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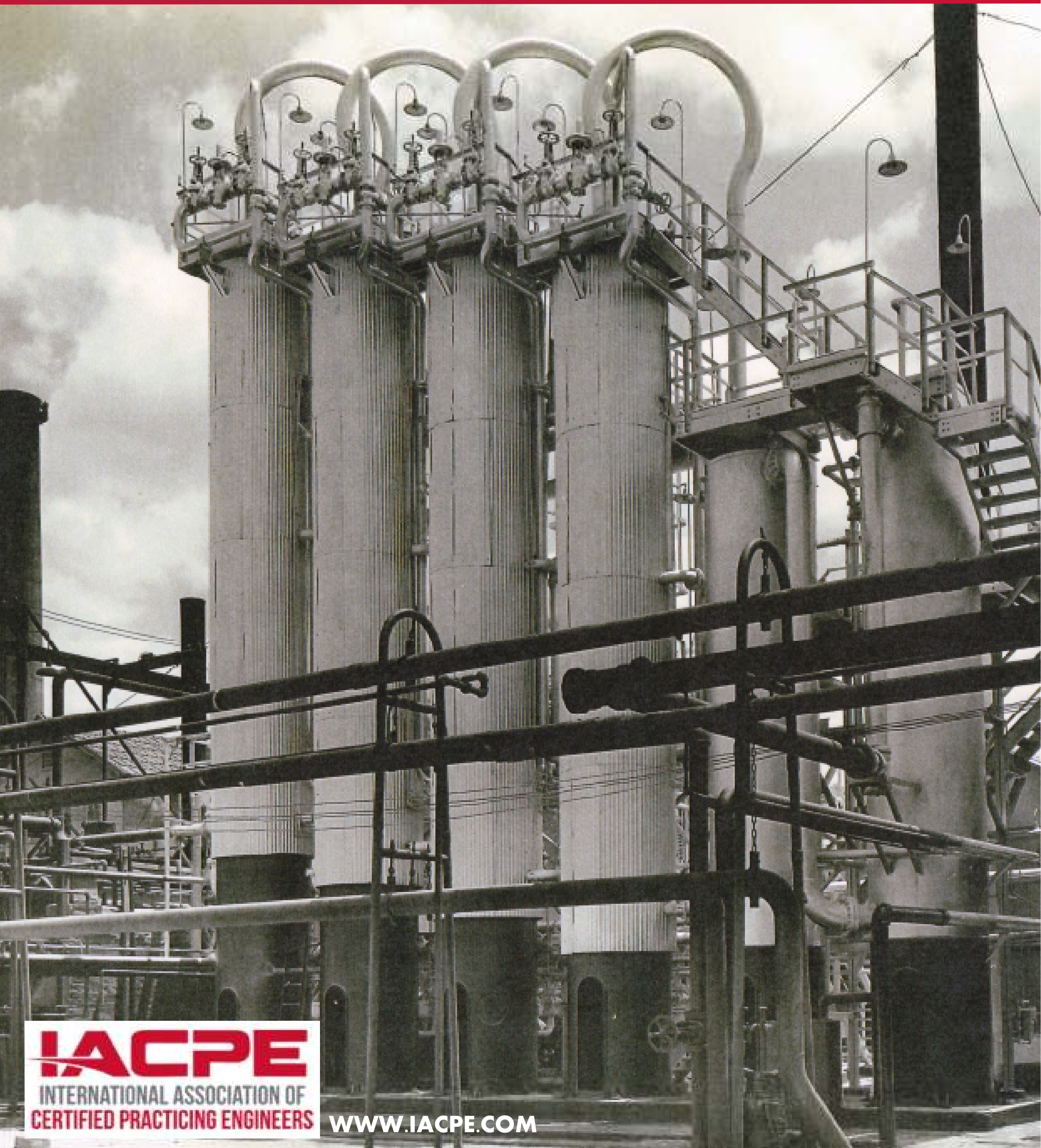

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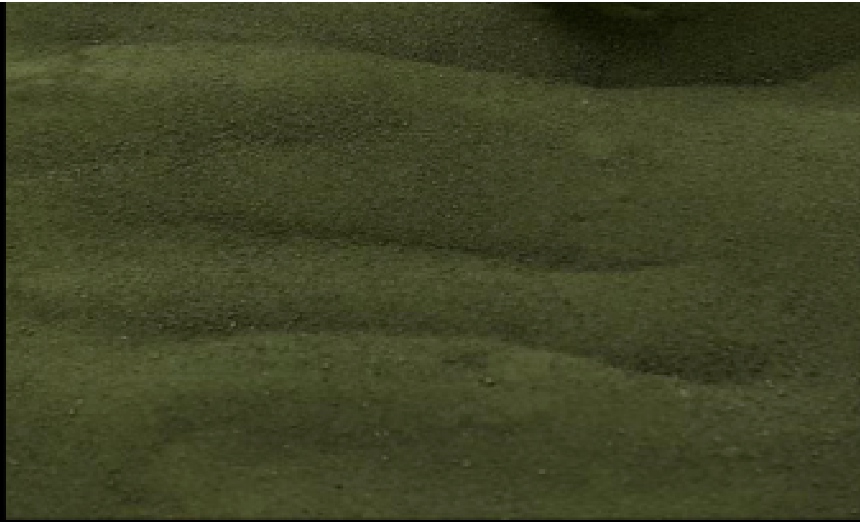
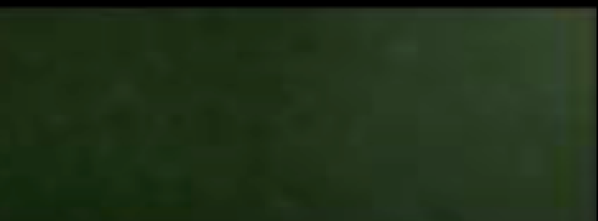
SPECIAL FEATURES



State-of-the-Art Catalyst & Process Solutions By Rezel



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Letter from the Editor: *Real Happiness*

I turned sixty-six in October. Sometimes I feel like I am twenty-five and other times I feel eighty-five. I have many happy days and I have had some sad days. What is real happiness? Superficial people might say being able to shop in the right places. I believe that real happiness has at least a few of these things.

1. Having Good Physical and Mental Health
One cannot really be happy without good physical and mental health. Everyone knows how to do both but struggle sometimes with each.

Good physical health – eat well and exercise - simple but hard.

Good Mental Health – each of us has two dogs inside of us that fight - a good dog, and a bad dog. feed the good dog – simple but hard.

2. Having Good People that Care About You
The first step in this process is to go out and find good people. They are out there – go find them – befriend them and they will befriend you. Care about them, and they will begin to care about you.

3. Having a purpose - working toward rewarding goals
Many times, we spend our most valuable asset, our time, working toward unrealistic, time wasting goals. Find your sense of purpose and work toward rewarding goals. Most people find great happiness in helping others.

4. Working to be a better person
It is hard to be a good person. Hard to feed to good dog. Each of us had fed the naughty dog at times, but rarely have we been happy afterwards. Joseph in the Bible was tempted, and he said – I will not sin again myself. When we fail we damage ourselves. Strive to be a better person.

5. Working towards financial security
Each of us should strive to be financially secure. Not to be rich because to be rich sometimes you have to sell your soul to the devil. Slowly work each day to become more secure.

Of course, we believe that one way to help yourself it to get knowledge and certification from IAC-PE. This can also help you find good people, help you to be a better person, and help you to be more financially secure.

All the best in Your Career and Life,

Karl

Catalyst Technology Q&A Roundtable

Panelist: Dr. Paul Jerus, Henrik W. Rasmussen, Rajesh Sivadasan, Raja Raman, Dr. Abrar A. Hakeem, John T. Haley

GENERAL CATALYST AREAS

1.Catalysts are the most important aspect of Reaction Engineering. How are we improving the life cycle of catalyst – from manufacturing, to utilization, to recycling and reprocessing?

Dr. Paul Jerus: Catalyst is considered the heart of the catalytic process. Therefore, engineers should understand and know the chosen catalyst for a process well in order to utilize, handle and recycle the catalyst. The main and original information must be provided by the supplier or producer which include the catalyst properties, Safety Data Sheet, and the instructions on how to use and handle the catalyst. Proper handling and operation will lead to a long cycle life.

Supplier or Vender Supplied Data

a. Speciation and Certificate of Analysis (COA) should include chemical properties {metals loading) and physical properties such crush strength, attrition loss, CBD (compacted bulk density) and bulk density. The metals loading would be an essential for engineers and servicing in term of safety and handling. Knowing the crush strength and attrition loss would definitely help in handling and loading properly.

b. Storage and Handling procedure must be provided or recommended by suppliers or venders. This procedure needs to be followed properly in order to obtain the correct usage and longest life out of the catalyst. CBD of the catalyst would tell how good the dense loading was performed. A good dense loading should show the density in the given reactor remarkably close to CBD. For sock loading the catalyst density in the reactor remarkably close to the bulk density provided by suppliers.

c. Operating Instruction are normally written based on either developing procedure if it is a new catalyst or from the commercial experience. The procedure should include the pre-activated procedure it is necessary. The operating instruction which including the operating conditions, and any feedstock impurities that need to be covered.

d. Unloading and Disposal procedures including unloading pre-treatment if it is necessary. This procedure should help to handling the spent catalyst to be safe and environmentally friendly.

Reaction Engineer and Servicing Team should know the catalyst and follow the instruction properly that leads to the best performance, long life, safe and environmentally friendly.

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe is continuously developing more active and more selective catalysts which improves the cycle length in the catalyst application at otherwise unchanged processing severity. Furthermore, most catalysts can today be recycled for metals reclamation and many catalysts can be regenerated, refurbished, and used again. Topsoe offers a process called ReFRESH that can refurbish used hydrotreating catalysts after which the catalyst can be re-used in the refinery application.

Raja Raman: The Catalyst Life Cycle (LCA) Management has evolved over the years and it's gradually maturing to be more use friendly applications. As mentioned it involves multiple companies like the catalyst manufacturer, Licensor of the process, End User and finally the spent recovery and disposal companies. Each of these steps faces several Environmental, technical, and organizational challenges requiring seamless coordination.

There have been tremendous improvements in manufacturing step, right from materials selection of the catalyst, energy efficient processes (with a view of sustainability) and shorter manufacturing steps. Clear example in this regard was the introduction of Type -II hydrotreating catalyst for the hydro processing application which happened when the refiners were struggling to make Ultra Low sulfur diesel and gasoline fuels.

The Catalyst life largely depends on the process conditions and the feedstock contaminants. The technology licensing companies have progressed changing the operating environment and pushing the envelope to new heights by incorporating several enabling features like Reactor Internals, Proper measurement, monitoring and control of operating conditions like pressure, temperature, and composition to optimize the LHSV and get better returns.

Also, the digitization and incorporation of real time monitoring is helping to improve the LCA but there is tremendous pressure for the end users to improve their reliability , consistent product quality and operating margins placing a higher demand for better utilization of the catalysts. The last step of recovery and re-use is still facing lot of logistic challenges though have made considerable progress in selected large use catalyst system.

Dr. Abrar A. Hakeem: Catalysts lose their activity over period depending on the type of process, feed composition and process conditions used in the reactor. The lifetime of a catalyst in for a typical diesel hydrotreatment (ULSD application) is around 4 years and for atmospheric resid hydrotreatment it is around 1 year. The catalyst life cycle can be improved either at particle level by various developments in catalyst manufacturing and by appropriate use in the reactors.

The appropriate utilization can be based on understanding sensitivity of catalyst towards different process parameters and making sure the reactor operation remains constrained within the applicable process values. In some cases, the catalyst can be regenerated depending on the type of deactivation the catalyst experiences. The regeneration of the catalyst helps to achieve the active phase of the catalyst and can be utilized further. However, in some cases of deactivation like poisoning of catalyst, regeneration is not an option and catalyst needs to be typically replaced.

John T. Haley, Rezel Catalysts Corp: In general, modern catalyst manufacturing is a near zero waste process due to recycle of process fines and process chemicals. Meanwhile improved emissions and effluent treatment facilities limit environmental exposures.

Improved chemistry, materials, and manufacturing processes are also improving activity and physical properties. For example, FCC catalysts can handle increasingly higher metals levels, reducing the catalyst addition rate, and improvements in activity of precious metals catalysts provide a longer life, while limiting contaminants and the impact of contaminants on precious metals-based catalysts also extends their live.

At Rezel, more efficient processes, like our ReFIX-Pro fixed bed PDH process, reduces hardware requirements, due largely on improvements in catalyst performance. Meanwhile, for example, Rezel has introduced a non-chromium catalyst for our fixed bed propane dehydrogenation (PDH) process. These new catalysts are approaching the activity and life of traditional fixed bed catalysts, while mitigating the environmental concerns of toxic chromium based catalysts.

Catalyst waste management remains a major concern. However, in most cases a range of waste mitigation practices are already in place. Precious metals are regularly recovered from catalyst. FCC catalysts are generally recycled to the end of their useful life, often employed as metals flushing catalysts or to reduced demand for high catalyst addition rates. Some existing processes reduce and recover contaminant metals to extend the useful life of the catalyst. And, wherever possible, where contaminant levels are managed to low enough levels, landfilling can be avoided by incorporating the waste catalyst into building materials such as road surfacing, concrete, bricks, mortar, etc.

2. Renewable Jet Fuel and Diesel are increasing in number and capacity. What are the challenges for this newer technology?

Dr. Paul Jerus: The demand of renewable jet and diesel is increasing but some challenges this still exist particularly gum or cloud point specifications. This problem is a new challenge to the catalyst vender to develop a mild de-waxing plus isomerization catalyst and / or absorbent to remove small amount of gum or wax. Engineering companies are looking to develop a better and low cost separation technology.

Coordination is another major challenge for the renewable process. The used feedstock is scattered, therefore logistical management is required. The fresh feeds in general are from both edible and inedible oil. The cost of the edible could be a challenge due to competing demand of consumption and the weather controlling agricultural products

Used plastics and rubber pyrolysis show good portion of the products are jet, diesel, and fuel oil but they contain olefins, sulfur, and wax. Most of renewable plastic and the used tires pyrolysis processes are batch process. Therefore, a new continuous process is needed in order to utilize the used tires and plastics. A substantial quantity of hydrogen is utilized in the process and low cost of hydrogen is needed.

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe is by far the most successful licensor of renewable fuels technology with many units in operation and many more in construction and engineering. The technology is well proven and produces a renewable diesel meeting and exceeding all of the D-975 ASTM specification. The same apply for the renewable jet fuel as it complies with the D7566 ASTM specifications.

There are many considerations that must be considered when designing and operating these units, which all relate to the quality of the renewable feedstock. These feedstocks can contain substantial amounts of contaminants and can be highly corrosive. However, with the proper process design and catalyst technology all the issues can be dealt with effectively.

Rajesh Sivadasan: The use of renewable sources (vegetable oils, used cooking oil, grease, tallow, inedible oils etc.) to produce transportation fuels (jet/diesel) is being widely employed as a means of decreasing dependence on fossil fuels. Use of these renewable feeds has posed some challenges to the development of technology and some of them are listed below:

a) Catalytic

Oxygen (O2):

Biological renewable feed sources contain high concentration of O2 (~ 10-15%) and is highly dependent on length and degree of saturation of fatty acid chains. Under normal hydrotreating operating conditions, O2 will react with hydrogen to form water. If generated in a significant enough quantity, water may create problems to the catalyst such as weakening of the catalyst support, redistribution of active metals and loss of surface area.

Carbon monoxide (CO) and carbon dioxide (CO2):

Due to the decarboxylation/decarbonylation reactions, generation of CO and CO2 is high and must be removed which otherwise may compete with the sulphur and nitrogen molecules for the same active sites for adsorption. Also, significant amount of CO inhibits catalyst activity.

Contaminants:

Renewable feed sources include significant contaminants like sodium, calcium, chlorides, and phosphorus, requiring tailormade guard bed catalyst system to prevent catalyst poisoning and pressure drop build-up. Pretreatment of feed is required before being fed to hydrotreating unit.

b) Design

Heat release:

Due to feed being unsaturated, reactions consume substantial amounts of hydrogen with high exotherms requiring changes in refinery hydrogen balance, revamp/replacement of makeup and recycle gas compressors. Selection of right quenching strategy (liquid or gas) is critical. Depletion of hydrogen combined with elevated temperatures may lead to accelerated catalyst deactivation and pressure drop build-up.

Corrosion:

Use of appropriate metallurgy due to chlorides and high content of free fatty acids upstream of reactors and NH4Cl, carbonic acid downstream of reactors.

Cold flow properties:

Main product from hydrotreatment of renewable feeds are n-paraffins with high cloud and pour points and may be problematic. Selection of the right process technology and dewaxing catalyst critical for meeting jet/ diesel cold flow specifications

Product separation:

Differences in yield structure may require separate product separation equipment

Raja Raman: The Renewable fuels is a novel approach, and this broadly can be segmented by feedstocks, technology, application (Defense/Commercial), and geography. The technologies adopted for producing renewable fuels will basically require a Hydrogenation process to saturate the olefinic feedstocks or to remove the contaminants like Oxygen compounds. There are several challenges like the metallurgy improvements and optimal usage of the high value hydrogen. Since source of feedstock varies the technology needs to adapt faster to handle different species within the process variables selected while designing the units.

Dr. Abrar A. Hakeem: The bio derived renewable jet fuel and diesel are indeed in demand in Europe. The bio-based feedstocks (used cooking oil, vegetable oils and other oxygenated molecules) contain lot of oxygen and are not pure hydrocarbons. They cannot be directly used as fuels and need hydrotreatment to meet the fuel specifications. The removal of oxygen leads typically to formation of CO, CO_2 and H_2O species as side products and have an impact on the conventional commercial catalyst lifetime.

The conventional hydrotreatment catalyst is designed and optimized for removal of sulfur and nitrogen for decades and almost same catalyst is now being used for removal of oxygen / processing bio-based oils. The new bio based feedstocks demands a better catalyst for removal of oxygen and better lifetime of the catalyst as well as the hydrogen consumption in a refinery.

3. How has Process Safety improved the safety and reliability of catalyst and reactor systems?

Henrik Rasmussen, Haldor Topsoe Inc.: Process control systems are a vital part of the safe and reliable operation of any reactor application and the operators, technology licensors and catalyst vendors continuously monitor the process responses and the knowledge gained is used to re-program the safety system to ensure that the process parameters are controlled.

Rajesh Sivadasan: For safety and reliability of catalyst and reactor systems, focus for past many years has been on installing an automatic emergency depressurization (EDP) system. Auto-depressure controls serve to vent reactor systems to flare in the event of an uncontrolled exothermic excursion, to stop the reaction and prevent vessel temperatures from exceeding metallurgical limits.

In recent years, EDP has been further reinforced by use of multivariable predictive controls (MPC) for weighted bed temperature (WABT) and temperature excursions. These control systems recognize when an excursion is imminent and automatically initiate action and leave the unit in a condition where restart can be fast and easy without de-pressuring the unit.

The accuracy of temperature measurement system in the reactor has also gone further improvements with flexible type thermocouples which provides a significantly faster response to temperature change than conventional systems and allows for distribution of a greater number of measurement points throughout the bed.

Maldistribution in catalyst beds can give rise to excess radial temperature spreads which can make the reactions unstable and potentially can lead to temperature excursion. Design of both catalyst loading machines and reactor tray internals have gone tremendous improvements to ensure good distribution of liquid and gas when it falls on the catalyst bed and avoid any potential maldistribution issues.

Improved steel making process has reduced the amount of tramp elements in base metals which in turn has minimized the susceptibility of reactors to temper embrittlement. The “J” factor [J = (%Si+ %Mn) *(%P + %Sn) x104] which shows the relationship of impurities to embrittlement has come down from around 300 in the early 70’s to < 100 today.

Raja Raman: Many of the end users in the developing countries are constantly adopting to improve the standards set by the world leaders in industry which reduces the valuable loss of production and personnel. As indicated earlier several improvements in measurements and fact responding control systems has improved the reliability in conjunction with the improvements in reactor internals like quench system, distribution system, heat removal or addition system …etc. . There is further scope, and the licensors and catalyst suppliers should work closely to improve the catalyst performance and reliability.

4. Should an MOC (Management of Change Review) be processed for a new or different catalyst change out?

Henrik Rasmussen, Haldor Topsoe Inc.: It is always recommended that the start up procedure and operation parameters of new catalyst is reviewed to ensure any deviations from the current procedure are identifies and incorporated into the new procedure via an MOC process.

Rajesh Sivadasan: An MOC is used to ensure that the environmental, health, and safety risks are carefully evaluated and controlled prior to implementing significant changes and gives a chance to identify potential new hazards that could result from these changes. A change in catalyst handling procedure than typically followed, should follow a MOC review to identify potential risks. A couple of examples below show how a new or different catalyst change out procedure for which if MOC not done, could have led to hazardous conditions.

Liquid N2 cool down of catalyst beds:

Liquid N2 cool down is becoming a standard practice for many units due to significant savings in down time cost. Before catalyst is unloaded, reactors must be cooled to a temperature of about 38°C (100°F). The heat of compression introduced into the system, when circulating N2 through the recycle gas compressor, together with low ΔT between circulating N2 and the cooling media, make the final cooling stage extremely time consuming. One way to reduce cooling time is the controlled injection of liquid N2 into the circulating stream. Potential problems associated with this procedure are:

- Risk of exceeding the minimum temperature of particular piping at the point of injection, since liquid N2 has a temperature of ~ -196°C
- Heater outlet piping embrittlement due to bringing the temperature too low at the point of liquid nitrogen injection
- Compressor damage due to operating a gas for which it is not designed
- Going beyond the recommended cooling rate and the minimum reactor temperature

With a good MOC processes, these risks can be reduced to near zero.

Use of ex-situ preactivated catalyst:

Use of ex-situ preactivated catalyst can save time on start-up and ensure high catalyst activity by minimizing the chances of metal oxide reduction. It also simplifies the start-up procedure and eliminates handling of hazardous sulfiding chemicals. Potential problems associated with this change are:

- Generation of sulfur dioxide and heat when exposing the material to air for extended periods prior to loading
- Risk of spontaneous combustion in a non-inert environment during catalyst loading
- Confined inert space entry and work in a hazardous area

Again, through a proper MOC process, the risk can be reduced to near zero.

Raja Raman: Yes. This will help the end user to have the better understanding of the catalyst and the limitations in the plant at the time of design. Also, if there is a change in the catalyst or promotor compositions the MOC will clearly highlight the issues and help to clearly establish the suitability of the new catalyst, or the adsorbent used for the process. MOC can used to create an awareness to the operating, maintenance, and monitoring teams to access the changes and develop mitigating plans if they are some incompatibilities.

Dr. Abrar A. Hakeem: Yes, any change or replacement of catalyst much be processed as a Management of Change review. It is especially important to consider the new catalyst (typically a new generation catalyst) may involve a different activation profile, requirements during loading of the existing reactor, sensitivities to different initial process conditions and different expected temperature profile for a normal operation/activation.

John T. Haley, Rezel Catalysts Corp.: It seems the focus of the discussion is on fixed bed processes. What about processes with continuous catalyst change out and frequent reformulations, for example FCC processes? At what point is a catalyst change significant enough to warrant a MOC review?

Most refiners evaluate catalysts in their own, or third-party labs prior to a potential supplier change associated with a tender process, or major reformulation within a given supplier's formulation range. In general, some MOC review is recommended, even if it is inherently associated with an ongoing tender or reformulation process.

On the other hand, at what point is a more formal review indicated, and to what extent does a MOC process act to limit consideration of alternative suppliers which might being significant value or benefits to the operator? The answer might lie in the nature of the process, ease of catalyst replacement, and inherent risk, for example the lower risk with incremental daily online catalyst replacement or catalytic additive addition in an and FCCU where such changes are well understood and commonplace, compared to complete catalyst replacement in a fixed bed process.

5. What is the latest in catalyst loading technologies? How are robotics and other non-entry techniques for unloading / loading developing?

Henrik Rasmussen, Haldor Topsoe Inc.: Loading companies are looking at robotics to minimize inert entry in reactors.

Rajesh Sivadasan: Catalyst dense loading enables more catalyst to be loaded per unit volume by distributing the catalyst in such a way to uniformly increase its packed density. It uses a special dense loading device, through which the catalyst particles are scattered along the radial direction of the reactor. Dense loading machines (DLM) have undergone a program of continual development and optimization. Some of the improvements seen in current generation of DLM's are:

- Light, easy to handle and faster to install even for large diameter (3 -7 m) reactors

- Full remote control dense loading from outside the reactor without any workers inside
- Higher instantaneous loading rate (15 to 40 tons/hour compared to 7-15 tons/hour)
- Improved system to prevent catalyst segregation and ballistic separation
- Bi-directional operation to eliminate any shadow effects
- Instantaneous level control and density reporting with possible adjustment
- Radar system for continuous checking of bed profile
- Capability to load vessels up to 100 mm below the distribution trays
- Customization to load top ceramic balls
- Better dust control

In terms of robotics, one EPC has produced a remote-operated, screw-propelled machine equipped with a vacuum hose for catalyst unloading, allowing plants to avoid subjecting personnel to enclosed work environments and inert atmospheres. This was successfully used in an LNG plant to unload spent catalysts from dehydrogenation reactors.

Some other non-entry techniques for catalyst unloading/loading that has been developed are:

- Passivation technology which retards oxygen penetration and reaction in pyrophoric or self-heating catalysts by application of proprietary coating chemicals which eliminates many of the hazards and expenses related to inert entry during catalyst unloading
- Technology to remotely unclog catalyst beds without going inside the reactor by using an instantaneous blast of CO2 for loosening the catalyst agglomerates
- Remote dense loading. Control of DLM is from outside the reactor where an expert has the entire control of the machine, without any workers inside the reactor during the dense loading

Raja Raman: Most of the catalyst loading continues with the traditional approach. Robotics can play a huge role in the unloading and loading operations, and this should substantially reduce the time requirements for catalyst turnarounds. With plant capacities going up this will reduce the turnaround time. Catalyst companies should invest resources and work with the Robotic companies with the support of the end user.

Dr. Abrar A. Hakeem: The catalyst loading mostly remains confined to sock and dense loading technologies with some technical improvements. In the reactor loading and unloading technologies the digitalization of equipment used for catalyst loading enhances the safety and video inspection with drones in an emptied reactor help visualize the inside of the reactor. In case of a tubular reactors, the use of digital pressure drop across the tubes ensures emptiness after unloading.

6. Do you see Artificial Intelligence helping monitor catalyst performance in the future?

Dr. Paul Jerus: The catalyst vendor has collected the operating data with the secrecy agreements with the end user for long time. The obtained data is utilized to evaluate and monitoring the performance of catalyst and then share them with the end user. Utilization of the rapid emerging of the Artificial Intelligent combine with a secrecy agreement and a better cyber security system would definitely help to evaluate or monitoring the catalyst performance on a real time basis.

Henrik Rasmussen, Haldor Topsoe Inc.: The use of machine learning has proven to be an interesting technology.

Rajesh Sivadasan: Artificial intelligence is rapidly emerging as a tool that can greatly accelerate the ability to employ plant data to calibrate first principles models and then use domain expertise to deliver performance-enhancing insights, straight to process engineers and managers through an online dashboard. Already many catalyst vendors (UOP, Topsoe, Axens) are providing connected service solutions based on cloud-based analytics.

In this connected system, raw plant operating data is automatically uploaded through a suitable cyber security system to cloud-based simulation tools/proprietary reaction models. Data analysts and technology specialists with domain expertise compares the unit performance with KPIs, benchmarks and normalized trends in real time. Results are shared on real time through dashboards and projection tools giving an easy overview of how to optimize operation and avoid potential trouble with respect to both individual catalyst and equipment performance.

Raja Raman: AI is already being adopted in different processes using catalyst and is gaining importance in many companies. With completion of implementing advance process controls , most of the end users have developed plans to transfer to Digitization and better monitoring of techniques to improve the plant performance. The technology companies also investing at an accelerated pace to incorporate their large knowledge base into real time monitoring to improve the performance of the equipment and catalysts. Yes, application of AI techniques will be the emerging science in improving the Catalyst life Cycle.

Dr. Abrar A. Hakeem: I believe artificial intelligence can play a significant role in monitoring the catalyst performance. A lot is data is available in a refinery over a period of time using different kind of commercial catalysts which can be used an input to an AI model. These models can help monitoring the catalyst performance at various process conditions used in the refinery.

AMMONIA CATALYST

1. How is ammonia catalyst changing to meet the latest requirements?

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe has developed and launched more active ammonia catalyst, but it is the same catalyst used in fossil ammonia (gray) production that is used to make blue and green ammonia. The difference in the “color” of the ammonia is based on the origination of the Nitrogen and Hydrogen and whether CO2 from the process is captured.

2. What is average cycle length and how are next generation catalyst addressing increasing cycle length?

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe is the leader in ammonia synthesis catalysts with more than 50% of all the world’s ammonia being produced with our catalysts. The lifetime is typically 15-20 years, but here it is often equipment that ends up limiting the cycle length due to required vessel inspection etc. In summary the catalyst is typically not the imitation.

3. What is average conversion rate / selectivity, and how are the next generation catalyst addressing increasing conversion rates / selectivity?

Henrik Rasmussen, Haldor Topsoe Inc.: A more active ammonia catalyst will be able to achieve a higher conversion per pass in the ammonia loop and/or operate at a lower pressure, thus reducing the energy consumption required to make the ammonia. The conversion of the N and H to ammonia is practically 100% if the ratio of the components is correct.

4. Shape is important in Ammonia Catalyst – what are some best practices for improved shapes?

Henrik Rasmussen, Haldor Topsoe Inc.: Shape and size will impact the activity and pressure drop profile, but in today’s advanced ammonia converter design the pressure drop is so low that we purposely increasing the pressure drop in the reactor design to ensure proper flow distribution. The catalyst particles are exceedingly small to optimize the activity. These catalysts are very robust, and the main focus area is the volume activity as mentioned above.

HYDROTREATING CATALYST

1. With lower sulphur limits for hydrotreating in many products, how is the technology changing to meet the latest requirements?

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe’s HyBRIM and HySwell catalysts provides our clients with unmatched volume activity to meet the sulfur requirement while processing increasingly difficult feedstocks. A targeted R&D effort have enables us to increase the volume activity for hydrotreating catalysts many folds over the past 25 years and we continue to find ways to modify the catalysts to increase the activity through fundamental understanding the surface science of these catalyst at a nano scale level.

Rajesh Sivadasan: The demand for low sulfur transportation fuels requires that different options be evaluated for reaching the target. Even though the basic hydrotreating process configuration has more or less remained the same, technological improvements has been made in the areas mentioned below to help reach the low sulfur target.

<u>Analytical techniques</u>: Latest innovative sophisticated analytical techniques have provided fundamental insights into catalysis by shedding light on atomic-scale structure of catalysts, origin of high-activity Type II sites and detailed molecular reactions. Characterization of feedstock and fresh / spent catalysts using these advanced techniques has provided valuable information about the efficiency of the catalytic process in troubleshooting, catalyst selection, unit optimization and guided future design of new catalysts.

<u>New catalysts</u>: Catalyst production has also evolved with optimum choice of raw material and supports, better metal deposition

technology, optimized catalyst formulation, preparation methods and better activation leading to the development of high activity TYPE II catalysts.

Advent of high-throughput experimentation (HTE) is helping with faster screening of prototypes in research programs and have accelerated the development and roll out of new catalysts to the market. Refiners are also taking advantage of HTE for catalyst selection as multi parallel fixed bed reactors with different catalysts enable the possibility to vary multiple parameters in one single experiment.

Reactor Internals: Reactor internals design has undergone lots of improvement. Current new generation compact tray designs facilitate maximum utilization of high activity catalysts by allowing good temperature control and in some cases provide extra reactor volume for catalysts.

Digitization: Digitization is rapidly evolving where hydro processing units are taking advantage of advanced analytics and connected solutions to improve operation and asset reliability. It has cut complexity, allowing refinery process engineers and domain experts to interact directly with the data of interest to optimize operation and avoid potential trouble with respect to both individual catalyst and equipment performance.

Raja Raman: The catalyst formulations such as raw materials, shape, size, ability to handle contaminants effectively, and method of catalyst preparation has taken the robustness and activity levels of catalyst multifold from first generation to latest generation catalyst.

The hydrotreating technology while leveraging the above improvements in catalyst with its conventional approaches , need to adopt AI and other better control techniques. More focused R&D efforts are required to optimally utilize the utilities like hydrogen ,power and steam, maximize the equipment efficiencies, incorporate more modern online analytical equipment to measure and control the operation while consistently producing ultra low sulfur fuels and accommodate the feed stock variation. These changes coupled with the improvement in catalyst can further enhance the technology companies to leverage the process condition envelope meeting the ever growing challenges.

Dr. Abrar A. Hakeem: Hydrotreatment technologies are one of the important applications in refinery to ensure that sulfur specifications are fulfilled. The latest requirement of IMO to have the marine fuel less than 0.5 wt. % in sulfur was met with latest generation hydrotreatment catalysts which ensure the product remains within the specification. This is due to great advancement in the past done for development of type II based hydrotreatment catalysts based on Ni,Mo and Co,Mo. Moreover, refineries nowadays often use independent catalyst testing to evaluate better catalyst systems which can bring benefit and add value to the refinery.

2. What is average cycle length and how are next generation catalyst addressing increasing cycle length?

Henrik Rasmussen, Haldor Topsoe Inc.: The cycle length is unit specific and will depend on the size of the unit, the feedstock that is processed and the number of barrels that is being processes. In general, a more active catalyst will enable the refiner to get a longer cycle, and/or process more barrels and/or process more difficult feedstock, so cycle length is not the goal. Combination of latest generation guard and bulk catalysts will maximize up-time of any units. The goal is to operate the unit for maximum profitability and for most hydro processing units that is not achieved by maximizing the cycle length, but by taking advantage of the catalyst activity to process more barrels and use a more difficult feedstock.

Rajesh Sivadasan: Cycle length is determined by a number of factors like feed quality, operating severity, equipment mechanical limits, product quality constraints, refinery TAR schedule etc. Since these limits varies from unit to unit, an average cycle life is difficult to predict. Typical cycle life for a ULSD unit is between 2-3 years.

Feed is becoming increasingly difficult with molecules that are not only refractory but are also making up a higher percentage of feed requiring innovative catalyst system designs. New generation TYPE II catalysts provide extremely high activity due to improved interaction between the active phase and the support resulting in greater relative effectiveness for HDN/HDS/HDA and for uptake of metals.

Tailor made stacked combination of CoMo and NiMo catalyst system is also increasingly being used to optimize for particular reactions within “zones” in the reactor. Next generation guard bed catalysts are also reducing the possibility of unplanned shutdowns and providing increased protection from poisons to the sensitive downstream catalysts. Full benefit of these new catalyst system designs is leveraged using the new generation reactor internals. Combination of all these features is helping in increasing the cycle life of catalysts.

Raja Raman: The cycle length typically matches with turnaround of the unit at about 3 years. Some units are being pushed to 4 -5 years for easy feed stocks but the operating conditions especially LHSV, Reactor Temp, Hydrogen to Oil are to be modified to meet the individual unit requirements. Most of the sophisticated operators are trying to achieve 4 to 5 years Refinery Turnaround cycles which will be a tough challenge for even the best hydrotreating catalyst and there is abundant scope for all the key stake holders to innovate new techniques to meet the end user's expectations.

Dr. Abrar A. Hakeem: The average cycle length for a hydro processing catalyst depends on the type of process, feed composition and process conditions. For kero hydro processing the cycle length is 4-5 years, for diesel hydrotreatment (ULSD) it is around 4 years, for VGO hydrotreatment it is around 2 years and so on.

It can vary from a refinery to refinery for the same application based on type of crude being processed, actual blend feed input to a hydrotreater (amount of cracked hydrocarbons from different units in it) and impurities it contains (specially any metals).

The next generation catalysts are more focused towards handling of impurities (enhanced grading) and cracked material. With the use of bio based materials used in co -processing the focus is to handle challenges it poses with respect to hydrogen consumption, and lifetime of the catalyst.

3. What is average conversion rate / selectivity, and how are the next generation catalyst addressing increasing conversion rates / selectivity?

Henrik Rasmussen, Haldor Topsoe Inc.: For production of renewable fuels Haldor Topsoe has developed a portfolio of catalysts with a much higher selectivity than traditional hydrotreating catalysts. These industrial proven renewable fuels catalysts provide our clients with a much higher diesel and jet yields, which significantly increases the profitability of the renewable fuels units.

Raja Raman: It depends on type of feedstock. In hydrotreating step the conversion is predominantly thermal cracking and its resultant effect of the operating envelope selected like Reactor temperature and pressure adopted for achieving the required desulfurization or denitrification. In naphtha distillate hydrotreating it's minimum and it will be high on the heavy feed stocks like VGO , RCO..Etc

For Example, in VGO FCC pretreat typically one would like to maximize feed to FCC thus restricting the conversion to 18-25 wt.% max with max selectivity to Naphtha (for Gasoline/ PC modes).

On the other hand, there are now units that are being pushed upwards of 35 % conversion where excess VGO is available but will consume more hydrogen and may add more hydrotreated distillates. If the FCC is the downstream unit there is an optimal hydrogen required for achieving the desired results in FCC and pretreat unit conversion should be adjusted to meet the overall objective of the refinery. Many refineries have executed revamps to convert their VGO HT unit to Mild Hydrocracking unit with or without hydrocracking catalysts but in general, going above 35 wt. % with only HT one need to compromise on the selectivity and quality of products.

Dr. Abrar A. Hakeem: The conversion will depend on the type of process in a refinery. For a ULSD application the conversion is typically >99.90 % in sulfur for a feed containing 1 wt. % sulfur. Most of the new generation catalysts are developed so that the higher conversion is observed at lower temperatures. This is done by appropriate modification in active sites or promoters or in catalyst support.

4. Catalyst Grading is important in Hydrotreating Catalyst. What are some of the best practices in Catalyst Grading?

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe invented the use of activated hydrotreating rings for use as grading in hydrotreating and hydrocracking units and introduced these products to the refining industry in 1978. The use of graded bed products is today the industry standard for pressure drop mitigation. Our graded bed portfolio today consists of more than twenty products to manage the many different refinery feedstocks with many different contaminants. We have also successfully installed scale catcher equipment in the top of many hydro processing units in combination with graded bed products to further mitigate the pressure drop development in very higher severity units.

Rajesh Sivadasan: Importance of catalyst grading is often underestimated when evaluating the overall efficiency of a hydro processing unit. Grading must be designed to ensure maximum retention while minimizing pressure drop. Each unit should be evaluated separately by considering all factors to mitigate that particular unit's constraints and then optimized over time, based upon operating experience, together with catalyst analyses at end-of-run. Some of the best practices no particular order are:

- Feedstock characterization for determining contaminants
- Grading by activity (increasing activity)
- Grading by particle void size (decreasing size)
- Grading by catalyst pore size
- Regular sampling for accuracy and insights
- Contaminant uptake monitoring based on analysis
- Operation in right temperature range for maximizing metals uptake
- Analysis of spent catalyst, agglomerates, deposits, etc. at end of run

Raja Raman: The catalyst loading typically goes with top layer acting as a final filer of particulates & bulk impurities followed with contaminants trimming (like metals removal). Catalyst grading and usage of graded beds has matured significantly over the last three decades and almost all the licensors are advocating the graded bed system and moved away from inert balls alone systems. Then goes to gradation of catalyst based on activity depending on the hydro processing objectives. Depending on the process, catalyst selected and specific objectives there can be certain changes and normally these changes will be decided by the catalyst vendors.

Dr. Abrar A. Hakeem: Catalyst Grading is important as it enhances the life cycle of the catalyst. The combination of grading with active catalyst is a good practice to prevent pressure drop build-up in the catalyst bed. As the feedstock becomes heavier it is important to remove poisons and convert coke precursors present in the feed. This will help bulk of the hydrotreating catalyst in the reactor to last longer, achieve significant revenue and saving on catalyst replacement.

5. There are some technical papers recommending filters before the reactors. What has been your experience with filters?

Henrik Rasmussen, Haldor Topsoe Inc.: We also recommend the use of feed filters to remove the part of the contaminates. The use of twenty-five micron filters is today an industry standard.

Rajesh Sivadasan: The purpose of a feed filter is normally to extend the unit's run length by reducing the fouling rate of the reactor or to extend the standing times of equipment such as coalescers and heat exchangers. Experience shows a feed filter is not necessary if the dirt holding capacity of the reactors is large enough to hold all the retained particles until the next scheduled shut down. It is also pointless to install absolute filters to trap particles that are so small that they will pass through all equipment.

Although feed filters offer the opportunity to prevent solid particles present in the feed from entering the reactor, they are expensive and often laborious to operate, which results in frequent bypassing of the filters defeating the very purpose for which it was installed. In addition, the filters do not trap gum precursors. Furthermore, feed filters are installed before the high-pressure circuit and will, therefore, not be effective in removing solids that form or tend to agglomerate at elevated temperature and pressure conditions.

Raja Raman: Mechanical filters typically able to handle up to certain microns. There are substantial improvements in the feed filters and refiners should pay proper attention is assessing the particulates and taking necessary steps to remove the same. Refiners using multiple crude diet also face lot of issues even in Naphtha HDT units and feed filtration will be great help to improve the reliability of the plant.

For particulate removal from the feed entering the reactor, various licensors are using different technique to remove the particulates apart from feed filters and refiners should critically evaluate this option if they have chronic issues because of the particulates in the reactor feed thus the additional reactor space created can be used for increasing the active catalyst volume However, mechanical filters alone are not sufficient and better grading materials and technology (special type of trays) are needed to achieve good catalyst life.

Dr. Abrar A. Hakeem: Filters can prevent particulate matter to enter the reactor which can cause severe pressure drop issues in the reactor over a period of time. However, filters cannot remove hydrocarbon precursors or metals present in the feed.

FCC PRETREATMENT CATALYST

1. How is FCC Pretreatment Catalyst changing to meet the latest requirements?

Henrik Rasmussen, Haldor Topsoe Inc.: The purpose of FCC pre-treatment catalysts is to reduce the S and N, remove the contaminants and generate volume swell barrels. This improves the performance and the profitability of the FCC unit significantly.

Raja Raman: With Type -II hydrotreating catalyst the FCC pretreat catalyst has improved substantially for straight run feed with moderate percentage of cracked feed like Coker Gas oils. With crude diet constantly changing like more heavier crudes and other contaminant components like shale crude distillates the refiners are always challenged to meet the cycle length. Also, many refiners are expecting some conversion in these units and also the objectives of the FCC units operation are expected to change from gasoline mode to propylene mode as the gasoline demand is likely to reduce with the introduction of electrical vehicles. So right hydrogenation of the VGO is a must and refiners should closely work with licensors and catalyst vendors while selecting the catalyst.

2. What is average cycle length and how are next generation catalyst addressing increasing cycle length?

Henrik Rasmussen, Haldor Topsoe Inc.: The cycle length is unit specific as mentioned above. We have recently launched a new line of HyBRIM™ CoMo and CoNiMo catalysts, enabling low- to high-pressure FCC pretreaters to meet the challenges of new clean-fuel regulations with maximum HDS, HDN, and volume-swell activity.

Raja Raman: Currently most of the refiners are expecting minimum 3 years but the industry average is much lower. Capacities of the FCC Pretreat units in the modern refineries are quite high needing huge catalyst volumes to achieve higher cycle length . Most of the refiners try to match the refinery shutdown with the FCC pretreat and FCC units requiring the catalyst companies to constantly innovate to improve the cycle length.

3. What is average conversion rate / selectivity, and how are the next generation catalyst addressing increasing conversion rates / selectivity?

Raja Raman: In a VGO FCC pretreat typically one would like to maximize feed to FCC thus restricting the conversion to 18-25 wt.% max with max selectivity to Naphtha (for Gasoline/ PC modes). On the other hand, there are new units that are being pushed upwards of 35 % conversion where excess VGO is available but will consume more hydrogen and may add more hydrotreated distillates. If the FCC is the downstream unit, there is an optimal hydrogen required for achieving the desired results in FCC and pretreat unit conversion should be adjusted to meet the overall objective of the refinery. Many refineries have executed revamps to convert their VGO HT unit to Mild Hydrocracking unit with or without hydrocracking catalysts but in general, going above 35 wt. % with only HT, one needs to compromise on the selectivity and quality of products.

4. FCC Pretreatment Catalyst focus on N2 and Sulphur removal. What are some best practice catalysts for N2 and Sulphur removal?

Raja Raman: Sulfur specification of the FCC Pretreat will be decided by the refinery configuration and with tighter sulfur specs for gasoline and diesel like less than 10 ppm refiners will be forced to install post treat units for gasoline and the cycle oils. Depending on the Crude diet, blending streams, refinery configuration the FCC Pretreat product sulfur level has to be fixed. FCC catalyst is more sensitive to basic Nitrogen components, and they are easily removed by the FCC pretreat system.

Though there are no Nitrogen specs for the fuels but high nitrogen in the cycle oils and gasoline can hamper the desulfurization reaction and hence it will be good to remove most of the nitrogen components in the FCC feed itself. So, fixing the sulfur and nitrogen levels in the FCC pretreat requires proper planning and typically most of the refiners expect about 200 Wppm of Sulfur and Nitrogen each in the FCC product.

5. What are some best practices to reduce loss of octane in the pretreatment catalyst?

Henrik Rasmussen, Haldor Topsoe Inc.: The higher severity the operation of the FCC pretreatment catalyst is the lower the sulfur will be into the FCC. A lower feed sulfur to the FCC means that the gasoline from the FCC will contain less sulfur and it is possible to make ten wtppm S gasoline directly from the FCC and therefore no gasoline post- treatment is required. That is the best viable way of conserving the valuable octane. Any post-treatment of the gasoline will result in some octane loss depending on the technology used and the degree of sulfur reduction.

Raja Raman: Optimum selection of the Sulfur target in the unconverted oil from FCC Pretreat is the best practice to minimize the Octane loss while achieving the desired sulfur specifications in the gasoline. Many refiners try to avoid post treat but with sulfur levels less than 10 wppm it's difficult to completely eliminate post treat and extreme care is to be taken while selecting the post treatment options.

Most of the available desulfurizing processes remove sulfur from FCC gasoline by converting the sulfur to hydrogen sulfide .However other side reactions occur due to presence of olefinic compounds which also get hydrogenated reducing the Octane of gasoline significantly. Hydrotreating can never be so perfectly selective as to provide reaction only with sulfur, but the selectivity can be substantially improved by choosing milder hydrotreating conditions.

Given the typical distribution of sulfur and olefines in the FCC Naphtha feedstock the most logical approach to reduce the sulfur is to fractionate the gasoline into lighter and heavier streams. The lighter stream will predominantly contain Mercaptans sulfur and that can be more easily removed at mild reaction conditions without saturating the olefines. The heavy cut can be hydrotreated at the desired conditions required to achieve the sulfur reduction without as much concern about saturating olefines that are present in smaller quantities.

FCC CATALYST

1. How is FCC Catalyst changing to meet the latest requirements?

Raja Raman: The latest requirements of the FCC catalysts are changing to accommodate the following objectives:

1. High matrix activity for primary cracking
2. Mesapore Zeolites with appropriate structure for maximizing light olefines
3. Good Isomerization with low hydrogen transfer
4. Ability to perform without any activity loss with suitable additives to improve bottoms cracking, gasoline cracking to lighter olefines , lower the sulfur content of the gasoline,..Etc......

John T. Haley, Rezel Catalysts Corp.: While FCC catalyst technology is relatively mature, there are significant differences in material science, manufacturing technique, and catalyst performance between suppliers. Although catalyst technology is relatively mature, improvements continue to address changing feedstocks, including bio feeds, and changing market demands.

Demand for petrochemicals feedstocks is expected to continue outpacing demand growth for transportation fuels. Petrochemical's demand is driving world crude oil demand, with a 30% of demand increase to 2030, increasing to 50% by 2050. Demand growth is driven by improving economies and living standards, increased population, and technology advances, and as we have seen more recently, demand for single use food and medical packaging, and a lack of economically viable alternatives. And as far as packaging options are concerned, there are no viable, more environmental viable alternatives.

Meanwhile transportation fuel demand will be limited by growth in battery electric vehicle and hybrid vehicle demand, and improved fossil fuel powered vehicle efficiency, resulting in a decrease in transportation fuels as a percent of total crude demand. Fuel demand is expected to increase in the aviation and commercial freight segments.

The drivers require a greater focus on catalyst matrix technologies for cracking heavier feeds and LCA maximization, feed contaminant metals management, and unique zeolites or combinations of zeolites including ZSM-5, in combination with shifts in operating conditions.

Improvements in material science will be at the forefront of catalyst development in the coming years.

2. What is average cycle length and how are next generation catalyst addressing increasing cycle length?

John T. Haley, Rezel Catalysts Corp.: FCC catalysts are replaced online, continuously, at a rate of anywhere from a fraction of a percent to several percent of the inventory per day. In the most extreme cases, catalyst replacement rates might be as low as 0.5 wt.% up to, in the most extreme, although unusual example, 10% per day.

The primary drivers for the catalyst make up rate are 1 make up for natural losses of catalyst from the system, 2 to maintain target catalyst activity, or 3 to maintain a predetermined maximum level of contaminant metals on the catalyst.

Improving catalyst physical properties, metals tolerance, and zeolite stability are the key areas to focus on for extending catalyst life or maintaining catalyst life with increased unit operating severity that usually goes along with the processing of heavier, dirtier feeds, or increase light olefin production.

3. Propylene is increasing in demand. How should operators increase propylene production?

Raja Raman: Propylene production from FCC is enhanced by proper feed stock (higher Hydrogen content), Increased reactor severity (temperature, low partial pressures, high cat-oil ratio etc.) and better recovery of propylene that is produced from reactors. There are now add-on process to FCC with further cracking of light olefins present in Gasoline streams. These process integration with propylene maximized from FCC further enhances the propylene production.

HYDROCRACKING CATALYST

1. How is Hydrocracking Catalyst changing to meet the latest requirements?

Henrik Rasmussen, Haldor Topsoe Inc.: Hydrocracking catalysts system is optimized for each hydrocracking unit to balance the activity and the selectivity to meet the product spec of all the product fractions from the unit. The use of specialized zeolites helps the catalyst vendors achieve better performing catalysts.

Rajesh Sivadasan: The world market for transportation fuels continues to be driven by an increased demand for high quality diesel despite the recent COVID crisis. New generation improved hydrocracking catalysts are being commercialized with higher selectivity to diesel to cater to this demand. High activity catalyst with better selectivity is helping the refinery to extend catalyst run lengths, increase throughput or process more difficult feeds.

Demand for petrochemical naphtha has increased in some local markets. To meet these demands, new hydrocracking units are being set for maximum production of naphtha. To cater to this new demand, new naphtha maximization catalyst has been developed which has higher yields and activity as compared to previous generation catalysts. Also, improvements in flexible catalysts have been made to swing the operation between maximum naphtha and maximum diesel modes of operation.

Raja Raman: Over the years hydrocracking catalyst has changed significantly and has played a vital role in producing ultra low sulfur fuels and higher refinery margins .But the pressure continues and now many companies looking for a flexi catalyst, meaning ability to shift between Naphtha and Distillates (ATF+Diesel.) to address varying market demand. This work is going on and substantial progress has been made by some catalyst/ technology companies.

2. What is average cycle length and how are next generation catalyst addressing increasing cycle length?

Henrik Rasmussen, Haldor Topsoe Inc.: The cycle length is unit specific and will depend on the size of the unit, the feedstock that is processed and the number of barrels that is being processes. For most units, the cycle length is not the main goal. The goal is the operate the unit for maximum profitability by taking advantage of the catalyst activity and selectivity to process more barrels and generate more volume swell.

Raja Raman: Depends on the process configuration, conversion level and feedstock. Single stage units and two stage units are able to achieve an average cycle length of about three years while the two stage of the two stage units can achieve 5-6 years. The cycle length of the first stage is mostly controlled by the contaminants like particulates, metals, and nitrogen. If the preheat catalyst performance are improved the hydrocracking units can easily achieve 5 to 6 years cycle length.

3. What is average conversion rate / selectivity, and how are the next generation catalyst addressing increasing conversion rates / selectivity?

Rajesh Sivadasan: The term "gross conversion" is usually defined as,

Gross Conversion, vol% = ((Fresh feed - fractionator bottoms)/ fresh feed) *100. where fresh feed = fresh feed rate, barrels per day (BPD) or m3/h and fractionator bottoms = net fractionator bottoms product to storage, BPD, or m3/h

Gross conversion varies based on unit configuration. For a once through design, conversion ranges from 40 -70 vol%. For a single recycle unit, conversion can vary from 80-97 vol% and for a two-stage unit, conversion lies between 80 to 99.5 vol% depending on if there is a HPNA (heavy poly nuclear aromatics) mitigation option.

Catalyst selectivity is expressed as the yield of desired product at a specific conversion. Yield is determined by the rate of formation of the desired product relative to the feed rate. Selectivity is affected by operating conditions. Typical selectivity is between 70-90 wt%

As discussed in one of the previous questions, just like improvements in hydrotreating catalyst design, hydrocracking catalyst design has also undergone improvements which lead to development of next generation catalysts that operate at higher activity but giving similar or better selectivity. While higher activity allows the refiner to increase conversion, extend catalyst run lengths, increase throughput or process more difficult feeds, higher selectivity produces more of the desired product.

Raja Raman: Combination of process configuration and catalyst address the requirements . Conversions of about 55-65 % going up to full conversion units are coming up . With more emphasis on Petrochemical slowly these units are aiming to get more selectivity towards Naphtha.

4. Hydrocracking is moving to opportunity priced crudes with higher challenges. How are we addressing these opportunity crudes which have, 1) Higher Total Acid Numbers, 2) Higher Aromatic Contents, 3) Higher Metals and CRC (Conradson carbon residue) and 4) Higher Nitrogen?

Rajesh Sivadasan: In recent years, many refinery schedulers and planners have been changing the crude diet. They have shifted away from the traditional crude mix to incorporate lower priced opportunity crudes. However, compared with traditional, more easy-to-process grades, these present the refinery with several challenges.

High TAN: Higher acid feed is tackled with special metallurgy, inspection and corrosion monitoring programs, and corrosion-inhibiting chemicals.

High aromatics content: Higher aromatics in feed puts pressure on distillate qualities and makes it more challenging to produce high-quality base oils. However, the combination of hydrocracking and distillate hydrotreating technologies has led to the development of sophisticated process configurations with catalysts applied specifically designed to reduce diesel density and aromatics, achieve substantial boiling point shift, and improve cold flow properties, thus making the processing of high quantities of aromatic crudes possible.

High metals and CRC: Metals such as iron, nickel, vanadium, magnesium, sodium, and calcium. These can cause serious fouling issues, but metals removal technology has made important advances recently. The proper selection and use of guard catalysts to ensure the protection of high-activity catalysts are vital.

High nitrogen: High nitrogen content puts pressure on the hydrocracker pretreat catalyst and may constrain hydrocracker capacity. The response from catalyst suppliers has been the co-development of much more active pretreat catalysts and cracking catalysts that have both higher activity and selectivity. This combination enables more reactor volume to be allocated to pretreat catalyst to handle the more difficult feed quality without significant loss of yield or cycle length.

Raja Raman: High TAN numbers typically above 1.5 needs unit metallurgical upgrade. The rest of the properties are handled with proper gradation of HT/HC (low and high activity) catalysts.

HYDROGEN / REFORMING CATALYST

1. How is Hydrogen / Reforming Catalyst changing to meet the latest requirements?

Henrik Rasmussen, Haldor Topsoe Inc.: Haldor Topsoe has recently launched our Titan series of high performing reforming catalysts which provide higher activity and at the lowest pressure drop in the steam reforming furnaces. This will enable the operator to run more feed or operate more efficiently

2. What is average cycle length and how are next generation catalyst addressing increasing cycle length?

Henrik Rasmussen, Haldor Topsoe Inc.: The cycle length is very much dependent of the steam reforming unit design. In a Topsoe designed side fired steam reforming unit we can easily obtain 8-10 year catalyst cycle, which is difficult to get in a top fired SMR design.

3. What is average conversion rate / selectivity, and how are the next generation catalyst addressing increasing conversion rates / selectivity?

Henrik Rasmussen, Haldor Topsoe Inc.: Reforming catalysts typically convert remarkably close to equilibrium and thus the main benefit of new generation catalysts is to ensure longer lifetimes and stable pressure drops.

PANELISTS

Raja Raman

33 years experience in Refining Industry. Extensive international working experience with varying responsibilities .India, Middle east (Kuwait) , Europe (London) and South east Asia (Singapore, Malaysia). Worked in major multi nationals (Madras Refineries Limited (IOC India), KNPC Kuwait, Petronas Malaysia and UOP (HoneyWell). Major areas Technical services, Project and Technology Licensing , Catalyst Sales.

First 17 years in Refineries mainly in technical Services at various capacities . From operating Refineries experience Joined UOP in 2000 as Technology Manager at Guildford UK , Moved to Accounts Manager (Sales Licensing,Catalyst) in India. Worked as Regional Service Manager in Singapore covering SEA from 2008-11.
Moved to Delhi in 2011 as head of Technology Licensing -sales Support Group and Catalyst Sales Support Group , starting from Establishing the Group and growing it in India.

Abrar A. Hakeem, PhD

10+ years of research experience in chemical, petrochemical and refinery catalytic applications. Assignments completed in US, UK, India and within Europe for different projects (sustainability, refinery & petrochemicals) which lead to implementation of novel efficient processes and added value to the company. Leading catalysis research projects with third parties, design of pilot plants and setting up research facilities. Hands-on experience in commercial pilot plants, high throughput units, micro flow reactors and research analytical techniques.
Lead Projects on following topics:
-Efficient Hydrogen Production
-Refinery Catalysis (Resid / Bottom of Barrel Hydroprocessing)
-Petrochemical Applications (Hydrogenation, Dehydrogenation and Isomerization)
-Bio based Fuels & Co-processing
-Gas phase CO chemistry (water gas shift, FT, methanol) & Separations

Henrik Rasmussen

I have been involved with Catalyst and Process Technologies from a marketing standpoint for 31 years. Topsoe's main business areas are:
-Refining (Hydroprocessing and Hydrocracking)
-Renewable fuels technology and catalysts
-Syngas and Petrochemical (H2, NH3, MeOH, Sulfuric Acid)
-Blue and Green Hydrogen and Ammonia

I am currently involved with our Catalyst and Licensed Technlogy in all business areas.

Rajesh Sivadasan

25 years of international experience in oil industry. Deep knowledge and expertise in hydrotreating and hydrocracking technologies with roles in Technical Services, Process Consulting, Commissioning and Operations.

John T. Haley

John is the Vice President of Overseas Operations for the Rezel Catalysts Corporation

Paul Jerus, PhD.

PhD and MS degree in Physical Chemistry from Texas A&M University . BS degree in Chemistry from Chulalongkorn University. Technical Support Manager for Sud Chemie Catalysts Japan Inc., Thailand Office(2003 – 2008). Technical Marketing and Sale Manager for Sud Chemie Catalysts Inc., Louisville, Ky USA (1995- 2003). Sectional Manager of Refinery Catalysts R&D, United Catalysts Inc., Louisville, Ky USA(1981- 1995). Post Doctoral at Texas A&M University(1978-1980). Instructor at Songkla University (1971-1972). Developed many catalysts and Absorbents for Refineries and Petrochemicals processes that are still in use worldwide include Thailand. Hand on experience for Technical Service and Problem solving for catalytic processes in refineries and petrochemical. Received three Patents during the work at Texas A&M Univ. Sud Chemie Catalysts Inc. Published seventeen Technical Publications. Received the recognition award from ExxonMobil for helping them to solved the process problem and also developed a new and better catalyst for their processes.

PT. WARU TEKNIKATAMA

HEAT TRANSFER TECHNOLOGY

Waru Teknikatama designs and fabricates heat exchangers, pressure vessels and other equipment to accomplish highest degree of client satisfaction.

Products | Air Cooled Heat Exchangers | Shell & Tube Heat Exchangers | | Pressure Vessels | Plate Heat Exchangers | Other Equipment

Services | Heat transfer related calculation, design and development & troubleshooting | Detail Design Packages : Mechanical, Civil, Electrical Engineering design of plant | After Sales Services by providing spare parts and special tools for heat exchangers

Codes & Standards

Pressure Vessel : ASME Sec VIII Div 1&2, PD 550
ACHE : API 661, ASME Sec VIII Div 1
STHE : TEMA, API 660, ASME Sec VIII Div 1&2
Storage Tank : API 650, API 620, AWWA D100
Piping System : ASME Sec I, ASME B31.3, B31.4, B31.8
Condenser : HEI (Heat Exchanger Institute)
LP Heater
HP Heater
Deaerator

Certifications

ASME U, U2, S
The National Board of Boiler and Pressure Vessel Inspectors (NB & R)
ISO 9001 : 2008
HTRI Member

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Paraffin Dehydrogenation: Maximizing Petrochemicals in the Refining Hardware

Marcio Wagner da Silva

INTRODUCTION AND CONTEXT

Face to the increasingly reduced refining margin, aggregate value to the derivatives produced is a well-known strategy to the crude oil refining chain. The application of the technological routes aiming to convert lower industrial application streams into products with higher interest and with high added value is a constant challenge to refiners and researchers.

According to some recent forecasts, the petrochemical market tends to rise in the next years and, in middle term, will be responsible by a major part of the crude oil consumption over passing the transportation fuels this fact have been made the refiners to looking for closer integration with petrochemical assets through the maximization of petrochemical intermediates in their refining hardware as a strategy to ensure better refining margins and higher value addition to the crude oil. Figure 1 present an overview of the trend of growing to the petrochemical market in short term.

According to Figure 1, is expected a growth of 4,4 % in the ethylene demand and 4,1 % of propylene demand until 2022. Due to its higher added value and growing consumer market, the production of petrochemical intermediates has become the focus of many refiners and process technologies developers. Among the main technological routes dedicated to the production of these compounds, we can highlight the production of light olefins through the dehydrogenation route of light paraffin (C2 - C5), according to the local market supplied by the refiner, the capital investment in process units capable to produce light olefins through paraffin dehydrogenation can be an attractive strategy.

LIGHT PARAFFIN DEHYDROGENATION TECHNOLOGIES

Light paraffin is normally commercialized as LPG or gasoline and present reduced added value when compared with light olefins.

Dehydrogenation process involves the hydrogen remove from paraffinic molecule and consequently hydrogen production, according to the reaction (1):

$$R_2CH\text{-}CHR_2 \leftrightarrow R_2C{=}CR_2 + H_2 \quad (1)$$

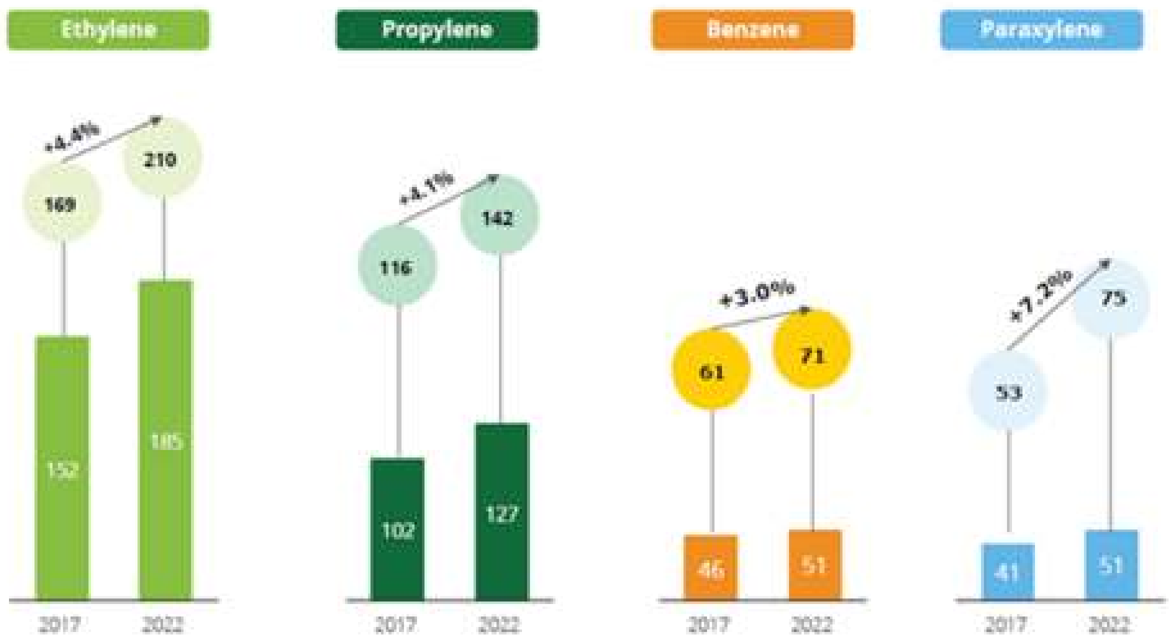

Figure 1 – Growing Trend in the Demand by Petrochemical Intermediates (Deloitte, 2019) - Note: Bars represent total demand (million metric tons or MMT), circles represent total capacity (MMT).

The dehydrogenation reactions have strongly endothermic characteristics, and the reactions conditions include high temperatures (close to 600 oC) and mild operating pressures (close to 5 bar). The catalyst normally applied in the dehydrogenation reactions are based on platinum carried on alumina (others active metals can be applied).

Figure 2 shows a schematic process flow diagram for a typical dehydrogenation process unit.

The main processes that can produce streams rich in light paraffin are physical separation processes as LPG from atmospheric distillation and units dedicated to separate gases from crude oil.

The feed stream is mixed with the recycle stream before to entre to the reactor, the products are separated in fractionating columns and the produced hydrogen is sent to purification units (normally PSA units) and, posteriorly sent to consumers units as hydrotreating and hydrocracking, according to refining scheme adopted by the refiner. Light compounds are directed to the refinery or petrochemical complex fuel gas pool, after adequate treatment while the olefinic stream is directed to petrochemical intermediates consumer market.

During the dehydrogenation process there is a strong tendency to coke deposition on the catalyst surface and, periodically is carried out the regeneration of the catalytic bed through controlled combustion of the produced coke.

Some process arrangements present two reactors in parallel aim to optimize the processing unit operational availability, in these cases while a reactor is in production the other is in the regeneration step.

COMMERCIAL TECHNOLOGIES

Due to the growing market and high added value of light olefins, great technology developers have been dedicated his efforts to develop paraffin dehydrogenation technologies. The UOP company developed and commercialize the OLEFLEX™ that is capable to produce olefins from paraffin dehydrogenation with a continuous catalyst regeneration process, despite the higher initial investment, this technology can minimize the unavailability period to regenerate the catalyst. Figure 3 presents a basic process flow diagram for the OLEFLEX™ technology by UOP Company. Another paraffin dehydrogenation technology from UOP Company is the PACOL™ process.

Another available technology is the CATOFIN™ process, licensed by Lummus Company, as aforementioned, in this case, is applied two reactors in parallel, as presented in Figure 4.

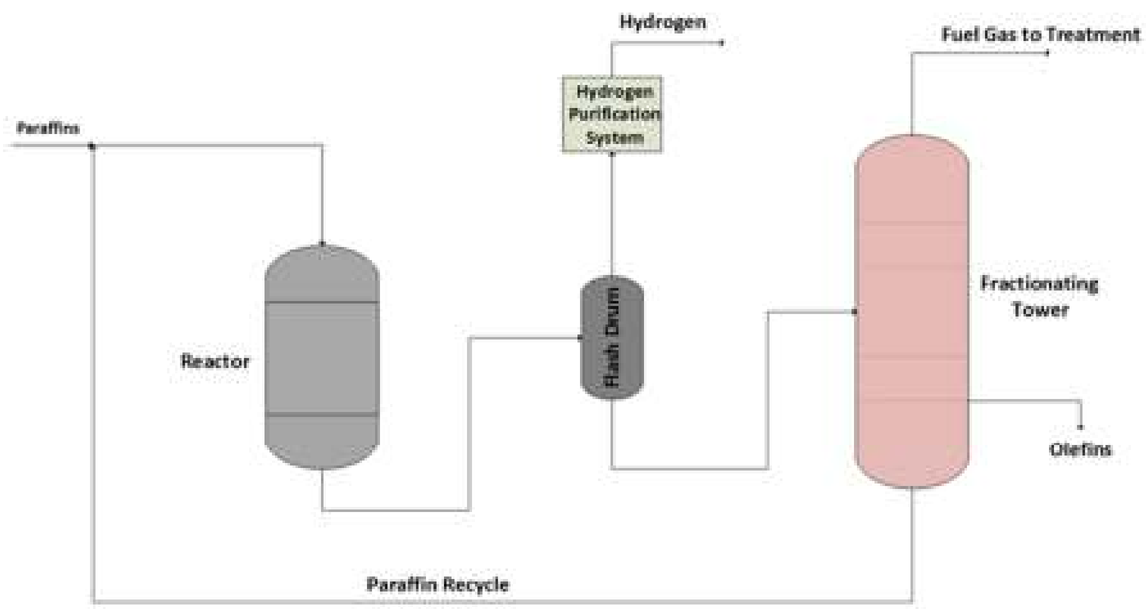

Figure 2 – Process Flow Diagram for a Typical Light Paraffin Dehydrogenation Process Unit.

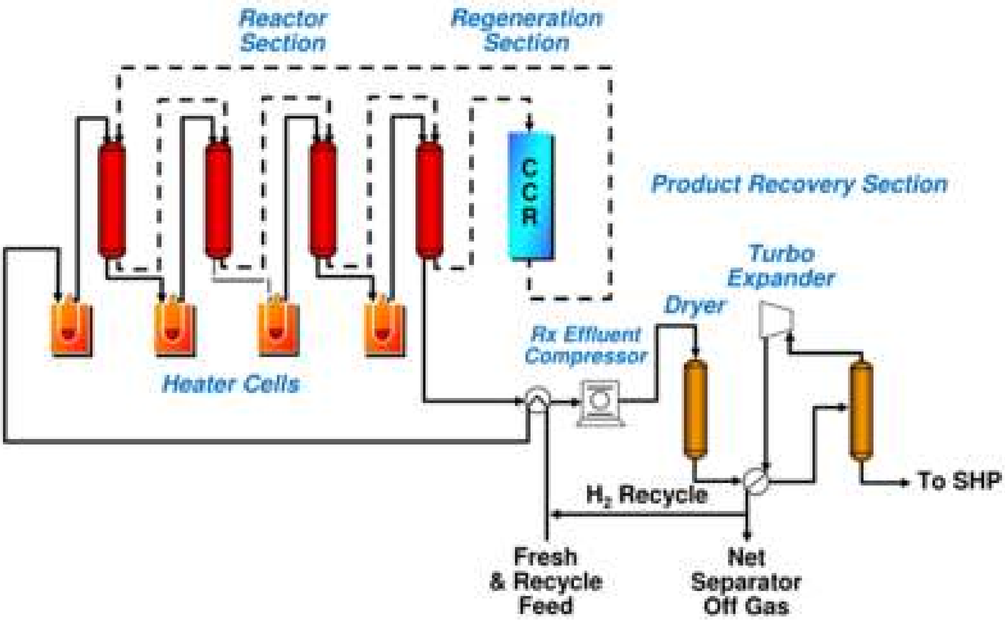

Figure 3 – Basic Process Flow Diagram for the OLEFLEX™ Technology by UOP Company (SABER, 2017)

Others dehydrogenation technologies available are the processes STAR™ commercialized by ThyssenKrupp-Uhde Company and the process FBD™ by SnamProgetti Company.

Due to his chemical characteristics, olefinic compounds can be employed in the production of a large quantity of interest products as polymers (polyethylene and polypropylene) propylene oxide and oxygenated compounds production intermediates (MTBE, ETBE, etc.).

As a process of high energy consumption, there is a great variety of research in the sense of developing more active and selective catalysts that reduce the need for energetic contribution to the dehydrogenation process. One of the main variations of the dehydrogenation process is the process called oxidative dehydrogenation that occurs according to reaction 2.

$$R_2CH\text{-}CHR_2 + O_2 \leftrightarrow R_2C{=}CR_2 + H_2O \quad (2)$$

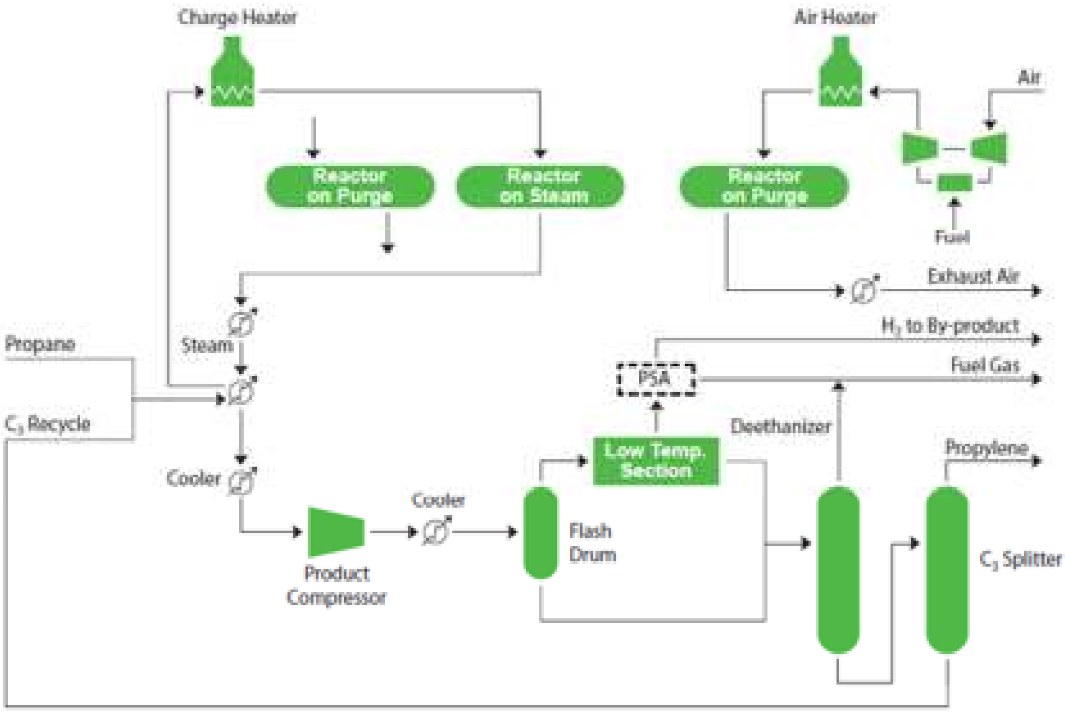

Figure 4 – Simplified Process Scheme to CATOFIN™ Dehydrogenation Technology, by Lummus Company.

This reaction is strongly exothermic, and this is the main advantage in relation of the traditional dehydrogenation process, due to the high risk of paraffin combustion against the dehydrogenation reaction.

PARAFFIN DEHYDROGENATION IN THE MODERN REFINING SCHEMES

Due to the increasingly trend of reduction in transportation fuels demand followed by the growing market of petrochemicals, the refiners are looking the add value to the processed crude oil through the maximization of petrochemical intermediates and closer integration with petrochemical assets. This trend made the technology licensors to develop more integrated refining configurations focused to produce petrochemicals against transportation fuels, like the example presented in Figure 5.

In the refining configuration presented in Figure 5, the propane dehydrogenation (PDH) technology is applied in synergy with a steam cracking unit aiming to maximize the light olefins production, ensuring maximum added value to the refiner.

Beyond the olefins production which presents high added value and growing demand, the paraffin dehydrogenation can also contribute with the hydrogen balance of the refineries, this is a key issue in the current scenario of the downstream industry considering the growing demand of hydrogen to meet the quality requirements over the crude oil derivatives like IMO 2020 and the restrictions of to produce hydrogen through traditional routes like steam reforming of natural gas due to the high amount of CO2 emissions.

CONCLUSION

Nowadays, is still difficult to imagine the global energetic matrix free of fossil transportation fuels, especially for in developing economies. Despite this fact, recent forecasts, and growing demand by petrochemicals as well as the pressure to minimize the environmental impact produced by fossil fuels creates a positive scenario and acts as main driving force to closer integration between refining and petrochemical assets.

The production of petrochemicals can ensure more added value to the crude oil reserves as well as a most noble destiny to a finite resource, in this sense, refiners inserted in markets with high demand by petrochemical intermediates can find in the dehydrogenation technologies a strong ally to ensure higher added value to the crude oil, a significant competitive advantage in the current scenario of the downstream industry.

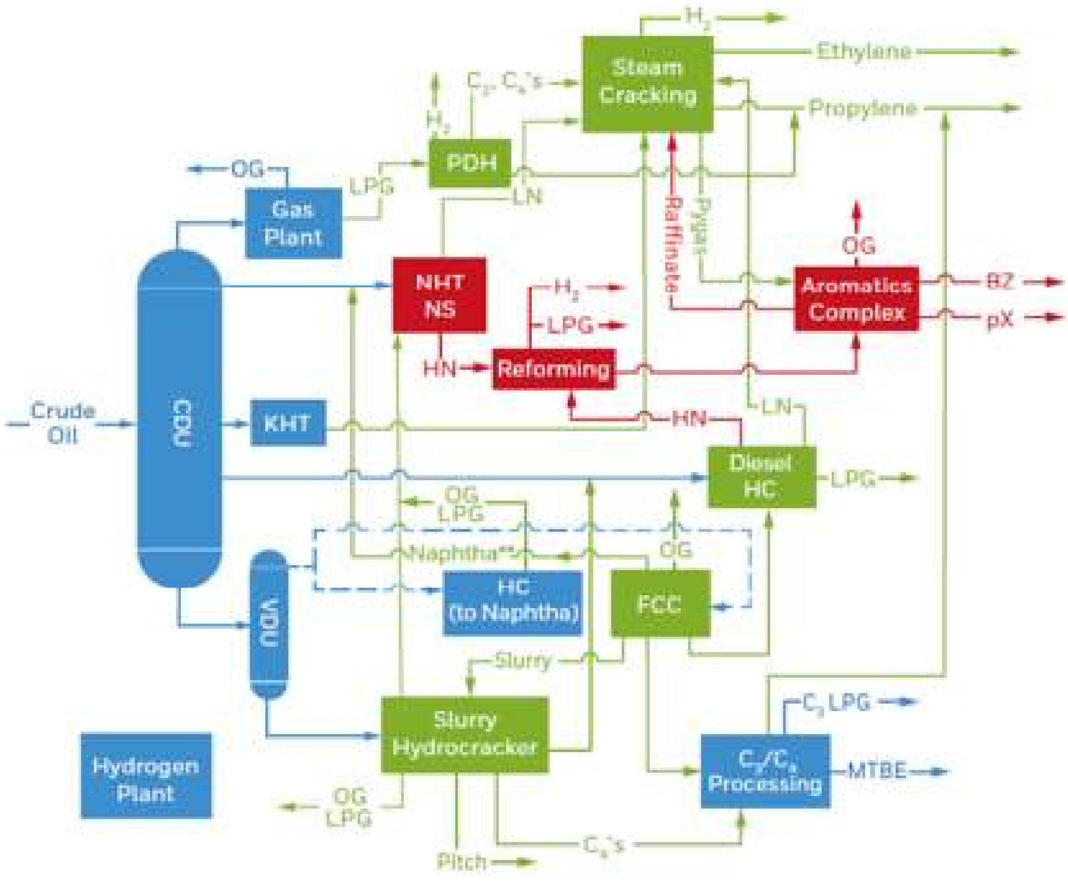

Figure 5 – Integrated Refining Scheme to Petrochemicals Maximization (UOP Company, 2019)

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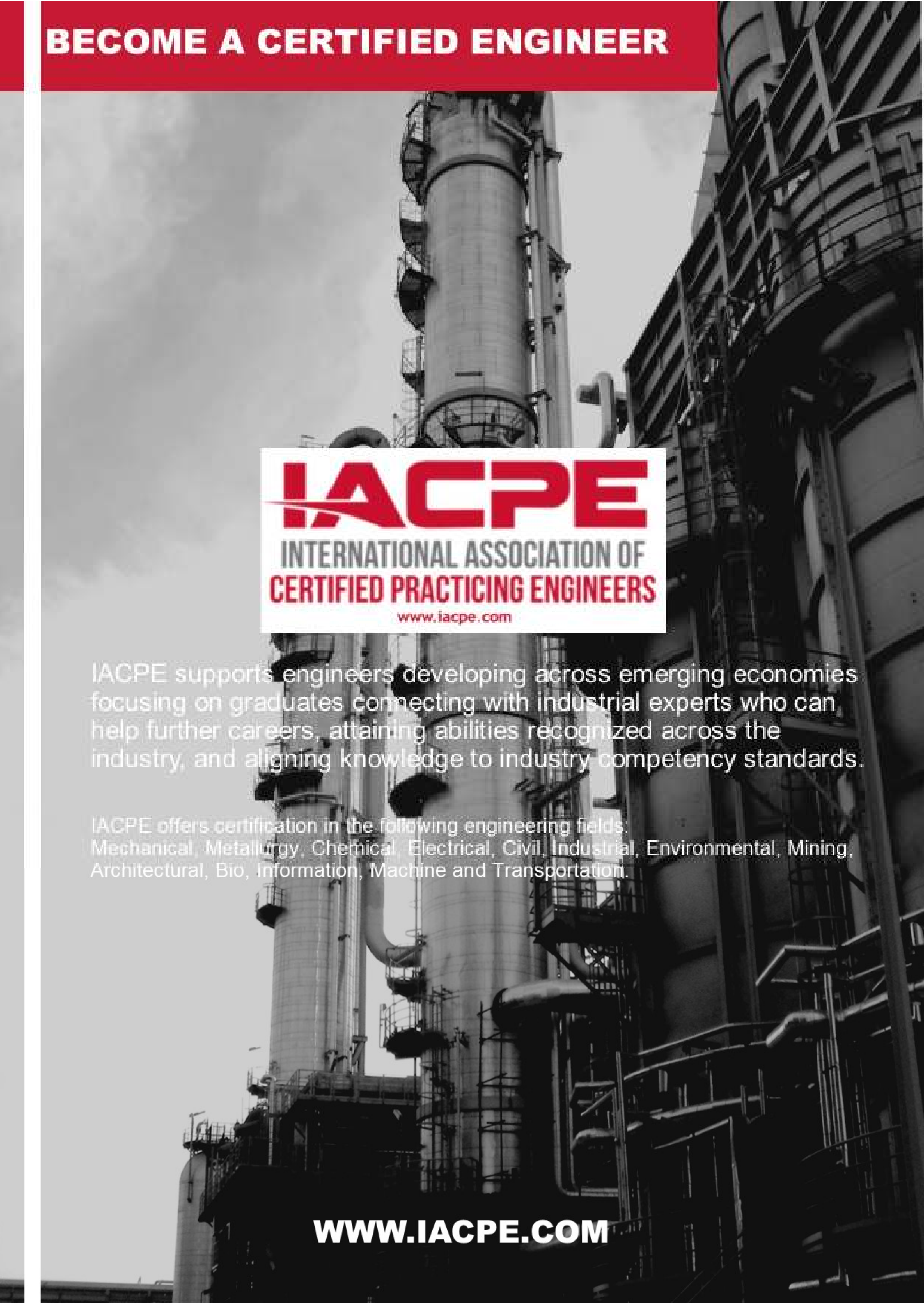
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Rock Bottom View

From DIY Home Improvement Products to Plastics Durable Goods, a Global Chemical Shortage Spikes Pricing

Ronald J. Cormier, *Engineering Practice* Contributing Author

Greetings from the porch of this old central-Texas ranch. Times are far from normal these days it seems, in an economy upended by the coronavirus, wildfires and hurricanes, shortages and price spikes. Few man-made goods have remained unaffected; materials from lumber to computer chips have been hit. As has been the case before, not even toilet paper escaped. Now, this chain of bad luck and shallow planning is cutting into one of the most basic and vital links in the global manufacturing supply chain: The plastic pellets that go into a vast universe of products ranging from cereal bags to medical devices, automotive interiors to bicycle helmets.

Like other manufacturers, petrochemical companies have been shocked by the pandemic and by how consumers and businesses responded to it. Yet petrochemicals, which are made from oil and natural gas, have also run into problems all their own, one after another: a freak winter freeze in Texas and Louisiana, which occurred back in February (see EPM March, 2021 edition; "View from Rock Bottom"). hurricanes and lightning strikes in Louisiana. More hurricanes along the Gulf Coast.
All have converged to disrupt production, and otherwise smooth supply chain distribution, which all result in rising prices. The overall situation cannot seem to find an orchestrated solution. Singularly something goes wrong, it gets sorted out, then something else happens. And it's been that way since the pandemic began.

The price of polyvinyl chloride or PVC, used for pipes, medical devices, credit cards, vinyl records and more, has rocketed 70%. Ironically, PVC supply for NorAm's consumption does not normally require structural imports at all to cover demand. Nearly all virgin PVC resin is produced close to home, but may not necessarily also include additives used in PVC recipe blends. These additives provide characteristics for UV, combustion resistance, and mold processing, etc., and used for plumbing pipe, windows, roof eves, rain gutters, and deck components. Building-block chemicals, not basic to the US and which ordinarily come form geographies to the east are, in may cases, back-ordered into 2022.

The price of epoxy resins, used for coatings, adhesives and paints, has soared 170%, on the back of ethylene. Ethylene and its by-products — arguably the world's most important base chemicals, used in everything from food packaging to antifreeze to polyester — has surged 43%, according IHS Markit.

The root of the problem has become a familiar one in the 18 months since the pandemic ignited a brief but brutal recession: As the economy sank into near-paralysis, petrochemical producers, like manufacturers of all types, slashed production. So they were caught flat-footed when the economy swiftly bounced back, and consumers, flush with cash from government relief aid and stockpiles of savings, resumed spending.

Suddenly, companies were scrambling to acquire raw materials and parts to meet surging orders. Panic buying worsened the shortages as companies rushed to stock up while they could.

Against the backdrop of tight supplies and surging demand, formed a perfect storm of Murphy's Law in action: Anything that could go wrong did. In 2020, Hurricanes Laura and Zeta pounded Louisiana, a hub of petrochemical production. Then, in February, a severe winter storm hit Texas, with its many oil refining and chemical manufacturing facilities. Millions of households and businesses, including chemical production and consuming plants, lost power and heat for days. Pipes froze and burst. Electricity generators and distribution lines were crippled. More than 100 people died.

A July lightning strike temporarily shut down a polypropylene (PP) plant in Lake Charles, Louisiana. PP is used in consumer packaging and automotive parts manufacturing. The industry was just beginning to recover when Hurricane Ida struck the Gulf Coast in August, once again damaging refineries and chemical plants. As if that weren't enough, Tropical Storm Nicholas caused flooding.

Some operators in the Gulf Coast are still shut down from Hurricane Ida. Logistics and supply chain managers have had an incredibly stressful year, at best only attempting attempting to make ends meet. The chemical shortages, combined with a near-doubling of oil prices in the past year to $75 a barrel of U.S. benchmark crude, mean higher prices for many goods. Economics 101 dictates that the consumer is ultimately the point on the value chain which will bear higher prices for these commodities. Many households, armed with cash from government aid and built-up savings, will be willing to pay higher prices, at least in the short term.

On the surface, problems in the petrochemical supply chain have been compounded by shortages of labor and shipping containers and by overwhelmed ports. Some Asian ports have been shut down by COVID-19 outbreaks. In the United States, ports like the one in Long Beach, California, are struggling with backlogs of ships waiting to be unloaded.

It has been rumored that the California port situation is caused by a driver shortage. However by digging a bit deeper, the situation is in part complicated by a California truck ban which stipulates that all trucks must be 2011 or newer models. Further, a law called CA AB 5 prohibits Owner Operators from operating at the ports, in lieu of union-controlled equipment. Traditionally the ports have been served by Owner Operators (non-union), yet California has now banned them. Long term, truckers in California are not investing in new trucks because California law also makes internal combustion-powered units illegal in 2035. The requirement is to incentivize purchase of electric trucks which do not exist as yet, at least on a widespread commercial basis.

This conundrum is forcing manufacturers to rethink some of their practices. For decades, companies moved production to China to capitalize on lower labor costs. They also held down expenses by keeping inventories to a minimum. Using a "just-in-time" (JIT) strategy, they bought materials only as needed to fill orders. But as the recession and recovery showed, keeping inventories threadbare carries now-unacceptable risk. During the summer, Ford Motor had some 25,000 F-150 trucks completed but lacking computer chips. The pick-ups were towed from their production lines to holding lots, until chips could be procured to even start them for the first time.

Since the '80s, the old management philosophy was to drive down cost to the lowest possible price point, including negligible inventories. What we are dealing with right now is a consequence of JIT. Companies have lost hundreds of millions, in some cases billions, of dollars in avoided profits because of that, because their supply chains failed. The petrochemical experience will force companies to monitor the lowliest links and single points of failure in their supply chains. This pertains not only not only big-ticket items, but the tracking needed for vital, simple plastics, as well.

Imagine trying to market breakfast cereal without availability of the disposable plastic bag to hold corn flakes or wheat bran. Now plastics are ubiquitous. Analysts expect the petrochemical crunch to last well into 2022. Ultimate improvement depends on Covid truly coming under normal control. In most cases the merchandise is loaded and sitting offshore of the US west coast, awaiting entry. The solution isn't aided by simply just throwing more ships and more containers on the water (though note that such attempts were not few in number). Single points of failure must be analyzed to avoid these crucial hangups reoccurring in the future.

Footnotes: HS Markit price history, Ford Motor production schedule


TrayHeart
Tower Internals Design
TrayHeart is a professional software that performs hydraulic calculations for all types of tower trays, random and structured packings and liquid distributors. The development of TrayHeart started in 1998 and was continued jointly by universities, companies of the chemical industry and tower internals suppliers. TrayHeart ...
is based on multiple calculation models and large databases of packings, float valves, fixed valves, bubble caps, and liquid distributor templates
is a supplier-independent tool. There are no preferred product placements or promoted designs
considers static dimensions, manways and fastenings
offers an interactive 3D-view for all designs
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Alarm Management: Guidelines for the composition of Alarm Message display in Human Machine Interface and Highly Managed Alarms

Praveen Nagenderan C

ALARM MESSAGE COMPOSITION

Alarm Messages are text strings typically displayed alongside the alarm indication in alarm displays of Human Machine Interface (HMI). Operators very often rely on the alarm message and the text description of the alarm. It is essential to provide well-thought-out messages that are easily understandable and consistent in the format given the text and character limitations of the system to help the operator diagnose the anomaly and formulate a timely response,

- The alarm message should identify the condition that has occurred in the process.
- The alarm message shouldn't duplicate other information provided by other displayed fields such as alarm priority, tag name, or alarm type.
- The alarm message should contain terms that the operators are familiar
- The alarm message should contain consistent abbreviations from a standard dictionary for abbreviations in case of character limitations. Abbreviations to be used to be in line with the company's defined and approved internal alarm management procedure.
- The alarm message should contain the text description of the device or equipment.
- The alarm message should contain Tag number of the equipment followed after the tag description.
- The Alarm message text size should be readable from the operator's ergonomically normal position.
- The alarm message display should have a defined background color and different text colors for the internally defined alarm priorities.
- Below guidelines for the color are generalized recommendations for field implementation; the onus lies with the plant operations group to decide based on the human engineering factors and provisional system limitations
    - "CRITICAL" priority class alarm message text color shall be indicated in the "RED" color.
    - "HIGH" priority class alarm message text color shall be indicated in the "YELLOW" color.
    - "MEDIUM" priority class alarm message text color shall be indicated in the "MAGENTA" color.
    - "LOW" priority class alarm message text color shall be indicated in "GREEN" color.
    - "SYSTEM" priority class alarm message text color shall be indicated in "BLUE" color.
    - The background color of the text display is to be indicated in "BLACK" color.
- A unique symbol (Example: Shape or Text) should be used to indicate each alarm priority to reinforce color coding.
- A distinctly audible indication to be used for each alarm priority.
- Apart from the alarm summary list, the alarm shall also be indicated in HMI graphics in the form of flicking or in the form of color or text indication.
- Plant Operations group to suggest the alarm message composition for system implementation to the Instrumentation department of the plant.
- The plant operations group to review the alarms message composition in line with the defined internal company procedures for the new and planned brown-field projects.
- Plant Operations group to suggest alarm message composition for any new alarm requirement in the running process plant through the internal Alarm rationalization process – Change/New request form to the plant Instrumentation department who then implements in the system and records accordingly.
- System/Instrument Engineer shall be responsible for implementation as per the request form.
- System/Instrument Engineer shall ensure and maintain the system by checking the message composition by the defined guidelines before field implementation.

HIGHLY MANAGED ALARM

Highly managed alarms are classes of alarms that require more attention from the operator and also require more administration & documentation than other class alarms. All alarms that come under the Alarm priority class of "CRITICAL" shall be considered "Highly Managed Alarms." Other alarm priority classes can also be considered for the HMA category if it falls under the below-mentioned criteria.

Below mentioned criteria to be used for defining Highly Managed Alarm class:

- Alarms which are critical to process safety of the protection of human life
- Alarms for personnel safety or protection.
- Alarms for environmental protection
- Alarms for commercial loss
- Alarms for product quality
- Alarms which are defined as critical by process licensor
- Alarms which are defined as critical as per company policy

All identified HMA alarms should have approved written procedures on causes for the alarm annunciation, operator action on alarm annunciation, communication hierarchy on annunciation of alarm, and consequences of inaction by the operator.

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Praveen Nagenderan C is a Chemical Engineer with experience in the field of Oil & Gas production & processing facilities and Refinery process units. Professional experience covers Production operations, Facility surveillance, Technical safety, Technical Services - Process, and Projects. Praveen has worked with major Oil & Gas companies in India, namely Nayara Energy, formerly known as Essar Oil Limited, Cairn Oil & Gas, and Expro North Sea Limited.

Seal Oil Systems in Centrifugal Compressors

Jayanthi Vijay Sarathy

Spending a fortune to buy the state of the art machinery is no big deal when compared to the headaches that follow due to bad maintenance of gas compressors. The dreaded situation for any engineer is when the hard earned piece of machinery starts to leak and reek oil, enough to make engineers work overtime. A compressor's mechanical seals are the barriers that prevent gas from escaping beyond the allowable limit and keep the safety inspector from issuing a notice. These mechanical seals have oil circulating in the sealing chamber to prevent gas from escaping to the ambient surroundings, while maintaining the required pressure inside the compressor casing. The following article briefly covers 8 points to address when the centrifugal gas compressor starts to suffer from oil leakages from the mechanical seals, right into the drip pan.

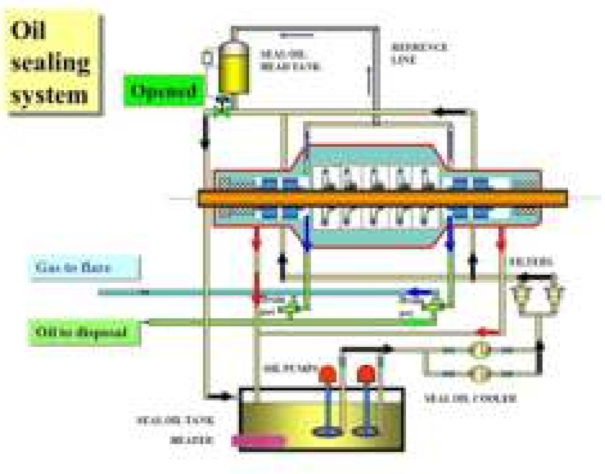

Fig 1. Compressor Seal Oil System [Ref. 4]

There are two methods of combining lube oil & seal oil systems: booster & combined systems. In the booster system the oil pressure is raised to the pressure required for lubrication purposes & then part of it is raised further to the pressure required for sealing. Alternatively in a combined system, all the oil is initially raised to the required pressure & flow, and then reduced to system component requirements. The hardware & operation of each of these types of oil systems are identical or nearly identical.

Mechanical face seals & floating ring seals are supplied with seal oil at a defined differential pressure above the reference gas pressure (pressure within the inner seal drain). The flow of seal oil is regulated by a differential pressure regulating valve, which changes the pressure of the seal oil relative to the changes in system gas pressure or as shown in fig. 1, by a level control valve that maintains a constant level in the overhead tank. The oil in the overhead tank is in contact with the reference gas pressure via a separate line, with a static head providing the required pressure differential. In addition, the oil in the overhead tank compensates for pressure fluctuations & serves as a rundown supply if the pressure is lost. If the level in the tank falls excessively, a level switch shuts down the compressor. A moderate oil temperature is maintained by a constant flow of oil through overhead tank.

For mechanical contact seal system, a regulating valve maintains the reference gas & the seal oil at constant differential pressure. As the name indicates, the mechanical contact seal serves as a mechanical standstill seal when the compressor plant is shutdown. The seal oil is split into two streams in the compressor seals. Most of the flow returns under gravity to the reservoir. A small quantity passes through the inner seal ring to the inner drain, where it is exposed to gas pressure. This oil, mixed with the buffer gas flows to the separator system, which consists of a separator & a condensate trap on each side. The separated gas flows to either the flare stack or to the suction side of compressor while the oil flows back into the tank for degassing. If oil is used as a sealing liquid & reused, degassing can be accelerated by heating or by air or nitrogen sparging. Sparging units perform on-stream purification of oil which can keep lubricants serviceable for a long time. Only if the oil becomes unusable, is it led away for separate treatment or disposal. The quantity of oil passing through the inner drain in a modern centrifugal compressor is small & ranges from 5 to 50 litres per day on new machines.

LOW FLOW CONDITIONS

A centrifugal compressor experiencing low gas flow at the suction conditions is a classical situation when surging can occur. During this situation, the high speed compressor shaft vibrates such that the compressor shaft on which the impellers are mounted begin to hammer and bounce off the face of the mechanical seals. This is a noisy affair and hence it is to be ensured that the compressor has provisions like an anti-surge system to prevent low flow conditions at the compressor suction.

UNEVEN WEAR OF ROTATING SEAL FACES

The rotating faces of the compressor seals rotate creating a wear pattern that is uniform. Any unevenness caused during rotation is a situation when the seal oil leaks more than expected. With unevenness on seal faces of a face contacting seal, high spots are formed that needs to be grounded down for a snug fit of the static and rotating seal faces. One method to attend to this issue is to lap the shaft sleeve and impeller hub against the seal's rotating face to grind the high spots by a few mils (1 mil = 1/1000 of an inch) till the wear pattern matches against both surfaces.

STICKY SPRINGS ON STATIONARY SEAL

Seal Oil is pumped from a seal oil tank using pumps after filtration. When the Seal oil tank has particulate matter like sludge, accumulating, the 'hard to filter' particulate matter can get dispersed with the seal oil and ends up in the compressor seals. Face contacting seals have a rotating and a stationary seal face that is tightened by a spring to cause sealing when the seal oil system is not in operation. If all that sludge debris accumulates in the seals, it can cause the spring to struggle to wind and kiss the stationary side against the rotating side face.

SEAL OIL QUALITY

The viscosity of seal oil is a key parameter that determines heating, wear & tear problems. If the seal oil contains water, it not only reduces viscosity to wear out the seal but the contaminant in the associated water would cause fouling and clogging. While using high viscosity oils, it can exacerbate by causing too much drag on the compressor shaft when the rotating and stationary part come into contact. The overwhelming majority of compressors are best served by premium grade turbine oils with ISO viscosity grades of 32 to 46. However there are many different types of compressors & each manufacturer is likely to recommend lubricants that have been used on a test stand and at controlled user facilities.

ADDITIVES IN SEAL OILS

Seal Oils contain a host of metallic additives for anti-foam, anti-oxidation, anti-wear, demulsification purposes, etc. Due to the high stresses and temperatures, these metals tend to precipitate out and cause fouling on the seal faces. Visibly it is noticed as streaks of various colours on the shaft sleeve like a rainbow. These additives constitute anywhere between 0.5% to 5% of the total oil volume for gas compressor applications. For e.g., Zinc in the form of Zinc-dialkyl-dithio-phosphate (ZDDP) is used for anti-wear and anti-corrosion purposes. Ideally seal oil should contain < 5 ppm of zinc compounds.

COMPRESSOR PRESSURIZATION PRIOR TO OPERATING SEAL OIL SYSTEM

Seal Oils systems are to be kept running even after a compressor is shutdown. This is not only to avoid any process gas from escaping to the ambient but also to prevent any particulate or liquid debris from being pressure-pushed into the space between the seals or the seal sleeve when a loss of oil pressure occurs.

BUFFER GAS CONTAMINATING SEAL OIL

Gas compressors that operate with Hydrogen sulphide (H_2S) in the process gas should not be allowed to mix with seal oil. However H_2S is a poison that not only contaminates seal oil but can also be lethal at higher concentrations. To prevent H_2S from escaping, a buffer gas (or barrier gas) like nitrogen is used as a barrier between the process gas and the seal oil. The pressure differential used to maintain any process gas from mixing with the seal oil is around 3 bar pressure for non-sour applications and can go upto 5 bar pressure for sour gas applications. If the buffer gas pressure exceeds ~5 bar pressure, the reverse can happen, i.e., where buffer gas (nitrogen) is ingested into the compressor casing. In such a situation the process gas exported to the client through the gas pipeline would not meet the client's gas purchasing specification.

SEAL OIL DEGASSING TANK

In Oil & Gas applications, raw gas that is received contains hydrogen sulphide (H2S) which is removed using Methyl-di-ethanol amine (MDEA). Raw gas is allowed to pass through a tray/column tower from the tower bottom and MDEA is fed from the top of the tower. Upon coming into contact with MDEA, hydrogen sulphide (H2S) is mostly removed. However in doing so, there's always some amount of MDEA and left over H2S that exits from the top of the tower along with process gas. When these gases reach the compressor, tiny amounts of MDEA laden gas bubbles contaminate the seal oil.

The seal oil system works on the principle of pumping oil to the compressor seals and recycling back to the seal oil tank that doubles up as a heated degassing tank as well (operating at ~850C to vaporize any carried over gases). MDEA on the other hand has a flash point of about 1220C and does not vaporize but instead settles to the bottom of the tank. With constant accumulation of MDEA, the liquid level in the degassing tank can rise till the stand pipe and can get entrained into the seal oil. Hence it is always a good idea to open the drain valve (say, once a month) at the bottom of the de-gassing tank to evacuate any liquids.

AUTHOR'S NOTE

Seal Oil systems for gas compressors can be considered becoming outdated, since gas compressors nowadays have 'dry gas' used for sealing purposes. However there are many old gas compressors in the industry to this day which operate with seal oil systems. This article is about sharing a few tips on seal oil technology which probably might be put to rest in the next couple of decades.

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Five Career & Leadership Tips for High-Performing Professionals in STEM

Dr. Tina Persson

Being a high-performing leader in the STEM field comes with many challenges and heavy responsibilities. As a leader, you must rely on your abilities to efficiently work towards company goals, guide and lead people.

However, it's far more logical for STEM professionals to prioritize and focus on the technical aspects of a problem. By using our creative, analytical, and problem-solving nature, we identify new innovative solutions.

As I am writing this article, many of us are returning to a more normal working situation following the height of the pandemic. Still, depending on the country, many people are required to continue working remotely. For some, remote working is a relief because the workforce is finding that they have a lot more spare time for personal and professional activities when they do not have to commute and have a more flexible working schedule. But, at the same time, many others feel isolated and long to go back to the office. So, what will be the new office style? Will we all get back to the office again? And how will the unique circumstances encountered over the past two years change the way leadership works?

The office environment of the future that we are most likely to see is a blended style of working. Some people in your team may work 100% remotely, while others will commute and be in the office 2-3 days per week, maybe even less. The new office style opens up a new and exciting perspective regarding recruitment and the streamlining of the reporting systems. But, with those positives comes a new set of challenges that the managing team will need to think more strategically to resolve. I would like to take this opportunity to ask you: What are the lessons we have learned during the pandemic, and how can we take advantage of what we have learned to prevent returning to “the time before Corona"?

I often hear this response from leaders: “We quickly transformed our organization from an onsite office to an environment where we could work remotely. Considering the circumstances and the speed of the process, we learned that we quickly managed to adapt to the new situation. The extreme case forced us to be creative and innovative in our solutions and look at our business from a top-down perspective.

Explorative coaching questions: What would happen in your organization if you continued with the creative and innovative transformational process you had during the pandemic? Is it possible? I say YES! Especially if you build up the leaders in your organization. How many of your leaders are ready for the challenges ahead? What weaknesses do you see in your leadership and organization?

If you want your company to be successful in the future, those last two questions can't go unanswered.

- Great leaders will attract the best, top-performing STEM professionals.

STORY FROM A HIGH-PERFORMING STEM PROFESSIONAL

I remember when I took my first management role. Honestly, I had no training for what was coming up. As a high-performing professional trained in the technical aspects of my work, I had no basic leadership training. My leadership style mainly focused on technical support and guidance, and how to get things done according to a plan. My communication style was telling people what to do and how to avoid mistakes. As a leader, I felt insecure , and I got easily irritated, even angry. I couldn't hide my feelings in stressful situations.

The turning point came when a person in my close surroundings said the following: Tina! You have excellent skills; you are a high performer, but working with you isn't pleasant. People are afraid of you. What are you going to do about that? I was in shock, but it was a critical turning point in my career. I decided to change.

The book Emotional Intelligence written by Daniel Goleman gives a comprehensive insight into the power of self-awareness, self-management, social skills, and empathy. When I read the book, I realized I had not understood the power of EQ and the power of leading an efficient team. Today, we know that you need to score high on all four EQ skills to become an effective leader. The great thing is, you can learn and improve your EQ skills continuously throughout your life.

Today, I have changed and I feel much more comfortable leading people. I have adopted a coaching leadership style; Avoiding micromanaging, and when I start feeling irritated, I know it's because of accumulated energy. I cure the accumulated energy with a HIT class in the crossfit gym. In addition, I have improved my empathy and social skills through self-awareness training, learning how to manage my feelings, and asking questions to understand my surroundings.

But in the end, you, as leaders, must want to change. It's not enough to read the book. You must implement the lessons you learn and work on yourself. As a career & leadership coach, that is what I help professionals with today – becoming the best version of themselves.

I could share many success stories from high-performing professionals in the STEM field, showing that social skills development led them to top positions in the corporate world. However, they all shared a common wish – They wanted to change.

Finally, I want to share some coaching tips on how to stay focused and effective while changing your leadership style.

5 TIPS TO BE A MORE FOCUSED HIGH-PERFORMING STEM LEADER

1) Become self-aware

Build and grow your self-awareness. Leaders who listen to their inner voice have more resources to draw on and make decisions from.

Connect with your inner self. This means listening to all your emotions. For instance, your gut feeling may be telling you that a specific decision will be terrible. Your intuition should not be ignored. Self-aware leaders also connect better with their team.

2) Strengthen your mental focus

With iPhone, e-mails, and Facebook, it's easier said than done to keep a mental focus in today's world. But, unfortunately, almost every single one of us has a hard time achieving mental focus.

But as a leader, you cannot afford to be distracted. After all, how are you supposed to lead a focused and productive team if you cannot remain focused yourself?

Here are some simple steps that you can try to strengthen your mental focus:

- Eliminate distractions – schedule your time effectively
- Stop Multitasking – Learn to say NO
- Practice mindfulness – Your reset button
- Take short breaks - Getting the energy back
- Organize your tasks – Organizing your to-do list by priority

3) How to organize - apply the Principle of 4Ds

- Do the tasks that only you can do.
- Delegate the tasks that are important but can be handled by someone else.
- Delay the tasks that do not have specific or approaching deadlines.
- Delete the tasks that are not important.

4) Use the 3Rs Principle

- Reflect. In the morning, take some time to sort out your priorities. That way, you start your day with a purpose and defined goals.
- Remember. It is easier to get lost in the activities of the day. Therefore, it is essential to step away for a few moments. Take a breather.
- Regroup. Before moving on to the next task, you should take a little time out. Even if you take it for 30 seconds.

5) Plan a consistent sleep schedule

In the end, it doesn't matter how much you train your leadership. If your brain and body are not getting enough rest, you will not stay focused, and you will not be an effective leader.

Sleep is crucial for your brain to perform well. Therefore, you must adjust your sleep schedule. The key is to go to bed early and wake up early. Waking up early gives you enough time to get a head start on the day.

You are only able to manage others if you can handle yourself.

Good luck with your leadership

AUTHOR

Tina Persson, PhD spent 20 years in academia as a scientist and leader, Tina entered the corporate world for over eight years as a Headhunter, Branch Manager, and Consultant Manager. Alongside her corporate career, her entrepreneurial spirit and business mindset created an opportunity. She proudly serves as the founder of Passage2Pro AB and Aptahem AB (a biotech start-up featured in over 20 scientific publications). Tina is also the inventor of 2 scientific patents, and she hosts two podcasts.

As coach Tina has supported 1000+ higher professionals, and performed 500+ assessments to entangle and pave the way for their career success stories. Tina's multifaceted background, creativity, and experience as a coach allow her to follow and transform her clients. She has developed an approach aimed at growing her clients' skills and building a long-lasting trust in their abilities and goal setting to become successful leaders in any organization or business.

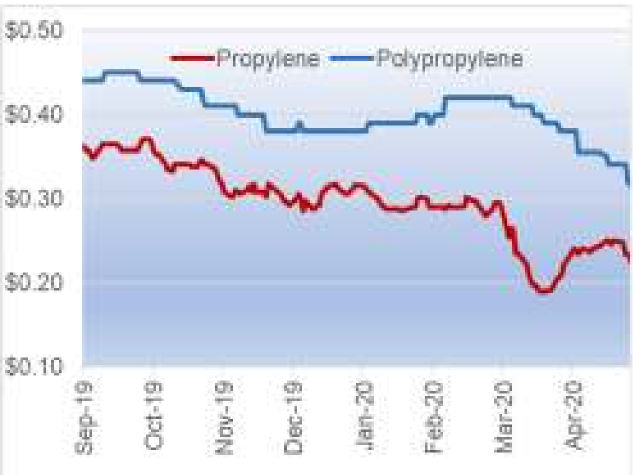
WIN, LOSE OR DRAW
A Trip Down Memory Lane and a Scorecard

Kathy Hall, Executive Director Product Management, Global Petrochemicals for OPIS

Today's news about the supply chain crisis ain't news to us …. It's just now hitting consumers at home. But some of the events and trends that emerged along the way were a surprise.

January 2020
It was a typical end to the year, demand drops off, operating rates are reduced, and we began 2020 in the usual way, but Lunar New Year celebrations in Wuhan gave rise to what appeared to be an epidemic, and the world watched what appeared to be a localized situation.

In the resin supply chain, prices fell, but feedstock prices fell even faster.



- The winners in the first quarter of 2020 were resin producers, although the panic was just beginning.
- The losers were the monomer makers, as commodities like ethylene reached historic lows (8 cents per pound!).
- It was a draw for consumers as they were still able to get supply and pass along costs.

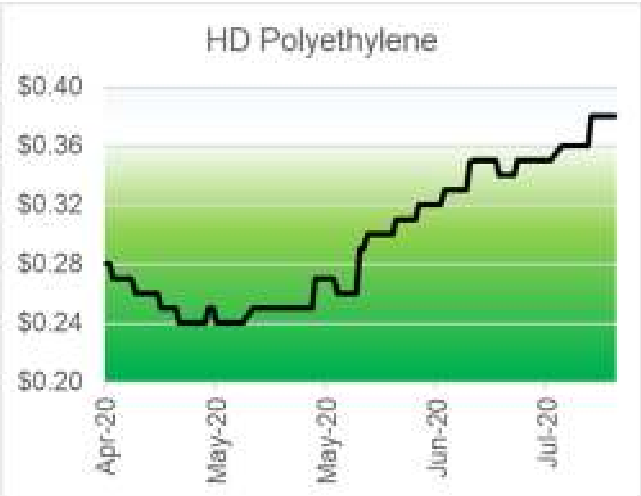
By May 2020, it was becoming apparent that Lockdown could be a long haul.

Demand and consumer behaviors adjusted. Businesses pivoted. Industries arose.

Staying home also shifted packaging demand in significant ways.

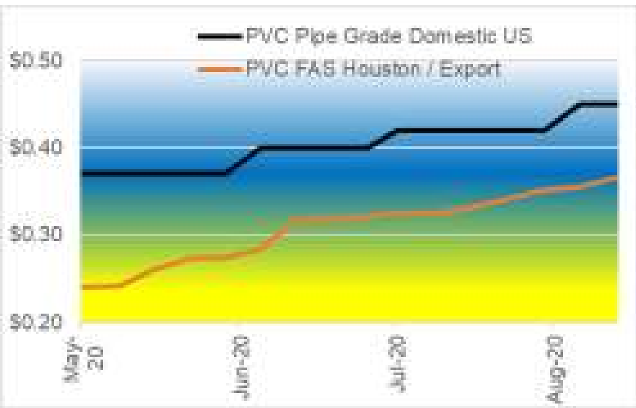
Single-use plastic was all the rage!

- Plants increased rates as workplaces adjusted & workers returned
- Exports resumed to an extent – high US prices limited activity
- Restocking of goods along the supply chain boosted demand
- Demand for single-use packaging, PPE and medical equipment stayed strong



- Trends were shifting but resin producers remained the winners.
- Upstream chemical prices improved, but performance was a draw at best.
- Resin consumers were beginning to lose, not in control of price or availability.

PVC Settles into an Unusual Year

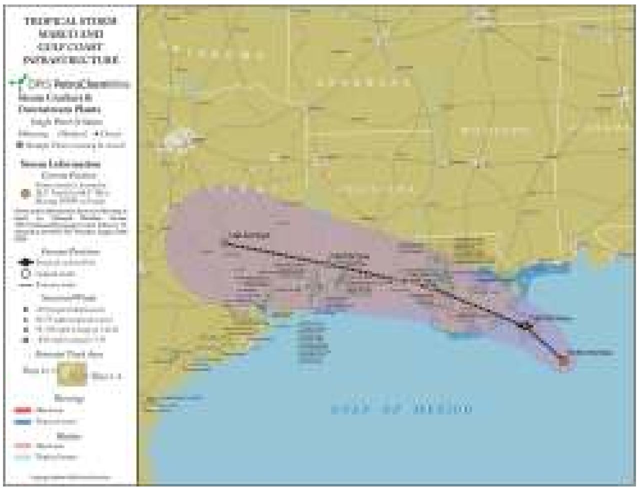


- Export prices rose, but volumes remained low and offers became less workable.
- Domestic PVC prices stood still in May but a resurgence in Home Improvement markets enables price increases starting in June.

And Now, For the Weather: August 2020 and the Aftermath

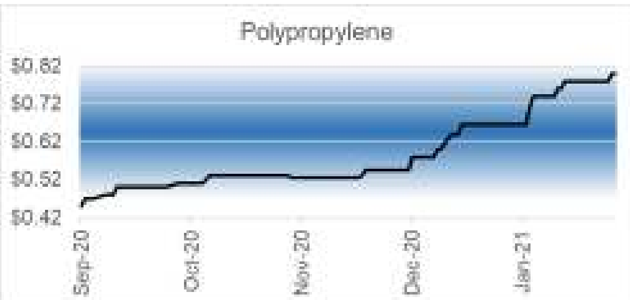
August 25-27, 2020
- Laura made landfall as a Category 4 Hurricane, which at the time was the strongest landfall on record since 1856.
- Laura's path ran through the Lake Charles area, forcing many plants there to close.

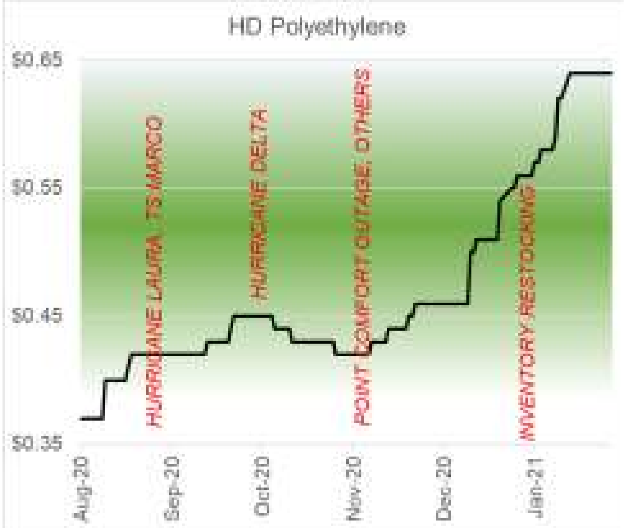
- Marco formed after Laura but reached the Louisiana coast around the same time, from a different direction.
- Not nearly as strong as Laura, Marco never developed beyond a Category 1 hurricane and was a Tropical Depression by landfall.
- Its main effect on the same area affected by Laura was flooding.



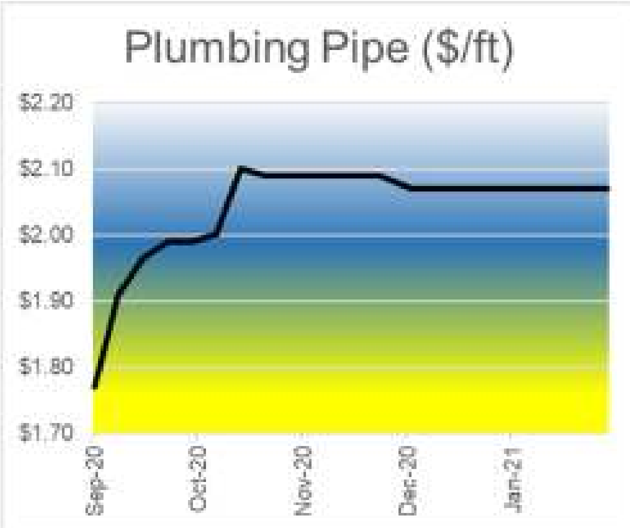
- A busy storm season begat storms named for the Greek alphabet by the end of September.
- Hurricane Delta hit Louisiana late October 9 as a Category 2 hurricane.
- It too passed through Lake Charles, where some sites were still shut from Laura/ Marco.

The effect was devastating – unless you were a resin producer. You could name your price.





- In particular, pipe order backlogs begin to get serious and fresh 2021 demand looms.



Some pipe order backlogs became so severe that producers stopped taking orders entirely and froze pricing or reverted to old pricing

February 13, 2021: Winter Storm Uri

Every chemical and plastics plant in Texas shut.

- The winners were companies that had high inventories.
- The losers were companies needing product.
- It was a draw for exporters as they could re-direct to the domestic market.

August 2021: Hurricane Ida washes over Louisiana – largely sparing Lake Charles, but some plants (Geismar, Taft, Norco areas) are still shut or struggling.

- Plastic buyers (including pipe makers) continue to struggle to get enough product to catch up on backlogs from 2020.
- An ongoing international slowdown of container ships has made importing and exporting plastic an expensive and slow nightmare.
- It's not over yet! But what can we do but wait for the future to unfold?

We can MANAGE RISK.
What will the 4Q 2021 Scorecard look like?
OPIS PCW Forward Curve: Oct 22, 2021:

	Ethylene	PGP
Oct-21	0.35000	0.76500
Nov-21	0.34250	0.74500
Dec-21	0.34250	0.72250
Jan-22	0.33125	0.71875
Feb-22	0.32250	0.71500
Mar-22	0.31375	0.71125
Apr-22	0.30625	0.70250
May-22	0.29875	0.69375
Jun-22	0.29125	0.68500
Jul-22	0.28625	0.67625
Aug-22	0.28125	0.66750
Sep-22	0.27625	0.65875
Oct-22	0.27250	0.65000
Nov-22	0.26750	0.64250
Dec-22	0.26250	0.63500
Dec-22	0.25125	0.58000

OPIS PCW Forward Curve: Feb 1, 2021:

	Ethylene	PGP
Feb-21	0.32375	0.81000
Mar-21	0.30875	0.77000
Apr-21	0.29125	0.73000
May-21	0.27250	0.69000
Jun-21	0.25375	0.65000
Jul-21	0.25375	0.63250
Aug-21	0.25500	0.61500
Sep-21	0.25750	0.59750
Oct-21	0.26000	0.57250
Nov-21	0.26250	0.54750
Dec-21	0.26375	0.52250
Jan-22	0.26375	0.52250
Feb-22	0.26375	0.52250
Mar-22	0.26375	0.52250
Apr-22	0.26375	0.52250
May-22	0.26375	0.52250
Jun-22	0.26375	0.52250
Jul-22	0.26375	0.52250
Aug-22	0.26375	0.52250
Sep-22	0.26375	0.52250
Oct-22	0.26375	0.52250
Nov-22	0.26375	0.52250
Dec-22	0.26375	0.52250

Some people knew what 4Q 2021 would look like because they bought and sold the market a year ago, or six months ago. Futures markets eliminate unforeseen events affecting your commodities. For physical futures contracts, they also assure delivery of propduct.

- Managing risk is the only way to forecast your own future.
- Managing risk protects you from volatility, which is rarely foreseen by even the best forecasters.
- Everyone can win when they manage their risk rather than take their chances.
- Chemicals and plastics can manage risk through active futures contracts for ethylene and propylene.

AUTHOR

Kathy Hall monitors market news and behaviors, including plant shutdowns, import/export activity and chemical industry investment commitments. She has watched these markets for 25+ years and can speak to the markets' history and evolution. Her perspectives on what drives and influences these markets are popular in the marketplaces and she is a sought-after speaker and trainer on these key markets. Kathy spent 10+ years at Platts, started PetroChem Wire in 2007 and sold the company to OPIS (owned by IHS Markit) in 2018.

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