lower than a comparable older plant operating at the Borcelik location with conventional ceramic media. Shortly thereafter, the old plant was shutdown when the new plant demonstrated sufficient hydrogen yield to sustain all necessary operations.

Plant performance was again evaluated in April 2009. No discernable change from initial performance was observed. At the same time, the old plant was restarted to perform a similar evaluation. Furnace temperatures and fuel consumption rates were observed to be considerably higher than the new plant.

In July 2010, after two years and 17,500 hours of problem-free operation, the performance of Catacel's SSR® remains indistinguishable from new. While principally anecdotal with respect to confidentiality constructs, the Borcelik installation suggests Catacel's SSR® as a viable alternative to ceramic catalyst en route to lower-cost hydrogen production.

HYDROGEN PRODUCTION: CERAMIC CATALYST

"The SSR® is proving itself as a viable cost-effective replacement for ceramic catalyst inserts for hydrogen generation."

— DOE Hydrogen Program; FY 2009 Annual Progress Report; II.J Hydrogen Production/Cross-Cutting/Production

Steam Methane Reforming of hydrogen has traditionally utilized alloy steel tubes filled with catalyst-impregnated, pellet-shaped ceramic media (*Figure 2*). These tubes are suspended vertically in a furnace and heated to typically between 1000°C and 1100°C. Steam and hydrocarbon fuel are then fed to the top of the tubes and syngas – containing between 50% and 70% hydrogen – is extracted from the bottom. Although this conventional production method has been in use for nearly a century, there are drawbacks.

Ceramic media tends to crush to powder after startup and shutdown cycles due to different thermal expansion rates between the tube and media. The tube expands when heated, but the media does not. Instead, the media settles. After shutdown, the tube cools and contracts – crushing some of the media to powder. Accumulation of this powder leads to clogging of the tube, so the media must be removed and replaced, on average, every three to five years. This recurring event has negative impact on plant life cycle cost. Besides material replacement, there are associated expenditures for labor and downtime as well as hazardous waste disposal of the catalyst.

A second shortcoming of ceramic media is heat transfer. As an endothermic reaction, SMR requires a constant supply of heat from the furnace through the tube wall. Media near the wall picks up heat readily but heat transfer to the center of the tube is less efficient, meaning the catalyst is less effective. Reaction efficiency is thus compromised due to imbalanced heat transfer throughout the tube.

HYDROGEN PRODUCTION: SSR®

Catacel designed the SSR® with the express intent of resolving the deficiencies of ceramic media. The company surmised a catalyst material that could last (at least) twice as long while continuing to deliver superior heat transfer would present compelling economic benefits for hydrogen plant operators. The superior heat transfer characteristics of SSR® are illustrated in *Figure 3*.

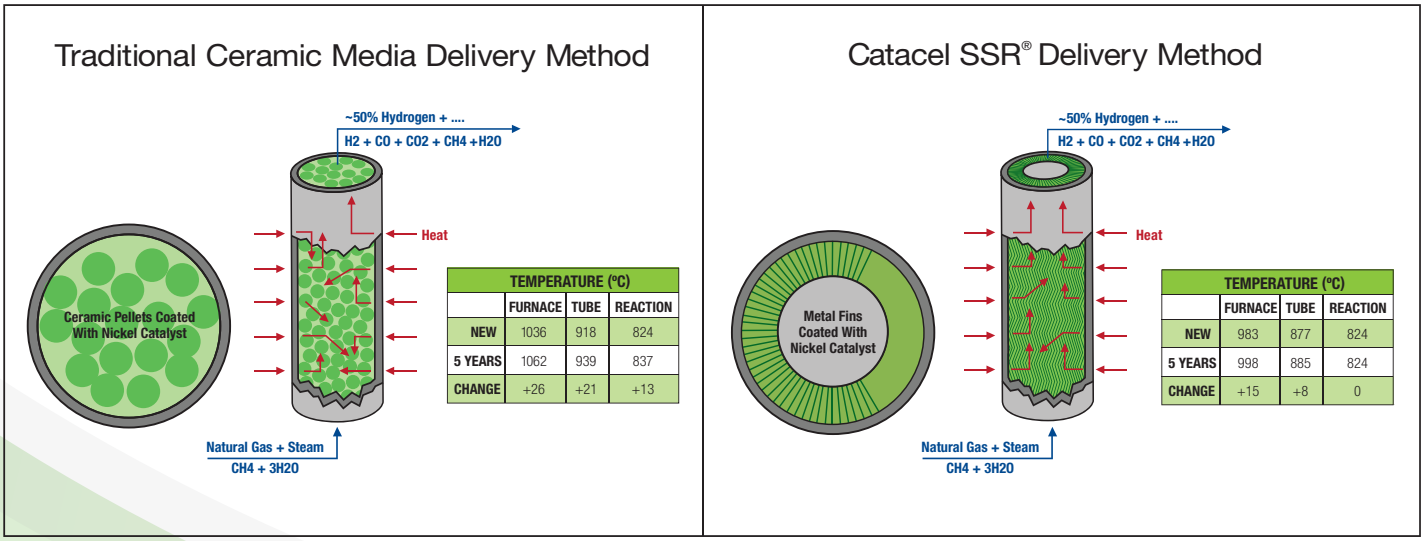


Figure 3 - Heat transfer characteristics of ceramic media and SSR®

The SSR® is a honeycomb made from a special grade of high temperature stainless steel foil coated with a reforming catalyst. Individual reactors are roughly the size and shape of a coffee can and are stacked – one upon another – inside the reformer tube.

As a durable metal foil structure, the SSR® is not subject to "crushing" as occurs with ceramic media when tubes expand and contract. Also, Catacel's reactor exposes approximately 2.5 times more catalytic surface area to the reaction process than does an equivalent volume of catalyst-impregnated pellets. Furthermore, tests conducted in collaboration with the NASA Glenn Research Center (Cleveland, Ohio) have demonstrated 30% heat transfer improvement over ceramic media.

SSR® COST BENEFIT

Catacel quantifies the cost-benefit of its stackable reactor technology to hydrogen plant operation in four ways:

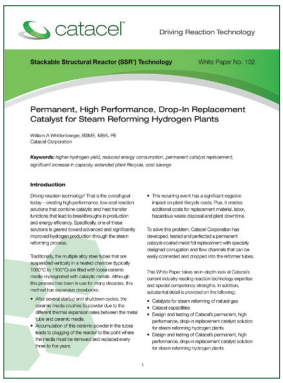
1. Improved heat transfer permits lower furnace temperatures to sustain SMR reactions – hence less fuel consumption, hence less fuel cost.
2. Durable metal foil design in tandem with increased catalytic surface area extends effective media life, necessitating fewer change-outs – hence less material and associated downtime costs;
3. In retrofit scenarios, improved heat transfer permits throughput yield increase from existing equipment – hence avoidance of additional capital investment.
4. In new plant scenarios, combined performance/durability advantages warrant fewer and/or shorter reformer tubes – hence reduced construction expense. The long-term cost benefit of SSR® is evidenced in *Table 1* as follows:

250m3/hr H2 plant **Nat. gas at $7/mm BTU**	**New**	**After Yr1**	**After Yr2**	**After Yr3**	**After Yr4**	**After Yr5**	**After Yr6**	**After Yr7**	**After Yr8**	**After Yr9**	**After Yr10**	**After Yr11**	**After Yr12**
CERAMIC MEDIA													
Reaction Temp. (°C)	824	824	824	827	831	837	845						
Tube Temp. (°C)	918	921	923	927	933	939	948	(replace)					
Furnace Temp. (°C)	1036	1039	1042	1047	1054	1062	1071						
Furnace Fuel, $/year	$79,887	$80,436	$81,234	$82,678	$84,539	$87,122	$90,309						
SSR® MEDIA													
Reaction Temp. (°C)	824	824	824	824	824	824	827	832	838	846	856	869	884
Tube Temp. (°C)	877	877	878	879	882	885	888	895	903	911	920	934	951
Furnace Temp. (°C)	983	985	988	991	994	998	1004	1010	1018	1027	1038	1050	1064
Furnace Fuel, $/year	$68,037	$68,590	$69,110	$69,764	$70,466	$71,213	$72,641	$76,596	$76,955	$76,786	$83,410	$87,939	$93,202
Savings	**$11,850**	**$11,846**	**$12,124**	**$12,914**	**$14,073**	**$15,909**	**$17,688**						
Total Savings	**$11,850**	**$23,696**	**$35,820**	**$48,734**	**$62,807**	**$78,716**	**$96,384**						

AN UNEXPECTED BENEFIT

In October 2009, a process upset dramatically reduced the Borcelik plant's hydrogen generating ability. While the exact cause was never determined, it is presumed that a problem with a gas treatment device allowed sulfur – which binds with the active ingredients in the catalytic material – to be introduced with the process gas. As a result, catalytic reactions were impaired and rendered ineffective.

Plant engineers attempted to regenerate the catalyst on the metal foil structures by using a rigorous steaming process. After two days, hydrogen production resumed at acceptable performance levels. Following the regeneration, Borcelik plant engineers noted that had ceramic media been used, it most likely would not have survived the failure event or corrective action – a significant savings in media replacement and labor costs for what would have been an unscheduled, unbudgeted complete catalyst change out.


catacel Driving Reaction Technology

Stackable Structural Reactor (SSR®) Technology White Paper No. 102

Permanent, High Performance, Drop-In Replacement Catalyst for Steam Reforming Hydrogen Plants

Download the SSR® white paper at Catacel.com

SSR® WHITE PAPER

Since the Borcelik installation, Catacel has developed an even better performing SSR® metal foil structure for SMR processes that holds the potential to deliver a multi-million dollar ROI for larger-scale operations. More information is available in Catacel Corporation White Paper No. 102 – Stackable Structural Reactor (SSR®) Technology – authored by company president William A. Whittenberger, BSME, MBA, PE. To obtain a copy, contact **dlensner@catacel.com** or visit **www.catacel.com**.

ABOUT CATACEL CORPORATION

Catacel, based in Northeast Ohio, provides solutions for challenging catalyst-based applications. Using its diverse background in durable metal honeycombs, reaction design, catalytic chemistry, and large-scale production techniques, the company has engineered solutions for a diverse range of global clientele including NASA Glenn and Acumentrics Corporation. Catacel primarily serves the advanced energy and chemical industries. Catacel solutions are geared to the fuel cell, hydrogen, gas-to-liquid, petrochemical and aerospace sectors.

09/2010

catacel™
Driving Reaction Technology

Catacel Corporation
7998 Gotham Road
Garrettsville, Ohio 44231
330.527.0731
sales@catacel.com
www.catacel.com.