CHEMPHORIA

MAGAZINE 2019 EDITION

Modern Simulation Tool

APJAKTU Corner

Boiler Feed Water

New ‘kg’ Standard

DISTILLATION COLUMN

IIChE STUDENT CHAPTER
DEPT. OF CHEMICAL ENGINEERING
TKM COLLEGE OF ENGINEERING

Chemphoria 2019 Edition

HOD's Message

A weak link is better than a strong memory. Nothing exemplifies it better than the nostalgic feeling one gets when leafing through the dusty old pages of his/her department magazine. It can make a reader travel down the lanes of memory, giving rise to a surge of emotions of many hues and colours. TKMCE CHED's Chemphoria is going to give the same pleasure to all the brilliant minds who traverse through the portals of this temple of learning.

I am happy to see the amount of enthusiasm of students and eminent members of the department to contribute to the magazine. Not to be outdone, our students have devoted time and plunged into creating powerful technical writings, contemporary industrial changes, and other informative articles. I stand awed by the sheer number of articles that have come pouring in for the magazine. This shows the positive and creative energy of faculty members and students present in the department.

We proudly publish the department magazine in order to show to the outside world, and also to remind the denizens of TKMCE CHED, the progress we have made so far. We intend to continue presenting the talent and creativity of our staff and students through Chemphoria every year.

I invite you to read and immerse yourself in the unfolding art and be exulted

Prof Femina A.

Associate Professor and Head

Department of Chemical Engineering

TKMCE Kollam

STAFF EDITOR'S EPISTLE

I feel great pleasure to present yet another issue of our annual technical magazine Chemphoria 2019.

"Success comes to those who work hard and stays with those, who don't rest on the laurels of the past".

The world today is changing at such an accelerated rate and we need to pause and reflect on this entire system of education. I am pleased to note that the increasing number of university ranks every year speak the excellent quality of education being imparted in our institution.

As Margaret Mead said, "Children must be taught how to think, not what to think," and to enable this, our motto of Knowledge, Imagination and Innovation is encouraged through a holistic approach.

Each issue of our department magazine is a milestone that marks our growth, unfolds our imagination, and gives life to our thoughts and aspirations. It unleashes a wide spectrum of creative skills ranging from technical writing to editing and even in designing the magazine. Chemphoria 2019 is a perfect blend of technical thinking, knowledge and wisdom which vibrates in the inner soul of various stakeholders. It is natural to find in his ambience, the intensive use of a variety of thinking activities, strategies and group dynamics to make this issue interesting and thought provoking. I congratulate the entire student editorial team for their effort in bringing out this magazine in a very innovative way under the guidance of IIChE staff coordinator Prof. Manikandan P. M. Special thanks to Akhilnand C (170235, 2017 – 2021), for the cover page design.

On this occasion, I seize the moment to congratulate all graduating students 2019. I am confident that they are going to lead their life extraordinarily.

Mr Amal G S

Assistant Professor (on contract)

Department of Chemical Engineering,

TKMCE, Kollam

STUDENT EDITOR'S NOTE

We are extremely happy to bring out this message for our department magazine released for the year 2019.

This magazine provides a platform for us students and Staff to share information, spread the latest technical Knowledge and cultivate right ways that will equip all of us to stay competent in our respective fields of study and research.

We congratulate and thank all the students and staff Coordinators who have made untiring efforts to bring out this magazine.

Reading this magazine would definitely be an inspiration and motivation for all students and staff to contribute even more to the forthcoming issues. We hope that everyone would continue to give their full efforts to keep the momentum and continue to enhance the standards of the magazine. The outside world will come to know about the calibre of the students and the faculty through this magazine.

We extend our thanks to all the contributors for their articles.

Irene Wilson (150740)

Swathinath P Unnithan (150856)

2015 – 2019 Batch

The department in a nutshell…….

Vision

Attainment of recognition by all stakeholders as well as peers as a department of choice for higher learning in the discipline and allied areas, that strives for excellence in teaching, outstanding research, scholarly activities and apply engineering expertise in meeting societal needs.

Mission

- Prepare the students for graduate study through an effective curriculum and produce chemical engineering professional who can serve the industry and the society at large by imparting the best of scientific and technological knowledge.
- Provide competitive and stimulating academic environment to nurture creativity, self-learning and inter-personal skills.
- Foster the pursuit of new knowledge and innovative ideas in chemical engineering through industry-institute interaction and facilitate progressive research.
- Practice ethical approach, pursue sustainable development and instill a passion for lifelong learning.

Program Educational Objectives (PEOs)

- Succeed in their chosen career path, as practitioners in process industries and organizations or pursue advanced technical and professional degrees.
- Exhibit the required mathematical and problem solving skills and competencies, necessary to adapt to the changing technologies and become lifelong learners.
- Possess integrity and ethical values both as individuals and in team environments and address global and societal issues including health, safety and protection of environment.

Programme Specific Outcomes (PSOs)

- Analyse and apply the knowledge of Unit Operations and Unit Processes to function as process engineer.
- Design process equipment and develop processes considering safety, economic, environmental and ethical aspects.
- Communicating effectively with peers and society and function as a member or a leader for managing projects, adapting to technological changes.

Program Outcomes (POs)

Engineering graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigation of complex problem**: Use research- based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage project and in multidisciplinary environment.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

About IIChE….

Indian Institute of Chemical Engineers is a confluence of streams of professionals from academia, research institutes and industry. It provides an appropriate forum for joint endeavours to work for human beings through application of chemical engineering and allied sciences. Programmes of IIChE are immensely beneficial, opening up doors of new and existing possibilities.

The student chapters guide its members in career choice and arrange lectures, seminars, short courses, plant visits, etc., at regular intervals to better equip and empower the students when they are out of their academic precincts

Vision

Over the years the Institute has developed a distinct profile of its own. Even though the IIChE is always moulding itself and playing a proactive role to keep up with the ever changing needs of the society and the economy, its basic objectives largely remain unchanged since its inception. One may shortlist them as:

- To promote advancement of chemical engineering and draw up a code of ethics in the profession
- To maintain and widen contacts with chemical engineering professionals in India and abroad
- To ensure regular exchange of ideas with other national and international professional institutes in this field
- To act as an authoritative body on matters pertaining to the teaching and the profession of chemical engineering
- To conduct examinations and assist persons engaged in the industry to qualify as chemical engineer
- To confer awards, diplomas and certificates to such persons as may be deemed fit.
- To undertake publication work i.e., journal, monographs, proceedings of seminars/symposia/workshops
- To conduct meeting and transact business in administrative, academic and technical matters relating to the profession

Mission

The primary objective of a student's chapter is to promote among chemical engineering undergraduates a feeling of fraternity, brotherhood and to complement the objectives and activities of the institute. It shall also render all possible assistance to the regional centres in matters relating to student members.

Objectives

The activities of the student's chapter specifically include the following:

- To arrange lectures, film shows and video shows related to the chemical engineering education and profession
- To arrange seminars, workshops, group discussions and debates and to promote interaction of the institute with industry
- To establish and operate book banks for the use of its members
- To arrange excursions and plant visits of interest to chemical engineers undergraduates
- To assist and guide student chemical engineers in their career planning and placement
- To assist any other activities of social, technical and educational interest to chemical engineering undergraduates.

IIChE Torch Bearers for the academic year 2019 – 2020

Faculty in charge	: Prof. Manikandan P. M.
Secretary	: Mr. Akhil Santhosh
Joint Secretary	: Mr. M Madhava Krishnan
Treasurer	: Miss. Alfina S
Executive Members	: Mr. Arjun P. V.
	Miss. Pravitha Pillai
	Mr. Muhammed Salman Haries
	Miss. Jovita Joseph
	Mr. Nithin T. N.
	Miss Devipriya Mudiyil
	Mr. Justin Reji
	Miss. Sreya Das C V

Dedication

This magazine is dedicated to all MARTYRS of Pulwama terror attack, February 2019

Contents

Boiler Feedwater

Fact at your finger tips

Microbial Control in cooling water

Modern Simulation Tools

Latest in the Industry

Distillation Column

Agglomeration Processes

GATE Corner

APJAKTU Corner

Industry Corner

TREATING BOILER FEEDWATER FOR RELIABLE OPERATION

These key elements of internal boiler feedwater (BFW) treatment will help avoid boiler tube failures due to scale and pitting

For many chemical processes, an industrial packaged-type boiler is a critical component for either power generation or for producing steam. In the event that boilers are taken offline due to a failure, the facility may experience a loss of power or production downtime, each carrying significant economic consequences. Improper treatment of boiler feedwater can result in boiler tube failures due to oxygen pitting and scale buildup on internal heating surfaces. This article provides an overview of proper boiler feedwater treatment to help plants avoid failures. Boiler feedwater treatment typically comprises a combination of several different processes, each designed to remove certain contaminants from raw make-up water or condensate return water. These processes can be divided into two parts: an upstream water-treatment system and a chemical treatment program. The upstream processes can include a combination of filtration, water softening, demineralization, reverse osmosis and de-aeration, depending on the quality of the raw water used. The chemical treatment program would include the introduction of chemicals to the boiler water to remove any remaining unwanted contaminants from the pressure vessel itself.

BOILER FEEDWATER OPTIONS: For any commercial or industrial boiler-type application, the boiler feedwater can include raw make-up water, condensate return, or any combination of the two. Raw make-up water is defined as freshwater introduced into the system to account for losses in water or steam due to consumption by the process or from wastewater that is removed from the system. Condensate return water refers to water that has been condensed from the boiler steam after it has delivered heat to the process, and is then recycled back to the feedwater system. For any application, the conservation of condensate return is ideal. Even though the condensate has lost some energy through the process, it is typically at a higher temperature (greater than 120°F, for example), and contains more energy than the raw make-up water (typically around 40–50°F). Note that regardless of how much condensate can be recovered, every application is going to require some make-up water due to losses throughout the system.

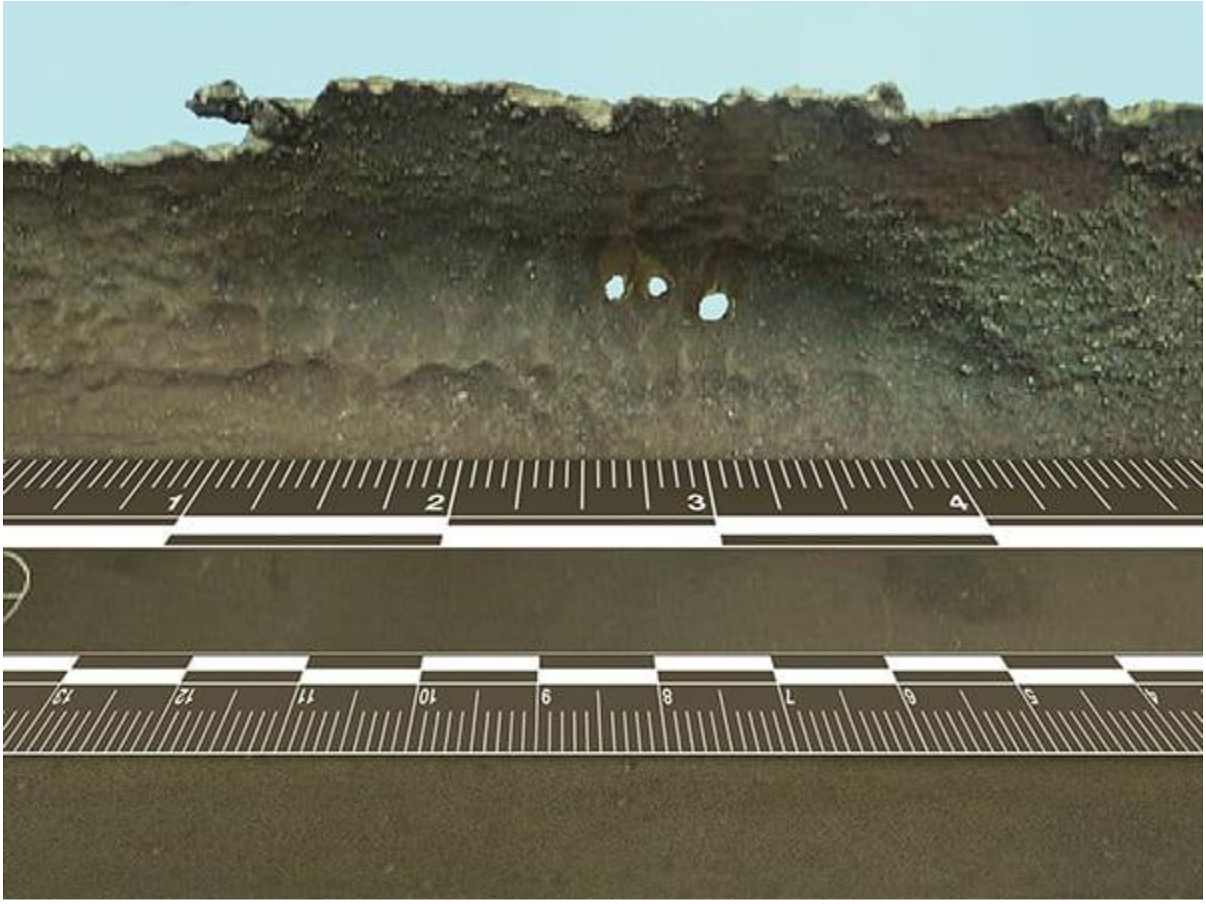

Figure 1. Pitting on the internal surface of a tube can result from the presence of oxygen in the boiler feedwater

DE-AERATIONDe-aeration is a critical feedwater treatment component for every boiler application. The raw make-up water fed from the upstream water-treatment system is saturated with oxygen. Because the industry standard for boiler components and piping is to use carbon-steel materials, oxygen in the water will cause extensive corrosion to the components if it is not removed. Typical damage to any carbon-steel materials, including piping, boiler tubes and drums, will include pitting and thinning of the components due to the oxygen attacking the iron in the carbon steel (Figure 1). This pitting is a result of the basic reaction for the formation of rust (Equations (1) and (2)).

$$4Fe + 6H_2O + 3O_2 \rightarrow 4Fe(OH)_3 \qquad \textbf{(1)}$$
$$2Fe(OH)_3 \rightarrow Fe_2O_3 + 3H_2O \qquad \textbf{(2)}$$

These reactions remove material from the carbon-steel heating surface and can create deposits that can collect on the internal surfaces. These deposits reduce heat-transfer efficiency and can also plug the tubes, which creates potential hot spots that can lead to tube failures. It may not seem that these reactions could pose such a threat to the boiler equipment. However, given that typical industrial packaged-type boilers can generate from 10,000 lb/h to more than 250,000 lb/h of steam, this type of flow would expose the boiler to a great deal of oxygenated water, and could result in corrosion and potential tube failures in a fairly short period of time.

In order to remove oxygen from the water and mitigate the risk of corrosion, there are two methods of de-aeration that can be used in combination with each other. The first is to use a piece of equipment that is referred to as a de-aerator, and the second is to use an oxygen scavenging chemical to remove any remaining oxygen from the system. A de-aerator is used for virtually every boiler application at some stage during the feedwater treatment process. There are two designs that typically are used, a spray type and a tray type de-aerator (Figure 2), which, for the purposes of this discussion, provide essentially the same end result.

Figure 2. Tray-type de-aerators are designed to remove oxygen from boiler feedwater to avoid corrosion issues

A de-aerator uses a combination of steam heating and turbulent mixing to remove the oxygen from the water to a level of 0.007 parts per million (ppm), as recommended by the American Society of Mechanical Engineers (ASME) Water

Quality Guidelines (Table 1). Note that the table shown here is abbreviated, and that the complete table includes recommended values all the way up to 2,000 psig.

TABLE 1: ASME WATER QUALITY GUIDELINES

ASME Document No. CRTD (Vol. 34) "Consensus on Operating Practices for the Control of Feedwater & Boiler Water Chemistry in Modern Industrial Boilers"			
Drum operating pressure, psig	0–300	301–450	451–600
Feedwater			
Dissolved oxygen ppm (mg/L)			
O_2 measured before chemical oxygen scavenging	<0.007	<0.007	<0.007
Total iron ppm (mg/L) Fe	<0.1	<0.05	<0.03
Total hardness ppm (mg/L)*	<0.3	<0.3	<0.2
pH at 250°C	8.3–10.0	8.3–10.0	8.3–10.0
Boiler water			
Silica ppm (mg/L)	<150	<90	<40
Total alkalinity ppm (mg/L)*	<700	<600	<500
Total Dissolved Solids in Steam			
TDS (maximum) ppm	1.0–0.2	1.0–0.2	1.0
*as $CaCO_3$			

In a tray-type de-aerator, the raw make-up water is sprayed into the top of the de-aerator column by means of a spring-operated sprayer or by spray nozzles. The spraying action generates small water droplets or a film, which flow downward between trays or deflection baffles. To avoid corrosion, the interior of the de-aerator includes stainless-steel materials for any wetted parts that come into contact with the oxygen-rich make-up water. The steam used to heat the water enters the de-aerator in the lower part of the tray section and rises through the sprayed water in a countercurrent-flow manner. As the steam and water mix, the incoming make-up water is heated from the typical inlet temperature of 40–50°F to the saturation temperature in the de-aerator, and the oxygen is driven out of the water as a result of the heating and mixing. The oxygen is allowed to vent to atmosphere from the top of the de-aerator. The steam is condensed into the make-up water as it transfers heat, and the mixture then flows downward into a feedwater storage tank. Note that the saturation temperature of the tank may vary depending on the specific operating pressure of the de-aerator. Typically, these are operated at pressures of 5–15 psig and temperatures of 228–250°F. The relationship between the oxygen saturation content in the water and the water temperature is demonstrated in Figure 3.

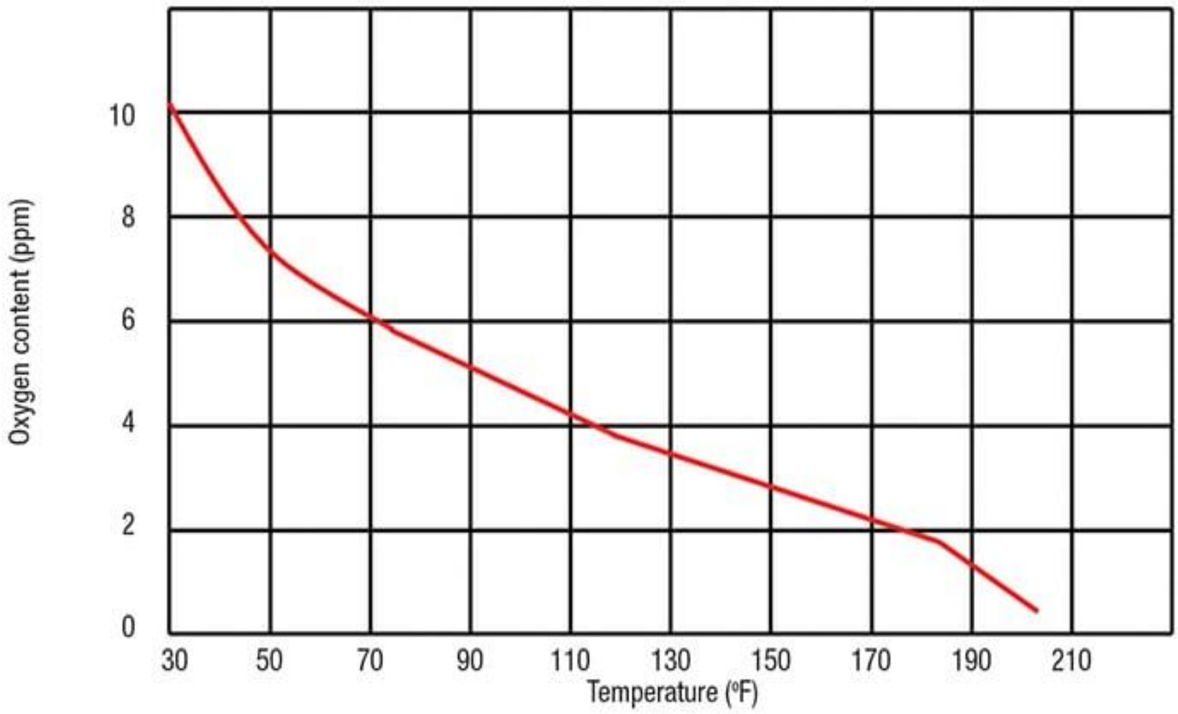

Figure 3. The relationship between oxygen content in the feedwater and temperature is shown here

OXYGEN SCAVENGING: Even after the reduction in oxygen from the de-aerator, there is still a small amount of oxygen remaining in the feedwater, and this is enough to cause corrosion. In order to remove this residual oxygen, the de-aerator can be supplemented with an oxygen-scavenging chemical. The typical system includes carbon-steel materials for the feedwater storage tank, feedwater pumps, piping between the de-aerator and the boiler, and boiler pressure parts. All of these materials would be subject to corrosion if the remaining oxygen is not removed. Because all equipment downstream of the de-aerator is made from carbon steel, the oxygen scavenger should be introduced as far upstream as possible, in the feedwater storage tank that is directly connected to the de-aerator itself. Three of the most common types of chemical treatment used for oxygen scavenging are sodium sulfite, hydrazine and carbohydrazide. Each of these chemicals provides different benefits that should be considered before selecting which oxygen scavenger should be used for a particular application.

Sodium sulfite. Sodium sulfite typically comes as a powder or in an aqueous solution, and is generally the most economical chemical used for oxygen scavenging. The sulfite is very effective and reacts with the dissolved oxygen in the water according to the reaction shown in Equation (3), removing the oxygen from the system. With this chemical reaction, the sulfite attacks the oxygen at a ratio (dosage) of approximately 7.5 parts sulfite to 1 part oxygen.

$$2Na_2SO_3 + O_2 \rightarrow 2Na_2SO_4 \qquad \textbf{(3)}$$

In this reaction, the sulfite and oxygen form a solid sodium sulfate product, which is carried through in the feedwater. The solid must be removed from the boiler water via the blowdown that is discharged from the boiler system as wastewater (Figure 4). Depending on the specific requirements of an application, this can be one of the drawbacks to using sodium sulfite — this end product adds to the overall solids concentration in the boiler water. With higher-pressure boilers, or boilers that are generating steam to drive turbines, maintaining a low solids content in the steam is more critical, and the use of a sulfite scavenger would not be recommended in those cases.

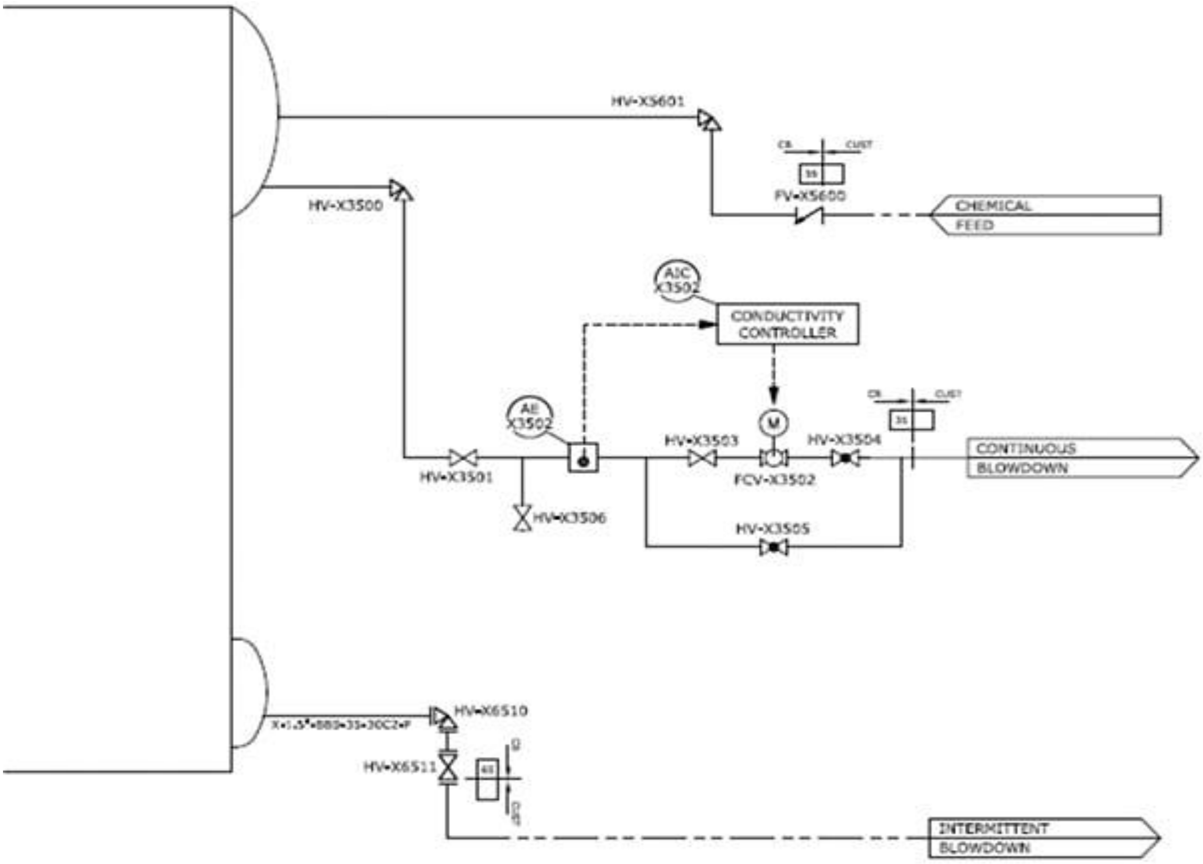

Figure 4. The diagram shows a typical boiler blowdown configuration

Another factor to note is that the sulfite can break down and react with the water at lower pressures (less than or equal to 600 psig), forming sulfur dioxide and/or hydrogen sulfide. These two gases are carried through the system in the outlet steam, reducing the alkalinity of the steam and any condensate return. This low alkalinity causes acidic conditions downstream of the boiler, and can result in corrosion to the system. One last item that should be considered regarding protection of the materials downstream of the boiler is that the sodium sulfite is nonvolatile, and would not be carried in the boiler steam throughout the system like the sulfur-containing gases would. Therefore, using sodium sulfite as an oxygen scavenger would not provide the benefit of protecting the materials downstream of the boiler, including any condensate that may be part of the boiler feed system.

Hydrazine. Hydrazine is the second option that may be used for oxygen scavenging. This chemical comes as a colorless liquid and also can be added directly to the feedwater storage tank upstream of the boiler. The hydrazine reacts with the remaining oxygen in the feedwater according to the reaction shown in Equation (4). The hydrazine attacks dissolved oxygen at a ratio of 1 part hydrazine to 1 part oxygen.

$$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O \qquad \textbf{(4)}$$

The products of the reaction are simply nitrogen and water, so this scavenger does not add any solids content to the boiler system and does not impact the boiler blowdown rate. This makes hydrazine a better choice for any applications where lower solids content in the steam must be maintained. Also, because the hydrazine does not create any corrosive gases that can be carried through, the alkalinity of the boiler system is not affected by the use of this chemical. Something that must be considered when using hydrazine is that if the given application calls for steam that is greater than 750°F, the hydrazine will start to break down and form ammonia. Depending on the trim and valve selections for the boiler and low-pressure feedwater system, the presence of ammonia can cause potential issues. Ammonia will attack any "yellow metals," or metals containing copper. This possibility must be considered in the design of any new systems, as well as existing systems that may use these types of materials.

Carbohydrazide. The third oxygen-scavenging chemical to discuss here is carbohydrazide. The reaction between carbohydrazide and oxygen is shown in Equation (5). The reaction is ideal, as it can be achieved at fairly low pressures and temperatures as seen in a typical deaerator. Similar to hydrazine, the lower molecular weight of carbohydrazide makes it able to react at a ratio of 1.4 parts carbohydrazide to 1 part oxygen.

$$H_6N_4CO + 2O_2 \rightarrow CO_2 + 2N_2 + 3H_2O \qquad \textbf{(5)}$$

This reaction also does not generate solids, so the boiler blowdown rate is not affected by this scavenger. One benefit that carbohydrazide offers, but hydrazine does not, is that it is volatile. Any carbohydrazide that is remaining in the water can be carried by the steam out of the boiler, which helps to protect any carbon-steel materials in the downstream system. It is important to be aware that this carbohydrazide can break down to hydrazine at higher temperatures (higher than 350°F). However, given the typical operating conditions of a de-aerator (228–250°F), this should not be an issue if injected directly into the feedwater storage tank, where it can react prior to being heated to above this 350°F threshold in the boiler. The three chemicals discussed here are considered to be among the most commonly used oxygen scavengers for industrial boiler systems. Each of the chemicals is capable of removing residual oxygen from the boiler feedwater, but should be evaluated based on its individual benefits. Beyond these three, there are also several other oxygen-scavenging chemicals used. It is recommended to coordinate the use of these chemicals with a local water-treatment or chemical provider based on the specific water quality in a given plant.

TREATMENT FOR SCALE AND SOLIDS: In addition to de-aeration and oxygen scavenging, boiler feedwater typically requires additional chemical treatment for the removal of solids that are left in the water after going through the upstream treatment system. These solids can include silica, calcium and magnesium compounds, and various others that contribute to the hardness of the water. Removing these solids helps to mitigate the risk of scaling and deposits collecting on the heat-transfer surfaces. Scale is formed when the water boils off of the heat-transfer surface and solids are left to precipitate out, sticking to the surface. In an industrial boiler, this scale would occur on the internal surfaces of the boiler tubes and drums. As the scale builds over time, deposits collect on the surfaces, causing fouling, which at a minimum, reduces heat-transfer efficiency. In extreme cases, the deposits can actually clog or plug the boiler tubes. This creates hot spots in the tubes due to a lack of circulation (water cooling), and may cause them to rupture. If a tube failure occurs, this is likely to require significant downtime and potentially costly tube-replacement work.

There are three primary chemicals that are used to treat water hardness. These typically include the use of a phosphate or a chelant in combination with a polymer.

The appropriate combination of these would be project-specific, depending on specific water quality and the water-treatment philosophy and standards of the facility. The phosphate treatment reacts with the scale-causing minerals, such as calcium and magnesium salts, and precipitates the hardness out of the water, since the products are insoluble. Chelant treatment is slightly different — the products of the reactions form soluble structures that remain in the water and do not collect on the heat-transfer surfaces. Both the phosphate and chelant treatments usually are supplemented with a polymer, which acts as a dispersant. The polymer prevents either the precipitated or soluble materials from collecting on surfaces and forming scale or buildup of deposits. The products of either of these treatments form a sludge that typically settles into the upper and lower drums of the boiler. Because the sludge has been conditioned by the addition of the polymer, it does not adhere to the surfaces and is removed via continuous or intermittent blowdown. The rate of blowdown required for removing this sludge can be set using manual valves, or can be monitored and modulated with the use of a conductivity controller.

PHOSPHATE TREATMENT: When using phosphates for water treatment, the precipitation of calcium and magnesium compounds are achieved through a number of reactions that can occur in combination with each other. These reactions are possible with the heating of the boiler water and the presence of calcium, sodium and magnesium. Several intermediate hydroxide and carbonate products can be formed due to the heating of the boiler water and the potential for carbon dioxide to be present. The reaction with the phosphate occurs when both calcium and magnesium are present as bicarbonates [Equations (6) and (7)].

$$3Ca(HCO_3)_2 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6H_2O + 6CO_2 \qquad \textbf{(6)}$$

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2^- + 2CaCO_3^- + 2H_2O \qquad \textbf{(7)}$$

For the calcium reaction, the desired end product is calcium phosphate, where the initial magnesium reaction forms a magnesium hydroxide. Both of these products will precipitate out of the boiler water and can be removed from the boiler with the blowdown. If silica is present, it is preferred that the magnesium hydroxide undergo a second reaction to form magnesium silicate. With this, both the magnesium and silica would be able to precipitate out of the boiler feedwater. One of the benefits of phosphate treatment is that it helps to maintain sufficient alkalinity for this reaction to take place. The phosphate treatment would be supplemented with a polymer to condition the solids to remain dispersed in the water until they settle to the bottom of the drum for removal with the blowdown.

CHELANT TREATMENT: A chelant is a molecule that is able to bind to a positively charged metal ion (cation). This type of chemical treatment involves the introduction of a fairly weak organic acid that is able to react with the calcium, magnesium and other metals in the water. Once this reaction has occurred, the resulting product is unable to deposit itself on the boiler heating surfaces because it is soluble in the water. Similar to the phosphate treatment, a supplemental polymer also would be added to act as a dispersant to allow the deposits to settle in the drum(s) for removal with the blowdown. Two common chelants that are used for boiler feedwater treatment are nitrilotriacetic acid (NTA) and ethylenediaminetetraacetic acid (EDTA), shown in Figure 5.

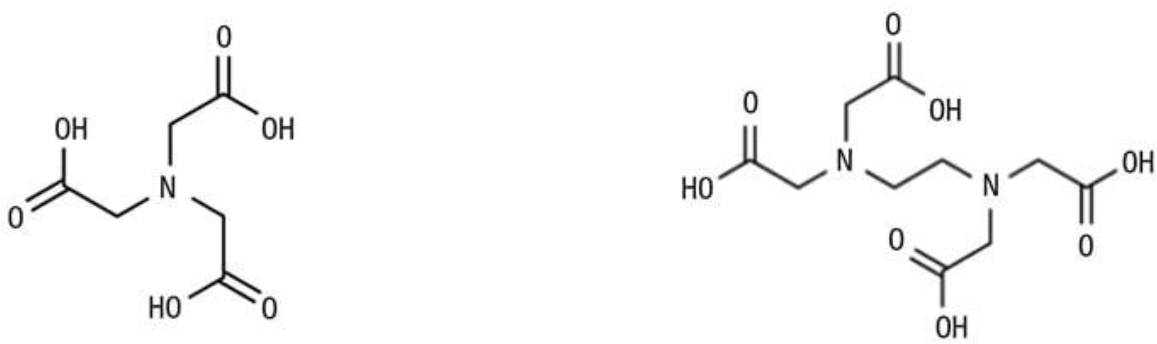

Figure 5. Molecules such as nitriloacetic acid (NTA; left) and ethylenediaminetetraacetic acid (EDTA; right) can chelate scale-causing minerals to prevent them from precipitating on heat-transfer surfaces

Both of these are very effective at binding with the metals in the water, as they each contain multiple reaction sites. NTA contains four sites (1 N + 3 OH), and EDTA contains six sites (2 N + 4 OH). Both chemicals form a ring-like structure when they react with the metals, and react on a mole-to-mole basis [Equations (8) to (13)].

$Ca^{+2} + NTA^{-3} \rightarrow CaNTA^{-}$ **(8)**

$Mg^{+2} + NTA^{-3} \rightarrow MgNTA^{-}$ **(9)**

$Fe^{+3} + NTA^{-3} \rightarrow FeNTA$ **(10)**

$Ca^{+2} + EDTA^{-4} \rightarrow CaEDTA^{-2}$ **(11)**

$Mg^{+2} + EDTA^{-4} \rightarrow MgEDTA^{-2}$ **(12)**

$Fe^{+3} + EDTA^{-4} \rightarrow FeEDTA^{-}$ **(13)**

Note that with these two chemicals, the EDTA will form a more stable ring structure around the metal atoms, because it has the two additional reaction sites. The NTA only is able to react at four sites, which makes the product more vulnerable to additional reactions with other negatively charged ions.Similar to the oxygen scavenging chemical treatments discussed, the combinations of phosphate-polymer and chelant-polymer chemicals discussed here are considered to be among the most commonly used. Again, it would be recommended to coordinate the use of any chemicals with a local water-treatment or chemical provider based on your plant's specific water quality.

CONCLUDING REMARKS: The chemical treatment required for boiler feedwater in any facility is dependent on the specific water quality at the given site and may require additional treatment outside of what was identified here. Boiler feedwater at any facility should be analyzed chemically and compared to the ASME Water Quality Guidelines to determine which chemical treatment options may be necessary, and which would best comply with the facility's water treatment program and philosophy.

References: Dan Skiles. sales engineer at Cleaver-Brooks – Engineered Boiler Systems Group

Fact at your finger tips

(Jaison Jose J., 160628, 2016 – 2020)

REDEFINING THE KILOGRAM STANDARD: The kilogram is the last of the SI units (International System of Units) still defined by a physical object, rather than defined in terms of universal fundamental constants of nature. However, this will change in November 2018, as a multi-year effort culminates in the adoption of a new definition for the kilogram that is based on Planck's constant. This one-page reference describes the effort to redefine the kilogram standard, shifting the definition from a physical object, which can change over time, and to a definition according to stable and reproducible constants of nature. The kilogram is currently defined as the mass equal to a polished cylinder of platinum and iridium known as the International Prototype of the Kilogram (IPK; photo). Cast in 1879, it is currently housed at the Bureau International des Poids et Mesures. According to the U.S. National Institute of Standards and Technology, The accuracy of every measurement of mass or weight worldwide depends on how closely the reference masses used in those measurements can be linked to the mass of the IPK.

LIQUID-LIQUID EXTRACTION: GENERATING EQUILIBRIUM DATA: Equilibrium data and related information gathered from a liquid-liquid extraction laboratory "shake test" can provide information for process feasibility and column-type selection in the scaleup of liquid-liquid extraction processes Most chemical engineers have had the experience of dealing with problematic separations, and most have a general understanding of distillation processes. When it comes to liquid-liquid extraction (LLE) processes, however, the details of how these processes work are often less clear. Most academic chemical engineering degree programs do not heavily emphasize liquid-liquid extraction, and most chemical engineering graduates did not receive more than a few days of instruction on generating equilibrium data for LLE in their degree programs. Commercial-scale liquid-liquid extraction processes often transfer solutes from an aqueous phase to a solvent[/caption] This article is focused on going "behind the scenes" and revealing more about the earliest stages of generating LLE equilibrium data.

FILTRATION PROCESS DESIGN: Designing a new solid-liquid filtration process or optimizing an existing one requires consideration of a number of factors aside from the type of filter that will be used. This one-page reference reviews two groups of considerations: one related to equipment, and another more related to the materials being separated. Material-related issues Solids properties. The physical characteristics of the solids being filtered have a substantial effect on the level of difficulty of the filtration process, and in turn on the appropriate type of filter and operating conditions. For example, particles that are incompressible (rigid) are usually easier to filter than those that are soft and compressible. Solids that are crystalline can be relatively easy to filter, whereas amorphous, slimy or gelatinous solids are more difficult to separate and require more complex techniques. Particle-size distribution. The solids in a slurry are often characterized by the average particle size, which can be a useful measure. However, the particle-size distribution is also very important.

PUMP SIZING PARAMETERS: A solid grasp of pump sizing allows engineers to make effective economic and practical decisions about process pumps. This one-page reference provides information about two key parameters and other considerations for pump sizing. Pump sizing steps Sizing a pump requires engineers to estimate the temperature, density, viscosity and vapour pressure of the fluid being pumped. Pump sizing can be accomplished in six general steps: Find the total dynamic head (TDH), which is a function of the four key parameters of a pumping system, shown in Figure 1. Correct for the viscosity of the fluid, since pump charts and data are given for water with a viscosity of 1 cP. Viscosity of other process fluids can differ dramatically. Calculate the net positive suction head (NPSH) to select a pump that will not undergo cavitation. Check the value of suction-specific speed to see if a commercial pump is readily available. Check for potentially suitable pumps using a composite performance curve and an individual pump performance curve.

LOW-TEMPERATURE HANDLING: Processes involving extremely low temperatures present unique process design and safety challenges. This one-page reference outlines considerations for low-temperature operations. Direct contact. Extremely low temperatures can rapidly freeze human tissue. Contact between a worker's bare skin and a low-temperature vapour, liquid or solid can result in cryogenic burns. Contact is most likely when objects are being moved into or out of a low-temperature zone, such as a liquid-nitrogen-storage bath, during maintenance activities, or when low-temperature fluids are being transferred. If cryogenic fluids are involved, workers should wear long sleeves, long pants, thermally insulating gloves, and face and eye protection (a full face shield over safety glasses is advisable). Pants should not have cuffs, and gloves should be loose so they can be quickly removed.

MICROBIAL CONTROL IN COOLING WATER

(PRASEEDA P NAIR, 160109, 2016 – 2020)

Industrial cooling-water systems are critical to the success of many chemical process industries (CPI) operations. Proper operation of cooling-water systems supports the financial drivers of energy efficiency, asset preservation and water savings, while optimizing overall process performance. When maintained properly, industrial cooling-water systems help enable processes to run seamlessly. Selecting the appropriate water-treatment solution for an industrial cooling-water system is critical, and typically includes consideration of mechanical, operational and chemical components of the system (Figure 1).

Figure 1. Microbial control must be considered for cooling tower systems to maintain operational efficiency

Among the important aspects of cooling-water treatment is the control of microbes. Biological control in an industrial water system is important for maintaining optimal performance in three areas: scale prevention, corrosion inhibition and fouling control. Failure to effectively control microbes in cooling water can cause the system to suffer from diminished operational efficiency, premature equipment failure, deteriorated product quality and increased health-related risks associated with biological fouling.

Sources of microbial contamination in industrial water systems are numerous and may include, but are not limited to, airborne contamination, water make-up, process leaks and improperly cleaned equipment. These microorganisms can establish microbial communities on any wet or semi-wet surface of the water system. Additionally, biofilms formed by growing microbe communities have strong insulative properties, which drive up energy usage if not managed properly. It is therefore important that microbial biofilms and other fouling conditions be controlled or reduced to the greatest extent possible to minimize operational concerns and health-related risks associated with waterborne pathogens. There are many biological control strategies available to the CPI today, including three chlorine-based oxidizing biocides: bleach (sodium hypochlorite; NaOCl), chlorine gas (Cl_2) and chlorine dioxide (ClO_2). Bleach is easily accessible and well accepted, and is used in most industries. Chlorine gas is common in ammonia and municipal water industries, while chlorine dioxide is often used in food-and-beverage, institutional and power industries. Important drivers in all these industries include safety, performance, water quality, compliance, convenience, reliability and sustainability. This article evaluates the three main chlorine-based biological control strategies for each of the seven drivers.

CHLORINE-BASED BIOLOGICAL CONTROL: The following paragraphs discuss bleach, chlorine gas and chlorine dioxide in the context of the seven drivers mentioned above.

Safety. A core tenet for major industrial operations is safety. The biological control strategy selected impacts safety in a variety of ways, including risk of exposure, environmental releases and sensitization of operators. Chlorine gas is highly toxic, making it a powerful disinfectant for water, but hazardous to humans, who must handle it in its gaseous form. As a result, operators require intense use of personal protective equipment for chlorine gas. For containment, chlorine gas requires high-pressure cylinders that come with an inherent risk of potentially large releases. It is important to note that safety and security legislation in many areas is expected to eventually force chlorine gas users to switch to a less hazardous program. Utilizing bleach for microbial control requires a steady stream of bleach deliveries, each of which carries a risk of spills and worker exposure. Both bleach and chlorine gas add significant amounts of chloride ions to cooling water, increasing the risk of operator sensitization when exposed to cooling water.

In contrast, chlorine dioxide adds very little free chloride. For the same level of antimicrobial effectiveness, bleach requires a greater volume than chlorine dioxide. This may be a factor in reducing handling and exposure risks. Chlorine dioxide is generated on-site, as needed, so there is a need for a ClO_2 -generation system, but no need for chlorine gas storage. This can be a factor in lowering the risk of a large-scale release. On-site generation equipment for chlorine dioxide requires integrated safety devices to monitor system parameters to ensure safe production of the chemical.

Performance. After safety, process performance is the next key area for which the choice of microbial control program has an impact. In many cases, the three biocidal programs being compared for biocidal efficacy are dictated by system conditions and the particular requirements will determine the antimicrobial program. In low-demand systems with near-neutral pH, bleach and chlorine gas are effective biocides. Chlorine dioxide is especially effective in challenged water systems. Chlorine dioxide is well known to control and remove biofilms from industrial water systems as the compound migrates, via molecular diffusion, from the bulk water into the biofilm, where it deactivates microbes that form the biofilm. In addition to microbial control, the impact of the water-treatment strategy on scale prevention, corrosion inhibition, and fouling reduction also must be considered. Bleach and chlorine gas both increase chloride and hypochlorite ions in the cooling water system. This can increase the rate of corrosion within the system, leading to shorter-than-expected asset lifetimes. Chlorine dioxide is not aggressive toward other cooling water chemicals that may be present in the system, such as azoles for corrosion inhibition and polymeric scale inhibitors. Finally, due to the broad spectrum of chlorine activity, chlorine gas and bleach can create taste concerns, which can be especially troublesome in process applications in the food, beverage and healthcare industries.

Water quality. Incoming water quality is important to understand, because the pH range of the water system will determine the activity rate of the microbial control program. Bleach is most effective at a pH range of 5.5–7.5, and it tends to increase the pH of a system over time. When working with bleach, some operators will treat with acid to maintain the optimal pH range. This works, but also introduces additional hazardous chemistries (acid) into the plant. Chlorine dioxide is effective at a broader pH range (pH 5–11) and requires less intervention to maintain a consistent pH (Figures 2 and 3). The effects of pH are discussed further in the next section.

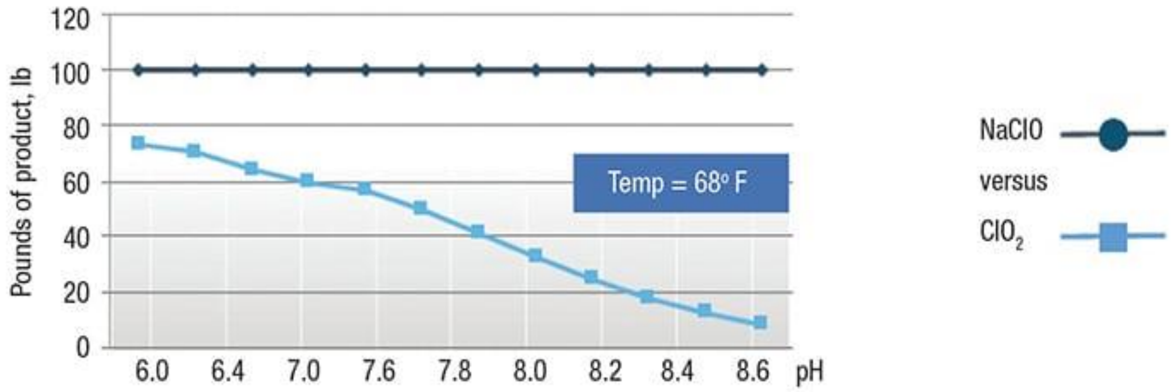

Figure 2. The graph shows the dosages of bleach and chlorine dioxide required to treat water at different pH levels

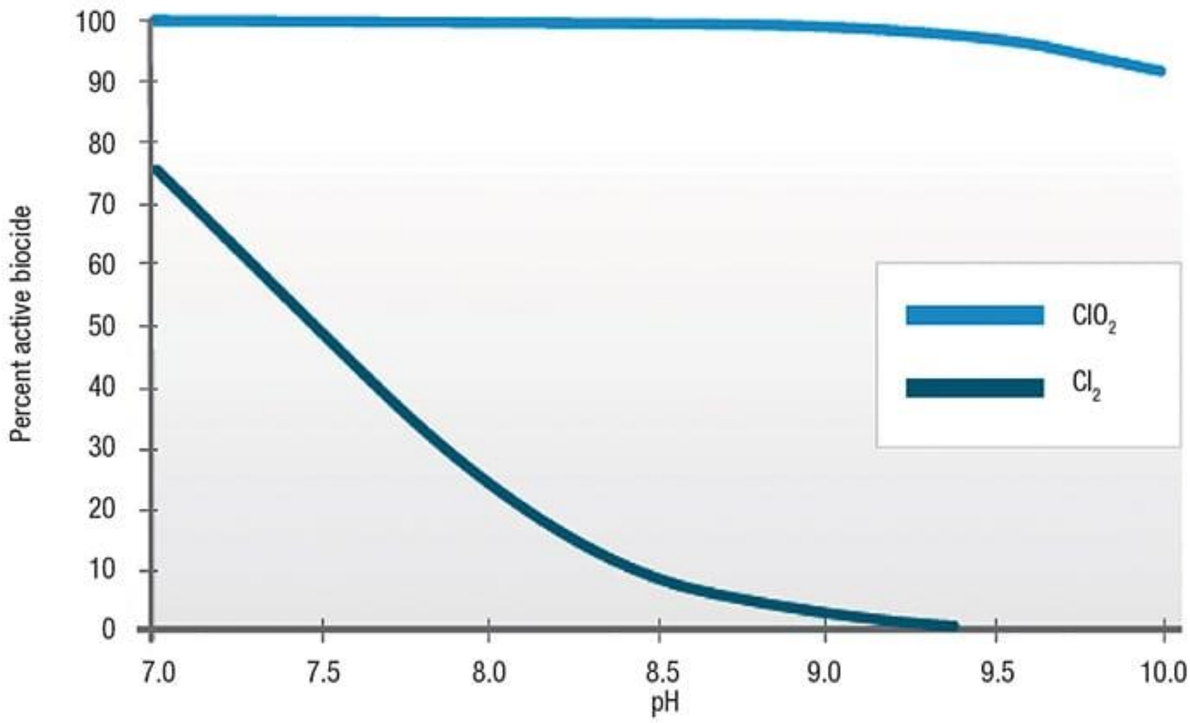

Figure 3. At pH levels greater than 7, chlorine gas is a less effective biocide, while chlorine dioxide maintains efficacy

Compliance. Regulatory compliance is a strong consideration when determining the best path forward for microbial control. In the U.S., all biocides must be used in accordance with the U.S. Environmental Protection Agency and state environmental agency guidelines. Certain industries also have U.S. Food and Drug Administration (FDA) and NSF International considerations to address. Discharge limits frequently regulate the amount of eco-toxic disinfection byproducts, such as trihalomethanes (THM), haloacetic acids (HAA), or adsorbable organic halides (AOX), that can be present in discharged water. The formation of these byproducts is significantly higher with bleach and chlorine gas than with the use of chlorine dioxide. In cases where the byproduct discharge limits are extremely tight, chlorine dioxide may be a strong candidate for microbial control.

Convenience. Ongoing maintenance is required for all biological control strategies. For chlorine gas, that means regular monitoring of the high-pressure system and hazard analysis on a routine basis. Bleach requires tank and line monitoring for impacts from corrosion. Chlorine dioxide requires regular maintenance of the on-site generation equipment. When selecting a program, consider the level of involvement that your staff is able to address. Preventive maintenance schedules that are managed by the supplier can provide assurance that technical experts have recently inspected the equipment and that it is in good working order. Operator training delivered by those same experts can ensure that as your workforce changes, knowledge of the cooling water system operation stays consistent. Another option that delivers convenience is remote 24-h per day, 7-d per week continuous digital monitoring of critical parameters with alerts to notify operators when the system requires attention.

Reliability. In today's world, the pressure to do more with less falls on everyone's shoulders, so having a reliable solution and the additional expertise available to support process operations are more critical than ever. Bleach is a common microbial control chemistry and is effective with constant and consistent delivery. This requires a continuous supply of bleach moving around your facility to the appropriate application points. Bleach has a relatively short shelf life, especially under hot conditions, which adds to the need for frequent deliveries. Suppliers of bleach and chlorine gas tend to be commodity chemical suppliers who do not focus on unique situations or custom applications that arise frequently in cooling water systems. On the other hand, chlorine dioxide requires on-site generation equipment that must be properly maintained to consistently and reliably deliver chemistry to water systems. Established chlorine dioxide suppliers have the expertise necessary to evaluate your application in order to survey, size and select the appropriate generation equipment for the needs of a particular process, and to apply the chemistry under the appropriate dosage scheme. The onsite generation of chlorine dioxide also enables the optimization of production throughput, as the system can accommodate fluctuations in production levels that may require variable production of chlorine dioxide.

Reference: Lynne Monticello, senior director, marketing for Nalco Water, an Ecolab Company.

MODERN SIMULATION TOOLS: EXPANDING APPLICATIONS

(VAISAKH B S, 170378, 2017 – 2021)

New user-friendly solutions help chemical processors tackle tasks beyond design and optimization

Initially, steady-state simulation was used in the chemical process industries (CPI) to design a plant or a process. Advances in the technology, along with the need to produce more product in a more efficient and profitable manner, kick started the trend of using simulation tools to optimize new and existing processes. Today's dynamic modeling, digitalization, more powerful computers and swifter calculation capabilities have led to increasingly prolific use of software by engineers in all facets of the chemical facility. Simulation software is now readily available to help with specific tasks, such as improving safety, operator training, increasing reliability and achieving corporate goals, including sustainability, energy efficiency and, of course, profitability.

SOFTWARE ADVANCES

While steady state simulators have been around for nearly 50 years and are still the go-to tool for designing and optimizing new processes or plants, the introduction of dynamic simulation has led to a wider berth of applications. "While steady-state simulators are doing a good job, dynamic simulators are the way to go for improving existing processes or checking the operability of a new plant," says Marina Velazquez, senior product manager with Aveva Group plc . "Steady state is typically used early in the design to calculate sizing parameters and it assumes that the finished plant, equipment size and piping are exactly as they were designed. However, by startup, the location or size of the equipment and final piping may not be exactly as expected by the steady-state simulator. A dynamic simulator accommodates these differences and can be used to determine whether the control scheme is adequate, equipment will perform as expected, interlocks for safety are properly designed and more." Meanwhile, digitalization is further expanding the use of simulation. The "digital twin" is an exact replica of the physical plant, not as designed, but as it actually exists. It also incorporates live process and operating information from the operating plant. "The digital twin provides an accurate representation that is always 'alive,'" says Rebecca Elgebrandt, portfolio marketing lead for Aveva's engineering business. "Since the digital twin incorporates differences between the design of the plant and the actual plant, it moves the simulation needs from steady state to dynamic and provides the current status of the true assets, allowing users to run a simulation with 'what if' scenarios in an accurate twin of the plant before taking any actions."

Roger-Marc Nicoud, CEO of Ypso-Facto agrees that digitalization is an important step in simulation. "With a virtual/digital representation of a given process, one can easily experiment, test, train and explore operating conditions without the time and cost induced by real-life experimentation and without endangering real-life production."

In addition, digitalization allows easy sharing of information between multiple engineering disciplines. "Operating processes and facilities requires the joint expertise of molecule specialists and simulation experts, of industry engineers and scientists and others, all with the single shared goal of inventing the best possible processes in an unbiased manner," says Nicoud. "And, today's simulation tools aim to bring all the necessary actors together and facilitate collaboration." Velazquez agrees that information sharing is a growing necessity. "Integration is becoming more important so that all the process data can be shared among all the engineering disciplines," she says. "The final design, sometimes completed two or three years after the first simulation was done, can be checked easily by the dynamic simulation before starting up, reducing and avoiding costly last-minute updates at startup. Chemical processes can benefit from checking operating and control schemes prior to startup and from other simulation activities such as operator training, and digitalization allows better integration to make the necessary information sharing and collaboration easier for all the disciplines involved in these steps," she says (Figure 1).

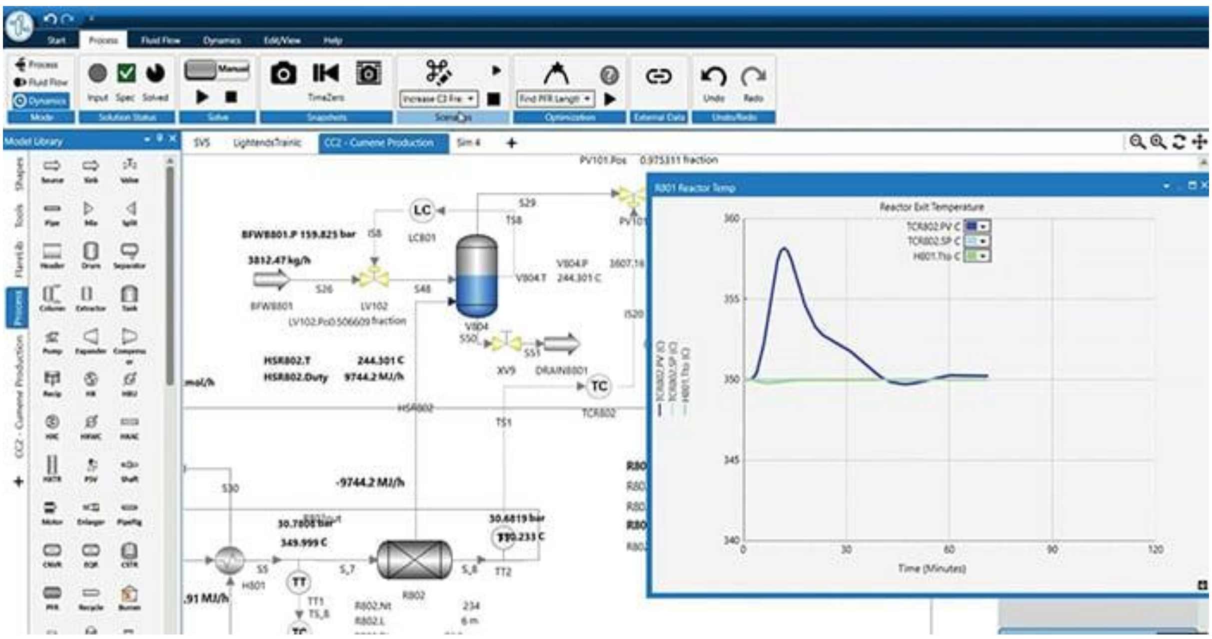

Figure 1. The SimCentral Simulation Platform from Aveva can improve the workflow, safety and design of a chemical process

Increased speed and improved user friendliness are also moving simulation into more applications. “While many simulation solutions are perceived as being very accurate, often the other perception is that they are time-consuming and take a lot of experience to use,” says Ahmad Haidari, global industry director, process, energy and power, with Ansys . “However, newer versions don’t require the same amount of experience and hands-on time as prior versions, which makes simulations more accessible and much more routine in the chemical processing industry.” For example, Ansys is focused on task-based workflow, which presents only the features and choices relevant to the task at hand and has best practices built in. “This provides the ability to use defaults and still get good answers, and also to customize and build workflows so that other engineers with less simulation experience can duplicate results. We are finding that this allows engineers to accomplish simulations two to three times faster than in the past with significantly less training,” explains Haidari.

The company is also working to improve meshing. “One area that has been frustrating with fluid-dynamic-based solutions has been the meshing process, because in order to get a good mesh for use with simulations, a certain amount of hand-repetitive tasks were necessary to fine tune that mesh,” he explains. “We are automating that process through a new technology to virtually eliminate the hands-on piece. Things that took two to three weeks to prepare are now getting done in hours. Engineers who are really experienced in chemical engineering, but don’t have experience with fluid dynamics will be very successful using these tools,” he says (Figure 2).

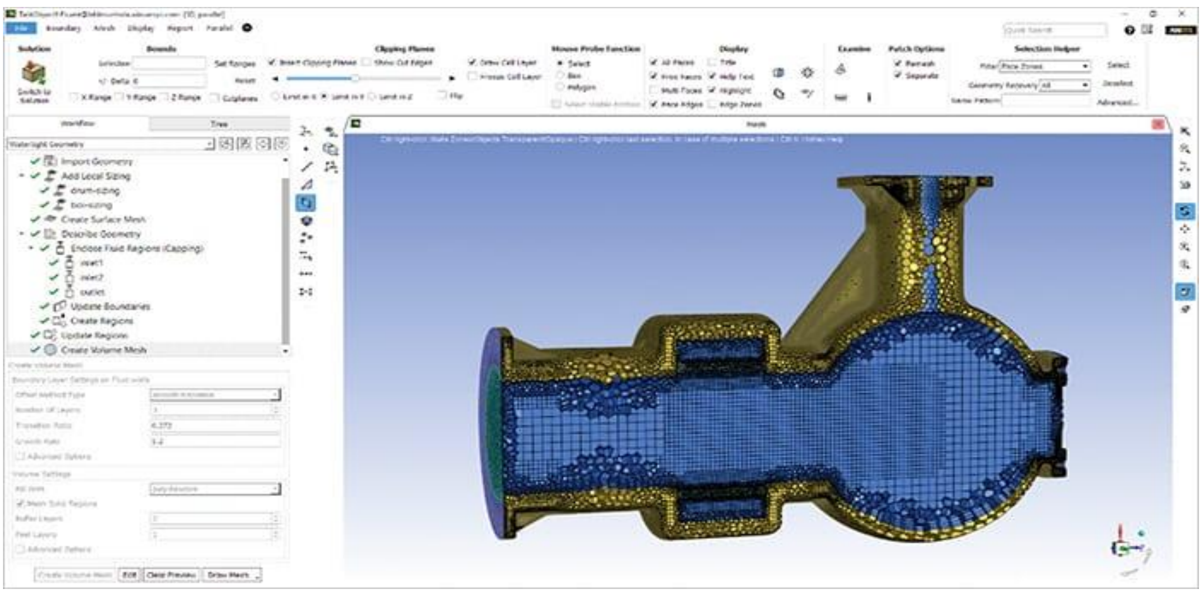

Figure 2. Ansys Fluent's Mosiac-enabled task-based workflow meshes complex geometries twice as fast with minimal user input

Another example is Chemstations , which is launching a new version of its first-principles-based simulation software with improved calculation speeds that come via parallel processing that uses all available computing cores. "This means that instead of using just one core of the user's computer, we can spread the workload across as many cores as are available, which will speed the process considerably," explains Steve Brown, president of Chemstations. While the initial intent of the improved calculation time was to allow faster execution of large optimization projects, Brown says the increased speeld also allows the software to be used for smaller projects. Wendy Young, marketing manager with Chemstations, agrees: "In the past, scaled-down versions of optimization, such as a sensitivity study, would take too long, but the calculation time has been reduced to such a degree that engineers are more likely to run simulations for smaller studies."

A WIDER BERTH OF APPLICATIONS: While simulation tools used to be firmly rooted in design and optimization of plant and processes, digitalization, easier collaboration and user friendliness have opened the door for the use of simulation throughout the plant.

Plant safety. "The evolution of computational power and the capabilities of the software have given engineers a chance to solve some different, even possibly more complex, problems, with a higher degree of confidence," says Haidari with Ansys. "Safety is one of the areas where simulation is now being applied to determine why or when leaks, corrosion or other factors that deteriorate performance and directly impact safety of the process and personnel are happening." For example, leaks may occur due to deteriorating seals or erosion of equipment, but because advanced tools allow users to model seals or examine corrosion in a given operation, the potential for failure can be determined. If there is a leak, simulation can be used to look at how gas may be dispersed within the plant using all sorts of possible scenarios, including wind and location of stacks. Safety valves can be better designed via simulation tools, and advanced software allows users to simulate what happens when an explosion occurs so they can better design equipment and plan for an emergency.

Paige Marie Morse, chemicals industry marketing director, with AspenTech agrees that simulation tools can be helpful in the area of plant safety. For example, the company has acquired Blowdown software technology, which is used to identify locations in a system where temperatures can decline dramatically during depressurization. Blowdown has been incorporated into Aspen Hysys in order to provide an accurate determination of these low temperatures, which is a critical activity in the design and operation of process plants as it can improve safety of the plant (Figure 3).

Figure 3. Simulation used throughout the entire plant asset lifecycle improves safety and other pillars of operational excellence

Simulators can also be used to avoid unnecessarily purchasing safety systems. "A digital twin environment can be used for testing levels of protection, as well as for reducing and evaluating capital investments for safety stewardship," says Mart Berutti, vice president of process simulation with Emerson . "The investment of capital in process safety is necessary and very important, but it's not one that increases the production of the plant. Simulation can help processors evaluate what levels of safety protection are required and eliminate the systems that aren't necessary."

Reliability. Today's simulators can also be used to enhance reliability of the plant and equipment, says Ansys's Haidari. "We call this 'fitness for service,' which means we look at things like fouling or degradation that may impact the performance of equipment. It is possible, through simulation, to look at a given design, either before it is built or during operation, and examine the range of operating parameters and variables it will be exposed to and understand the life of that asset," he says. Further, he says it is possible to use simulators to look at issues that may be occurring, such as vibration, and use the model to perform a cause-and-effect analysis to understand why it may be vibrating and remedy the situation.

Training. Training is another area where simulators are making a major impact. "There's a lot of interest in the use of simulation for operator training," says AspenTech's Morse. "The advantage of using a digital representation of the plant is that it allows you to, offline, take operator trainees through different scenarios. Because it is a digital twin, it reflects what is going on at the unit so operators can learn how to handle various tasks without making an impact on the actual plant. It can also be used to train new operators before a newly constructed plant is up and running. "Additionally," Morse continues, "Simulation can be used to create scenarios that involve process upsets, safety emergencies or environmental incidents and train operators to react so that events are properly managed and so operators have experienced the issues and don't panic in a real-life incident." Emerson's Berutti agrees that simulator training is a vital application. "Statistical information shows that it takes six to seven years for a chemical plant operator to be able to make good risk-based decisions concerning operation of the plant, but most facilities are not in a position to spend this amount of time getting operators up to speed," he says. "A digital plant environment provides us with a time machine. It allows new operators to get comfortable with running the plant and controls for daily operations without actually practicing in the real plant. And, operators can have experiences — upsets and failures — that we would never want to see, but if they happen, the operators have had the opportunity to experience them over and over in the digital twin. This allows them to think clearly and not be intimidated by the gravity of a situation and have the competency to handle it. It makes them ready to operate the plant and deal with emergencies in a shorter period of time."

Corporate goals. Modern simulation tools can also help processors achieve corporate goals, including energy efficiency, sustainability and profitability. "Simulation was created for the purpose of increasing efficiencies, so it makes sense that it is used for corporate goals such as sustainability and energy efficiency," says Stephane Dechelotte, CEO at ProSim . "Advances in software, such as better thermodynamic models and those specifically designed to assist with energy evaluations, allow better simulations of energy estimation and profitability calculations. Today's users require models that are predictive and that cover a wide range of mixtures, temperatures and pressure conditions, so thermodynamic models are a critical component to running simulations that achieve corporate goals, such as energy efficiency and the impact it has on yield, he says" (Figure 4).

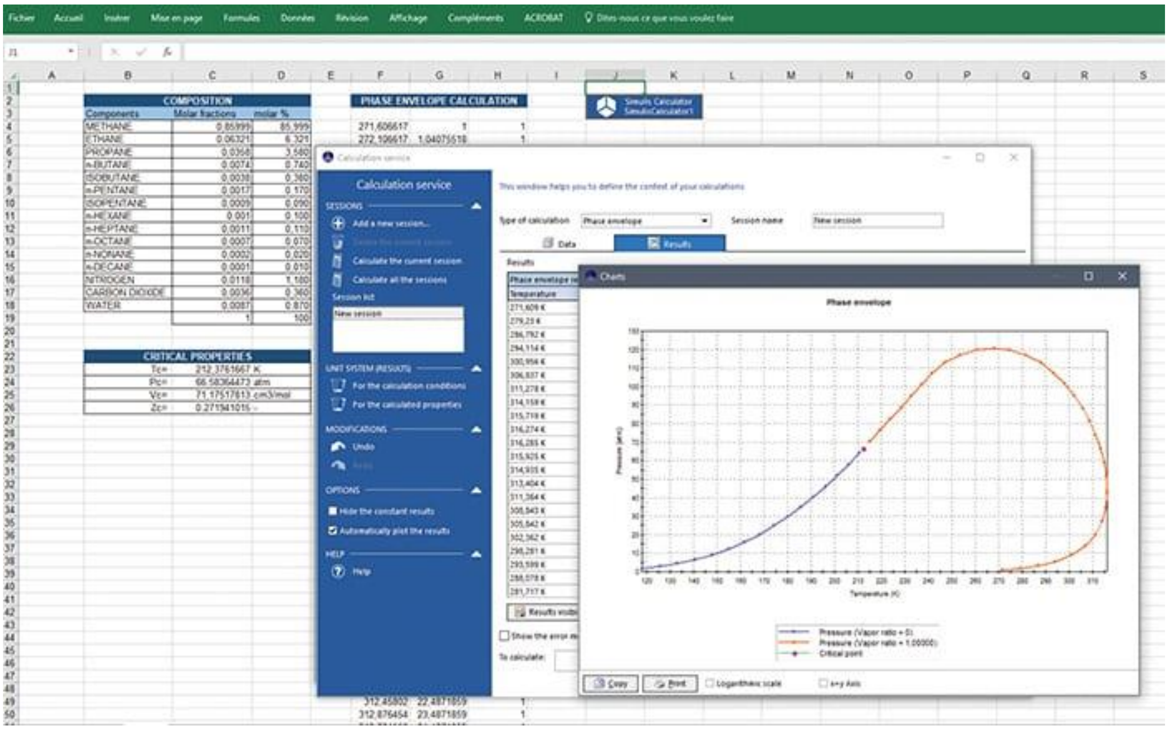

Figure 4. ProSim's Simulis Thermodynamics provides the thermodynamics knowledge needed for chemical process simulation. It is available as a Microsoft Excel add-in, a toolbox in MatLab or as a software component that can be plugged into any other application/software requiring reliable and accurate thermophysical properties. The figure shows a phase-envelope calculation diagram

Chemstations's Brown agrees that simulation is finding greater application in this area. "Companies will do an analysis to see where they can boost profitability and this is almost always tied to energy consumption. However, the same company may also consider energy efficiency a corporate social goal," he says. "We've seen them use simulation to perform a multi-objective optimization where they have the first objective as profit and the second as the societal or environmental impact. They can use the simulation to look at how they may want to operate the facility and examine the results and decide, on a corporate level, with input from various engineering disciplines, where to balance profitability with social or environmental impacts. They can find the overall optimum that works for their company." These same types of simulations can be applied to almost any corporate goal, says Ansys's Haidari. "

Latest in the industry

(Shana K P, 160306, 2016 – 2020)

AN INEXPENSIVE, RENEWABLE AEROGEL SHOWS PROMISE FOR HANDLING OIL SPILLS: Many methods have been developed to remove spilled oil and organic pollutants from water, but they all entail shortcomings, such as low absorption ability and poor buoyancy. Now, a team from the School of Light Industry and Chemical Engineering, Dalian Polytechnic University, and Zhejiang Ji-Hua Group Co. has prepared a low-cost, ultralight absorbent aerogel from renewable corn straw and filter paper with good performance and high absorption capacity. According to the team, the corn-straw-based spongy aerogel could serve as a good oil-absorbing material. To make the aerogel, raw corn straw is first added to an aqueous sodium hydroxide solution, and stirred for 4 hours at 30°C. Next, the pH is adjusted to 7 by the addition of HCl. After thorough filtration and washing with deionized water, the filtered corn straw particles are dried for 12 hours at 60°C. Small filter paper fragments are then mixed with the treated corn straw, and dispersed with a high-shear emulsifier. The suspension was then frozen at –25°C for 12 hours, followed by freeze drying at –55°C for 36 hours, resulting in a spongy aerogel.

ANTIFOULING MEMBRANES FOR SINGLE-STEP DESALINATION: NA filter for water purification that can replace, with a single step, the complex, time-consuming and multi-stage processes currently needed, has been developed by a team from CSIRO Manufacturing, led by Dong Han Seo. The team has demonstrated water desalination via a membrane distillation (MD) process using a graphene membrane, called graphair. Water permeation is enabled by nanochannels of multilayer, mismatched, partially overlapping graphene grains. As described in a recent issue of Nature Communications, Graphair is made by a chemical-vapor-deposition (CVD) process, and the film is then transferred onto a conventional MD membrane, such as polytetrafluoroethylene (PTFE). The CVD process takes place at ambient-air conditions using renewable soybean oil as the source for the graphene growth. This graphene film allows water to permeate through, but rejects salts and pollutants, such as surfactants and oils. Moreover, it prevents one of the great problems associated with desalination and filtration methods: fouling. The team tested the pristine PTFE and permeable graphene-based membranes using saline solutions containing surfactants such as sodium dodecyl sulfate (SDS).

ADVANCED WATER ELECTROLYSIS LAUNCHED: Last month, thyssenkrupp Industrial Solutions AG launched industrial-scale water electrolysis systems that make large-scale hydrogen production from renewable electricity economically attractive. The advanced water electrolyzer (diagram) features a well-proven cell design paired with an especially large (2.7 m^2) active cell area. By further optimizing the proven "zero-gap" electrolysis technology (leaving virtually no gap between membrane and electrodes), very high efficiencies of more than 82% are achieved, says the company. "We transferred our knowledge and experience from chlor-alkali zero-gap to the alkaline technology," explains Roland Käppner, head of Energy Storage and Hydrogen at thyssenkrupp Uhde Chlorine Engineers. "Throughout more than five years of research and development, our engineers optimized the cell architecture, current density, materials, coatings and other parameters. Since we were running full-size cells in an industrial test environment during this time, we were able to create very realistic conditions in order to achieve very precise results," explains Käppner.

A COMPACT SYSTEM CLEANS FLUEGAS FROM GLASS-MELTING FURNACES: Furnaces used in the production of glass are normally equipped with fluegas-cleaning plants that have separate steps for the treatment of particulate matter, acid crude gases and oxides of nitrogen (NOx). GEA Group AG has developed a technology that performs all these tasks in a single step, in a single reactor. The fluegas is cleaned using ceramic candles — rigid filter elements consisting of coated mineral fibers (diagram). These candles are well-proven and very flexible to use, even with regard to modifications of operating parameters, especially at high gas temperatures. Even stricter future requirements set in German Federal Administration's Regulation "Technical Instructions on Air Quality Control (TA Luft)" will be underrun, says GEA. Dust emissions are reduced to near detection limit, the company adds. Although GEA has already delivered plants of this kind for the purpose of hot-gas filtration, the company has now recently refined these plants in order to include deNOx capabilities, under the tradename BisCat (Bischoff Catalysator). The ceramic candles are installed in a walk-in clean gas chamber to ensure easy access for maintenance and inspection. The BisCat technology will be…

WATER-POLLUTANT-REMOVAL TECHNOLOGY EXTENDED TO PHOSPHORUS: A project has been announced to demonstrate Microvi's pollutant-removal-and-recovery technology for phosphorus in water. The objective of the demonstration is to reduce total phosphorus levels to 0.1 mg/L at a wastewater treatment plant. The nine-month project is a collaboration between Microvi, U.K.-based Southern Water Ltd., WesTech Engineering, Inc. and the University of Portsmouth. Current methods for phosphorus removal from wastewater rely on dosing high levels of expensive metal salts, Microvi says, which locks up the phosphorus and generates solid wastes with high disposal costs.

DISTILLATION COLUMN INTERNALS: IT'S WHAT'S ON THE INSIDE THAT COUNTS

(MR. AMAL G S, FACULTY)

New column internals boost efficiency and improve reliability of distillation towers

In the chemical process industries (CPI), the majority of separations are done via distillation columns. And, when the rest of the process relies upon those columns, inefficiencies, bottlenecks and shutdowns are problematic. In an effort to keep distillation processes — and the rest of the plant — chugging along, column internals are being tweaked and re-worked to help optimize efficiency and reliability of the columns. "Whether it is in refining, chemical processing or producing plastics, most of the separation between organic chemicals is being done with distillation. At the same time, there is a constant pressure for chemical processors to make their processes more cost effective," says Izak Nieuwoudt, chief technical officer with Koch-Glitsch. "Because distillation columns are a huge energy consumer and because people don't want to spend a lot of time fixing equipment, increasing efficiency and reliability of the columns is at the forefront right now." Often after a process is up and running, processors find that the energy consumption is much higher than they were expecting, says Antonio Garcia, mass transfer business development manager with AMACS Process Tower Internals. "To obtain better energy efficiency, they must explore their options to improve the mass-transfer performance," he says. "In addition, processors are often looking for ways to de-bottleneck the process in order to obtain better separation and capacity requirements and fouling is a common cause of bottlenecks, so finding technologies that assist with these issues is also important." Bottlenecks and downtime caused by fouling or mechanical issues, such as vibration or mechanisms within the columns coming apart, can become very costly. "It's very expensive every time you have to shut down a distillation column, because it often results in the shutdown of upstream and downstream units, as well," says Nieuwoudt. "And, these unplanned shutdowns result in large losses per day." For this reason, manufacturers of column internals are developing products designed to aid processors in increasing energy efficiency and reliability.

IMPROVING EFFICIENCY & RELIABILITY: Replacing conventional trays and packings with newer, advanced solutions is often necessary for a processor who is seeking higher efficiency, capacity and reliability, so manufacturers are constantly looking to improve upon their offerings. For instance, Raschig has recently released the Raschig Super-Ring Plus, a new, high-performance random packing that exceeds the performance of the previous Raschig Ring. "The optimized structure of Raschig Super-Ring Plus enables a further capacity increase at constant efficiencies," says Micheal Schultes, technical director at Raschig. "The product is the result of design development based on many years of research. The target was to stay with all the advantages of the Super-Ring, but improve capacity and reduce pressure drop." The resulting product minimizes pressure drop by arranging flat sinusoidal strips into an extreme open structure, maximizes capacity by film flow preference on continuous sinusoidal-strip arrangements, increases efficiency by minimizing droplet formations inside the packing and decreases fouling tendency by reducing droplet development and offering low pressure drop. Fouling sensitivity is also reduced by generating continuous liquid films, wetting the entire packing element. Likewise, AMACS has been doing research to improve its SuperBlend product. "Research has shown that by replacing existing random packing with our SuperBlend 2-PAC, tower efficiency can be increased by 20% or capacity by 15%," says Moize Turkey, manager, applications engineering, with AMACS. The SuperBlend 2-PAC technology is a blend of high-performance packing sizes placed in a single bed. "We blend two sizes of the best metal random geometry and, when combined, the patented blend achieves the efficiency benefits of the smaller packing size, while retaining the capacity and pressure drop of the larger packing size," he says. The blended bed is recommended for absorption and stripping, fine chemical distillation, refinery fractionators and retrofit opportunities in any mass- or heat-transfer tower limited by conventional or third-generation random packing.

Improvements to internals are also being developed to assist with issues such as fouling and difficult conditions. "Reliability is extremely important for day-to-day considerations. No matter how well a device performs, if it can't stand up to the fouling conditions in a process, it won't be successful," says Mark Pilling, manager of technology USA with Sulzer . "Sulzer has spent a tremendous amount of time over the last five years developing a complete line of fouling-resistant equipment." In trays, the company offers VG AF and anti-fouling trays, and recently launched UFM AF valves, which are both high performance for capacity and efficiency, as well as extremely fouling resistant. In packings, the company launched Mellagrid AF anti-fouling grid packings, which are suitable for highly fouling packing applications, such as vacuum tower wash sections. Pilling adds that for foaming issues, Sulzer has been working on a two-pronged approach. "While we develop equipment and designs to handle foaming applications, we also work with our customers to determine potential foaming applications," he says. "Once you know foaming exists, you can design for it. It's the cases where a customer will have a foaming condition and not know about it that tend to create problems. We see all sorts of foaming, such as Marangoni, Ross foams and particulate foams and work with customers to identify such situations."

And, for applications where fouling and coking can be very severe, Koch-Glitsch developed Proflux severe-service grid packing, says Nieuwoudt (Figure 1). The new high-performance severe-service grid packing combines the efficiency of structured packing with the robustness and fouling resistance of grid packing. It is an assembly of sturdy corrugated sheets welded to heavy-gauge rods. The combination of welded rod assembly and corrugated sheets of increased material thickness provides a robust design that resists damage from tower upsets or erosion. The gaps between the sheets provide improved fouling resistance. "The packing has been installed almost 100 times now in very severe-fouling services and is really doing well compared to the products it is replacing. The longer run life and the lower pressure drop it provides results in lower operating costs for the customer," says Nieuwoudt.

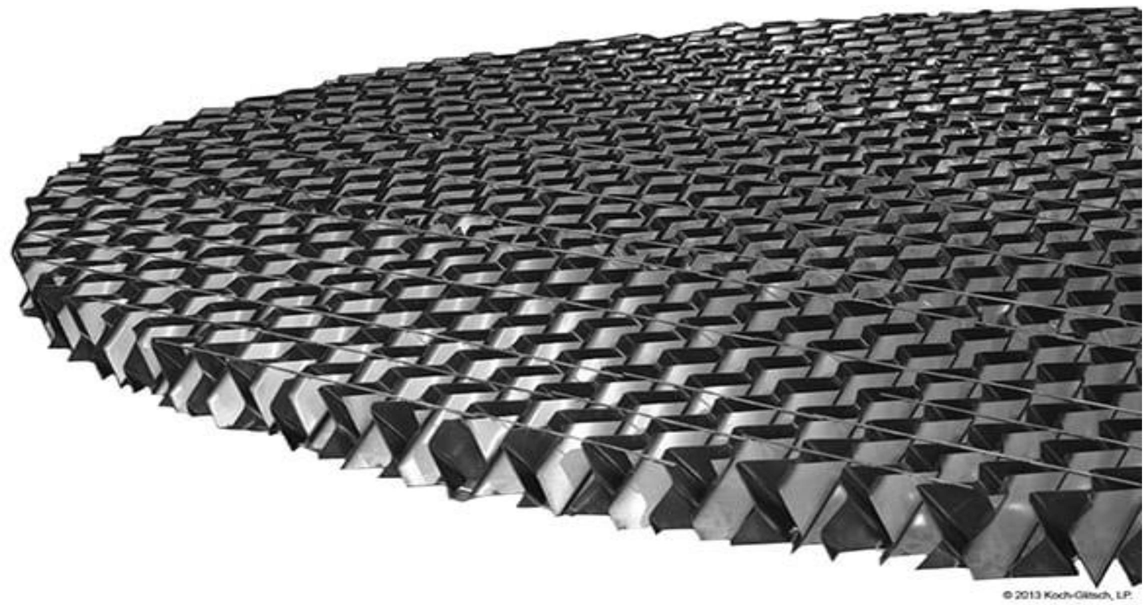

Figure 1. Proflux severe-service grid packing is a high-performance severe-service grid packing that combines the efficiency of structured packing with the robustness and fouling resistance of grid packing

ADDRESSING SPECIFIC CHALLENGES

When it comes to distillation, there are also often challenges specific to a process that need to be addressed through special measures. "There is a market for tailor-made solutions that are tuned to the specific process and customer needs," says Christian Geipel, managing director, with RVT Process Equipment . "This is especially valid for revamps of existing plants that are modified to fulfill new demands. The challenges are various and include objectives such as longer and more predictable run lengths for fouling applications, higher capacity and lower pressure drop or wider operating ranges for more flexibility."

To address specific needs, RVT has developed a high-capacity structured packing, the SP-Line (Figure 2). "Due to modified channel geometry, lower pressure drop and higher capacity are achieved." Further, for very low liquid loads, another application-specific challenge, these packings can be combined with new types of liquid distributors. "An improved spray nozzle distributor that combines spray nozzles with splash plates was developed and is successfully used in applications like refinery vacuum columns," says Geipel. "It reduces entrainment and therefore fouling in the packing sections above the distributor without sacrificing liquid distribution quality to the packing section below."

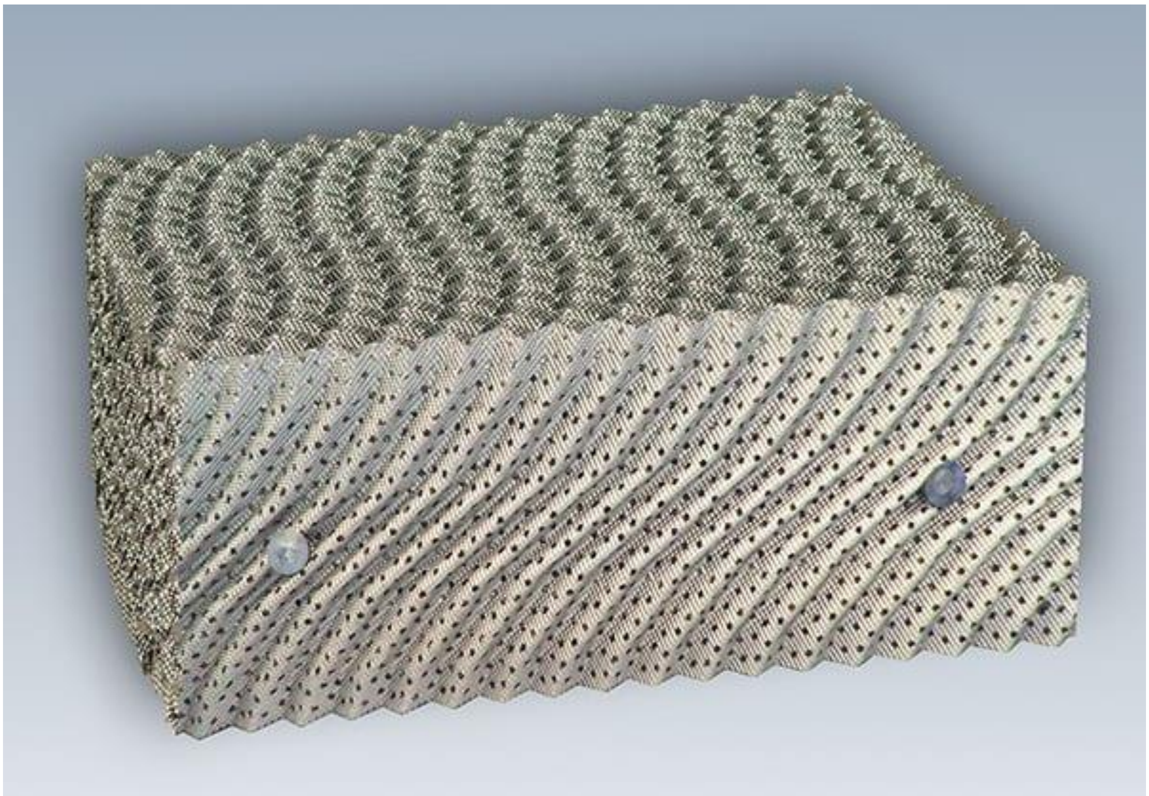

Figure 2. A new, high-capacity structured packing, the SP-Line from RVT, offers modified channel geometry, lower pressure drop and higher capacity RVT Process Equipment

Another new liquid distributor from RVT (Figure 3) is a trough-type distributor with splash plates that combines low liquid rates with a higher operating range and a robust, fouling-resistant design.

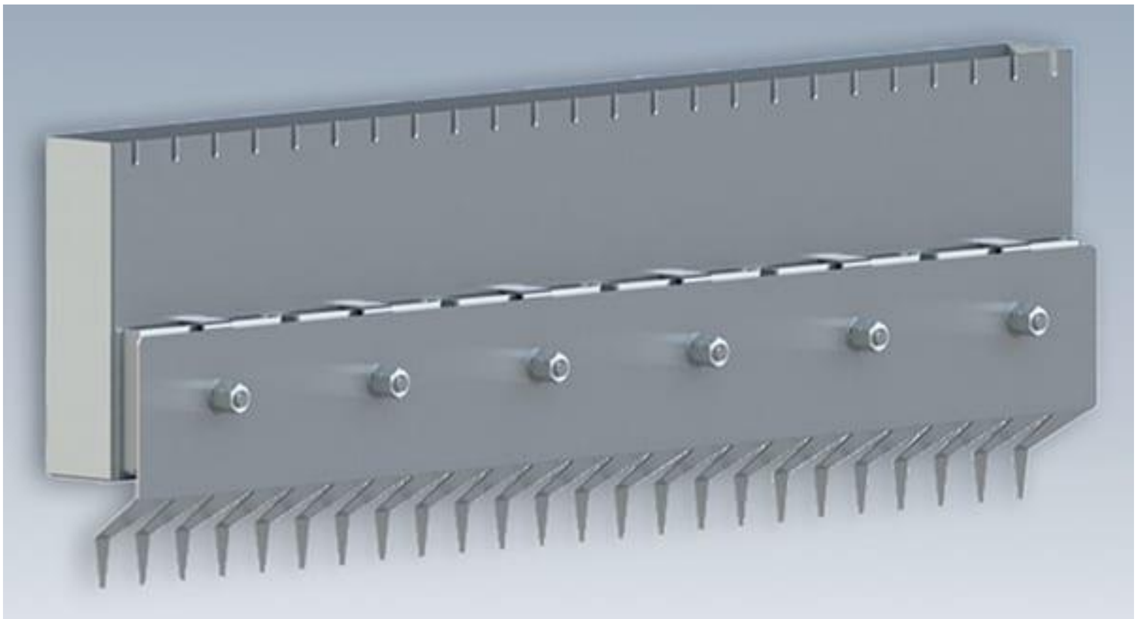

Figure 3. For very low liquid loads, another application-specific challenge, packings can be combined with new types of liquid distributors

Similarly, GTC Technology US, LLC is developing new products to assist processors with improving the performance of distillation columns based on their specific needs. One of the latest developments includes GT-OPTIM high-performance trays, says Brad Fleming, general manager for GTC's Process Equipment Technology division. Hundreds of industrial installations plus testing at Fractionation Research Inc. have demonstrated that the high-performance tray achieves significant efficiency and capacity improvement over conventional trays. The cross-flow trays are customized to the end user's needs to achieve high efficiency via a combination of patented and proprietary devices that make up each tray design. "We can provide a collection of technologies and features that can be employed in order to address specific objectives," notes Fleming. "One processor's objective might be to increase efficiency, while another wants to increase capacity and still another wants to minimize pressure drop, mitigate fouling or extend runtime. We have many different weapons in our equipment design arsenal, so we are able to focus on the customer's targeted objective for their specific process improvement."

Meanwhile, AMACS has addressed another common distillation challenge faced by petroleum refineries, petrochemical plants, gas plants and similar facilities. Often, a vertical knockout drum or separator with mist-elimination equipment installed fails to remove free liquid from a process gas stream. "Instead of trying to address or repair symptoms, we look for the root cause, which usually involves the mist-elimination equipment in the knockout drum," says AMACS's Garcia. To address the problem, the company developed the Maxswirl Cyclone, a high-capacity, high-efficiency mist-elimination device that uses centrifugal forces to provide state-of-the-art separation performance. The Maxswirl Cyclone tubes consist of a fixed swirl element, which applies centrifugal force on mist-laden vapor to separate entrained liquid from gas flow. In this axial-flow cyclone, the resulting centrifugal force pushes liquid droplets outwards, where they create a liquid film on the cyclone inner wall. The liquid passes through slits in the tube wall and gets collected at the bottom of the cyclone box and drained by gravity. The dry gas concentrates in the center of the cyclone tube and exits through the cyclone.

Meanwhile, DeDietrich is focusing effort on providing columns and internals for highly corrosive processes at temperatures up to 390°F, says Edgar Steffin, head of marketing with DeDietrich. “Columns up to DN1000 are made of QVF borosilicate glass 3.3 or DeDietrich glass-lined steel. Bigger columns up to DN2400 are made of DeDietrich glass-lined steel only. The corrosion-resistant materials are made of borosilicate glass 3.3, SiC, PTFE or Tantalum” (Figure 4).

He adds that most processes at elevated temperatures above 300°F require the avoidance of PTFE. SiC has a higher temperature resistance and permits the design of bigger distributors and collectors that are less sensitive for feeds containing solids or those tending to foam, degas or to flash. The company’s Durapack structured packing in borosilicate glass 3.3 is suitable for corrosion-resistant glass 3.3 or glass-lined steel columns, as it has the same corrosion resistance as the glass column and keeps its thermal stability at higher temperatures compared to polymers. Borosilicate glass 3.3 is non-porous, which substantially cuts erosion and corrosion compared to equivalent ceramic packing.

And, towers that have a side cut, but are thermally inefficient, says GTC’s Fleming, may be good candidates for dividing-wall column technology. “Many distillation columns have a top and bottom product, as well as a side-draw product, but with this comes a lot of thermal inefficiency. Dividing-wall column technology — where you revamp the traditional column — is one way to increase capacity while reducing energy consumption or reducing the yield impurity of the products,” he says (Figure 5). The dividing-wall column separates a multi-component feed into three or more purified streams within a single tower, eliminating the need for a second column. The design uses a vertical wall to divide the middle of the column into two sections. The feed is sent to one side of the column, called the pre-fractionation section. There, the light components travel up the column, where they are purified, while the heavy components travel down the column. The liquid flow from the column's top and the vapor flow from the bottom are routed to their respective sides of the dividing wall.

From the opposite side of the wall, the side product is removed from the area where the middle-boiling components are most concentrated. This arrangement is capable of producing a much purer middle product than a conventional side-draw column of the same duty, and at higher flowrate.

Figure 4. DeDietrich focuses on columns and internals for highly corrosive processes at temperatures up to 390°F. Columns up to DN1000 are made of QVF borosilicate glass 3.3 or DeDietrich glass-lined steel. Bigger columns up to DN2400 are made of DeDietrich glass-lined steel only.

Figure 5. Towers that have a side cut, but are thermally inefficient, may be good candidates for dividing-wall column technology GTC Technologies

“The conversion to a dividing-wall column is investigated when you’re looking at making significant improvements you couldn’t do otherwise within the constraints of a traditional tower, but if you can convert to dividing-wall technology, you will see significant decrease in energy consumption,” he says. “Generally, there is a 25 to 30% reduction in overall energy consumption for a given throughput, dramatically improved yield and purity of products and often an increase in throughput, as well.” He adds that there is also opportunity to use a dividing-wall column to replace a traditional two-tower sequence. “You can use dividing-wall columns to perform the same operation and produce the same products, but you’re doing it in one physical tower in comparison to a two-tower scheme. In the grassroots realm, a substantial reduction in capital expenditures can be achieved with dividing-wall column technology.”

EXPERIMENTAL METHODOLOGIES TO VERIFY DISTILLATION SIMULATIONS: The use of process simulation tools for modeling distillation columns is invaluable for designing plant-scale columns. However, it can be difficult to know if the simulator is generating accurate predictions. Additionally, there are potential problems associated with distillation columns that process simulators do not address. Hence, experimental distillation studies are quite important to either verify the simulation results or to provide a path forward to improve the simulations. Computer-generated simulations of distillation processes are often validated experimentally. This reference discusses three concepts that influence comparisons between experimental results and simulation predictions: vapor-liquid equilibrium (VLE) of the components; relative liquid-to-vapor flowrates (L/V ratios in the column); and vapor-liquid contactor (tray) efficiency. Understanding these concepts can help explain discrepancies between experimental data and simulation results. Vapor-liquid equilibrium The relative volatility of an ideal binary chemical system is equal to the ratio of the two pure-component vapor pressures. If the components' interactions are close to ideal and the components have sufficient relative volatility (>2), then small errors in VLE predictions may not significantly affect the separation. However, if the relative volatility is small (<1.5), deviations between predicted and actual VLE will lead to large differences between the actual and predicted number of stages required to accomplish the separation.

AGGLOMERATION PROCESSES

(DEVIPRIYA MUDIYIL, 180080, 2018 -2022)

Agglomeration converts fine powder particles into larger ones by introducing external forces. Major benefits for solids processors include dust reduction, easier handling, more complete utilization of raw materials and densification. Agglomerating particles happens by a variety of means, including mixing with a liquid, applying pressure and heating. This reference reviews equipment for these approaches.

TUMBLE-GROWTH AGGLOMERATION: In the first stage of wet agglomeration, fine powder, liquid and binder are combined in a mixing chamber. Fine particles are wetted with an appropriate liquid, typically water. Surfactants or other chemicals can be added to improve the wettability of the solid particles and improve pellet formation. Next, moist particles are joined together to form green (wet) agglomerates. Green particles are generated by first forming nuclei, which then grow into larger aggregates by layering or coalescence. Nucleation and aggregate growth may take place in separate pieces of equipment. For example, agglomerates from a pin mixer can be fed into a disk pelletizer. The final stage is drying or curing, which takes place in a separate device. Binders are frequently introduced to improve the agglomerates' crush strength. In a wet tumble-growth process, powder, liquid and additives are fed continuously into the chamber, where the wetted mass is then sheared or kneaded until the liquid is evenly distributed and the granules have the desired size and strength. Examples of organic binders are waxes, rosin, starch and alginates. Inorganic binders include alkali silicates, bentonite and various aqueous solutions and dispersions. The major criteria for selecting a binder are cost, availability, compatibility with the product's final use, and its ability to give the agglomerates their desired crush strength.

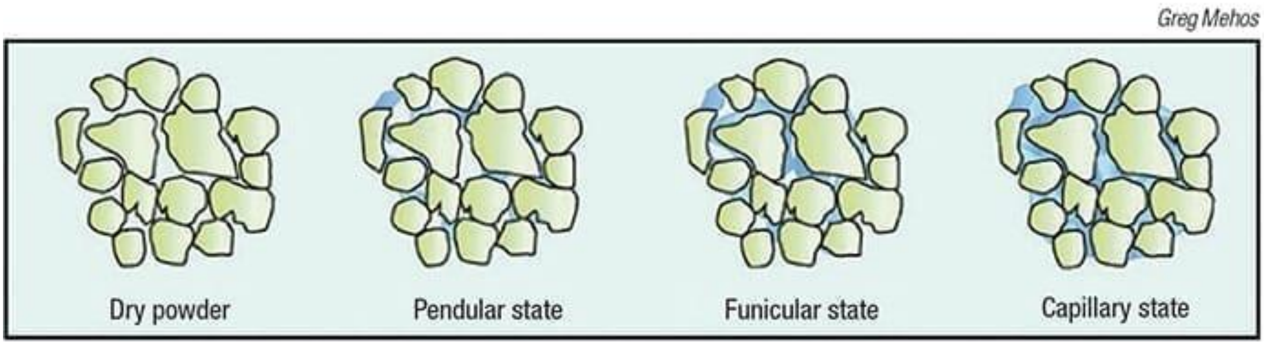

Figure 1. When liquid is added to powder, the agglomerates formed typically have their optimal strength at 40–90% of their full saturation amount

PRESSURE AGGLOMERATION: Because attractive forces between particles intensify as the distance between them decreases, applying pressure can lead to exceptionally strong agglomerates. Pressure agglomeration falls into two general categories: roll compaction and die compaction. Roll compactors use a mechanical force to press powder. Fine particles are fed between two counter-rotating rolls, which draw material into the gap between them. The powder is compressed into a sheet if smooth roles are used, or formed into strips if the compactor is equipped with corrugated rollers. The sheet or strips are then fed through a flake breaker. The agglomerates are irregular in shape, but often have sufficient flowability. The powder is fed by gravity or with a feeder. The equipment works best when the powder is de-aerated before it reaches the rolls. Die compaction also relies on mechanical forces to press fine powders, but also allows agglomerates with a desired shape. Pressure agglomeration equipment tends to have higher capital costs, but lower operating costs, than tumble-growth agglomeration. Agglomerates formed by pressure have a higher bulk density, but may be more prone to attrition.

HEATING AGGLOMERATION: Extruders can heat powders to temperatures high enough to cause melting or sintering. Two types of extruders are used — ram extruders are used batch-wise, while screw extruders are for continuous processing. In a ram extruder, powder is fed into a barrel equipped with a die plate and then isolated by a hydraulically-driven piston. The powder is then forced toward the die. The barrel may be heated (although temperatures rise due to friction, even without external heating). The entire plug of powder does not necessarily have to reach its melting point, because only a thin layer of liquid needs to be sheared between the wall and the plug. The extruder is equipped with cutters immediately downstream of the die plate. Because high pressures are generated, the feed material must have a low moisture content. Otherwise, the liquid will flash upon leaving the die plate and potentially fracture the pellets that are formed.

Auger or screw extruders comprise four sections: feed, conveying, melting or sintering, and pumping. A feed hopper contains the powder material and allows it to enter the screw beneath its outlet. The conveying section is followed by the melt or sintering section. Friction or a heated barrel increases the temperature of the conveyed powder. Pressure is generated by pumping the material through a die plate or restricted orifice. Cutters are used to convert the extrudate into pellets.

References: Mehos, G. and Kozicki, C., Choosing Agglomeration Equipment, *Chem. Eng.*, October 2017, pp. 51–57.

Q1 **For a nominal interest rate of 20% compounded continuously, the effective annual interest rate Will be**

a) Equal to 20% b) More than 20% c) Less than 20% d) Equal to or less than 20%

Q2 **If the cost of a shell and tube heat exchanger of Am^2 is Rs. X, then the cost of two number of shell and tube heat exchangers of $A/2m^2$ each will be**

a) Rs. (3x/4) b) Rs. x c) Rs.(4x/3) d) Rs. (5x/3)

Q3 **Rs. 10,000 is invested now at 10% interest per annum on a compound basis.**

What will be the accumulated sum at the end of 5 years?

a) Rs. 15,000 b) Rs. 16,105.10 c) Rs. 15,105.10 d) Rs. 17,105.10

Q4 **A property has an initial value of Rs. 10,000, service life of 10 years and final salvage value of Rs. 2,000. What is the annual depreciation cost if straight-line depreciation is used?**

a) Rs. 1,000 b) Rs. 1,200 c) Rs. 200 d) Rs. 800

Q5 **For most chemical plants the ratio of working capital to total capital investment varies from**

a) 10 to 20% b) From 80 to 90 % c) From 51 to 65 % d) From 1 to 2 %

Q6 **Phosphate fertilizer is graded based on its**

a) P_2O_5 b) P content c) PCl_3 d) H_3PO_4

Q7 **The best fertilizer for rice paddies is**

a) urea b) ammonium sulphate c) superphosphate d) calcium ammonium nitrate

Q8 **Urea is a**

a) nitrogenous fertilizer b) phosphatic fertilizer c) Potassic fertilizer d) mixed fertilizer

Q9 **Ammonium nitrate which is used as fertilizer contains about**

a) 35 % N b) 25 % N c) 46 % N d) 82 % N

Q10 **Which of the following is a sulphur compound ?**

a) Ethyl mercaptan b) pyridine c) Naphthenic acid d) cumene.

Q11 **Aromatics are desirable in**

a)	kerosene to improve smoke point	b)	high speed diesel oil to improve cetane number	c)	gasoline to improve octane number	d)	none of the above

Q12 **Marcaptans are low boiling**

a)	sulphur compounds	b)	oxygen compounds	c)	nitrogen compounds	d)	organometallic compounds

Q13 **Which of the following products contains maximum sulphur ?**

a)	LPG	b)	ATF	c)	LDO	d)	Furnace oil.

Q14 **The chemical most commonly used to speed sedimentation of sewage is**

a)	sulphuric acid	b)	copper sulphate	c)	lime	d)	sodium permanganate

Q15 **The quantity of chlorine in ppm required to satisfactorily chlorinate sewage is usually**

a)	125-150	b)	95-120	c)	60-90	d)	0-25

Q16 **In treating turbine water a popular coagulant is**

a)	calcium sulphate	b)	chlorine	c)	ferric sulphate	d)	iodine

Q17 **The lowest layer of atmosphere is called**

a)	ionosphere	b)	troposphere	c)	stratosphere	d)	exosphere

Q18 **The positron is almost as heavy as**

a)	an electron	b)	a proton	c)	a neutron	d)	a meson

Q19 **The antiparticle of electron is**

a)	proton	b)	positron	c)	antiproton	d)	neutron.

Q20 **Which of the following particles is unstable?**

a)	neutron	b)	proton	c)	electron	d)	alpha particle

APJAKTU Corner (Prof. Manikandan P. M.)

Mass Transfer

1. Differentiate between molecular diffusion and eddy diffusion. Give the expressions for total molar flux in both the case. Give an examples of industrial processes in which only molecular diffusion take place.
2. Define permeability and solubility for diffusion in solids. How are they related?
3. What is the basic difference between the mass transfer coefficients k_y and k_y'? Obtain a relation between them.
4. A gas diffuses through a non-diffusing stagnant film B of thickness 2 mm. Given mole fraction of A on the two sides of the film are $y_{A1} = 0.3$, $y_{A2} = 0.05$; total pressure = 1 atm; molar flux $N_A = 0.37$ lbmol/ft^2.h . Calculate the mass transfer coefficient in SI units.
5. For mass transfer from a sphere to a stagnant liquid show that Sh = 2. Make necessary assumptions.
6. Differentiate between point efficiency and Murphree efficiency. At what conditions they become equal?
7. Define absorption factor. How is it related to stripping factor? What are their physical significances?
8. 'A cooling tower is a special type of heat exchanger'. Justify the statement. Classify cooling towers on the basis of air draft.
9. On a Relative humidity (on y axis) vs. Moisture content (kg moisture/kg dry solid) plot, label the following: bound, unbound, equilibrium and free moistures.
10. Give industrial applications of microfiltration, ultrafiltration and reverse osmosis. What type of membrane is used for reverse osmosis?
11. With the help of a graph briefly explain the concept of minimum liquid rate for absorption.
12. Estimate the liquid film mass transfer coefficient for O_2 diffusing from an air bubble rising through water with a velocity of 27 cm/s at 25^0C and 1 atm total pressure. Choose a bubble size of 4.0 mm assume a spherical shape and assume rapid circulation of gas inside the bubble. Neglecting the change of bubble size with distance travelled, calculate the fraction of oxygen absorbed from the air in 1m of travel if the water contains no dissolved water. The Henry's law constant at 25^0C is 4.01×10^4 atm / (mole fraction) at 1 atm pressure. Diffusivity for the system is 2.19×10^{-5} cm^2/s. Partial pressure of O_2 at these conditions is 0.209 atm.

13. A macromolecular solution(molecular weight = 6000; concentration = 1% mass) is passed through a tubular ceramic UF membrane of 2 cm internal diameter and 1 m long at 27^0C. The membrane admits of a pure water permeability of 2.11 gal/ft^2 .day. psi. Given the following data, calculate the flow velocity to be maintained in the tube in order to prevent formation of gel layer on the membrane surface. Rejection coefficient R' = 0.995; effective pressure difference ΔP = 15.43 psi; diffusivity of the solute D = 5 x 10^{-7} cm^2/s; viscosity of solution = 4 cP; density of solvent is 995 kg/m^3concentration at which solute forms a gel C_g (= C_m) = 10.5% mass. Pore leakage and fouling may be ignored. Assume turbulent flow and use the Dittus – Boelter equation. $Sh = 0.023(Re)^{0.8} (Sc)^{0.33}$

14. Explain in detail film and penetration theories of mass transfer. State all the assumptions used, correlations, disadvantages etc.

15. Explain any one direct heat continuous drying equipment with the help of a neat sketch.

16. Explain the concept of adiabatic saturation temperature and wet bulb temperature with the help of examples and hence develop an equation for the adiabatic saturation curve.

17. Define the following: Wet bulb temperature, Adiabatic Saturation Temperature, Relative Humidity , Absolute Humidity and Percentage Humidity, Humid Heat and Humid volume, Dehumidification

18. With the help of neat labelled diagrams perform mass balance on steady state counter current and cocurrent gas liquid contact equipment and hence obtain the operating line equations. Draw the necessary plots to validate the proof. Device a graphical method to find the number of stages in counter current contact. Using the above plot, explain the concept of minimum solvent rate for absorption and its significance in the design of absorption column.

19. What is critical moisture content? With the help of a plot, explain the drying rate curve. Develop equations for drying time in constant rate period and falling rate period(assume the drying rate, N is a linear function of X, the moisture content in the falling rate period , i.e. N = pX + q where p and q are constants). Solve the following: If critical moisture content is 6% , equilibrium moisture content is 0.2%, initial moisture content is 28%, final moisture content is 1 % calculate the drying time required for this operation. Given that in a laboratory test it took 8 hours to reduce the moisture content of the same solid to 2%.All the moistures are in bone dry mass of solid. Assume the falling rate of drying is linear in the free moisture content.

20. Derive equations for the diffusion of a solute through a stagnant solvent film and for equimolal counter diffusion. Using the above solve the following: A test tube 1.5 cm in diameter and 12 cm long has 0.4 g camphor ($C_{10}H_{16}O$) in it. How long will it take for the camphor to disappear? The pressure is atmospheric and temperature is 20^0C. The sublimation pressure of camphor at this temperature is 97.5 mm Hg, diffusivity for the system is 5.64 x 10^{-6} m^2/s.

21. Define molar flux and diffusivity. Why the flux and diffusivity values of liquids are lower than gases? Name the analogues of diffusivity in heat and momentum transfer with their SI units.
22. Define effective diffusivity and Knudsen diffusion model for diffusion in solids.
23. Develop a relation expressing the equivalence of diffusion coefficients in a binary system.
24. What are the limitations of film theory of mass transfer?
25. The Stanton number for heat transfer in a certain system is 0.0048. What is the Stanton Number for mass transfer under identical geometrical and hydrodynamic conditions if the Lewis Number is 1.2?
26. Draw two plots showing the nature of the operating line and equilibrium line for concurrent and counter current contact in the case of absorption and stripping. Why operating lines are not straight lines in mole fraction scale and when will it be straight?
27. Differentiate between ideal stage and real stage. Write an algebraic equation to find the number of ideal plates required for absorption for a dilute solution. Explain the notations used.
28. What are the mechanisms of moisture transport in solids?
29. Define dry bulb temperature, humidity, relative humidity, percentage humidity.
30. What is HETP? Explain its significance in the design of packed towers.
31. What are the criteria used for the selection of solvent for absorption?
32. An ethanol(A) - water(B) solution in the form of a stagnant film 2.0 mm thick at 293 K is in direct contact at one surface with an organic solvent in which ethanol is soluble and water is insoluble(N_B = 0). At point 1 the concentration of ethanol is 16.8 wt% and the solution density is ρ_1 = 972.8 kg/m^3. At point 2 the concentration of ethanol is 6.8 wt% and ρ_2 = 988.1 kg/m^3 . The diffusivity of ethanol is 0.740 x 10-9 m^2/s . Calculate the steady state flux N_A .
33. Compare plate column and packed column. Consider atleast six important parameters.
34. Draw the various cooling tower arrangements. Explain any one arrangement in detail.
35. With the help of a neat sketch explain the principle of electrodialysis. Clearly state its advantages, disadvantages and industrial application.
36. Explain the drying rate curve with the help of a neat sketch.

37. Determine the following psychrometric properties of a moist air sample having a dry bulb temperature of 27^0C and a humidity of 0.015 kg/kg dry air using the psychrometic chart. The Antoine equation for water is $lnP_A^v(bar) = 11.96481 - \frac{3984.923}{T(K)-39.724}$. Determine Relative humidity, Dew point, Adiabatic saturation temperature and wet bulb temperature, enthalpy, humid heat.

38. Explain the two resistance theory and hence develop expressions for overall mass transfer coefficients in both gas and liquid phases. Explain the individual terms in the expression and also the concept of fractional resistance. Using the above generated equations to solve the following: The equilibrium distribution of a solute A between air and water at low concentration at a particular temperature is given as $y = 1.2x$, At a certain point in a mass transfer device, the concentration of solute A in the bulk air is 0.04 mole fraction and that in the bulk phase is 0.025. In which direction does the transport of the solute A occur (i.e. from the gas to the liquid or vice versa)? Calculate the overall gas phase and liquid phase driving force for mass transfer? If k_y = 8 kmol/h m^2 Δy and k_x = 3.2 kmol/h m^2 Δx. Calculate the overall mass transfer coefficients K_x and K_y. Which resistance controls the overall process?

39. An absorber is used to remove 99% of solute A from a gas stream containing 4 mole % of A. Solutions of A in the solvent follow Henry's law and the temperature rise of the liquid can be neglected. (a) Calculate the number of overall gas phase transfer units, for the operation at 1 atm using solute free liquid at a rate of 1.5 times the minimum value.(b)For the same liquid rate, calculate number of overall gas phase transfer units for operation at 2 atm, 4 atm and 6 atm(c) How would the pressure change affect height of an overall gas phase transfer unit?

40. Explain in detail ultrafiltration and microfiltration. What is the role of MWCO in ultrafiltration? Explain the concept of concentration polarization in UF and do a theoretical analysis on it and hence derive an equation for concentration polarization modulus. Draw plots where ever necessary.

Career Corner: Common Interview Questions (Prof. Shan S.)

Fluid Mechanics

1. What is the equation for pressure drop in fluid flow through pipe when flow is laminar?
2. What is the corresponding equation for turbulent flow ?
3. You have a 2” pipe line, 2 KM long connecting two points. For a particular flow of water, we experience 2 Kg/cm2 pressure drop. If the diameter of the pipeline is changed to 4”, what will happen to the pressure drop?
4. The pressure drop equations for fluid flow through pipeline considers only straight length of pipe. How do we handle pipe fittings ?
5. In what service are globe valves used ? Where do we use gate valves ?
6. How can we explain the increase in flow through a water tap in the toilet in a household when the tap is opened more?
7. What is water hammer? How severe is its impact ?
8. What is the Schedule number of a pipe ? Where do we use higher schedule pipes and fittings ?
9. What is the function of a control valve ? What is the Control valve Cv ?
10. What is a check valve ? Name a service in your house where a check valve is used ?
11. What is the difference between head and pressure (explain at a pump discharge)
12. What are the classifications of pumps ?
13. How does a centrifugal pump work?
14. What is the difference between a centrifugal pump and a Positive displacement pump ?
15. How is a centrifugal pump started ? How about PD pump ?
16. What is the NPSH of a pump ?
17. You have been told that the pump has got an NPSH problem . How can you improve NPSH ?
18. What are the 2 NPSHs for a pump ? What is the relation?
19. Calculate the maximum lift possible in a centrifugal pump from the NPSH equation.
20. In the lab test for a centrifugal pump using suction lift, why is the suction pressure always –ve ? Then how will the pump get the Net “Positive” Suction Head ?
21. In the above case, the suction is negative even if the discharge is blocked. Why ?
22. What are the affinity laws for a centrifugal pump ?
23. Why centrifugal pumps sometime require priming ?
24. I have connected a pressure gauge and a barometer in the discharge of a centrifugal pump. The pressure gauge reads 1 kg/cm2. What will be the reading in the barometer ? Predict the readings in the two meters when the pump fluid is changed from water to glycerine/mercury maintaining same flow rate?
25. Why are variable frequency drives used for motors connected to centrifugal pumps ?
26. Why are submersible pumps used in steam condenser services ? What is the principle?
27. What is Bernaulli’s equation ?
28. Name a few applications of bernaulli’s equation in your household
29. What is the principle of operation of steam ejector?
30. Why barometric legs are provided for multi-stage ejectors ?
31. Why a cricket ball swings ? Why it does not happen in the case of a golf ball ?

Heat Transfer

1. What is the equation for heat transfer by radiation ?
2. What is that for convection ?
3. What is “critical radius” of pipe insulation ? How is optimum thickness arrived at ?
4. What is LMTD ?
5. Why is correction factor provided for LMTD ?
6. Why is the correction factor for double pipe exchangers always 1.0 ?
7. What are the guidelines of shell side/tubeside allocation of fluids ?
8. Why are floating head exchangers used ?
9. Where is U-tube bundled exchanger used ? Name a service where U-tube is not recommended.
10. What is the purpose of using multiple shell exchangers ?
11. What is the use of baffles in an exchanger ?
12. Why are tie rods and spacers provided ?
13. What are the guidelines for choosing the tube layout for exchanger bundles ?
14. What is Dittus Boetus equation ?
15. A heat exchanger with a design U of 200 provides only 120 when the flow through the exchanger is reduced to 70% of the original value . Is the exchanger performing well ?
16. What is exchanger fouling ? How is it caused ?
17. What is the difference between heat exchanger design and rating ?
18. What is TEMA ? What is the significance of TEMA classification of exchangers
19. Why are air preheaters provided in furnaces ?
20. Why are the top rows of tube bundles in a furnace provided with fins or studs ?
21. Define “draft” in a furnace ?
22. What are balanced draft furnaces ?
23. An operator reports a change in process fluid temperature for the same furnace flame temperature when the fuel composition changes. Why ?
24. What is the share of latent heat of vaporization in the total enthalpy of steam at 5 Kg/cm2 abs and 50 deg C superheat ?
25. What is a steam trap ? Why is it used ?
26. What are thermosyphon reboilers ?

Mass Transfer/VLE

1. Name 2 mass transfer operations happening in your kitchen.
2. What is HETP ?
3. How the pressure cooker is able to cook fast ?
4. Why is an LPG cylinder in the house cool after some use ?
5. What is the function of reflux and reboiler in a distillation column ?
6. Can columns operate without a reflux or rebolier ?
7. How is the feed plate in a distillation column located ?
8. Draw the pressure and temperature profile in a distillation column.
9. In a gas absorption column/distillation column, gas flows up and liquid flows down even though both follow Hagen Poisuelle equation . How this happens ?
10. What is column flooding ?

Industry Corner: Time to smoke your brains…..

(Mr. Amal G S, Faculty)

The summer was very severe. Gosree chemical's water supply source was getting dried up. There was regulation in daily water supply by State Water Authority. The plant was on the verge of a shut down. Efforts to minimise water consumption were actively pursued.

One Saturday morning, Mr Bhat, representative of Cooling Water Chemicals Inc. Approached the purchase department with his offer to treat the 5000 m^3/h light ends cooling tower with his "Cycles Magic". The chemical was costing Rs 170/Kg as against the current chemical cost of 150 Rs/Kg . The Materials manager turned down the offer. "See Mr Bhat, your chemical is costlier than the present one by Rs 20/Kg"

"You should not evaluate my chemical based on per Kg cost. With my chemical, you can improve the cycles of concentration from the current level of about 4 to 7. You will save on the total chemical cost and also on saved water. I understand you pay Rs 20 for a Cubic metre of water"

"I do not know the "cycles" concept. Unfortunately my technical group is not working today. Let me see whether the in-plant trainees can do a rough calculation. If it is directionally favourable, you can immediately approach for a plant trial. We are starving for water, you know".

The following schematic of the cooling tower was given to the in-plant trainees.

Can you help them?


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