

NEW MATERIALS: IN-REACTOR OPTIMIZATION USING ACTIVE PURIFICATION MEDIA

MULTI-CLIENT STUDY PROPOSAL

October 2016



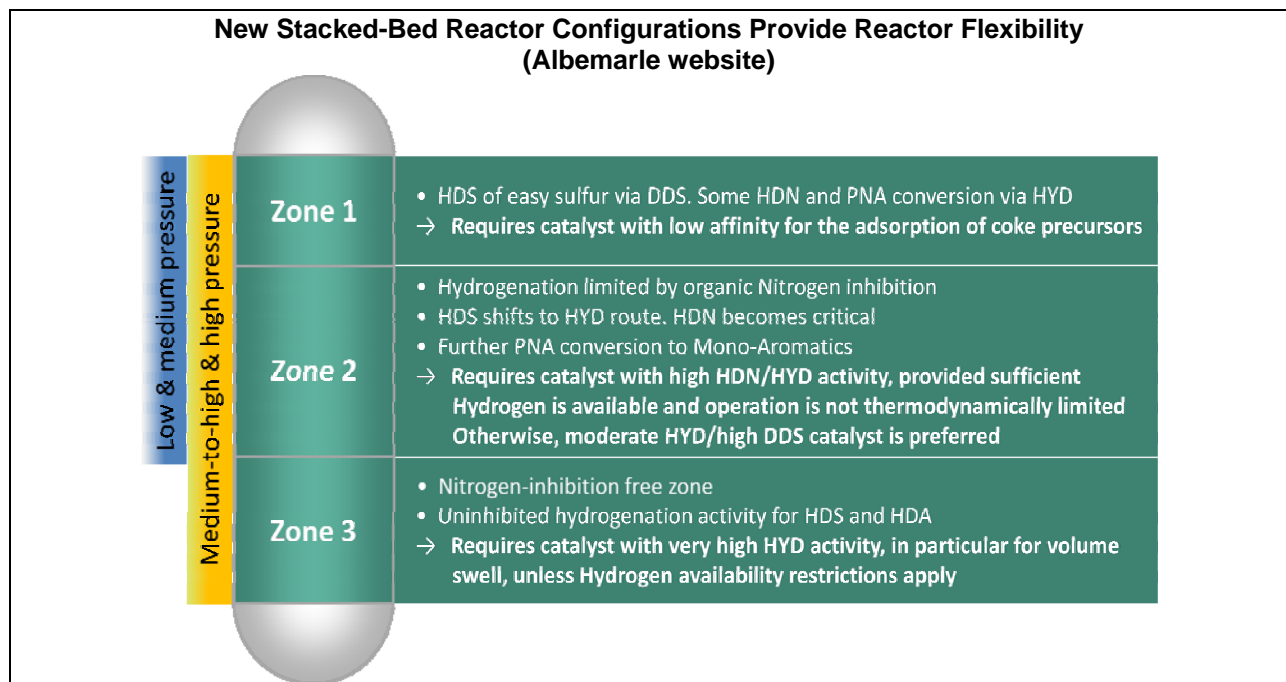
NEW MATERIALS: IN-REACTOR OPTIMIZATION USING ACTIVE PURIFICATION MEDIA

I. ABSTRACT

Traditionally, chemical and refining endusers are vastly familiar with feedstock and intermediate purification processes using adsorbents or chemicals to remove impurities that would deactivate catalysts within downstream reactors, such as selective hydrogenation of dienes, V and Ni passivation before FCC operations, or ZnO traps for chlorine or activated carbon for mercury removal. But an increasingly important trend is occurring in two newer directions: 1) stacked catalyst bed reactor configurations using multiple catalyst types within one reactor that enhance yields, as well as; 2) the use of in-reactor active media to remove specific reaction by-products or detrimental by-products which deactivate the catalysts in-situ.

At first glance, one might dismiss these developments as somewhat trivial! However, in practice depending on the product reaction, feedstock or intermediate deployed, these controls can allow improved yields as well as the increased reactor space velocities resulting in increased productivities of 10% + or more. This is not trivial, particularly if this type of retrofit, largely goes directly to the bottom line!

Therefore this proposed study from TCGR will explore the latest developments in enhanced in-reactor catalyst protection, poison purification systems and methodologies to improve productivity.



II. BACKGROUND

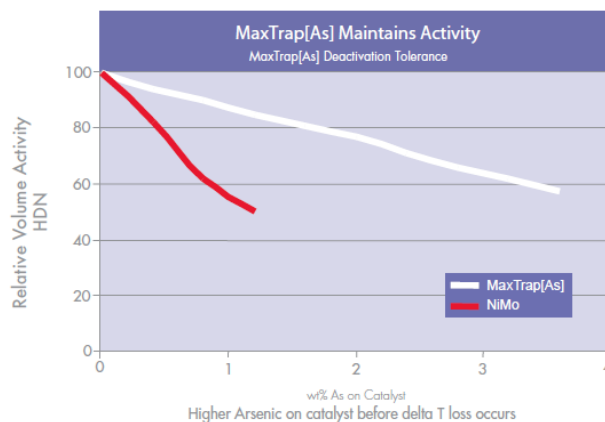
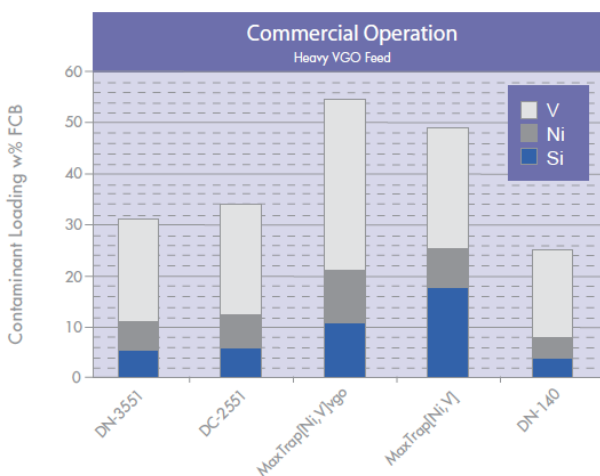
It will not be surprising to practitioners, that catalysts are very sensitive to any impurities (or poisons) that can impact and affect active surfaces. This will be any substance that changes the chemical or physical properties of the surface, restricting the activity or life. This might involve competitive adsorption, by alloy formation, covalent competition or anything that inhibits the desired reaction schemes. Also even small amounts of contaminant, even in trace amounts, can actually build up and block of the access to the huge inner pore structures significantly reducing activity.

The advancement of instrumentation to measure these affects, along with a stronger understanding of chemical mechanisms has now reached the point, where we can take an active role in mitigating these issues, closer to the catalyst surface. For example, we know inorganic poisons like silica tend to be deposited on the inlet catalysts and tend to be retained there, whereas chlorides and sulfurs tend to migrate further down through the catalyst beds and downstream series reactors. This allows us to predict where and how to apply preventative measures into the process chemistries, closer to where they are most effective.

Historically, the recognition of reactor fouling control, as well as catalyst poisoning control has been most developed in the refining catalyst industry, particularly in hydrotreating/hydrocracking, where processing more difficult feedstocks, like heavy VGO's, has been an industry challenge. So it is not surprising to find licensors/catalyst suppliers like Albemarle, Axens, Chevron/ART, Haldor Topsøe, and Shell/Criterion, having developed tailored solutions and services to address these in reactor challenges. By way of example, Shell/Criterion has developed the SENTRY Guard Portfolio

(<http://www.criterioncatalysts.com/en/products/product-applications/grading-poison-control.html>)

SENTRY Poison Guard Catalysts	
MaxTrap[As]	High-HDS/HDN-activity arsenic-trapping catalyst
MaxTrap[Si]	High-surface-area silicon-trapping catalyst
MaxTrap[Ni,V]	Metals-trapping catalyst for high end-point feed processing
MaxTrap[Ni,V] ^{VGO}	High-HDS/HDN-activity metals catalyst for VGO



Haldor Topsoe offers shape-optimized toppings, particulate traps and high void fraction ring-shaped catalysts under its TopTrap™, MultiTrap™ and HyOctane brands aimed at avoiding pressure drop, build-up and premature shutdowns (<http://www.topsoe.com/processes/pressure-drop-control>).

This background establishes that this is already a commercialized practice. The trend we are now witnessing is spreading beyond hydrocracking/hydrotreating into more refining/petrochemical/ chemical and polymerization processes. We are seeing continuous improvements in refining, now spreading across segments so all segments remain of interest.

III. THE NEED FOR THE STUDY

In terms of increasing process efficiencies, increasing the profitability of existing plants, and effectively increasing the LHSV, as well as extending catalyst life optimizing these variables for each application provide significant industry incentives. Such an extension, of known and existing science into a well-known adjacency, with more modern scientific tools provides industry opportunities for producers, catalyst suppliers, services and raw materials suppliers.

Documenting these advances, as applied to new applications, will assist the industry process end-users to consider and retrofit in-reactor active media to remove poisons and detrimental by-products which deactivate specific catalysts in-situ.

Moreover new materials sciences in MOFs, COFs and ZIFs; zeolitic and MCM mesoporous materials and carbon-based structures, will provide a pipeline of new active/modified materials which can add breadth and depth to future solutions.

These are three strong reasons to seriously consider supporting this study as an emerging science.

IV. SCOPE AND METHODOLOGY

The objective is to document, by way of industry case examples, leading processes where active/reactive media and/or active structured packings have been used more recently, as opposed to passive media, for example such as NorPro Denstone™ alumina balls or Sulzer Mellapak™ internals, just used to support the catalyst beds.



Mellapak™ structured packing



Structured grid packings



ActiPhase Disks-Crystaphase

These case studies will demonstrate how existing reactor internals can be modified to:

- Provide 10-20% increased catalyst volume space by reducing the quantity of passive bed supports.
- Increase the void volumes, decrease pressure drops and allow for higher space velocities – LHSV's which take more effect use of catalyst productivities.
- Adjust bed reaction temperatures, reducing the catalyst sintering rates to extend catalyst life.

The above packings can be modified by impregnating with “active chemical, metal and inorganics” so that closer reactor control is achieved. There is even a higher advantage to be gained in higher space velocity applications and this would apply to natural gas purifications, olefin purification, chemical hydrogenations and the like.

A preliminary Table of Contents for the proposed study appears on page 5. At this stage in study development, TCGR is welcoming inputs on the specifics to be addressed and nominations for the case studies to be completed. These so-called “charter” subscribers are requested to indicate their interest in supporting the study by returning a completed Order Form (see page 9) by November 4, 2016 after which TCGR will contact them for their inputs.

Preliminary Table of Contents:

NEW MATERIALS: IN-REACTOR OPTIMIZATION USING ACTIVE PURIFICATION MEDIA

- I. Background/Introduction**
- II. Executive Summary**
- III. Market Size, Growth and Commercialization Status**
 - A. Commercialization and Status.
 - B. Market Size and Growth of Active Media vs Passive Purification/Separation
 - C. Profiles of Participants, Competition and SWOTS.
- IV. Applications and Case Study Optimization Improvements**
 - A. Refinery Hydrotreating and Hydrocracking.
 - B. Chemical Hydrogenation Reactions.
 - C. Petrochemical/Aromatic Alkylation Reactions.
 - D. Natural Gas Purification Optimizations.
- V. New Technology Developments/Pipeline Advances**
 - A. Patent Analysis and Pilot Plant Trials.
 - B. Regulations and Reduction Limit Implications.
 - C. Competitive Entry Routes and Value Chain Opportunities.
- VI. Competitive/Strategic Implications**
 - A. Competitive/Market Reactions to Changes
 - B. Strategic Implications
- VII. Conclusions and Recommendations**

**Charter subscribers (those who sign up for the study before November 4, 2016) will have the opportunity to work with TCGR to further refine the scope of the report by delineating areas of particular interest for inclusion in the assessment, including nominations for coverage via the "Case Studies" (Sxn. IV).*

V. QUALIFICATIONS

The Catalyst Group Resources, a member of The Catalyst Group, works with clients to develop sustainable competitive advantage in technology-driven industries such as chemicals, refining, petrochemicals, polymers, specialty/fine chemicals, biotechnology, pharmaceuticals, and environmental protection. We provide concrete proven solutions based on our understanding of how technology impacts business.

Using our in-depth knowledge of molecular structures, process systems, and commercial applications, we offer a unique combination of business solutions and technology skills through a range of client-focused services. Often working as a member of our clients' planning teams, we combine our knowledge of cutting-edge technology with commercial expertise to:

- Define the business and commercial impacts of leading-edge technologies
- Develop technology strategies that support business objectives.
- Assess technology options through strategy development, including:
 - Independent appraisals and valuations of technology/potential
 - Acquisition consulting, planning and due diligence
- Provide leading-edge financial methodology for shareholder value creation
- Lead and/or manage client-sponsored R&D programs targeted through our opportunity identification process.
- Provide leading information and knowledge through:
 - World-class seminars, conferences and courses
 - Timely technical publications

The client-confidential assignments conducted by The Catalyst Group include projects in:

- Reinventing R&D pipelines
- Technology alliances
- Technology acquisition
- Market strategy

We have built our consulting practice on long-term client relationships, dedication, and integrity. Our philosophy is clear and focused:

We Provide the "Catalysts" for Business Growth by Linking Technology and Leading-Edge Business Practices to Market Opportunities

VI. DELIVERABLES AND PRICING

This report is timely and strategically important to those industry participants and observers both monitoring and investing in the development and implementation of active media advances. TCGR’s report, based on technology evaluations, market assessments and interviews with key players will assess results and provide opinions beyond the public domain information. As a result, subscribers are requested to complete and sign the “Order Form and Secrecy Agreement” on the following page.

The study, “***New Materials: In-Reactor Optimization Using Active Purification Media***” is expected to be available in January/February 2017.

<u>Participation</u>	<u>Deadline</u>	<u>Price</u>
<u>“Charter” Subscribers*</u> <i>New Materials: In-Reactor Optimization Using Active Purification Media</i>	<u>before November 4, 2016</u>	<u>\$15,500</u>
<u>Post-launch Subscribers</u> <i>New Materials: In-Reactor Optimization Using Active Purification Media</i>	<u>after November 4, 2016</u>	<u>\$18,500</u>
Report in PDF format, in addition to subscription price		\$1,000

**Charter subscribers (those who sign up for the study before November 4, 2016) will have the opportunity to work with TCGR to refine the scope of the report by delineating areas of particular interest for inclusion in the assessment and nominations for the case studies to be completed.*

* * * * *

ORDER FORM AND SECRECY AGREEMENT

The Catalyst Group Resources, Inc. Gwynedd Office Park P.O. Box 680 Spring House, PA 19477 - USA -	Tel: +1-215.628.4447 Fax: +1.215.628.2267 e-mail: tcgr@catalystgrp.com website: www.catalystgrp.com
---	---

Please enter our order for “***New Materials: In-Reactor Optimization Using Active Purification Media***” to be completed in January/February 2017, as follows:

_____ “***New Materials: In-Reactor Optimization Using Active Purification Media,***” as a “charter” subscriber (i.e., prior to November 4, 2016) for \$15,500 (\$18,500 after study launch)

_____ Please enter our order for the study to be delivered in PDF (Adobe Acrobat) format for use across our sites/locations (i.e., site license) for an additional \$1,000.

_____ Please send us _____ additional printed copies @ \$250 each.

In signing this order form, our company agrees to hold this report confidential and not make it available to subsidiaries unless a controlling interest (>50%) exists.

Signature: _____ Date: _____

Name: _____ Title: _____

Company: _____

Billing Address: _____

Shipping Address (no P.O. Boxes): _____

Express delivery services will not deliver to P.O. Boxes

City: _____ State/Country: _____

Zip/Postal Code: _____ Phone: _____

E-mail: _____ Fax: _____

This report and our study findings are sold for the exclusive use of the client companies and their employees only. No other use, duplication, or publication of this report or any part contained herein is permitted without the expressed written consent of The Catalyst Group Resources.