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CHEMICAL ENGINEERING WORLD

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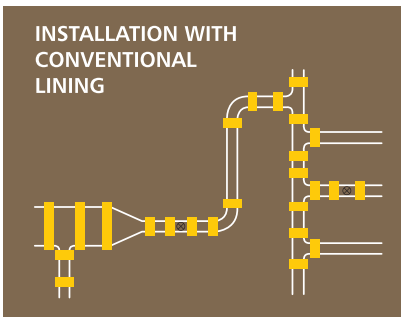

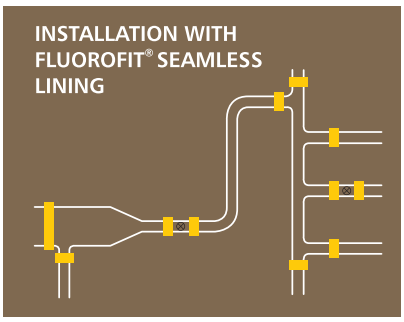

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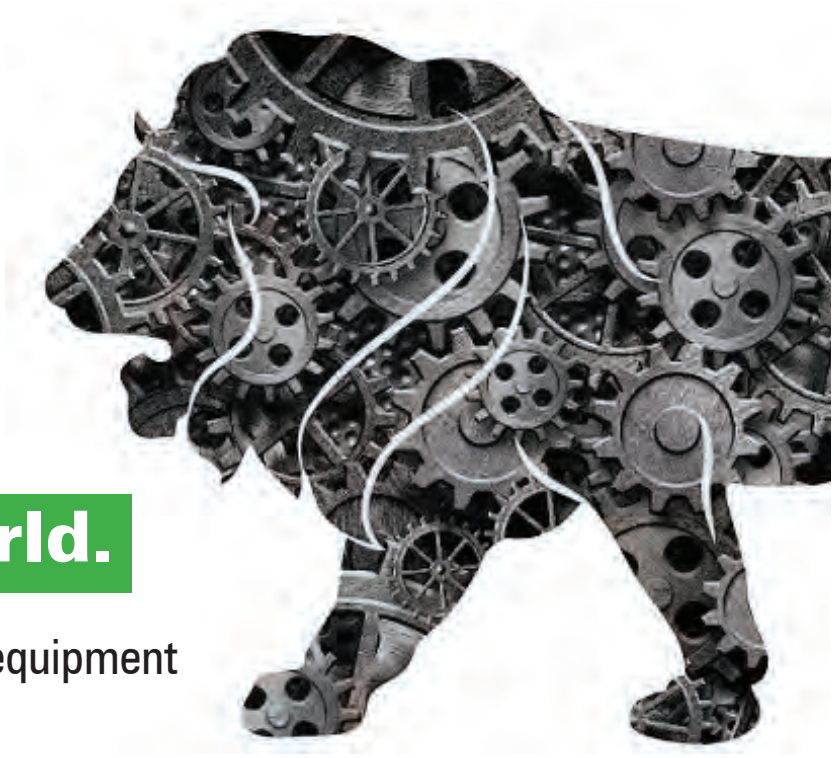

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Maulik Jasubhai Shah

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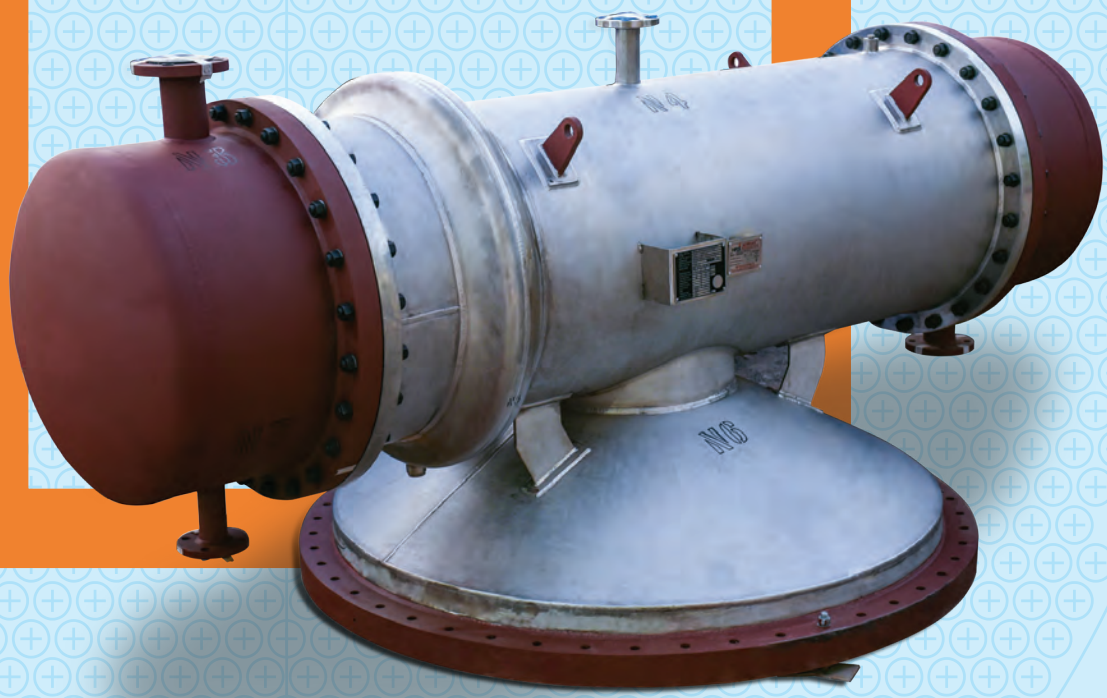

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"We have planned to spend seven and a half lakh crores in creating oil and gas infrastructure over five years": PM

New Delhi, India: The Prime Minister Shri Narendra Modi dedicated to the nation and laid the foundation of key projects of the oil and gas sector in Tamil Nadu today via video conferencing. Prime Minister dedicated to the nation the Ramanathapuram – Thoothukudi natural gas pipeline and Gasoline Desulphurisation Unit at Chennai Petroleum Corporation Limited, Manali. He also laid the foundation stone of Cauvery Basin Refinery at Nagapattinam. Governor and Chief Minister of Tamil Nadu, and Union Minister for Petroleum and Natural Gas were present on the occasion.

The Prime Minister raised the issue of India importing over 85 percent of oil and 53 per cent of gas to meet the demand in 2019-20. He asked, can a diverse and talented nation like ours be so energy import-dependent? He stressed had we focused on these subjects much earlier, our middle class would not be burdened. Now, it is our collective duty to work towards clean and green sources of energy, reduce energy dependence. "Our Government is sensitive to the concerns of the middle class", he emphasized.

To achieve this India is now increasing the focus on ethanol to help farmers and consumers. There is a focus on furthering usage of solar power to become a leader in the sector. Public transport is being encouraged and alternative sources like LED Bulbs are being embraced to enable huge savings for middle-class households, The Prime Minister said.

The Prime Minister asserted that while India is working to meet the growing energy demand, it is also reducing our energy import dependence and diversifying import sources. For this capacity is being built. In 2019-20, India was 4th in the world in refining capacity. About 65.2 million tonnes of petroleum products have been exported. This number is expected to rise even further, said the Prime Minister.

Talking about the overseas presence of Indian oil and gas companies in 27 countries The Prime Minister said that have investments worth approximately INR 2,70,000 crores

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Grid' vision, the Prime Minister said "we have planned to spend INR 7.5 lakh crores in creating oil and gas infrastructure over five years. A strong emphasis has been laid on the expansion of city gas distribution networks by covering 407 districts."

The Prime Minister informed that consumer-focused schemes like Pahal and PM UjjwalaYojana are helping every Indian household access this gas.95% of Tamil Nadu's LPG customers have joined the PAHAL Scheme. Over 90% of the active customers get direct subsidy transfer. Under the UjjwalaYojana, over 32 lakh BPL households in Tamil Nadu have been given new connections. Over 31.6 lakh households benefited from free refills under the PM GaribKalyanYojana, informed the Prime Minister.

The Prime Minister pointed out that Indian Oil's 143 Km long natural gas pipeline from Ramanathapuram to Tuticorin launched on 17th February 2021 will monetise the gas from ONGC gas fields. This is a part of a larger natural gas pipeline project being developed at a cost of INR 4,500 crore. It will benefit Ennore, Thiruvallur, Bengaluru, Puducherry, Nagapattinam, Madurai and Tuticorin.

These gas pipeline projects would also enable the development of City Gas projects which are being developed at 10 districts in Tamil Nadu at an investment of Rs.5,000 Crore. The gas from ONGC field will now be delivered to Southern Petrochemical Industries Corp Limited Tuticorin. This pipeline is going to supply of natural gas as feedstock at a cheaper cost to SPIC for manufacturing Fertiliser. Feedstock will now be continuously available with no storage requirements. This is expected to result in saving in the range of Rs.70 toRs.95 Crores in cost of production annually. This will also bring down the final cost of production of fertilizer, said the Prime Minister.

Prime Minister expressed the country's plan to increase gas share in our energy basket from 6.3 per cent currently to 15 per cent.

Enumerating the benefits for local cities the Prime Minister said the CPCL's new refinery at Nagapattinam anticipates about 80% indigenous sourcing of materials and services. The refinery is going to boost the development of transport facilities, downstream petrochemical industries and ancillary and small scale industries in the region.

Dwelling on India's stress on increasing the share of energy from renewable sources. By 2030, 40% of all energy will be generated from green energy sources, said the Prime Minister. He said CPCL's new Gasoline desulphurisation unit at its refinery in Manali inaugurated today is another effort for a greener future

In the past six years, over Rs. 50,000 Crore worth of oil and gas projects have been approved for implementation in Tamil Nadu. In the same period, over Rs 9100 crores worth projects sanctioned before 2014 were completed. In addition, over Rs 4,300 crore worth of projects are in the pipeline. All the projects in Tamil Nadu are a result of joint efforts of our consistent policies and initiatives for sustainable growth of India, the Prime Minister concluded.

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PM inaugurates important Oil & Gas projects and Engineering Colleges in Assam

Honorable Prime Minister at the Inauguration Ceremony

New Delhi, India: Prime Minister Shri Narendra Modi dedicated to the nation INDMAX Unit at IndianOil's Bongaigaon Refinery, Oil India Limited's Secondary Tank Farm at Madhuban, Dibrugarh and a Gas Compressor Station at Hebeda Village, Makum, Tinsukia remotely from Dhemaji in Assam today. He also inaugurated the Dhemaji Engineering College and laid the foundation stone for Sualkuchi Engineering College in Assam.

Governor of Assam Prof. Jagdish Mukhi, Chief Minister of Assam Shri Sarbananda Sonowal, Union Minister for Petroleum and Natural Gas Shri Dharmendra Pradhan and Minister of State for Food Processing Industries Shri Rameswar Teli was also present on the occasion. Addressing the public at the event, the Prime Minister said North East will be the new growth engine of India and he is inspired to work more for the people of Assam. He recalled how the North Bank in the Brahmaputra gave birth to Assamese cinema eight decades ago with the film Joymoti. He added this region has produced many personalities that enhanced the pride of Assam's culture. He said the Centre and State Governments are working together for the balanced development of Assam and the major basis of this is the state's infrastructure. He further listed the infrastructure projects in Assam which were inaugurated by the Government.

The Prime Minister said, today, energy and education infrastructure projects worth more than Rs 3000 crore are launched in this region. He said these projects will strengthen the identity of the region as a hub of energy and education and would act as a symbol of Assam. The Prime Minister stressed the necessity for India to continuously become self-sufficient, to increase its strength and also its capabilities. He said over the years, the refining capacity in India has greatly increased, especially at the Bongaigaon Refinery. He added the gas unit plant launched today is going to increase the capacity of LPG production and will make life easier for the people in Assam and Northeast. It will also increase employment opportunities for the youth in this region.

He added several fertilizer industries in the region were either shut down or declared ill

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due to lack of gas, thereby adversely affecting the poor, needy and the middle class. PM said that under the Pradhan Mantri Urja Ganga Yojana, eastern India is being connected to one of the world's largest gas pipeline networks.

The Prime Minister said a strong talent pool of our scientists, engineers and technicians plays a major role in giving impetus to a AatmaNirbhar Bharat. In the past years, we were working to create an environment in the country, where the youth of the country can solve the problems with startups. Today, the whole world is recognizing India's engineers. The youth of Assam has amazing potential. The state government is working hard to increase this capacity. Due to the efforts of the Government of Assam, today there are more than 20 engineering colleges in the state. Today, this position has been strengthened by the inauguration of Dhemaji Engineering College and the foundation stone of Sualkuchi Engineering College. He announced that the work on three more engineering colleges is going on. He said the Assam Government is trying to implement New Education Policy at the earliest.

Clariant Chemicals' nine monthly operational PBT grew by 50% over previous year's corresponding period

Mumbai, India: Clariant Chemicals (India) Limited, a focused, sustainable and innovative specialty chemical company today announced its financial results for the nine months ended December 31, 2020. The company reported Profit before exceptional item & tax of Rs. 35.3 crore for the nine months ended December 31, 2020, as compared to Rs. 23.6 crore in the similar previous year period – witnessing a significant growth of 50%. Sales fell by 13% at Rs. 511.9 crore, for the nine months ended December 31, 2020 as against Rs. 587.8 crore in the similar previous year period, severely impacted by the Covid nationwide lockdown in the initial months.

Adnan Ahmad, VC & MD, Clariant Chemicals (India) Ltd

The Profit before exceptional item & tax stood at Rs. 19.0 crore for the quarter ended December 31, 2020, as compared to Loss before Tax of Rs. 3.1 crore for the similar previous year period. Sales rose by 7%, at Rs. 202.1 crore, for the quarter ended December 31, 2020 as against Rs. 188.3 crore for the corresponding quarter in the previous year. The Board has recommended an Interim Dividend of Rs. 50 per share (500%).

Adnan Ahmad, Vice Chairman & Managing Director, Clariant Chemicals (India) Limited, said, "The gloom over Covid is lifting as consumption across different sectors is

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bouncing back. At Clariant, we delivered a strong performance in Q3, with our sustained efforts on working capital, cost control and operational productivity all coming good. The Board is pleased to announce an interim dividend of Rs. 50 per share (500%), as we continue to reward our shareholders for their trust in us. Our continued focus on Excellence in Execution helps us deliver on our top priorities of safety, sustainability and innovative offerings to all of our stakeholders".

SGL Carbon Delivers Steam Generation Hydrochloric Acid synthesis unit to TCCL in South India

HCl synthesis unit with an integrated steam generation

Pune, India: SGL Carbon delivered a Hydrochloric Acid (HCl) synthesis unit with integrated steam generation to Travancore-Cochin Chemicals Ltd. (TCCL), a major producer in the chlor alkali business in South India. End of January, TCCL officially inaugurated its plant in Kochi in India's Kerala state. Since then, the unit has already been ramped up at the customer's site to full capacity.

The synthesis unit uses the efficient membrane wall technology and has a capacity of 60 tons of HCl per day. As an additional benefit, this innovative design enables the recovery of waste heat generated in the synthesis unit from the reaction of Hydrogen & Chlorine to produce up to 33 tons of steam at the high pressure of 10 bar every day. This steam can be used elsewhere in the chlor alkali plant, for example when concentrating caustic to flakes. As a result, the energy efficiency of TCCL's plant goes up substantially since a huge portion of their steam demand can be covered by SGL's unit. Thereby this helps to save costs as well as reduces CO2 emissions by more than 1.500 tons per year potentially.

The HCl synthesis has been completely engineered and produced at SGL's production site in Pune, India. Scope of supply also included civil modification services at the customer site on a turnkey basis.

"Our innovative combined HCl synthesis and steam production units offer a great business value to our customers in the growing Indian chemical market. Together with our proven technical and engineering competence on a global scale we can help our customers to enhance their energy efficiency as the example of TCCL shows", comments Suneet Sangam, Sales Manager at SGL Carbon India.

"By engineering and producing our units also at SGL's production site in India, we further strengthen our position as a global process solution provider for corrosive applications leveraging our extensive expertise from our worldwide network. Realizing such ambitious projects in these challenging times of Covid restrictions shows how capable our global team is," says Christoph Koch, Director Sales EMEIA at SGL Carbon.

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inhouse

Hikal accords record breaking performance in Q3

Jai Hiremath, CMD, Hikal Ltd.

Mumbai, India: Hikal Ltd., a preferred long-term partner for leading global life sciences companies, has shown record breaking performance in Q3 ending December 2020. Better sales volumes of new and existing products as well as penetration in new markets led to record breaking performance. Steady improvement in EBITDA Margins continues aided by products portfolio as well as geographic expansion.

Pharmaceutical sales were up by 8% to Rs. 269 crores as compared to Rs. 248 crores in the corresponding period of the previous year. Continued customer demand provides a positive outlook on the business. Hikal has a strong pipeline of new products in Contract Manufacturing and Generics

Business excellence initiatives yielding better utilization of production capacities. Crop Protection sales were up by 25% at Rs. 194 crores as compared to Rs. 156 crores in the corresponding period of the previous year .The company has strong pipeline of inquiries and new products under commercialization & business excellence initiatives continue to drive better throughput.

Commenting on the results, Jai Hiremath, Chairman & Managing Director, Hikal Ltd. said, "I am pleased to report that we have achieved the highest ever quarterly revenue and net profit as a company. After facing several challenges through the pandemic both our businesses are now back on track. The Crop Protection business has grown significantly by 25% for the quarter on the growth of new products and higher volumes of existing products. We have a healthy pipeline of new projects in the business and expect to commercialize several products soon.

Our Pharmaceutical division sales were up by 8% for the quarter as compared to the same period last year. Both our generics and contract manufacturing businesses continue to do well as we expand our product portfolio and geographic diversification. We have received several new inquiries from global customers looking to diversify their supply chain and are confident that the division will continue to do well over the next several quarters. Our EBITDA margins improved significantly in the quarter as several of our business excellence initiatives have started yielding results. We continue to generate positive free cash flows as a result of increased sales and margins. We

expect to continue this momentum as we go forward. Our capex plans are on track and we are expediting the execution to meet the increased demand of our customers.

ICRA has reinforced the Credit Rating of the company at "A", indicating improvement in the overall business and strong cash flows. We have reduced our total borrowing costs and we expect to further reduce the overall interest rates in the quarters to come. We see significant tailwinds in both our businesses and are confident that growth momentum will continue throughout this year into the next year for both our divisions."

Nayara Energy Crosses Milestone of 6,000 Fuel Retail Outlets in India

B Anand, CEO, Nayara Energy

Mumbai, India: Nayara Energy, a new-age downstream energy company of international scale, today announced the achievement of a significant milestone of 6,000 fuel retail outlets across the country. Over the past five years, the number of its fuel retail outlets have tripled. The company added ~600 retail outlets in the last fiscal year. Since October 2020, Nayara Energy has been launching new retail outlets with the Nayara brand and has already unveiled more than 200 new Nayara Branded fuel retail outlets in the country. Speaking on the occasion, B Anand, CEO, Nayara Energy said, "In FY19-20, the retail business generated 18% year-on-year volume growth. Nayara Energy aims to maintain the growth trajectory of the retail network and further expand to 7,600 fuel retail outlets by the end of 2024 to secure the rising energy demand of India's aspiring population. We are expecting domestic demand for gasoline and gasoil returning to pre-Covid levels by the first half of 2021."

"The accelerated retail growth over the past few years is testimony to the trust Nayara Energy has earned mile-by-mile across the length and breadth of the country. As the fastest growing pan-India private fuel retail network, we are committed to meeting the growing needs of mobility and convenience, and elevating our customers' experience," Stephan Beyeler, Chief Marketing Officer, Nayara Energy, added.

ABB recognized as a globally leading innovative corporation

Zurich, Switzerland: ABB has been named one of the world's most innovate companies 2021 by Clarivate, a global leader in analytics, including scientific and academic research, patent intelligence and compliance standards.

Since 2012, Clarivate's list has identified global innovators and celebrated companies

Björn Rosengren, CEO, ABB

and research institutions at the very top of the innovation ecosystem. Using the same methodology every year, Clarivate analyzes the patented ideas of over 14,000 entities for their levels of investment, impact and quality. 2021 marks the fifth time that ABB has been listed.

"We are very proud to be named once again as one of the world's 100 most innovative corporations. Innovation has been in our DNA since we were founded more than 130 years ago and we will continue to invest in R&D to maintain our leading technology position in order to drive long-term profitable growth and create value for our customers and society", said Björn Rosengren, CEO.

In 2020, ABB has increased R&D and digital spend to 4.8 percent of Group revenues, corresponding to around $1.3 billion. The company employs some 7,000 researchers globally, of which more than 60 percent are focused on software development and digitalization. The company continues to partner with more than 100 leading universities around the world. Among them ABB is working with Carnegie Mellon and Stanford University in the United States, University of British Columbia in Canada, Imperial College in the UK, the Indian Institute of Technology, China's Tsing Hua University, Sweden's Royal Institute of Technology and ETH Zurich in Switzerland.

Birla Carbon recognized with the fifth consecutive Gold rating by EcoVadis for sustainability practices

Joe Gaynor, Chief Legal, Sustainability & Risk Officer, Birla Carbon

Mumbai, India & Marietta, USA: Birla Carbon has been awarded a Gold level rating for the fifth consecutive year by EcoVadis, an independent sustainability rating agency. This recognition confirms Birla Carbon's position as an industry leader in advanced sustainability practices and reporting and places it in the top 3% of companies in its sector. The rating was provided after reviewing

Birla Carbon's sustainability practices in its recently published eighth sustainability report, Bending Towards Circularity.

Commenting on the achievement, Joe Gaynor, Chief Legal, Sustainability and Risk Officer, Birla Carbon, shared, "At Birla Carbon, sustainability is more than a commitment -- It is central to who we are and how we operate. We are both proud and humbled to receive this award in a year when we, like most of the world during this global pandemic, have remained laser-focused on ensuring a safe workplace for our employees and uninterrupted supply and services to our customers." He further added, "Five consecutive Gold ratings is a noteworthy achievement, but it would not be possible without the consistent and devoted efforts by all of our employees. I would like to thank our employees for their continuous commitment to our Purpose to 'Share the Strength', for it is through that collaboration that we are able to remain a good neighbor in our communities, a reliable supplier to our customers and a safe home for our employees. We at Birla Carbon are committed to constant improvement in order to remain an industry leader in sustainability, and we are making plans to have an even greater impact in the years to come."

Man Industries (India) Limited appoints Narendra Mairpady as Independent Director

Mumbai, India: Man Industries (India) Limited has announced the appointment

Narendra Mairpady, Former CMD, Indian Overseas Bank

of Narendra Mairpady as an Independent Director for a term of 5 years with effect from 23 February 2021. He has over four decades of rich and varied experience in banking industry and was also Chairman & Managing Director of Indian Overseas Bank. He is also an Independent Director in reputed firms like Adani Enterprises Limited, Mahindra First Choice Wheels Limited, Mahindra Rural Housing Finance Limited and others. Speaking on the appointment, Dr Ramesh Chandra Mansukhani, Chairman, Man Industries India Ltd said, "We are extremely pleased to have Narendra Mairpady as an Independent Director in our organisation. His vast experience will immensely help the company in planning its growth strategy."

Haldor Topsoe commits to the SBTI and sets short-term targets to reduce carbon emissions

Lyngby, Denmak: Topsoe joins the Science Based Targets initiative (SBTi) in recognition

Roeland Baan, CEO, Topsoe

of the pressing need to reduce carbon emissions and the fact that the chemical sector is responsible for one eighth of global industrial carbon emissions. This means that companies in this sector have a crucial role to play in limiting global warming. Topsoe is among 32 chemical companies who have joined the initiative globally and the 31st Danish company to commit.

"Our commitment to the Science Based Target initiative goes hand-in-hand with our vision: To be recognized as the global leader in carbon emission reduction technologies by 2024. We support customers in cutting their emissions, and we are determined to cut emissions in our own operations. Short term, our target is a 15% reduction by the end of 2021, compared to 2019. For next year and beyond, we will define long-term reduction targets to be validated by SBTi," says Roeland Baan, CEO of Topsoe.

The SBTi target-setting process involve three categories of emissions as defined by the Greenhouse Gas Protocol. Scope 1 and 2 are direct emissions where the company has operational control and indirect emissions from electricity consumption. Scope 3 includes all other indirect emissions that occur in a company's value chain, e.g. supply chain operations and end-product usage by customers. Topsoe will report on Scope 1 and 2 emissions in its upcoming Sustainability Report 2020. Topsoe is committed to contributing positively to the UN Sustainable Development Goals and joined the UN Global Compact in May 2020, pledging to align policies and action with its Ten Principles. ■

Proper Design of Shell and Tube Heat Exchangers

This paper provides an overview of key design parameters and recommended practical engineering tips for properly designing shell and tube heat exchangers.

Shell and tube heat exchangers are widely used equipment for heat transfer applications. Thermal design of heat exchangers is generally carried out using specialized softwares like HTRI, HTFS, etc. While these softwares use rigorous design techniques, user needs to carefully configure the problem, optimize the solution and analyze the design outputs. A consistent design approach is required to standardize the shell and tube heat exchanger designs.

Input Data Review:

Adequacy, consistency and completeness of process data for initiating the thermal design should be verified. Below are few important parameters that shall be reviewed firmly at the onset of thermal design.

Physical properties: It is crucial that the physical properties are available over the entire temperature range for both hot side and cold side. In case of presence of multiphase mixtures or for phase change cases, properties of relevant phases should be stated separately. The missing physical properties required to carry out the thermal design can be estimated using steady state simulation softwares. The thermal design software has a limited thermodynamic ability for mixture property predictions.

Temperature cross: For exchangers having a temperature cross, multiple shells in series would be required.

Heat release data: For reboilers, condensers or any other heat exchanger, wherein, phase change is taking place, heat release data is required as the enthalpy would be different at different locations in the exchanger. When only pure components are involved then the heat release will be linear and as the phase change occurs at the same temperature, heat release data is not required. For multicomponent mixtures, if the mixture is of 'close boiling range' type, then heat release can be assumed to be linear. For multicomponent mixtures with wide boiling ranges, the heat release data impacts the heat transfer area calculations. When the phase change is occurring over a range of pressure then heat release data at multiple pressure points would improve

the thermal design accuracy. For other cases wherein the pressure range is small, heat release data at one single pressure point is adequate.

Cleaning requirements: Based on the cleaning requirements, shell type, tube layout pattern, tube diameter can be selected during thermal design. As an example, if shell side cleaning is required then use of square pitch is recommended. Similarly, for low shell side Reynolds number, tube pattern of 45 deg is preferred and for moderate to high shell side Reynolds number pattern 90 layout is preferred. If no shellside cleaning is desired then shell type can be selected as fixed tubesheet else a floating head needs to be considered.

Fluid allocation: For fluid allocation, Many times the criteria below contradict with each other but broadly serves as a screening guide while allocating hot and cold side fluids to shell side and tube side.

- High temperature streams preferred in tube side.
- High pressure fluids in tube side
- Viscous liquids are better handled in shell side.
- High allowable pressure drop streams on tube side.
- Dirtier fluids are preferably placed in tube side.
- More corrosive fluid through tube side is preferred.
- Low flow rate streams are better handled in tube side.

Process design margins: The process margins are generally specified on heat duty and flow rates. Sometimes, the overdesign on heat duty is stated as 110% and overdesign on flowrates is specified as say 120%. This means that the heat exchanger to be thermally designed for 110% of specified duty and at the same time, the allowable pressure drop is not exceeded at 120% flow rate. User has to provide adequate design margin on the surface area over and above the process margins specified in the process data sheet.

Basis of design:

Generally, the basis of design is unique for each project. Preparation of basis of design is a first step during the thermal design. Following parameters, as a minimum, are addressed in basis of design.

Fouling factors: Fouling factor varies with the given service application. To maintain consistency across the thermal designs a uniform fouling factor for the given fluid should be used.

Shell type: Shell type selection is generally based on the cleaning requirements and fouling factors. Below is the generic recommended practice. Various shell types and its TEMA designations are provided in figure 1.

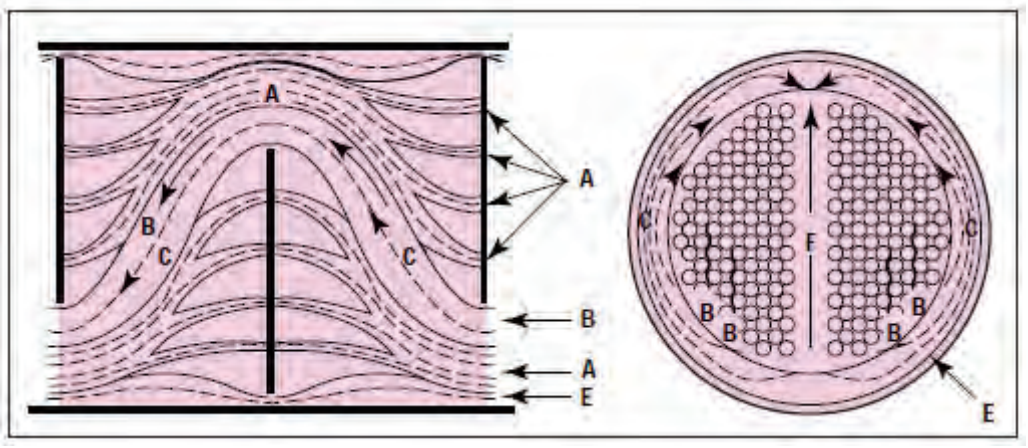

Figure 1. TShell side flow streams

- Floating head is used if both shell side and tube side fouling factors are more than 0.0002(hr-m2-Oc/kcal).
- Fixed tube sheet is used if the shell side fouling factor is less than 0.0002 (hr-m2-Oc/kcal) and tube side fouling factor is greater than 0.0002 (hr-m2-Oc/kcal).
- U bundle is used if the shell side fouling factor greater than 0.0002 (hr-m2-Oc/kcal) with tube side fouling factors less than 0.0002 (hr-m2-Oc/kcal)
- For the services having both side fouling factors less than 0.0002 (hr-m2-Oc/kcal) then either a fixed tube sheet or U bundle are recommended configurations.
- For vacuum services, to keep shell side pressure drops to minimum; X shell is recommended
- Horizontal thermosiphon reboilers are often employed with J, G or H type of shells.
- Floating head or U tube is sued to avoid the bellow otherwise required for thermal expansion.

Cooling water velocity: Salts in the cooling water starts precipitating due to reverse solubility at higher temperatures. Due to high film temperatures in the heat exchanger, this precipitation leads to scaling and fouling of the heat exchanger. The exchanger performance degrades due to fouling. It is thus necessary to maintain certain minimum velocity for all cooling water services. As a general practice, cooling water velocity is to be maintained at minimum 1 m/s for lowest possible steady continuous long operation flow rate. Steady and long operation flow rate does not include the start up cases but sometimes includes turndown cases. It is practically very difficult to design exchanger for minimum 1 m/s velocity when turndown is too low.

Bundle diameter: The maximum bundle diameter is limited lifting machinery (crane) specifications. In order to pull the bundle, the maximum bundle diameter restrictions are applied. The number varies from case to case basis. It is recommended that the thermal designer

obtains this number before the start of the design and should be part of basis of design.

Shell Diameter: Restrictions to shell diameter apply based on maximum weight that the lifting machinery can take at the given site for erection and dismantling purpose. Thermal designer should restrict the designs within the defined constraints of maximum shell diameter. For the cases wherein the surface area requirements are larger than those defined by these constraints, then multiple shells in parallel should be used.

Tube lengths: Tube lengths are either selected in multiples of 1000mm or as standard TEMA lengths which are basically rounded of values in feet. Basis of design should state the tube lengths selection to maintain consistency of all exchanger designs for the given project. The basis of design should also specify the maximum tube lengths permitted by the plot and layout constraints. This is generally restricted to 6 or 9 metre.

Tube diameter, pitch and pattern: Basis of design should address the considerations for selecting tube geometry including tube wall thickness. The tube wall thickness can be considered as per BWG or it can be rounded of in multiples of 0.5 mm. Tube OD is function of fouling factors and cleaning requirements. Preferred tube ODs based on fouling factor can be standardized. As a recommended practice, if the tube side fouling factor in excess of 0.0004, minimum 1" tubes are used. Basis of design should clearly state if tube ODs are based on standard in inches or standard in mm.(E.g. ¾"& 1" or 20mm, and 25 mm)

Overdesign on surface area: The design margin on surface area is required to account for inaccuracies and limitations to the empirical correlations used during rigorous thermal design. Typically, the design margins on surface area are kept at 6% to 8 %.

Design Pressure and design temperature: Preferably, the low pressure side design pressure should be 10/13 times design pressure of high pressure side. The design pressure of pumped liquids should be based on (estimated) pump shut off pressure. All the exchangers with phase change service should also be designed for full vacuum condition. Steam out conditions should be specified separately. Many times it is likely that the steam out design condition turns out to be governing criteria for exchanger design. All possible alternate operations of the equipment should be considered before specifying design conditions. When cold side fluid is in tubes, its design temperature should be equal to design temperature of shell side.

TEMA class: Basis of design document should specify the applicable TEMA class (R, C or B) for the exchangers in the given project. Many design parameters like tube

pitch, corrosion allowance; mechanical clearances are based on the TEMA class selected.

Data Entry:

Nozzles: Nozzle size and number are required for accurate prediction of pressure drop. Specify the vapor and liquid outlet nozzle sizes separately for partial condensers. For thermosiphon reboilers, ignoring this data entry can sometimes have large impact on the resistance calculations.

Design Pressure: Though the thermal design softwares have the ability to estimate the design pressure and tube sheet thickness, shell thickness, baffles thickness, etc, it is recommended that user specifies the design pressure so that the estimations of mechanical design from the program are closer to actual designs.

Mechanical clearances: In case of rating an existing exchanger, make sure that all the mechanical tolerances as shown on fabrication drawing are inputted to the program. For new designs, these fields can be left blank. However, after the mechanical design is carried out, it is recommended to input these clearances and re-run the thermal design program for verifying exchanger performance.

Impingement plate: To avoid tube rupture due to high velocity of fluids at bundle entrance and exit, impingement plates are required. Impingement plate occupies a significant portion of the shell. The shell diameter required for given number of tube increases with presence of impingement device.

Tube Layout: As a general experience, for a given shell diameter the thermal design program accommodates more number of tubes than the actual mechanical design permits for. After mechanical design is completed, it is recommended that original run is revisited and performance of the exchanger reviewed before released for vendor enquiry or for construction.

Baffle design: Center to center baffle minimum spacing should be 1/5th of the shell diameter subject to minimum 150mm which is mechanical fabrication limitation. Generally, the baffle spacing is rounded off in the multiple of 5mm. Baffle cut orientation may vary based on application. Vertical cut is provided for total condensers. The baffle spacing and baffle cut design depend on stream analysis and vibration analysis. User to avoid baffles being placed under the nozzle. For low pressure drop and vacuum service applications, “no tubes in window” option can be utilized.

Review and analyze output data:

Controlling coefficient: Observe the individual shell side and tube side heat transfer coefficients and the thermal resistances from the output. Enhancement

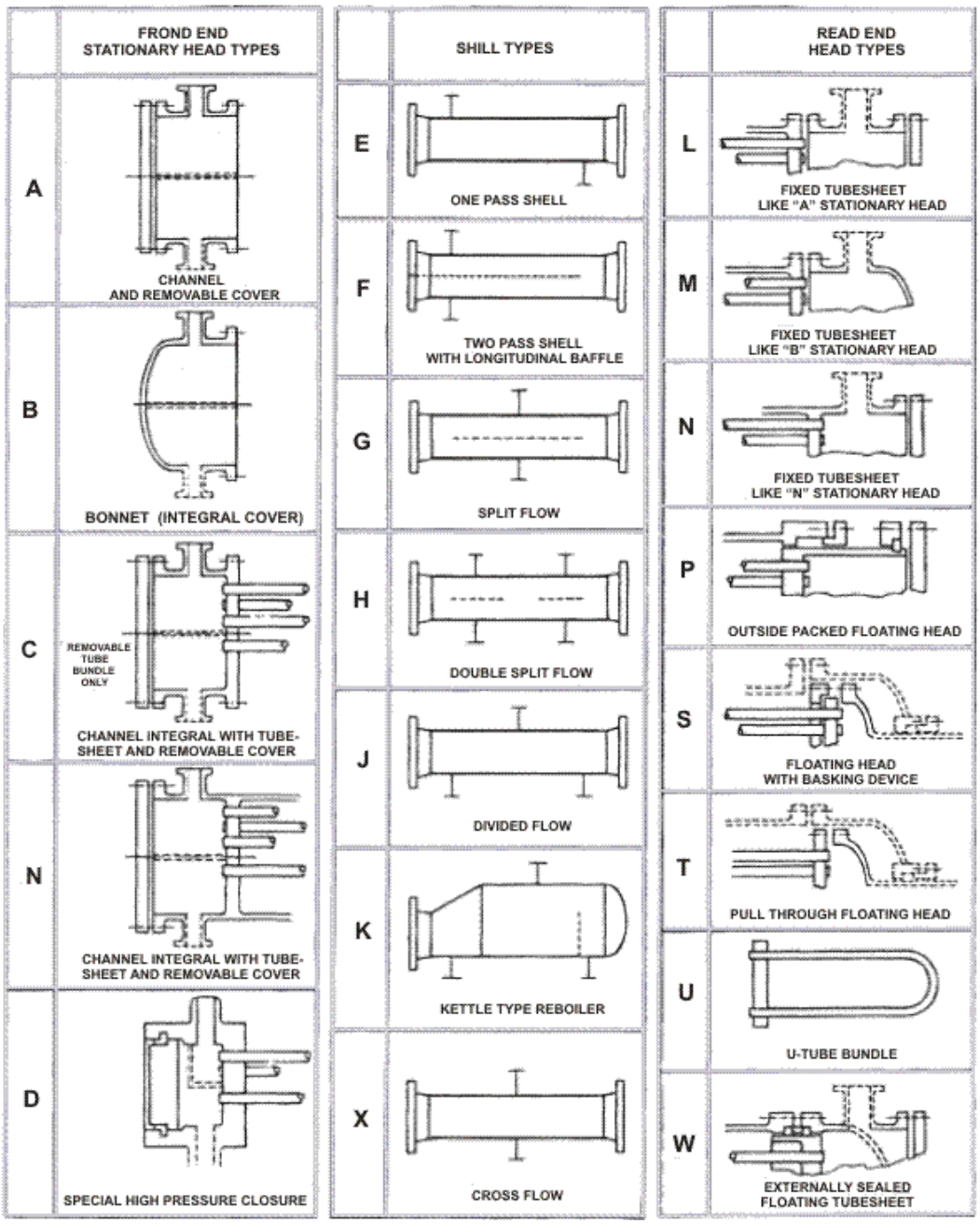

Figure 2: Exchanger Shell Type and Designations as per TEMA

in overall heat transfer coefficient can be targeted by first identifying the controlling resistance. Check if the case is fouling controlled. The side having lower heat transfer coefficient will be controlling side. Try to enhance the governing coefficient to the possible extent by consuming most of the allowable pressure drop.

Enhancing tube side heat transfer coefficient is relatively easy. Tube diameter, Tube length and number of tube passes are the variables available. Please note that velocity affects pressure drop more strongly than it affects heat transfer coefficient. Within the permissible limits of pressure drop, try to reduce the tube count or increase the tube passes to enhance tube side coefficient. As allowed by basis of design, reduction in tube diameter can help sometimes.

Shell style, Baffle geometry, Tube layout pattern and tube pitch are the variables available to enhance the shell side heat transfer coefficient. Use multiple shells in series for a temperature cross or to increase shell velocity and heat transfer coefficient. Multiple shells in series

reduce the penalty due to temperature profile distortion. Decrease the centre to center baffle spacing and reduction in shell diameter enhances the heat transfer coefficient. Baffle type selection also has impact on shell side coefficient as the leakage pattern changes from the selection. As an example, double segmental vs. single segmental baffles, heat transfer coefficient in the later case is generally found to be more.

Pressure drop: Try to consume as much of the allowable drop as possible. Any increase in velocity causes increase in heat transfer coefficient. Thus increase in pressure drop increases heat transfer coefficient and in turn lowers the required heat transfer area. Tube side pressure drop can be increased by decreasing tube dia. or increasing the tube passes. Shell side pressure drop can be increased by changing baffle configurations or putting multiple shells in series.

Velocity: Check that the velocity restrictions if any stated in the datasheet and/or design basis are satisfied. As a general rule of thumb, for liquids in the shell side, minimum velocity should be 0.2m/s.

Design heat duty: Many times, user leaves the outlet temperatures or flow rates to be calculated by the program. For thermosiphon reboilers, make sure that the absolute quantity of vapors at reboiler outlet matches with process data sheet. Check that heat duty multipliers if applicable for the given case are adequately added and the exchanger is designed to meet all the operating condition specified in the process datasheet.

Stream Analysis: There are 5 types of flow streams defined for a shell and tube exchanger. See figure 2 for details. These streams are defined as below.

- ”A” stream is tube to baffle hole leakages. The magnitude of tube-to-baffle clearance affects size of the A leakage stream. Because the ” stream is thermally effective, a significant A stream does not have a large negative impact on thermal performance of the exchanger.
- ”B” stream is main cross flow. The cross flow as indicated by B stream should be minimum 45%.
- ”C” stream is bundle to shell bypass: This clearance has a strong effect on the tube count.
- “E” stream is baffle to shell leakage: Because the E stream is not thermally effective, a large E stream has a large negative impact on the exchanger’s thermal performance. If user specifies a fouling layer thickness, it has no effect on this clearance or on the E-stream calculation. Being thermally inactive stream, this should be always less than 20%. Very large amount of C and E streams causes temperature

profile distortion due to bypass and leakage.

- "F" is pass partition line bypass. The F stream travels along tube pass partition lanes. Because these bypass streams can affect heat transfer and pressure drop performance, they must be modeled accurately. The F stream, the leakage stream that flows through the pass lane partitions in multiple tube pass bundles, is only partially effective for heat transfer. Use F-stream seal rods to reduce the F-stream flow fraction.

Tube Layout: The software program generally has the ability to produce a tube layout for given configuration. Ensure that the number of tubes specified does not exceed number of tubes calculated for the given shell geometry. This layout is only suggestive and indicative. Final tube layout shall be based on mechanical design. Based on past experience, as a general rule of thumb, specify 2% to 3 % of less number of tubes than programs default count to minimize design iterations.

Percent over design: This is the margin on surface area over and above the process heat duty margins. This margin is applied to account for inaccuracies, programming limitations and empirical correlations used by the program. Maintain this margin as per the design basis.

Vibrations: Vibration analysis is integral part of thermal design. For two phase services and low pressure gas applications in particular, special user attention is required to avoid exchanger vibrations. Thermal designer must ensure that the design is vibration free. Parameters that affect various type of vibration includes tube thickness, baffle spacing, clearance under nozzle, nozzle size, bundle entrance and exit velocity. Flow induced tube vibrations and acoustic vibration are two common types of vibrations encountered in thermal design.

Flow induced vibrations: Tube unsupported span is the key to flow induced vibrations. It can be reduced gradually and no resonance would occur. Various shell types with different baffle configurations can be tried to get rid of flow induced vibrations. The suggested approach in the order of preference is as below.

- E shell and single segmental baffles
- E shell and double segmental baffles
- J shell with single segmental baffles
- J shell with double segmental baffles
- No tubes in window configuration
- X shell
- Use of rod baffles

Below is the suggested approach to avoid the vibrations.

- Cross flow velocity should be less than 0.8 times critical velocity at

all locations. Higher the cross flow velocity, higher the turbulent buffeting frequency.

- Fluid elastic instability is characterized by tubes vibrating in whirling manner. This occurs when cross flow velocity is larger than critical velocity.
- Vortex shedding frequency is described by strouhal number. Tube natural frequency varies inversely as the square of tube unsupported span. Vortex shedding and turbulent buffeting requirements to be 0.8 times natural frequency.
- Unsupported tube span is less than 0.8 times TEMA limit

Acoustic vibrations: Most of the problems occur to 45 degree tube layout. The use of 60 degree layout often eliminates acoustic vibrations. Acoustic vibrations can be avoided by using de-resonating baffles.

Mean metal temperature: For fixed tube sheet type of exchangers, mean metal temperatures decide the need for a bellow to take care of thermal expansion. Process engineer should analyze the failure scenarios to arrive at design mean metal temperature values. This includes, mean metal temperatures when one of the fluids is lost, start up conditions, upset conditions, Turndown requirements, etc. For Floating head or U tubes, however, it is not necessary to provide mean metal temperatures.

Concluding Remarks:

Shell and tube heat exchanger thermal design is generally carried out using specialized softwares. These softwares follow a rigorous design methodology and the technology provides the opportunity to select the exchanger configuration in a quicker manner. However, it is very vital that the design approach followed for the shell and tube exchangers on a given project is highly consistent. In addition to the optimized configuration, A uniform design methodology and design standardization helps in maintaining lesser inventory, better maintenance planning. ■

Author

Atul Choudhari
General Manager
TATA Consulting Engineers Ltd
E-mail: achoudhari@tce.co.in

Challenges in Setting Up ETP For Refineries

Petroleum refining is a complex operation and unit operations within refineries vary depending on the type of crude and the type of end products. Refining is a water intensive operation which generates large quantity of waste water that needs to be treated so as to avoid environmental degradation. A proper understanding of the unit operations as well as pollutant loads is necessary in order to set up a suitable Effluent Treatment Plant (ETP). This article discusses about various challenges that we have faced in the designing and operating of several Refinery ETPs in India.

Characterisation Of Waste Water

In order to design an ETP for an upcoming refinery, design parameters like the flow rate, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), Oil & Grease (O&G), Sulfides, Phenols, Ammonia etc., have to be assumed. The selection of the scheme and the estimation of unit sizes depend on the inlet characteristics and hence it is imperative that the assumed design parameters be as close to the actual parameters that will be encountered once the plant is commissioned. It is quite normal to assume higher values while designing the plants. However, one should keep in mind that some processes do not perform efficiently when they are over designed.

Typical Treatment Scheme

The treatment philosophy adopted to treat refinery waste waters consists of a series of steps to sequentially remove the pollutants so that the treated wastewater meets the required regulatory norms. The typical treatment
steps are:

- **Removal of O&G:** This is necessary as downstream operations are sensitive to the presence of

high levels of O&G. In a refinery wastewater treatment system, two steps of oil removal are typically required to achieve the necessary removal of free oil from the collected wastewater prior to feeding it to a biological system. This oil removal is achieved by using an American Petroleum Institute (API) or Tilted Plate Interceptor (TPI) or equivalent oil water separator followed by a Dissolved Air Flotation (DAF) or Induced Air Flotation (IAF) unit.

- **Flow Equalisation:** Flow of wastewater generated from refinery from various manufacturing process units is not uniform. The flow variation is equalised by providing an equalisation tank of sufficient capacity and constant flow is maintained in all downstream treatment units. This makes the process control much easier.
- **Removal of Suspended Solids:** This is achieved using a clarifier or it can be combined with O&G removal in a DAF unit
- **Removal of Sulphides:** Lower sulphide concentration can be handled in biological treatment system. However, high concentrations of sulphides need to be taken care before wastewater enters into biological treatment system. Oxidation of sulphides using Hydrogen Peroxide is most popular method of oxidising them.
- **Biological Treatment:** Various biological systems have been adopted including Activated Sludge Process, Bio-tower, Sequential Batch Reactor, Anaerobic reactors, Membrane Bioreactors etc. Every process has its own inherent advantages and disadvantages and a suitable system has to be selected by the designer based on factors such as organic load, treatment efficiency required, land area available etc.
- **Polishing of Treated Waste Water** This step includes units like Pressure Sand Filters (PSF), Dual Media Filters (DMF), Activated Carbon Filter (ACF) to remove the residual suspended solids as well organic pollutants that have passed through the earlier treatment steps.
- **Reuse and Recycle :** As the refinery consumes a large quantities of water, it is imperative one must try and reuse the treated waste waters back in the process. Additional treatment units like Microfiltration, Ultrafiltration or Reverse Osmosis may be adopted in order to meet the reuse water quality that is required

Challenges and Solutions in Biological Treatment of Refinery Wastewater

The key treatment step in the refinery ETP is the biological treatment as the bulk of the pollutants are removed in a cost effective manner in this step. Hence it is important to design this system in a robust manner so that it can operate efficiently. It is important to note that in the biological treatment step, the pollutants are degraded by microorganisms and it is imperative that a conducive environment is maintained such that the microorganisms can operate up to their maximum potential. A list of various factors that influence the design and operation of the biological system are given below:

- **Fluctuation of Wastewater** Characteristics: One of the main challenges in refinery wastewater treatment is its variation in characteristics. As mentioned earlier, when assuming the pollutant load for design of the ETP, it is normal to assume higher values so that the designs are 'safe'. This causes problems during the operation of the ETP when the actual pollutant load is much lower. Also, based on variations in quality of crude and refining process, wastewater quality also varies. The biological system should be selected to take care of these variations. The biological system should be able to vary process parameters such as air supply, Mixed Liquor Suspended Solids (MLSS), Food to Microorganism (F/M) ratio, etc., to suit variations in feed.

Figure1: Foam in refinery

Figure2: Typical Refinery ETP

Modular design of biological process also helps in handling variations of wastewater quality. If provided with multiple process tanks, plant can be

operated based on the actual pollution load by using all process tanks or part of them.

- **Oil & Grease:** The performance of the O&G removal equipment is sometimes upset due to a surge in the inlet O&G quantity due to dumping of oil within the refinery. This causes O&G to slip into the biological system affecting the microorganisms. This also causes foaming in the aeration tanks that affects the quality of the treated water. A figure showing the foaming in a biological system of a refinery is shown here (Figure 1).

- **Sulphides:** Refinery wastewaters contain high levels of Sulphides that are toxic to microbes and hence have to be removed prior to the biological treatment. In case sulphides slip into the biological system, it exerts demand on the aeration system since it consumes the oxygen that is meant for the respiration of the microorganisms. Hence it is normal to consider a safety margin in the design of the air blowers so that it can meet any contingency due to sudden air demand because of sulphides. Care should be taken that sulphide concentration in biological system are below toxic limits.

- **Complex Organic Compounds and Heavy Metals:** Complex organic compounds such as phenols, benzene products, etc. are also part of refinery wastewater. Their concentrations depend on the source and quality of crude oil. These compounds are not easily biodegradable and may be toxic to biological system at higher concentrations. Hence, the ETP should be designed to handle these complex organics in case they are present in wastewater. Heavy metals also pose problem to biological treatment. Both complex organics and heavy metals should be taken care in pretreatment if present in higher concentrations.

- **Nutrients:** The growth and performance of the microorganisms depend on the availability of critical nutrients like nitrogen and phosphorous in the waste water. Ideally, a BOD:N:P ratio of 100:5:1 is required for best performance. Normally abundant nitrogen is present in the refinery wastewater. However, it is important to constantly analyse the wastewater and add nitrogen (typically as Urea) and phosphorous (as Phosphoric acid or Di Ammonium Phosphate) to make up for any deficit.

  Many a times, total nitrogen levels in the wastewater are much more than required which necessitates treatment

to reduce them. Hence, the biological system selected should be able to remove excess nitrogen along with organic pollutants.

- **Energy efficiency:** The oxygen required for the microorganisms are delivered through fine bubble diffusers that release small bubbles of air from the bottom of the aeration basins. Air blowers are installed to supply air into biological process. Air blowers constitute major portion of power consumption in the ETP. Any steps taken to optimise energy consumption shall result in energy efficiency of the plant.

  Biological process should be provided with oxygen control system to supply air as per the organic pollution load coming into it. Dissolved Oxygen (DO) or Oxygen Uptake Rate (OUR) based blower control optimizes both energy consumption and process performance. Energy efficient blowers further improve the energy efficiency of the ETP.

- **Process Automation:** Due to variations in wastewater characteristics, it is advisable to install process automation to control vital process parameters such as DO, OUR, MLSS, Sludge recirculation, Sludge wasting, etc. This helps in automatically keeping the process parameters at their optimum levels and generates consistent quality of treated wastewater.

Conclusion

Refinery wastewater characterisation is very complex exercise that requires an understanding about the refining processes involved. The designing of the ETP is a challenging job as treatment units have to be robust enough to handle continuous variations in the concentration of pollutants. The operation of the biological system governs the performance of the ETP, as it removes the bulk of the pollutants. Ideal operating conditions have to be provided for the microorganisms in order to ensure effective treatment. The biological system should be selected to handle any variations in flow and characteristics of refinery wastewater. ■

Author

Satya Narayana Y V V
SFC Environmental Technologies Pvt Ltd
satya@ctechsbr.com

Demystifying Sustainability:
An Invitation to be an Inspiring Company

Rajiv Ramchandra
Founder & Director, Recreate India Research Foundation

For a long time, it has felt to me that sustainability – as an idea or in application – has been perceived as a somewhat exotic endeavor. As if being sustainable or making sustainable choices is some kind of additional activity to be done, over and above the normal course of business, is costly, and produces no financial returns. This is patently false and a deeply unfortunate interpretation of what sustainability is, or what it means to be a sustainable enterprise. This misinterpretation may be particularly pronounced because of the long history of corporate social responsibility (CSR) which dates back to the 1800s1, as well as the term 'sustainability' being used interchangeably with CSR or 'Corporate Responsibility'. As a result, the line between embedded sustainability – making wise, environmentally conscious, socially sensitive and fiscally responsible choices – and philanthropy has become blurred. Another factor that has played a powerful role in seemingly absolving companies2 from making responsible choices is 'Shareholder Theory' which is also known as the Friedman Doctrine, named after American economist Milton Friedman. The central premise of this theory is that a firm's sole responsibility is to its shareholders which invariably led to profit maximization as the primary purpose of business. The myopic and one-dimensional perspective this theory offers is self-evident. Yet it was widely adopted starting in the 1970s. Today,

this view of the purpose of an enterprise continues to be abandoned. Most notably, the Business Roundtable3, an association of chief executive officers of America's leading companies redefined the purpose of the corporation in 2019. The updated 'Statement on the Purpose of a Corporation'4 specifically expands the role of business in serving all its stakeholders by saying: "While each of our individual companies serves its own corporate purpose, we share a fundamental commitment to all of our stakeholders". This commitment by businesses, now encoded in the revised statement, includes delivering value to its customers, investing in its employees, dealing fairly and ethically with its suppliers, supporting the communities in which it works, protecting the environment by embracing sustainable practices, and generating long- term value for shareholders.

Corporate Knights, one of the world's largest magazines focused on the intersection of business and sustainability5 publishes an annual index of the world's most sustainable companies6. The ranking methodology includes up to 24 key performance indicators (KPIs)7 which include:

- **Environmental Metrics** (energy productivity, GHG productivity, water Productivity, waste productivity, VOC, NOx, SOx and particulate matter productivity, clean revenue, and clean investment)
- **Social Metrics** (injuries, fatalities, employee turnover, paid sick leave, and CEO- average employee pay ratio)
- **Governance Metrics** (sustainability pay link, non-males in executive management and on boards, racial diversity among executives and on boards, and supplier sustainability score), and
- **Economic Metrics** (percentage tax paid, pension fund quality, and sanction deductions)

Being a sustainable company is so much more than reducing waste, minimizing pollution, and generally trying to do less harm. It is an invitation to partake in a bold and inspiring vision of creating a beautiful world and a reality that reflects our highest ideals.

And yes, these companies outperform their peers in terms of profitability.

As if being sustainable or making sustainable choices is some kind of additional activity to be done, over and above the normal course of business, is costly, and produces no financial returns is patently false and a deeply unfortunate interpretation of what sustainability is.

According to Corporate Knights8, "From its inception on February 1, 2005, to December 31, 2020, the Global 100 index has generated a total return of 263% versus the 220% increase of its benchmark, the MSCI ACWI (All Country World Index). For the calendar year 2020, the Global 100 was up 26% compared with a rise of 16% for the MSCI ACWI".

It is only natural that as the level of ambition continues to grow, the very architecture of the chemical industry – as well as the business models of chemical companies – will continue to evolve , particularly towards greater circularity. According to a study by Accenture9, in a chemical industry circular economy, "Materials and molecules are constantly cycled back through the value chain for reuse, resulting in less energy and resource consumption, creating new opportunities to realize cost savings and reinvest for growth". The report goes on to highlight five business models for growth in the chemical industry circular economy. These are:

- **Circular Supply Chains:** Companies focus on eliminating toxic, single-use or other non-renewable inputs across their supply chain
- **Product-as-a-Service:** Companies offer product access but retain ownership. Physical assets like cars and clothing are often thought of with this model. However, chemical leasing is a great example of how the chemical industry can shift to service-based sales that focus on selling function and quality rather than volume
- **Recovery and Recycling:** Salvaging useful resources and/or energy from disposed products or byproducts creates a huge opportunity, particularly to treat and repurpose plastic material.
- **Product Life Extension:** By developing more durable product offerings, chemical companies can extend the life of products downstream without the need for modification
- **Sharing Platforms:** Product utilization can be optimized by leveraging shared use, access and ownership via online marketplaces where companies can trade inventory.

While sharing platforms are often considered for finished consumer goods, they can also be applied to the chemical industry. There are principles that can be applied, resources available from a variety of credible organizations, and examples of companies that have embodied this vision and live it as their reality every day.

A set of principles that serve as a powerful North Star for companies in the chemical industry are the 12 Principles of Green Chemistry10. According to the US Environmental Protection

Agency (EPA), "Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances. Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. Green chemistry is also known as sustainable chemistry". The 12 principles are:

1. **Prevent waste:** Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.
2. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.
3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.
4. **Design safer chemicals and products:** Design chemical products that are fully effective yet have little or no toxicity.
5. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.
6. **Increase energy efficiency:** Run chemical reactions at room temperature and pressure whenever possible.
7. **Use renewable feedstocks:** Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
8. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
9. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.
10. **Design chemicals and products to**

While embracing such bold paradigms with an open mind and open heart can feel daunting, especially for smaller organizations, it isn't.

degrade after use: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.

11. **Analyze in real time to prevent pollution:** Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.

12. **Minimize the potential for accidents:** Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Additionally, the World Business Council for Sustainable Development (WBCSD) has developed a roadmap11 for companies in the chemical industry to contribute to achieving the Sustainable Development Goals (SDGs) "through more effectively managing its own operational footprint, working with others to enhance capacities along the value chain, and leveraging its expertise and innovation to unlock new business opportunities that are aligned with the SDGs".

So where should you start?

- **Create a culture**[12] of sustainability within your company by developing a strong understanding of the sustainability imperative, establishing and following a sustainability vision, and embedding sustainability in all decision-making processes
- **Perform an assessment** to identify the opportunities that you have direct control over (such as energy efficiency measures, renewable energy procurement, hiring practices, process efficiency, waste reduction or elimination, to name a few)
- **Identify and monitor key metrics** of performance which will help in tracking progress, maintaining accountability, and reporting.
- **Engage with stakeholders** across your value chain. Inform them of your aspirations and explore ways in which you can work together to meet sustainability goals. Sustainability is a team sport not a solo endeavor.
- **Set goals and initiate projects** for the short, medium and long-term, that have clear objectives, defined scopes, realistic timelines, and allocated budgets

As your company's sustainability culture matures, your circle of influence and action will start to widen and you will be able to venture into greater levels of innovation and ingenuity including radical shifts in product, process and business-model design.

Where we end up on this journey, is entirely dependent on the choices we make. Sustainability isn't a destination, it is a way of being, an invitation to live an inspired life.

The American essayist, poet, and practical philosopher Henry David Thoreau[13] said, "I know of no more encouraging fact than the unquestionable ability of man to elevate his life by conscious endeavor"[14].

What choices will you make? ■

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Five Steps to Effective Predictive Maintenance

Worley
energy | chemicals | resources

Imagine this. Your maintenance work orders are automated. Unplanned outages have plummeted. And your equipment is telling you what its maintenance and turnaround needs are.

It's the ultimate goal for many operators. And advanced Predictive Maintenance (PdM) like this is now becoming a reality thanks to digital enablers, such as the Industrial Internet of Things (IIoT) and 5G that support massive machine-type communications (mMTC) and Ultra-Reliable Low Latency Communications (URLLC).

But value from PdM doesn't happen instantly. To successfully capture value, organizations must manage its path through three fundamental levels: people, process and data.

To achieve this, organizations can consider a five step process:

Step 1: Organize your data

Processes are determined by data. That's why a robust data creation and governance model is critical for advanced PdM. Most organizations have systems in place to record data, but it may not be in the most useful format. For example, the data could be stored in multiple systems,

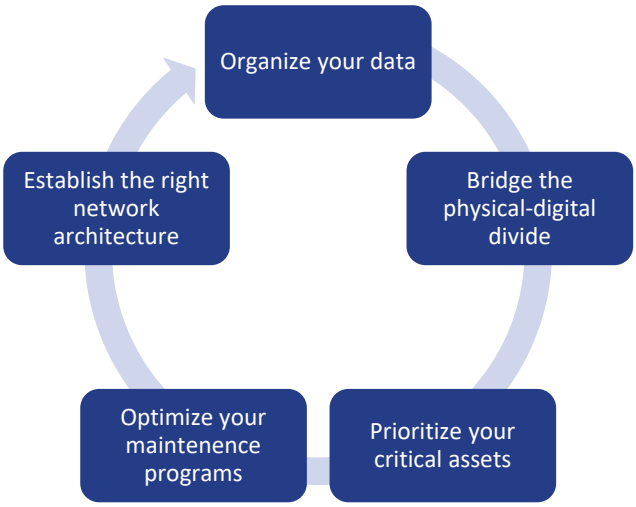

Figure 1: Five steps to maximize value from advanced predictive maintenance (PdM)

be handwritten or in spreadsheets, or simply not available for analysis.

Integrating data from multiple sources into a single platform – often called a data lake – is what drives digital transformation. For example, real time streaming data from equipment, combined with industrial control systems data and Computerized Maintenance Management Systems (CMMS), can provide insights into failure root causes. It can completely transform organizations who are dependent on traditional linear data and analysis by giving a complete picture of how assets are performing.

Step 2: Bridge the physical-digital divide

Once the data lake has been established, physical assets can be digitized to create a digital model of the physical asset – a digital twin. This integrates asset information into a structured information model spanning engineering, maintenance, operations and the supply chain. It provides an immersive interface for users to access, navigate and engage with asset information.

Digital twins improve the speed and quality of decision making across the organization by providing the right information at the right time.

It can have wide-reaching implications to the way work is managed and delivered. For example, a large energy company recently utilized a digital twin during the construction and commissioning work on its project development in europe. The learnings and insight they gained during this phase is expected to improve future asset support and maintenance scopes. Many tasks historically conducted offshore will be possible to complete onshore, saving both time and cost.

Step 3: Prioritize your critical assets

Organizations need to prioritize and determine the right asset maintenance strategy and process for their operation. Creating a PdM for an entire asset is a daunting task. It could even increase the potential for management paralysis, or poor quality of analysis and decision making, as a result of information overload. That's why it's important to identify what's critical and target the equipment could lead to potential catastrophic unplanned outages.

Central to asset management is knowing the current health of an asset and estimating its remaining useful life (RUL). Each asset has a functional specification, which identifies the function that the asset must perform to achieve the desired results. Engineers often look at RUL in terms of the potential failure to functional failure (P to F) curve.

The potential failure curve illustrated below plots condition versus time. As time goes on, without intervention, the costs of repair go up. If a decision is made to repair equipment, this will extend its life. Or, if the equipment is replaced, the P to F curve restarts. This is illustrated below. The goal is to have a predictive system to determine asset health and allow for early intervention before the asset function degrades.

Step 4: Optimize your maintenance programs

But how do organizations set up a predictive system to monitor asset health? Once a list of assets is created (e.g. an asset registry) in a format that meets the intent of ISO 14224, the criticality and risks for each asset can be determined by performing a Failure Mode Effect Criticality Assessment (FMECA). The FMECA identifies which assets are critical

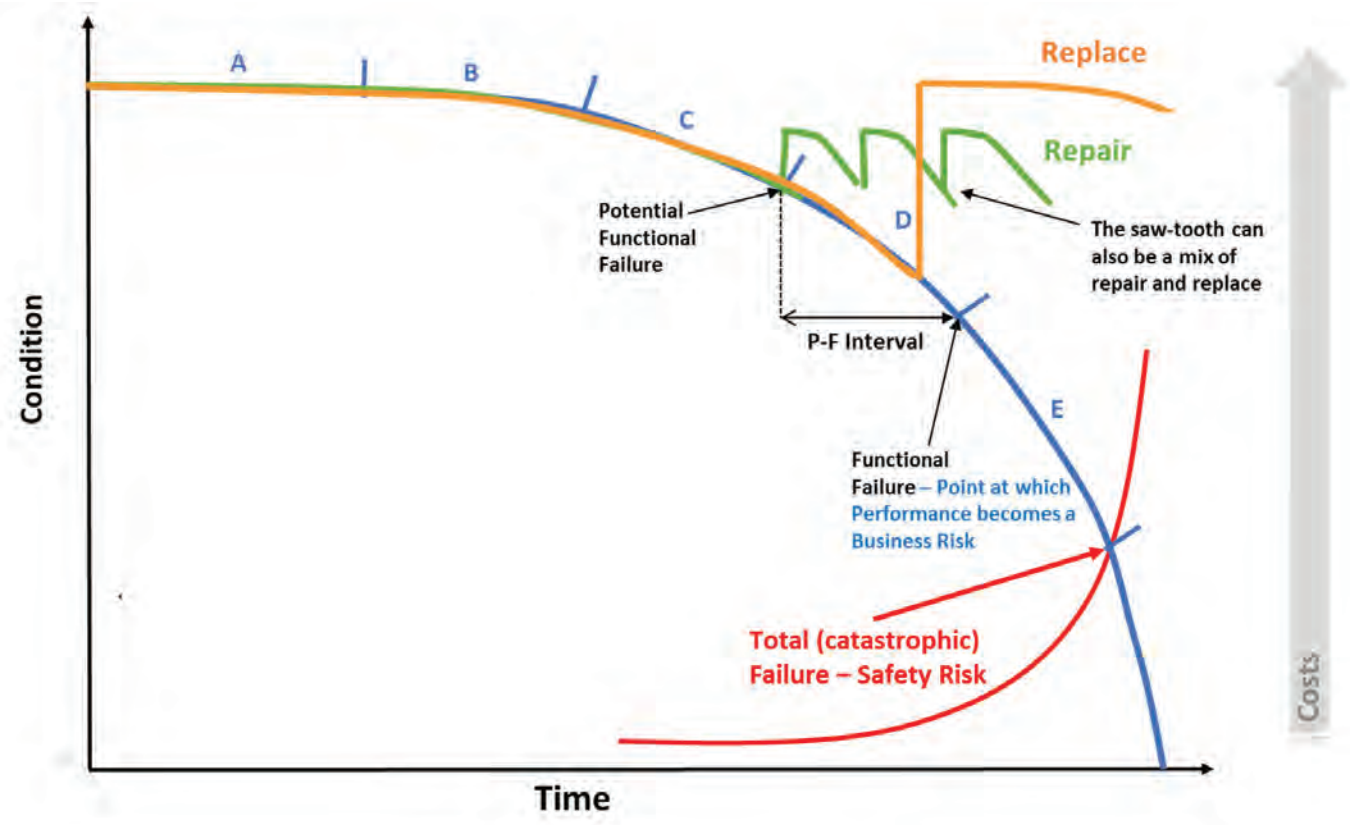

Figure 2 - The potential failure curve

to the success of the plant based on an agreed criteria. For each critical asset, the potential failure modes are identified. Guidelines for risk assessment and asset management are defined by ISO 31000 and ISO 55000.

For the failure modes that can be detected early, the required data and associated sensors are selected. Those that can't be easily detected may require physical inspection or prescribed component replacement.

Maintenance processes can be optimized considerably once PdM is implemented and time to decision and action is much quicker. It's important to ensure that processes are streamlined, and operators are trained to understand the value PdM brings and act on it quickly. The juxtaposition of performance and effectiveness metrics of each equipment and real time streaming data and advanced analytics, provides unique insights that render traditional processes obsolete.

Step 5: Establish the right network architecture

Most assets have wi-fi networks that operate as a process control network that's local to the asset. However, while keeping the asset data local provides maximum security, it also creates challenges with leveraging the critical PdM technologies

like cloud computing, data lakes, native cloud applications and data visualization. Therefore, cybersecurity is an important consideration.

Private Long-Term Evolution (LTE) and private 5G networks are ubiquitous and can achieve this balance. The mMTC and URLLC provide the backbone for connected industries and automation by providing instant information from equipment, while providing unparalleled network uptime and reliability.

In addition, connected assets also provide the opportunity for machine-to-machine communications, allowing operators to optimize operations with real time upstream and downstream data, as opposed to looking at equipment and processes in isolation.

IIoT and the implementation of digital technology can be overwhelming. But, it doesn't need to be.

It's clear that digital technologies promise big changes and opportunities for industry. And with such a prize at stake for those who can effectively embrace them, it's right that organizations should think big.

Determine what success looks like for your operation. Audit your data and core process. And identify labor intensive or hazardous work tasks to paint a clear and honest picture of your current state. If your data isn't good enough for what you need, then invest in building a data infrastructure that's fit for purpose and capable of supporting advanced data uses. Consider your costs: hardware, software, installation and training. Understand your burdened labor cost for technicians and support people. And know the value of your product and on schedule delivery.

Digital technology moves on at a rapid pace and organizations can become overwhelmed, paralyzed or lose touch with the core benefit. Implementing it needs to work with the organization rather than against it. Start small and move fast, but always with the bigger goal in mind.

Digital technology alone only goes so far to help organizations reach the much desired 'future state' of PdM. To capitalize fully on digital technology, organizations should follow a structured roadmap – such as this five-step process – invest in change management and engage with trusted and experienced partners. Failure to do so could cause technology to miss the mark, changes won't stick, and opportunities could be lost. ■

Authors

Vishal Mehta
Senior Vice President , Worley Digital

Pushkar Rao
Head of Worley Data Refinery

Malcolm Werner
Senior Director, Reliability and Maintenance

Extruders for Polyethylene & Polypropylene Plants: Criteria for Selection Of Energy Efficient Design

Extruder or Pelleting is a critical package unit in every Polyolefins (PO) plant namely Polyethylene (PE) and Polypropylene (PP). PE can be either HDPE (High Density PE), LLDPE (Linear Low Density PE) or MLLDPE (Metallocene LLDPE) or LDPE (Low Density PE). PP can be either Homopolymer PP, Random Copolymer PP or Impact Copolymer PP (also sometimes called Hetero Phasic PP).
Extruder package has four main attributes which underline its importance in any PE / PP plant. First, it is the largest package unit in the plant. Second, it is the most expensive package in the plant. Third, it is the most power or electricity consuming item in the plant. It consumes approximately 65 to 70 % of power consumed by the whole plant. And four, to some extent, it is independent of the technology selected. In spite of the above, the Extruder package remains relatively less understood in any PE / PP plant. This article intends to focus on specifications and selection criteria in order to address the above attributes.

Every PE or PP plant has proprietary reaction system which is licensed by the respective Licensor. The reaction system is typically followed by resin degassing and product purge bin. The resin degasing separates the resin from the vent gases. Vent gases are processed further to recover monomers, other HC and N2 (e.g. Ethylene, Propylene, Butene 1, Hexene 1, Iso Pentane, Iso Butane, N2 etc.) and returned to the reaction system.

Polymer resin in powder form is collected in product purge bin wherein the residual catalyst and co-catalyst is typically deactivated and the resin is further fed to the Extruder package which converts polymer resin in powder form in to pellets or granules and is called product or product in pellet form. The product pellets are further conveyed to blending silos, storage silos and finally to packaging section to bag the product in desired packages typically 25 kg bags, jumbo bags or big bags (500 to 1000 kg) or simply filled in to containers for transport. The

Extruder package is preceded by the polymer additives section. The different type of additives depending on product application are added to resin and fed to Extruder. The polymer additives typically include primary antioxidants, secondary antioxidants, process stabilisers, slip agents, anti-block agents, nucleating agents, whiteners etc. in different composition required by specific polymer application.

The Polymer additive package can be procured separately or along with Extruder package as per the procurement philosophy of the licensee. The polymer additives and polymer resin powder are fed to the Extruder Feed Hopper which is the feed point for the Extruder package. At the end of the Extruder package, the pellets are collected in the Pellet Hopper from where the pellets are conveyed to the blending silos.

Thus the Extruder package starts from the Extruder Feed Hopper and ends with Pellet Hopper. This generally forms the entire scope of the Extruder vendor.

Extruder Package – Main Components

Extruders are either resin powder fed or resin melt fed. LDPE and solution PE process feed melt to the Extruder. Other PE and PP processes feed resin powder to the Extruder. This article is intended to cover only the resin powder fed Extruders. Also the Extruders will be of Co-Rotating Twin Screw type only which is the industry norm.

LDPE and solution PE process which are melt feeding Extruders can either be single screw or twin screw. Single screw Extruders are quite common while

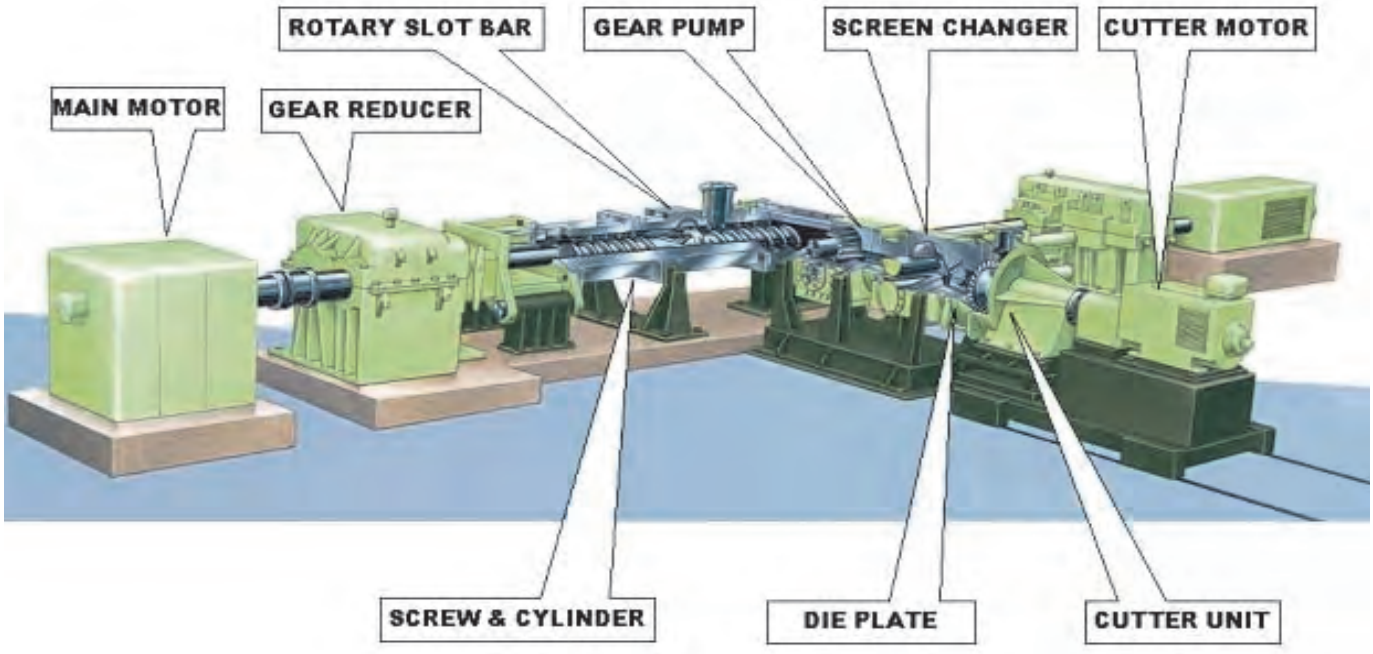

Fig 1: Typical Extruder Set-Up with Gear Pump

handling product MFI (Melt Flow Index) in excess of 1. Inherently duty demand by melt fed Extruders is low because of absence of melting zone and to some extent mixing zone. Twin Screw Extruders are preferred only when MFI is fractional that is less than one e.g. 0.5.

All other PE and PP processes are resin powder fed and use twin screw Extruders. Hence the focus of this article is only on twin screw Extruders which account for nearly 75 to 80% of all PE and PP. The Extruder package is a large unit in any polymer plant consisting of several components. (Fig.1)

Main components of the package include

- Main Extruder or Mixer as it is sometimes called which houses the Screw Elements
- The main Motor for Extruder
- The Extruder Gear Box
- Extruder Vent Housing
- Melt Pump or Gear Pump
- Melt Pump Motor or Gear Pump Motor
- Diverter Valve
- Melt Screen Unit
- Die Plate
- Underwater Pelletizer
- Pellet Water Tank
- Agglomerate Remover
- Pellet Dryer
- Pellet Water Pumps
- Pellet Water Cooler
- Pellet Screener
- Die Plate Hot Oil System
- Hydraulic System
- Extruder Feed Hopper
- Pellet Hopper

The Extruder main Motor Drive is invariably the largest motor by rating in any PE / PP plant and the entire Extruder package consumes approximately 65 to 70% of the electricity consumed by the whole PE / PP plant.

Extruders for PE and PP

The configuration of the Extruder package is essentially the same for PE and PP plant. However, the main Extruder design varies for the two on account of the nature of the polymer.

Differences between PE and PP

- PE Grades vary in MFI (Melt Flow Index), Density and MWD (Molecular Weight Distribution).
- On the contrary, PP Grades vary mostly in MFI and to some extent in MWD but very little in Density. PP has also property called Isotactic Index which is absent for PE.
- PE Grades can either be Homopolymer or near Homopolymer

with little incorporation of co-monomer or with large incorporation of co-monomer up to 10%.

- PP is made as Homopolymer or copolymer. The copolymer PP contains generally Ethylene up to 6% which is called Random PP. The Impact Copolymer PP contains "Rubber" phase in the form of PE and is also called "Hetero Phasic" for same reason. The Rubber phase in PP can vary approximately from 10 to 30%. PP therefore varies in MFI and in type in terms of Homopolymer, Random Copolymer or Impact Copolymer.
- PE is extruded at temperature ranging from 190-250°C due to inherent lower melting temperature of PE.
- PP is extruded at much higher temperature ranging from 230-290°C due to inherently higher melting temperature of PP compared to PE.

Extruder Specifications

Extruder package is specified either by the licensor for the new plant or by the licensee - either in consultation with the licensor or independently, based on the experience for the expansion. The licensor has obligation to provide the process specifications for the Extruder package for a new plant. The licensee has freedom to improve over it for their benefit. The following guidelines will outline the basic specifications, whether process or mechanical, which can be used by the licensee or the purchaser to improve or optimize the specifications. These specifications will automatically assist in formulating selection criteria.

The Extruder package specifications comprise mainly of following parameters in terms of performance for capacity and product quality:

Capacity

Usually specified for three cases namely: Normal, Maximum and Minimum.

The typical range is:

- Normal = 100%
- Maximum = 110 to 120 %
- Minimum 50 to 60% of Normal which is = 50 to 60%.

For Example, Normal / Maximum / Minimum = 60 TPH (Tonnes per Hour) / 72 TPH / 36 TPH.

The Extruder vendor will typically offer performance warranty or guarantee based on the Extruder capability for the reference product mix (mix of different product grades). Vendor can either agree on all the parameters or suggest deviations for some of the product grades.

The commercially operational maximum Extruder capacities range from 80 to 100 TPH from the reputed vendors keeping in line with rising single line PE / PP plant capacities. Typical performance

Typical Performance Requirement for PE or PP

Description	Unit	Example Grade
Warranted Product		Name of the Grade
Product Type		HDPE / LLDPE / MLLDPE PP Homopolymer / PP Random / PP Impact Copolymer
Controlled Rheology		For PP Only
Melt Flow Index (I 2.16)	dg/min	Licensor to Provide Data
Melt Flow Index (I 21.6)	dg/min	For PE Only
Melt Flow Ratio (I 21.6/I 2.16)		For PE Only
Density	g/cm3	Note 1
Resin Powder Bulk Density	kg/m3	Licensor to Provide Data
Resin Pellet Bulk Density	kg/m3	Licensor to Provide Data
Shear Rate Viscosity		Licensor to Provide Data
Enthalpy	kwh/kg	Licensor to Provide Data
Flow Rate - Minimum	kg/h	50 % + 1% Additives
Flow Rate - Normal	kg/h	100 % + 1% Additives
Flow Rate - Maximum	kg/h	120 % + 1% Additives
Normal Inlet temp at Mixer Hopper	C	Note 2
Melt Screen to Remove all Particles Greater than	mm	Note 3
Maximum Resin Temp at Die Plate	C	Note 4
Total Specific Energy Input at Normal Rate	kwh/kg	Note 4

Typical Values Only for Example

Note 1	0.905 for PP
	0.918 to 0.935 for LLDPE 0.940 to 0.963 for HDPE
Note 2	50 to 70 C
Note 3	Typical 1.4 to 2.5 for PP Typical 1.4 to 1.5 for PE Licensor to Provide Data for Each Product
Note 4	Typical 0.150 to 0.250 for PP Typical 0.140 to 0.250 for PE Licensor to Provide Data for each Product

Table 1: Typical Performance requirement for PE or PP

requirement template is shown in Table 1

Licensor to Provide Data for each Product

The performance requirement has to be specified for all the warranted PE and PP grades appropriately for Extruder vendor to configure and design the package suitably. The Extruder vendor will design the Screw Configuration optimally based on the required product performance range notably considering high melt flow grades, low melt flow grades, fractional melt flow index grades, LLDPE film, HDPE film, BOPP film, PPTQ film, blow molding grades from very small to very large size, Pipe grades, BM Pipe (Bi Modal) grades, Metallocene grades, PP Random grades, PP Impact Copolymers etc.

In short, the Extruder is expected to perform

optimally for range of grades, different applications, density, MFI i.e. low to very high molecular weight and wide range of molecular weight distribution with the given screw configuration.

Depending on the product mix, the vendor can sometime propose two Die Plates i.e. Die Plates of two different Hole Numbers or Hole Size or combination of both to cater to vastly different set of properties, e.g. vastly different MFI. Vendor can also propose two different speeds for Main Motor. The purchaser can suggest option of variable speed drive. Similarly requirement of Melt Pump is governed either by vastly different MFI or Die Plate temperatures or Extruder capacity. Some licensor can mandate not to use Melt Pump if the licensor proposes to use higher Die Plate temperature. Salient design features are summarised below for critical Extruder components. These guidelines have been developed based on the norms for the best practices and the industry experience with different licensors, different technologies and vendors who are industry leaders, supported by relevant reference literature [1] [2] [3] [4].

Main Mixer Motor

It can be single speed, two speeds or variable speed drive. Single speed motor is recommended if the product mix is not very large in range of MFI. Two speed motor is recommended if the product mix is reasonably large in terms of MFI thus allowing to operate the Extruder at optimum speed based on the product mix. Variable speed drive or variable frequency drive is recommended as the energy conservation measure at the design stage if the product mix has large range of MFI and there is a strong possibility of operating the plant at different rates from Turn-Down (TD) to full capacity. The choice of motor speed is governed by the initial investment decision by the client e.g. large variable speed drive will be substantially costlier than single speed or two speed motor. Though variable speed drives appear attractive, very few really prefer it. The most common drives are one speed or two speed.

Melt Pump Motor

Variable speed drive - always a variable speed drive because of the nature of the service.

Underwater Pelletizer Motor

Variable speed drive- always a variable speed drive because of the nature of the service.

Mixer Processing Section

Twin Screw – Length/Diameter Ratio (L/D)		
Polymer	**Without Melt Pump**	**With Melt Pump**
HDPE	18-24	18-21
LLDPE	18-24	18-21
BM HDPE	Not Applicable	23-29
PP	24-30	21-24

Table 2: Twin Screw Extruders – L / D Ratio (Typical)

Diameter (D) and length to diameter ratio (L/D) depends on type of polymer, product mix and residence time or capacity as shown in Table 2.

It can be noticed that Melt Pump reduces the L/D ratio. The longer lengths would mean relatively higher residence time. The screw profile is optimised according to L / D ratio.

Melt Pump or Gear Pump

Inlet design pressure rating shall equal or exceed discharge pressure rating of Mixer. Design discharge pressure is usually minimum 300 kg/cm2g.

Screen Pack

It will cater to different opening specified in the product performance requirement. Clean pressure drop shall be generally 100 kg/cm2 for all warranted products.

Die Plate

Single Die Plate will normally cover a Melt Flow ratio of 1:50.

Pressure drop can vary from minimum of 20 to maximum of 180 kg/cm2. The maximum pressure drop is guided by the "partially blocked" scenario which is time dependent as well as grade dependent and which restricts the flow and can constrain the Extruder capacity.

Die Plate Holes

Number of Die Plate Holes are typically in the following range:

Pelleting Water System

Pellet Water Tank

Tank working volume shall be minimum of 3 minutes of Pellet Water Pumping, e.g. for 600 m3/h pump, Tank working volume shall be minimum 30 m3.

Pellet Water Pump

Typically 12 to 16 m3/T of Pellet Rate with 12 as minimum, e.g. for 60 TPH Extruder capacity, 60 * 12 = 720 m3/h.

Agglomerate Remover and Pellet Dryer

Agglomerates are typically defined as polymer particles or pellets having

Die Plate Holes for PE and PP				
Type of Polymer	**MFI**	**Maximum kg/h/Hole**	**Limitation Due To**	**Diameter of Die Holes**
PP	Full Range	15 to 25	Delta P	3 to 4mm
HDPE	Full Range	12 to 17	Delta P	3 to 3.5mm
LLDPE	Full Range	8 to 12	Melt Fracture for Film Grades	3 to 3.5mm

Table 3: Die Plate Holes for PE & PP

equivalent diameter more than 13 mm (0.5 inch). Normal rate of removal of agglomerates:

- Normal = 0.015 % of total resin rate by weight
- Start-Up = 0.30 % of total resin rate by weight in first 2 minutes

Pellet Dryer: Moisture in the pellets at the outlet of Dryer = 0.05 % maximum by weight (500 ppmw)

Pellet Water Cooler: Design cooling duty shall be minimum of 15% above highest pellet cooling duty for each of the warranted products.

Pellet Water Piping (If supplied by the Extruder vendor): Minimum 15 seconds from Pelletiser to the agglomerate Remover assuming 55°C water temperature. Maximum pellet temperature allowed is 80°C for PE and PP.

Extruder Feed Hopper and Pellet Receiver

Extruder Feed Hopper to have minimum of 6 minutes and maximum of 12 minutes hold-up volume. **Pellet Receiver (also called pellet mass flow meter)** to have minimum of 5 minutes and maximum of 10 minutes hold-up volume.

Hold-up volume is required to provide a positive solid seal and absorbs flow fluctuations.

Resin Feed Properties for Granular PE or PP Bulk Density – Specify for PE or PP

Particle Size: Typically 75 to 850 micron (200 to 20 US Standard Screen)

Particles < 75 microns & > 850 microns to be maximum 1%

Polymer Additives are typically added up to 1% by weight of Resin Feed in the form of powder or pellets

Pellet Product Properties

- Maximum 0.05% moisture by weight
- Free of Agglomerates over 13 mm equivalent diameter
- Substantially free (minimum 98% of pellets) of tails (filaments, shreds or shavings attached to pellets) and marriages (joined pellets)
- Free of degradation (black spots)
- Free of single or multiple voids
- Uniform additive dispersion
- Uniform Pellet Size and Shape:
- Length of pellets, diameter of pellets, symmetry of pellets – all minimum 99%
- Bulk Density of Pellets: to be specified for PE or PP
- Pellet material particle size to be between 0.5 to 9.5 mm minimum 99%

Industry Leading Vendors Supplying Extruder Packages

The three vendors who dominate the Extruder market globally and offer machines up to 100 TPH are:

- Coperion of Germany
- Japan Steel Works (JSW) of Japan
- Kobe Steel of Japan

All the PE and PP technology licensors recommend these three as approved vendors.

Extruder Energy Input

The main source of energy input into Extruder package is from the Main Mixer Motor which is by far the largest motor in the polymer plant which accounts for approximately 65 to 70% of the total power consumption. Thus any attempt to reduce the power consumption in the Extruder package needs to start from the Mixer or Extruder itself.

The resin powder is fed to the Extruder and is converted to molten state or to melt by shear forces applied by co-rotating twin screw. This power is transmitted by electric motor or Main Extruder Motor through the Gear Box to the co-rotating screws. The resin powder in the Extruder Hopper at about 50- 60°C is fed to the Extruder and is heated generally by steam in the barrel to its melting range depending on MW and MWD of the polymer grade. Once fully melted in the melting zone, the melt is further heated for easier processing i.e. kneading and mixing, then conveying through Screen Pack and through the Die Plate to eventually form the pellets in the pelletiser.

This entire energy; assuming there is no melt pump; is transmitted by Main Extruder Motor.

The Energy thus required is:

- Q * MSEI / (MME * MGE * MTE) = MKW (KG / H * KWH / KG) / (MME * MGE * MTE) = (KWH / H)

Where

- Q = Total Feed = KG/H
- MSEI = Motor Specific Energy Input = KWH / KG
- MKW = Mixer Power Input, KW
- MME = Mixer Motor Efficiency = 0.92 to 0.96 (Typically when motor operates at or above 75 % of its rating)
- MGE = Mixer Gear Efficiency = 0.95 to 0.97
- MTE = Mixer Thermal Efficiency = 0.92 to 0.97
- Considering average values for example: MME = 0.94, MGE = 0.96, MTE = 0.94
- Q * MSEI / (0.94 * 0.96 * 0.94) = Q * MSEI / 0.848 = 1.179 * Q * MSEI = MKW
- **Or MSEI = MKW / (Q * 1.179) = 0.848 * MKW / Q**

Thus this becomes the simple but basic formula for computing Extruder energy efficiency which underlines the importance of efficiency of motor, gear box and mixing.

If the Melt Pump is also part of the Extruder, then the equation will include Melt Pump power input and its efficiency added to the equation.

Hence the best efficiencies are obtained when the Extruder is operated at higher rates i.e. at or around design rates or even higher without affecting product quality.

Specific Energy Index (kWh/kg) is also a function of MFI i.e. lower the MFI higher is the Specific Energy in general for PE as well as PP. Beyond a certain MFI, Specific Energy practically remains the same. Higher MFI will require lower energy input or lower SEI than lower MFI. Lower MFI would mean higher melt viscosity and hence higher melt temperature and the vice versa. This data is best obtained from the licensor.

Conclusions

- The specifications and selection of the extruder package has increasingly become important because of rising capacities of single line PE and PP plants which routinely range from 400 to 600 KTPA.
- The article elaborates the salient features of Extruders for energy efficient design and accordingly the strategy for specifications and selection of the package unit which is the most expensive unit in the plant. The Extruder Operation consumes about 65 to 70% of plant's total energy in terms of power and hence the article focuses on items which are critical to power consumption for
- The monitoring of Extruder for energy efficient operation using empirical equations is a matter which can be dealt with in future work. ■

Author

Jayant D Divey
Polyolefins Technology Consultant

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Condensate Case Study: Next-Gen Robust & Proven Technology For Ethanol Industry

RADICO KHAITAN: 1st Plant in India to treat evaporator condensate generated from 3 different feedstocks - Sugar cane molasses, BMSW and Grain

Radico Khaitan is the largest manufacturer of Indian Made Foreign Liquor (IMFL) in India. In March 2019, Paques India has successfully commissioned CPU with NEXT GEN ANAEROBIC BIOPAQ®ICX reactor at their Rampur Distillery Plant, Uttar Pradesh.

The Challenge

Radico Khaitan Rampur Distillery is among the largest distilleries in India and has been a key player in the Indian Distillery Industry since 1943. The distillery produces high-grade Extra Neutral Alcohol ("ENA") from molasses, grains and Scottish design malt spirit from barley malt.

Being a brownfield project with limited space, Radico plant was facing some issues of organic pollutants and the available technologies were not viable, whether technical or commercial.

Water reuse is becoming increasingly important in order to reduce the environmental footprint and to solve the water scarcity issue. To deal with this situation, Rampur Distillery was looking for a reliable and robust system to treat condensate and to achieve ZLD (Zero Liquid Discharge) in their production process.

Major Challenges faced prior to commissioning -

- Condensate from 3 different streams mixed together
- High Ammonical Nitrogen at the inlet
- Strict timelines
- Space constraint

The Solution

Paques CPU powered with Biopaq® ICX seemed to be the perfect fit for treating the wastewater to be reused in the fermentation process of the distillery, same is proven with Paques global installations. The modular design of the reactor also required minimal space, best suitable

for urban areas for saving on land and costs. Paques therefore commissioned a BIOPAQ® ICX High rate reactor with granular Biomass to treat their effluent from 3 different condensate streams.

The BIOPAQ®ICX (Internal CirculationX Advance reactor) is a cost-effective high rate anaerobic effluent treatment for industrial wastewater. The condensate effluent enters the ICX reactor where it is mixed with granular anaerobic biomass in the distribution system. A part of the effluent is recycled to the factory as process water in the fermentation stage. Good granular biomass from the production process is also harvested from the reactor to seed other reactors.

Technical benefits of BIOPAQ®ICX

BIOPAQ®ICX

- Excellent Granular biomass retention (2-stage separators)
- High biomass level in reactor: high COD capacity (VLR)
- Robust, proven influent distribution system designed to also extract biomass from the reactor
- Smart Reactor design and automated control
- No clogging issues and CIP of all internals is possible

The Performance

Paques CPU has given proven results with much higher efficiency as committed to client. And remarkably, in almost 2 years of installation the results are consistent even though there was high NH4N present.

Highlights of the Project

- Treated wastewater by Paques CPU is utilized for fermentation in alcohol production
- Despite of high Ammonical Nitrogen in waste water the COD reduction efficiency across the reactor is 95% - 97% on a consistent basis
- Since major organic load is reduced by BIOPAQ®ICX the downstream operating expenses for post-treatment has been significantly optimized
- Despite frequent shockloads, both in

Andy – The Anaerobic Bacteria

Condensate Polishing Unit at Radico Khaitan

flow & COD, the ICX system has been giving a consistent output efficiency

- Although a brownfield project with limited space, CPU has been successfully installed & commissioned and the plant has been running consistently since April 2019

Biogas Utilised as Green Energy

The Methane purity in the Biogas generated is around 80% which was generally not possible in any of the conventional reactors. This is utilized for green energy generation as they take the same to Biogas engine.

Client Satisfaction

Radico Khaitan was extremely satisfied with Paques technology for which we were also presented with a performance certificate for the operation efficiency of BIOPAQ® ICX reactor. Our robust technology has also been appreciated & recognized at several technical platforms by Radico Khaitan team. ■

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Contact Information

Roshansingh Navlur
Cadmatic Software Solutions Pvt Ltd
Director - India and South East Asia - Sales and Operations
Tel: +91 22 2541 0715, Mobile : +91 98 33511 557
E-Mail : roshansingh.navlur@cadmatic.com
Website: www.cadmatic.com

Fill the Gap: APM 4.0 Bridges the Technology and Generation Divide

By Kim Custeau, Vice President, APM Business AVEVA

The workforce has always adapted to ongoing generational shifts, and today's employee landscape is no exception, particularly in the engineering and industrial sectors. With many baby boomers still in the workplace but potentially thinking about career exits and retirement plans, businesses must think not only about succession plans surrounding people, but also how technology can help bridge the knowledge gap.

New research revealed that 77% of finance directors are concerned about the skills gap and the negative impact from the widespread retirement of baby boomers over the next five years. Beyond this, there are also concerns beyond the new demands and expectations from the younger Generation Y and Z workforce, especially surrounding technology. It's essential that we align people, process and technology.

Kim Custeau, Vice President, APM Business AVEVA

Inspire people to shape the future

If machines could talk, they'd tell us that now is the time to unlock and capitalize on the knowledge of the retiring workforce so that Millennials and Generation Z can reap the rewards of their hard earned

experience. In industrial operations in particular, it's time to consider how to blend the institutional knowledge that the retiring generation carries to benefit the younger generation that has additional skill sets in digital technology.

The next generation of industrial workers expect an easy, modern, scalable solution to conduct their work processes – high-speed internet access, mobile devices, touch screens and virtual reality. This combination of an evolving workforce and proliferation of technologies such as predictive maintenance, cloud, big data and mobility is bringing asset performance management 4.0 (APM) to the forefront of business.

Collaborate and Create

APM 4.0 is bridging the technology and generation gap, enabling people to communicate and collaborate beyond traditional boundaries. As your business evolves, APM 4.0 enables continual digital transformation designed to accommodate the knowledge and expertise of your workforce.

BP is a great example of the power of collaboration. The company wanted to simplify and standardize its oil and gas downstream supply chain management creating an intuitive environment that enables refinery analysts to identify economic opportunities and share best practices. . There was a lack of transparency and duplication of efforts across the supply chain, which was largely down to using outdated technologies that required rare specialized skills, often limited to a small number of specialists.

By adopting APM 4.0, BP was able to enhance data management and transparency to improve decision-making and knowledge share across global feedstock planning and refinery operations teams, spanning countries and generations.

- 1.1.1.1. Ascend Performance Materials is another great example of a company that gained real business value from APM, and how workflow enabled organizational collaboration amongst all teams, from junior to senior level team members.
- 1.1.1.2. Ascend's goal was to transform from a '1950s' era plant, into a modern manufacturing facility able to leverage the hidden insights in industrial data in order to help prevent plant shutdowns.
- 1.1.1.3. Prior to implementing APM 4.0, Ascend was collecting data manually on pieces of paper that stayed on a clipboard until the clipboard was full. It was a challenge to track down who implemented work, and what they posted in the system. Using APM 4.0, Ascend was able to eliminate the manual input of data and visualize the overall manufacturing process across all teams, improving communication

and knowledge share, and saving over $2 million in potential plant closures.

APM 4.0 to Revolutionize Industry and Enhance the Human Experience

APM 4.0 also unlocks the potential of your assets, opening new opportunities to bring together cyber and physical systems, the Internet of Things and cloud computing to create smart factories, facilities or plants. As organizations invest in their people and technology to bridge any generational divides, they should be looking at APM 4.0 as a critical component of that strategy in order to help business to quickly adapt to market changes and capitalize on economic opportunities.

APM 4.0 is an evolutionary step that brings together many components we see now and that have the potential to make an impact in the future. At its core, APM 4.0 includes prescriptive analytics and machine learning, smart connected assets and services, IIoT platforms, industry best practices and digital twin as a mashup. It empowers companies to adopt predictive and prescriptive maintenance strategies, giving them the ability to look ahead, prescribe the most economically advantageous course of action that prevent costly failures and reduce unplanned downtime.

We believe industry advancement should enhance the human experience, and not only revolutionize industries, but also empower the people behind them. Our comprehensive Asset Performance Management software portfolio is designed to overcome today's industrial challenges by leveraging industrial big data. With improved analysis, you'll eliminate inefficiencies, bridge the generational divide of your people, optimize operations, and improve profitability.

About AVEVA

AVEVA Group plc provides innovative industrial software to transform complex industries such as Oil & Gas, Construction, Engineering, Marine, and Utilities. AVEVA's software solutions and platform enable the design and management of complex industrial assets like power plants, chemical plants, water treatment facilities and food and beverage manufacturers – deploying IIoT, Big Data and Artificial Intelligence to digitally transform industries. ■

For more details contact

Ms. Srilakshmi Lakshmanan
AVEVA India Marketing
E-mail: Srilakshmi.lakshmanan@aveva.com
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