New Long Life Replacement Catalyst for Steam Reforming Hydrogen

A Special Report from Catacel Corporation

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For nearly a century, catalyst-impregnated ceramic pellet media has driven Steam Methane Reforming (SMR) reactions in hydrogen plants. Catacel Corporation (Garrettsville, Ohio) (*www.catacel.com*) has tested and perfected a new higher performance alternative — the Stackable Structural Reactor (SSR®). This precision engineered, catalyst-coated metal foil reactor, which replaces traditional ceramic media in steam reforming hydrogen plants, provides 30 percent improved heat transfer; 2.5 times more catalytic surface area; and is "break" and "crush" resistant — two constant failure modes associated with ceramic pellet media.

The specific benefits derived from Catacel's SSR technology are observable and quantifiable throughout three major hydrogen plant applications.

In the first application, direct replacement of ceramic pellet media with SSR can enable reduction of heat input and energy consumption necessary to sustain SMR reactions. Traditional ceramic media is known to have modest heat transfer capability and typically operates within a 90°C to 100°C temperature differential between the media and tube wall. SSR catalyst features significantly improved heat transfer capability, decreasing this temperature differential by 35°C or more. Thus, plant operators can reduce furnace temperature by 40°C to 50°C. This decreases energy supplied to the furnace by approximately 10 percent and also extends furnace life. Additionally, the 2.5 times increase in catalytic surface area results in extended catalyst life; predictably by two or even three times the durability of ceramic pellets, resulting in fewer catalyst change-outs over time and the consequential production downtime necessitated by a change-out event.

Alternatively, plants retrofitted with SSR can increase hydrogen gas production from existing equipment, thereby eliminating the need for additional capital investment. The improved heat transfer of SSR facilitates an increase in throughput (at the same furnace and tube temperatures of the original plant) for up to 25 percent greater product yield without heat energy penalties. This enables captive plants to more easily manage increased short- and long-term demand for process gas production. The degradation of catalytic performance and process pressure drop caused as ceramic pellets crush to powder, which reduces plant efficiency and drives up operating expense, can be avoided with SSR technology.

Hydrogen plants, regardless of size, can be designed smaller, more compact, and with fewer and/or shorter reformer tubes by incor-

Catacel's Stackable Structural Reactor (SSR)

Conventional Ceramic Pellet Media

porating SSR into new plant builds. Due to the longer life of SSR catalyst compared to ceramic media, a hydrogen plant with this technology can be more cost-competitive and enjoy differentiation advantages including reduced construction, transportation, installation, and maintenance expenses.

A 21st Century Technology

Catacel's SSR is a flow-engineered structure made of high temperature metal foil coated with a reforming catalyst. Each lightweight "cell" is about the size and shape of a coffee can; cells are stacked one upon another inside the vertical reformer tubes. The catalyst-coated foil design combines high performance, high surface area catalytic reaction with superior heat transfer. To move heat convection and process flow in desired vectors and volumes, the foil surfaces can be tailored to a variety of geometries.

Figure 1 provides a heat transfer comparison between ceramic, modified ceramic and metal foil catalyst media. This comparison shows the effect of attempting to modify a ceramic support to operate in a higher heat transfer window. While more reaction area is attained, pressure drop increases significantly. Metal foil changes the operating window, delivering the required heat transfer and much higher surface area at only a modest increase in pressure drop.

The fundamental properties of the foil support allow the process to occur in a previously unavailable operating window that is very favorable in terms of size, weight, and throughput.

Most catalytic combustion and many reforming reactions operate in the 700°C to 900°C range. Thus, the foil substrate for the applied catalyst needs to be strong and stable at those temperatures. This normally limits the choice to one of the very expensive "super alloys" in the $100 per-pound cost range. To control costs, Catacel specifies a special alloy for its foil structures that can be attained for significantly less cost. A blend of iron, chrome, aluminum and rare earth, the alloy has proven to be ideal for the application of catalyst to the foil surface, and enables the catalysts to remain chemically stable in most high temperature environments over long periods of time.

The result of SSR's precision-engineered design is improved heat distribution from the tube sidewalls, excellent catalyst utilization, longer catalyst life and superior heat transfer. As the surface area available with SSR media is typically 2.5 times that available with ceramic media, more active catalyst ingredients are available to the reaction. This is extremely significant as catalyst material degrades over time. The additional surface area will allow SSR media to last twice as long as ceramic media before deterioration is a factor.

Close-up of SSR Metal Foil Surface

Hydrogen Plant Case Study

A 250-cubic-meter-per-hour conventional captive plant supplying hydrogen to a steel factory in Europe has been in operation since July 2008. It is a can-type reformer with up-flow and four 22-foot-long tubes holding eight cubic feet of SSR media. A companion plant at the same location has been operating with ceramic pellet media since the early '90s.

The new plant with SSR technology started up immediately and was quickly stabilized at equilibrium conditions. After nine months, the plant continued to operate as when new. Today, the plant remains fully operational at the same level of performance achieved at startup. There has been virtually no degradation in catalytic activity or increase in plant operating expenses as the SSR catalyst has aged.

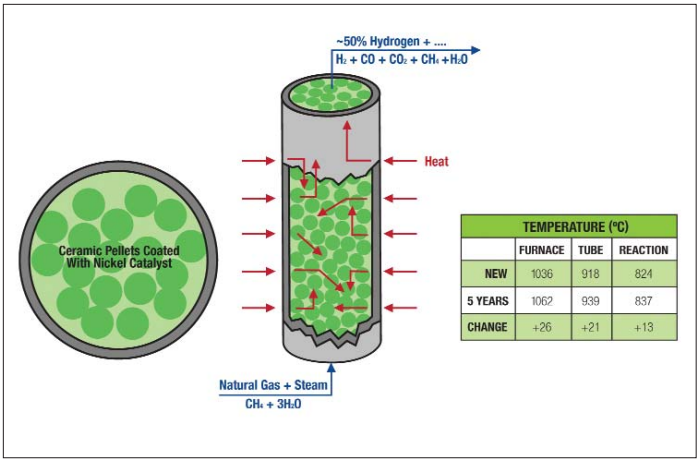
Long-Term Use Model

A finite-difference model of a reformer system was created to estimate the short- and long-term performance effects of SSR vs. conventional ceramic media. The model was validated against both lab and actual performance data from the above-mentioned hydrogen plant.

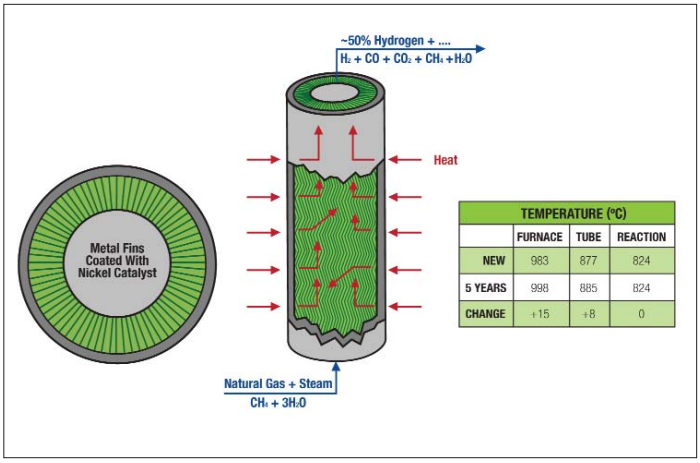
At startup and with new SSR catalyst — where reaction temperature is approximately 824°C, tube temperature 918°C and furnace temperature 1036°C — the model

Catalyst Media Property Comparison

	Ceramic	Modified Ceramic	Metal Foil
Heat Transfer	1.0	1.3	1.3
Surface Area	1.0	-1.5	-2.5
Pressure Drop	1/0	-5.0	-1.5



TEMPERATURE (°C)			
	FURNACE	TUBE	REACTION
NEW	1036	918	824
5 YEARS	1062	939	837
CHANGE	+26	+21	+13



TEMPERATURE (°C)			
	FURNACE	TUBE	REACTION
NEW	983	877	824
5 YEARS	998	885	824
CHANGE	+15	+8	0

predicts that after six years, the reaction temperature will be increased by 21°C to 845°C to achieve the same throughput, but that the SSR catalyst will not require replacement. Tube and furnace temperatures will increase to their practical limits of 948°C and 1071°C, respectively. The model further predicts that ceramic catalyst replacement would be required at this juncture to bring temperatures back into acceptable range, assuming a catalyst change-out event had not already occurred due to breakage and "plugging".

The model is capable of estimating fuel usage for the reformer over a 12-year period. It shows a clear fuel cost advantage for SSR in years one through six. It also shows that SSR media can last through year 12, avoiding entirely an expensive and time consuming catalyst change-out at the end of year six.

This is an abbreviated version of a White Paper written by William A. Whittenberger, BSME, MBA, PE, Catacel Corporation, Garrettsville, Ohio. For further information, or to obtain a copy of the White Paper, contact dlensner@catacel.com. ■