CHEMPHORIA

MAGAZINE 2017 EDITION

Liquid-liquid Extraction

Solid Friction

GATE Corner

Pump Sizing

PRESSURE MEASUREMENT

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

Chemphoria 2017 Edition

HOD's Message

I am extremely happy to note that 'Chemphoria', the student's magazine being brought out by the enlightened, enthusiastic students of the Department.

Empowerment of students for their all-round development through education is our cherished motto. Today education means much more than merely acquiring knowledge. It is acquisition of knowledge and skills, building character and improving employability of our young talent, the future leadership.

My heartiest congratulations to the editorial team for their splendid efforts in assimilating and bringing the true essence of life at Department of Chemical Engineering, TKM College of Engineering into these pages. I hope it instills new thoughts and ideas in the minds of all readers and help them explore new horizons throughout the read.

I take this opportunity to convey my best wishes for all success.

Dr. K. B. Radhakrishnan

Professor and Head,

Department of Chemical Engineering,

TKM College of Engineering Kollam

Staff Editor's Note

The Chinese philosophy talks of two archetypal poles of nature – the 'ying' – the intuitive and dreamy mind and the 'yang' – the clear and rational intellect. These two seemingly opposite poles are said to be in a symmetrical arrangement in all forms of nature. The same is expected to be true in humans as well. Education is expected to develop in oneself, a balance of the above, not only a rational intellect, but also a creative and responsive frame of mind – one that responds and is able to be in sync with the happenings around. This development of the ability to be responsive and to act responsibly to the environment is the goal of education and self-development.

I am happy that this edition of the department technical magazine, titled "Chemphoria" brings into focus the plethora of topics that are of relevance to the modern industrialized society. I congratulate the student editor and his team, as well as, all those who contributed to the magazine in its present form, for their persistent effort in bringing out this edition of the magazine.

Wish you all a Happy Reading.

Prof Manikandan P. M.

Assistant Professor,

Department of Chemical Engineering ,TKMCE

Student Editor's Note

It gives me great pleasure to bring you this issue of 'Chemphoria', the annual technical magazine of Chemical Engineering Department. The name and fame of an institute depends on the calibre and achievements of the students and teachers. The role of a teacher is to be a facilitator in nurturing the skills and talents of students. This magazine is a platform to exhibit the technical writing skills and innovative ideas of teachers and students. Chemphoria presents the achievements of students and contributions of teachers. I would like to place on record my gratitude and heartfelt thanks to all those who have contributed to make this effort a success. I profusely thank the management for giving support and encouragement and a free hand in this endeavour.

Last but not the least I am thankful to all the authors who have sent their articles. I truly hope that the pages that follow will make an interesting read.

Jeena Mary Saji (13403027)

Nithin Sebastian K (13403046)

2013 – 2017 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.

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 2017-18

Faculty in charge	: Dr. K B Radhakrishnan
Secretary	: Mr. Kiran Chand P
Joint Secretary	: Mr. Ajmal Ashraf Puthenpurayil
Treasurer	: Miss. Anakha Dilkumar
Executive Members	: Mr. Salman Fajis
	Miss. Tressitta Sebastian Kochupurackal
	Mr. George Benny
	Miss. Sruthy C Nair
	Mr. Muhammed Hafiz
	Miss. Pravitha Pillai
	Mr. Thaha Thajammal K T
	Miss. Kartiyani Sangeetha

Dedication

This magazine is dedicated to all Chemical Engineering Aspirants

Contents

LIQUID-LIQUID EXTRACTION

(Jeena Mary Saji , 13403027, 2013 – 2017)

Liquid–liquid extraction (LLE), also known as solvent extraction and partitioning, is a method to separate compounds or metal complexes, based on their relative solubilities in two different immiscible liquids, usually water (polar) and an organic solvent (non-polar). There is a net transfer of one or more species from one liquid into another liquid phase, generally from aqueous to organic. The transfer is driven by chemical potential, i.e. once the transfer is complete, the overall system of chemical components that make up the solutes and the solvents are in a more stable configuration (lower free energy). The solvent that is enriched in solute(s) is called extract. The feed solution that is depleted in solute(s) is called the raffinate. LLE is a basic technique in chemical laboratories, where it is performed using a variety of apparatus, from separatory funnels to counter current distribution equipment called as mixer settlers.[not verified in body] This type of process is commonly performed after a chemical reaction as part of the work-up, often including an acidic work-up.

The term solvent extraction can also refer to the separation of a substance from a mixture by preferentially dissolving that substance in a suitable solvent. In that case, a soluble compound is separated from an insoluble compound or a complex matrix. From a hydrometallurgical perspective, solvent extraction is exclusively used in separation and purification of rare earth elements etc., its greatest advantage being its ability to selectively separate out even very similar metals. One obtains high-purity single metal streams on 'stripping' out the metal value from the 'loaded' organic wherein one can precipitate or deposit the metal value. Stripping is the opposite of extraction: Transfer of mass from organic to aqueous phase. LLE is also widely used in the production of fine organic compounds, the processing of perfumes, the production of vegetable oils and biodiesel, and other industries. It is among the most common initial separation techniques, though some difficulties result in extracting out closely related functional groups. Liquid–

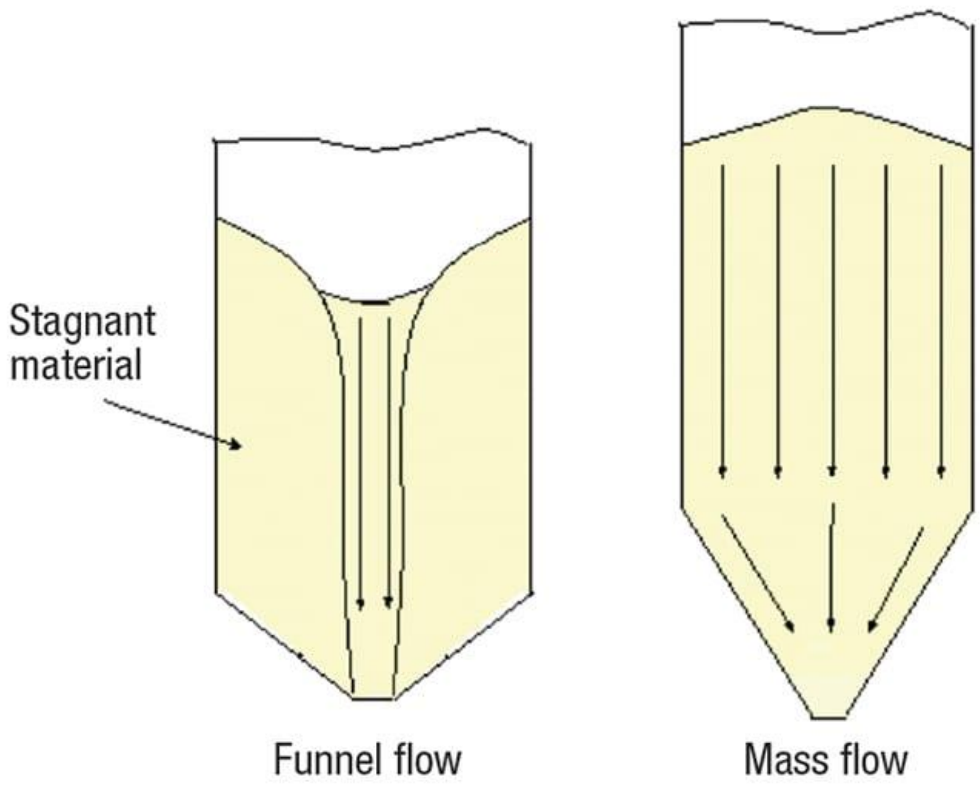
liquid extraction is possible in non-aqueous systems: In a system consisting of a molten metal in contact with molten salts, metals can be extracted from one phase to the other. This is related to a mercury electrode where a metal can be reduced, the metal will often then dissolve in the mercury to form an amalgam that modifies its electrochemistry greatly. For example, it is possible for sodium cations to be reduced at a mercury cathode to form sodium amalgam, while at an inert electrode the sodium cations are not reduced. Instead, water is reduced to hydrogen. A detergent or fine solid can be used to stabilize an emulsion, or third phase. Liquid-liquid extraction is a common mass-transfer operation in which a target solute material is transferred from a feed phase into a solvent. The process is used in a number of applications, including: the removal of valuable products from fermentation broth; the removal of high-boiling-point organic materials from wastewater; recovery of hydrogen-bonded organic compounds (formic acid, acetic acid and others) from water; recovery of reaction products from a broth; washing of acids or bases from an organic stream; and others. In liquid-liquid extraction, a feed solution is contacted with a liquid solvent that is immiscible with some of the components of the feed, but that dissolves another component of the feed solution. In the course of this contact, a desired material can be removed from the feed and transferred to the solvent phase. The solvent phase refers to the solvent with the dissolved solute, while the feed solution without the solute is called the raffinate phase. There are a number of extractor types for liquid-liquid extraction, including agitated columns, static columns, rotating disc etc.

SOLIDS FRICTION IN BINS AND HOPPERS

(EMIL VINCENT, 13403021, 2013 – 2019)

To avoid problems with solids flow in bins and hoppers, the friction between the equipment walls and the flowing solids is an important factor to understand. Provided here is a review of flow patterns in bins and hoppers, and practical design considerations for overcoming challenges related to wall friction.

In the past, bins and hoppers were typically designed primarily from an architectural or fabrication standpoint (for instance, hopper walls were sloped 30 deg from vertical to reduce the waste of wall materials, or 45 deg to minimize headroom requirements and simplify design calculations). However, experience has shown that designing equipment without regard to the actual bulk materials being handled often leads to flow problems, such as arching, ratholing, erratic flow and even no flow. By measuring the flow properties of a bulk solid, including wall friction, the flow behavior of the material can be predicted, and more reliable hoppers and bins can then be designed.



FLOW PATTERNS

Two types of bin flow patterns are possible when solid material is discharged from a hopper, bin or silo (Figure). A mass-flow bin has a relatively long, tapered discharge section. In mass flow, all of the material is in motion during discharge, so no stagnant regions form. Conversely, a funnel-flow bin has a relatively short converging section. While storage capacity for a given height is greater in a funnel-flow bin, this geometry allows material in the center to move while material at the walls is stationary. The resultant stagnant regions may interrupt flow.

FRICTIONAL PROPERTIES

Both internal and external friction values are important when characterizing the flow properties of a bulk solid. Internal friction is caused by solid particles flowing against each other, and can be determined using a direct shear tester. External friction is expressed as the wall-friction angle or coefficient of sliding friction. The lower the coefficient of sliding friction, the less steep the hopper walls need to be to achieve mass flow.

WALL-FRICTION TEST

The test method for wall friction measures interfacial friction between the powder sample and hopper wall material at increasing consolidation stresses. The test is performed using an instrument that involves placing a sample of powder inside a retaining ring on a flat coupon of wall material. Various normal loads are then applied to the powder, and the powder inside the ring is forced to slide along the stationary wall material. The resulting shear stress is measured as a function of the applied normal stress.

The materials of construction used to simulate the surface are based on actual hopper design — instrument vendors provide a range of different grades of steel and plastic routinely used in hopper construction.

The coefficient of sliding friction is the ratio of the shear force required to cause sliding, to the load applied perpendicular to the plate surface. The arctangent of this value is the wall-friction angle.

Wall-friction angles above 30 deg are considered high, and may lead to flow difficulty in powders. Wall-friction results can help determine the recommended hopper angle to ensure mass flow.

FACTORS AFFECTING FRICTION

The following variables can affect the internal and external friction values of a bulk solid and are similar to those affecting cohesiveness:

Pressure. Typically, as consolidation pressure increases, the effective angle of internal friction decreases. Similarly, the coefficient of sliding friction often decreases as pressure acting normal to the plate increases. However, the internal angle of friction is an intrinsic characteristic of the material, which may increase, decrease, or remain the same as pressure acting on the material increases.

Moisture content. As moisture increases, many bulk solids become more frictional.

Particle size and shape. Typically, fine materials are somewhat more frictional than coarse materials, so their flow is often more troublesome. Particle shape plays a role also, in that angular particles tend to interlock with each other and also dig into a wall surface, thereby creating more friction.

DESIGN CONSIDERATIONS

In cases where powder frictional properties dictate hopper designs that are impractical, alternative options for finding solutions to flow problems could include changes in hopper wall material or an increase in cleaning frequency for the hopper surface. Another approach for improving flowability is to incorporate additives into the powder formulation. Similarly, mechanical-assist devices, such as vibration and aeration, are other possible considerations. Trade-offs must be evaluated between the cost of these interventions versus the consequences of the lost processing time due to flow stoppages related to equipment downtime or poor product that requires rework.

References:

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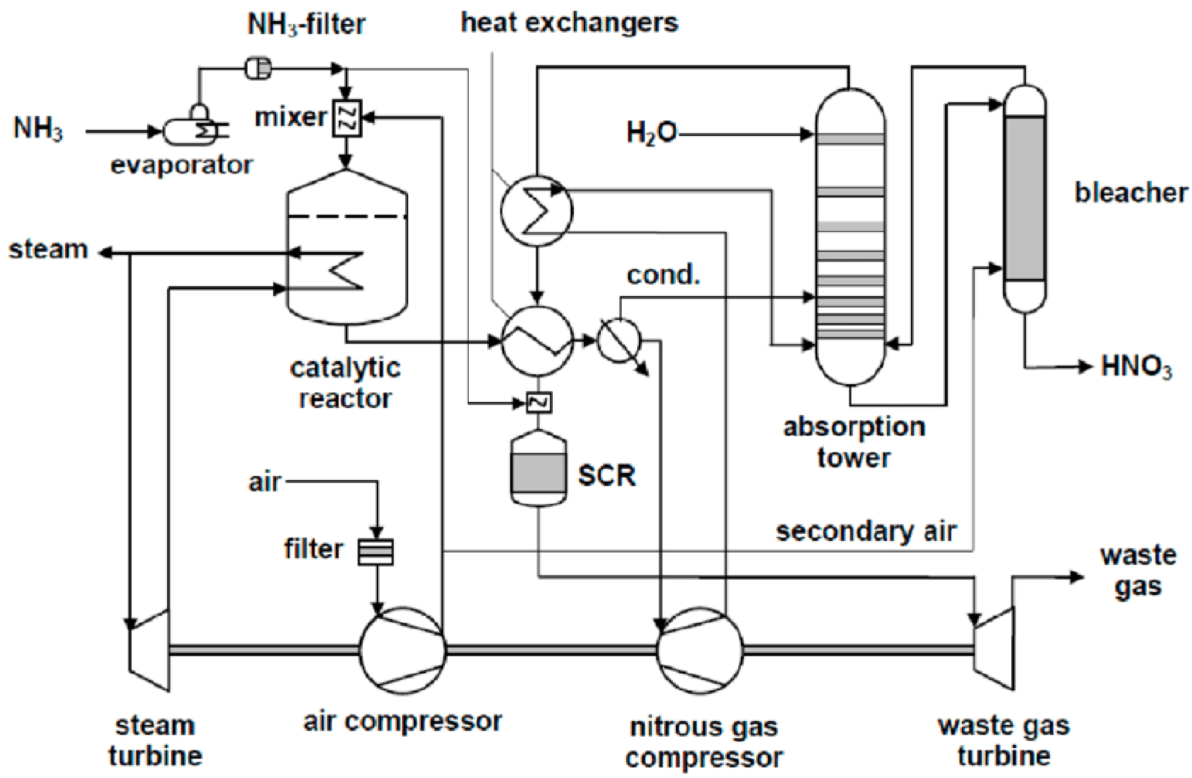
2. Carson, J., Pittenger, B. and Marinelli, J., Characterize Bulk Solids to Ensure Smooth Flow, Chem. Eng.*, April 2016, pp. 50–59.*

3. Mehos, G. and Morgan, D., Hopper Design Principles, Chem. Eng.*, January 2016, pp. 58–63.*

THIS NEW, DUAL-PRESSURE NITRIC-ACID PROCESS IS COMMERCIALLY AVAILABLE

(Megha T Bhasi, 13403035, 2013 – 2017)

Recently, Weatherly Inc., a wholly owned subsidiary of KBR Inc. introduced its new dual-pressure nitric acid (DPNA) technology, which enables economically viable production of HNO_3 in large scale [over 1,000 metric tons per day (m.t./d)], as part of large fertilizer-production complexes. The technology was launched at the 2016 AN-NA (Ammonium Nitrate – Nitric Acid) conference (September 16–23; Eindhoven, the Netherlands). In the DPNA process (diagram), ammonia is first oxidized with air over a platinum catalyst at high temperature and low pressure (LP). The product of the LP oxidation is passed through a heat exchanger to recover a major portion of the heat. The process gas is cooled and oxidized further in a LP cooler condenser, where NO, NO_2, O_2 and water combine to form dilute HNO_3. Some of the reaction energy is recovered and used to reheat the tail gas. The LP process gas is then compressed in the NO_x-gas compressor, and fed to high-pressure (HP) cooler condenser and absorber to form product HNO_3 (68%). Tail gas from the absorber is reheated to 1,150°C and used to drive a hot-gas expander to generate power for the air compressor and NOx-gas compressors.



Latest in the industry…

(Aby Cyriac, 14403005, 2014 – 2018)

- **ADVANTAGES GAINED IN AUTOMATING INDUSTRIAL WASTEWATER TREATMENT PLANTS**

Process monitoring and automation can improve efficiencies in wastewater treatment systems. A number of parameters well worth monitoring, as well as tips for implementation are described There is growing interest in automating wastewater treatment processes across a broad range of industries. In particular, a paradigm shift is starting in automating industrial wastewater treatment in various sectors of the chemical process industries (CPI), such as foods (especially grain processing, sugars, sweeteners and edible oils), beverages (mainly soft drink bottlers and breweries), and hydrocarbon and chemical processing (particularly petroleum and petrochemical plants). The driving forces behind this evolution are economic. Wastewater process optimization most often leads to a more efficient use of chemicals, reduced energy consumption and less solid waste. Most wastewater-treatment systems use a common sequence of steps (Figure 1), with the purpose of first removing solids materials in the influent wastewater, recovering lost product, removing solids, fats, oils and greases (FAG), treating the water biologically and chemically enhancing flocculation, coagulation and physical removal of the biological solids and sludge.

- **MOBILE APPS FOR INCREASING PROCESS EFFICIENCY**

Industrial mobile apps help chemical processors overcome process, maintenance and inventory issues Due to the portability and propagation of smartphones and tablets, mobility is all around us. Plugging in on the fly has become second nature in our personal lives thanks to mobile applications (apps) that allow users to take pictures and post directly to multiple social media sites in a split second, apps that create personal playlists based upon our musical preferences and a host of other apps that provide modern day conveniences. So, it makes sense that the intersection of mobile apps and the industrial world quickly followed suit. As a result, there's been a proliferation of industrial mobile apps that conveniently assist with process engineering and maintenance activities, inventory and logistics and even simulations. And, because of the existing comfort level with mobility, chemical processors are quickly and easily embracing these mobile apps as useful tools that help ensure reliability of equipment, process and product quality.

Process and engineering management Reliability of process is the "Holy Grail" of the chemical process industries (CPI) and, as such, apps designed to assist with managing processes are not reliable to its core.

- **HEAT TRANSFER IN WIPED FILM EVAPORATORS**

Simulations demonstrate the complex, changing properties of materials within the evaporator. Such information can help in both designing and selecting the proper evaporator a wiped film or agitated thin-film evaporator is very effective with difficult-to-handle materials. The evaporator consists essentially of a sealed cylinder that is provided with a heating jacket. The feed material is distributed on the inside as a thin film by means of a mechanical system. Due to the heating and the applied vacuum, the volatile components are evaporated and liquefied in an external condenser. In a short-path still, the condenser is fixed concentrically inside of the evaporator, so that a distillation at fine or even high vacuum is possible. A special version of the film evaporator is the horizontal dryer, where the material is conveyed with special conveyor elements through the evaporator. The non-evaporative components are pumped as a residue or discharged as powdery solids. The evaporation process is mainly heat transfer controlled. For a simulation, the evaporator is advantageously divided into several zones.

- **A NEW ADSORBENT FOR WASTEWATER TREATMENT**

A team at the Graduate School of Energy, Environment, Water and Sustainability (EEWS) of Korea Advanced Institute of Science and Technology, led by professor Cafer T. Yavuz has developed a water-treatment adsorbent that can selectively remove water-soluble micromolecules, such as those of dyes and pesticides, which cannot be removed completely during conventional water-treatment processes. The adsorbent has the added advantages of being inexpensive, easily synthesized and renewable. In order to remove very small molecules — which also tend to be electrically charged — with high solubility in water, and to do so selectively, the team had to develop a new adsorbent technology. It developed a fluorine-based nanoporous polymer that has all the desirable properties. By controlling the size of the pores, this adsorbent can selectively adsorb aqueous micromolecules of less than 1–2 nm in size. To separate specific contaminants, the adsorbent had to be able to interact strongly with the target substance. Fluorine, the most electronegative atom, interacts strongly with charged soluble organic molecules.

PRESSURE MEASUREMENT: HANDLING DIFFICULT PROCESS APPLICATIONS

(IRENE WILSON, TKM15CH032, 2015 – 2019)

A better understanding of what pressure instruments do and how they work can help improve measurement performance, especially in troublesome applications

Effective use of process instrumentation is critical in any chemical manufacturing environment. These instruments are strategically located throughout various units and measure all types of process variables, and are the operators' eyes and ears to the world inside the vessels and pipes. Ensuring good performance requires careful selection, proper installation and ongoing maintenance. These concepts apply to all types of instrumentation, including flow, level, temperature, pressure and other measurement categories. We will concentrate on pressure in this article because these instruments are at the heart of many techniques for measuring not only pressure, but also flow and level. Getting reliable and accurate pressure measurements can be a challenge, often due to installation difficulties and other issues. But modern industrial pressure instruments address many of these issues and are exceptionally stable, accurate and durable.

Spending a few moments thinking about how pressure is measured can help a user sort through the mechanics of an application and ensure that it performs exactly as desired. The simplest pressure instrument is a manometer, a U-shaped tube partially filled with a liquid of known density such as water. If both ends are open to the atmosphere, the two sides of the liquid slug will be of equal height. If pressure is applied on one end but not the other, the liquid will go down on the side where pressure is applied and up on the other. The difference in height can be measured, and this unit of measure is commonly used to determine pressure. If unequal pressure above atmospheric pressure is exerted on both ends, the greater pressure will overcome the lesser. This is differential pressure (DP), since there are two dynamic sources of pressure on opposite sides of the slug of liquid. Pressure measurements can be thought of as differential measurements referenced to different points. These reference points can be tied to atmospheric pressure in the case of a gage transmitter, vacuum in the case of an absolute pressure transmitter, or other process points in terms of a DP reading.

Most applications use gage or DP, although for some applications, absolute pressure readings are necessary.

What is a Pressure Instrument?

In the manometer tube, the liquid indicates the pressure visually. With a pressure instrument, a diaphragm essentially replaces the slug of liquid in the manometer tube, and there is a mechanism capable of measuring the amount of displacement. The diaphragm and its measuring mechanism together make up the sensor, which creates an electrical signal in proportion to the pressure. Consider what a pressure instrument does and its construction (Figure 1). Measuring process pressure requires a liquid, gas, slurry or some other media to apply pressure against an isolating diaphragm capable of moving the sensor to create a signal. In the example in Figure 1, when pressure is applied, the isolator applies pressure to the fill fluid, often oil, which in turn will move the sensor. The movement of the sensor can then be electronically processed by the transmitter.

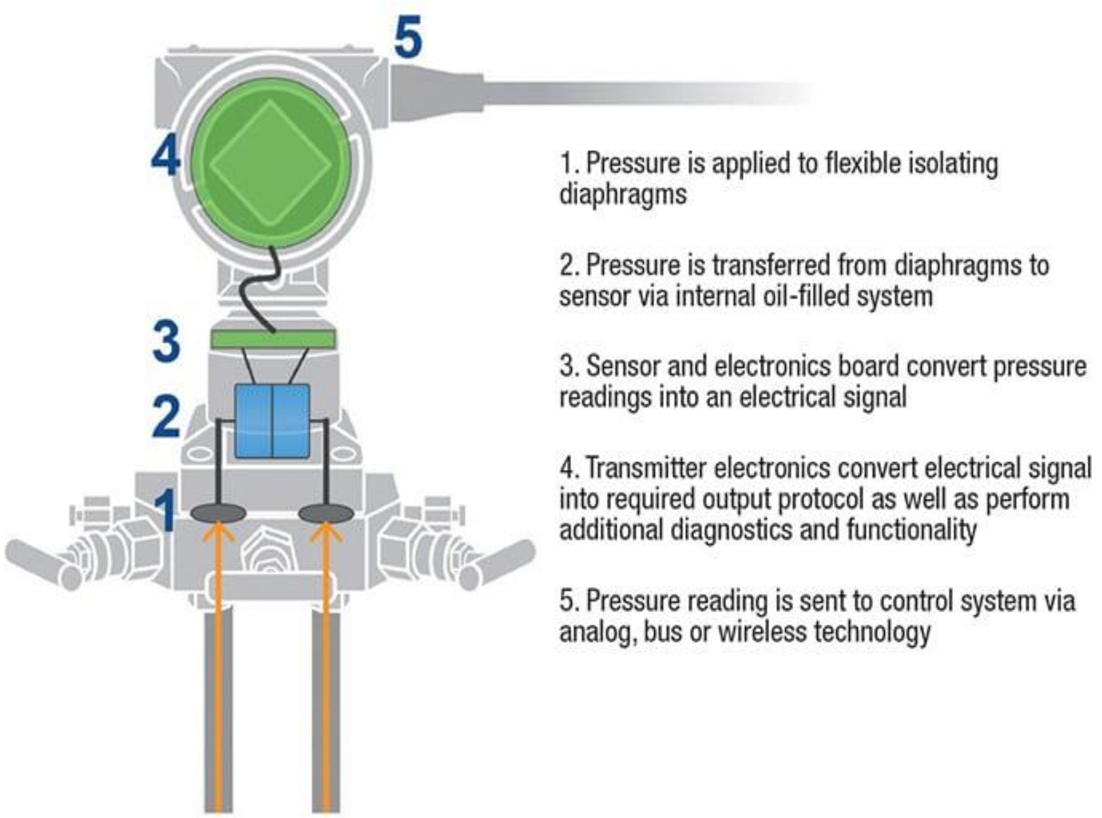


Figure 1. This is a representative illustration of the working of a differential pressure instrument.

This measurement mechanism can be capacitive, where the capacitance between the moving diaphragm and stationary surface can be measured, or mechanical, where a strain on the sensor causes flexing. The key function of the sensor is to convert small mechanical movements into electrical signals. These signals are then often converted mathematically in the transmitter to produce a pressure reading. The final output of an instrument uses a standardized signal protocol, which can be integrated into an automation system. With simple pressure-measuring devices, such as manometers or Bourdon-tube gages, the process fluid is often allowed to flow into the instrument and come into direct contact with the sensor, which can work well for non-corrosive types of applications, such as water. In these simple examples, the sensor is often referenced to the atmosphere, thus displaying a gage reading. If, on the non-process side of the sensor, the air has been evacuated to create a vacuum, this yields an absolute pressure measurement. Another way to create an absolute pressure reading is to correct a conventional gage value by deducting atmospheric pressure. For a DP instrument, the backside of the diaphragm is connected to a second process pressure inlet.

For most applications, the sensor's raw signal is not very useful, so the pressure instrument processes the signal and converts it to a standardized format or engineering unit, such as bars, pounds per square inch (psi) or inches of water (in. H_2O). This processing is necessary because pressure sensors are non-linear and affected by temperature. Therefore, the transmitter also includes at least one temperature sensor to compensate the pressure readings for temperature conditions. The transmitter will often make this additional measurement available digitally. The processor in the transmitter will also convert this information to a digital protocol so the transmitter can report the pressure to an automation system. For instance, this can be done with a 4–20-mA output with the HART protocol. For small, inexpensive pressure devices, often referred to as transducers, the sensor and transmitter may all be built into a single compact housing with a threaded inlet and wire pigtails for the connection. For typical chemical-process installations, pressure instruments are often designed with DP configurations with the sensor housed in a manifold. Connections can be made using impulse lines from the process penetration. If used in a gage pressure application, the second connection is simply left open to atmosphere. Elaborate manifold configurations (Figure 2) can be outfitted with valves to close off and bleed the impulse line, simplifying maintenance.

Figure 2: Manifolds have a wide variety of configuration to assist with routine maintenance activities.

In some situations, where the process is especially hot or fluid characteristics are dangerous, containment is critical and impulse lines are undesirable. A remote seal can be installed at the process penetration, and its connection back to the instrument can be filled with oils, inert liquids or other fluids, which move the sensitive electronics away from the hot conditions via remote seal lines (Figure 3). These seal lines also act as a temperature barrier. The pressure information is passed hydraulically via the fill fluid to the sensor, while containing the process fluid in the piping or vessel.

Figure 3: This remote seal configuration can be mounted in direct contact with the process fluid, and the pressure transmitted via an inert fluid to the pressure sensor

This same methodology can be used for installations in hazardous environments, which often also use an isolator to separate the transmitter electronics from the process connection. The remote seals add one or more additional layers of process protection, especially important in highly corrosive installations. If the diaphragm fails and allows process fluid to escape, some less robust instruments may provide a path for process fluid to flow through the housing and out the electrical conduit, allowing it to reach the connection point or some point in between. More advanced transmitters provide isolation with dual compartment housings able to isolate the sensing side from the loop connection side

The Transmitter

The transmitter is integrated into the overall pressure instrument and contains a significant amount of electronics to perform a variety of functions to make it widely usable for many different applications. Understanding what these devices do can help clarify equipment selection for specific applications. As previously mentioned, the electronics in the transmitter are responsible for taking the raw sensor information and turning it into pressure information. Depending on the sensor type, this correction addresses things like sensor non-linearity and temperature correction, as well as providing the other features found in the transmitter. In many cases, pressure transmitters require a temperature sensor near the pressure measurement point for correction of the pressure reading. In some cases the electronics can also accommodate a process temperature sensor, which is very helpful for multi-variable DP flowmeters where process temperature correction is required in the flow calculations. These temperature and pressure measurements are often available as secondary variables and can be conveyed digitally to an automation system. Additionally, the transmitter must convert the pressure information into an output signal, which may be an analog current or voltage value, or a digital signal. For analog, 4–20 mA is by far the most common transmitter interface, often including digital HART data superimposed on the analog signal. Digital signals are usually Foundation Fieldbus, Profibus PA, Wireless HART or other industrial protocols. Few field instruments these days are simple analog, with most including both analog and digital capabilities. With the digital capabilities, these instruments can transmit data in addition to the process variable including configuration, secondary variables and critical diagnostic information. With the flexibility added by configuration features, pressure transmitters enable users to set many parameters often including the following:

Ranging. A pressure sensor has a fixed useful range. With that said, many transmitters offer range-down capabilities. This enables a transmitter with a wider sensor range to be ranged down to meet an application with lower pressure requirements. This range-down is limited by accuracy, so care must be taken to ensure sufficient measurement sensitivity even at very low pressure changes. If a sensor has a useful working range of 0–250 in. H_2O, using it to measure 0–25 in. H_2O is a reasonable range-down of 10:1. Even though the range can be set for the lower values, this will not affect the mechanical characteristics of the sensor and some accuracy will be lost. Investing in devices with a wider range-down capability can optimize pressure instrument inventories.

Diagnostics. Some pressure instruments are aware of their surroundings and what is happening with the process. They get used to the normal operating patterns and can warn operators when conditions change. The transmitter also typically monitors itself, looking for changes in its own internal components. If given the means to communicate, as with a digital instrument, it can report changes and developing problems to the automation system and operators, so action can be taken before failure.

Temperature. As mentioned, sensor technologies are often affected by temperature. As a result, an instrument will have a useful working temperature range to protect sensitive electronics, as well as suitable process temperatures for which correction is possible, just as it has a working pressure range. Some applications can be too hot or cold for the sensor and electronics, an area which will be covered in more detail later in this article.

Protocol. Pressure instruments need mechanisms to convey all their information, which digital communication uses to get more information from the field to the automation system. For example, in the case of a fieldbus protocol, digital information is provided with regular updates. With greater sophistication comes greater complexity as adding capabilities requires more settings and configuration. The protocol selection is often hardware based. A Foundation Fieldbus instrument cannot be changed to HART via a menu. However, external devices can add wireless connectivity, sending and receiving data via Wireless HART, but this is defined by the hardware components rather than by setting a configuration.

Hazardous location requirements. Most modern field instruments are designed to operate in many environments, including hazardous areas such as Class 1/Div. 1 or Zone 0, provided they are installed and maintained properly. But, it is still very important to determine what ratings are required for each application.

Function Influences Application

Once the working fundamentals of pressure instruments are clear, it is easier to see where one might encounter difficulties. Incorrect specifications can happen, such as choosing operational characteristics unsuited to the application. For example, choosing a 0–10-bars instrument for an application where the normal working pressure is 10 bars is not correct, because the working pressure is too close to the instrument's maximum measurement range. Instruments installed incorrectly can interfere with normal operation. Manufacturers provide extensive information as to installation practices, and it is important to follow these for reliable performance. Maintenance problems can be the result of misspecification. Instruments made over the last 10 years or more are calibrated at the factory using highly sophisticated and accurate equipment and are exceptionally stable. Maintenance workers who may believe electronic sensors need to be tweaked out of the box for accuracy, like a mechanical gage, will often take the instrument out of specification if they do not have the proper training and calibration equipment. After some number of years, most manufacturers do recommend recalibration. The traditional concepts of "sensor drift" applied to mechanical instruments have evolved, and recommended best practices are to calibrate when required. Process pressure spikes can cause damage to pressure equipment. These can come from improper valve movements, process upsets and sudden pressure events. Installing instruments with high-pressure ranges capable of withstanding these spikes is one solution, but running a process at the lower end of an instrument's range may cause sensitivity issues. Selecting quality instrumentation able to handle overpressure conditions can help withstand pressure spikes and deliver good measurement performance.

Impulse Lines

One option when measuring pressure is to transmit the process media condition hydraulically. A pipe or tube can be mounted between the sensor and the tap, allowing the sensor to be mounted a considerable distance from the process equipment (Figure 4). This approach works because the pressure is static, so there is no significant pressure loss over the length of the tube. An instrument can be mounted in a location based on easier access, distance from a hot or dangerous process, or proximity to both ends of a differential measurement.

Where gases are involved, usually the process gas fills the impulse lines, which are called dry legs. As long as they stay dry, there are rarely problems, but liquid can find its way into these dead legs through condensation or other sources. Liquid intrusion doesn't necessarily cause immediate problems, but if the liquid freezes, it can block the line or damage the tubing or sensor due to expansion. Bleeding dry legs routinely, particularly during cold weather, may be necessary. Where liquids are involved, the process liquid fills the impulse lines, which are called wet legs. Again, if the lines are filled completely with liquid, no problems may develop. However, gas can become trapped in a line, and adding a compressible element to the chain can interfere with accurate pressure transmission. Bleeding wet legs to eliminate gas slugs may be necessary.

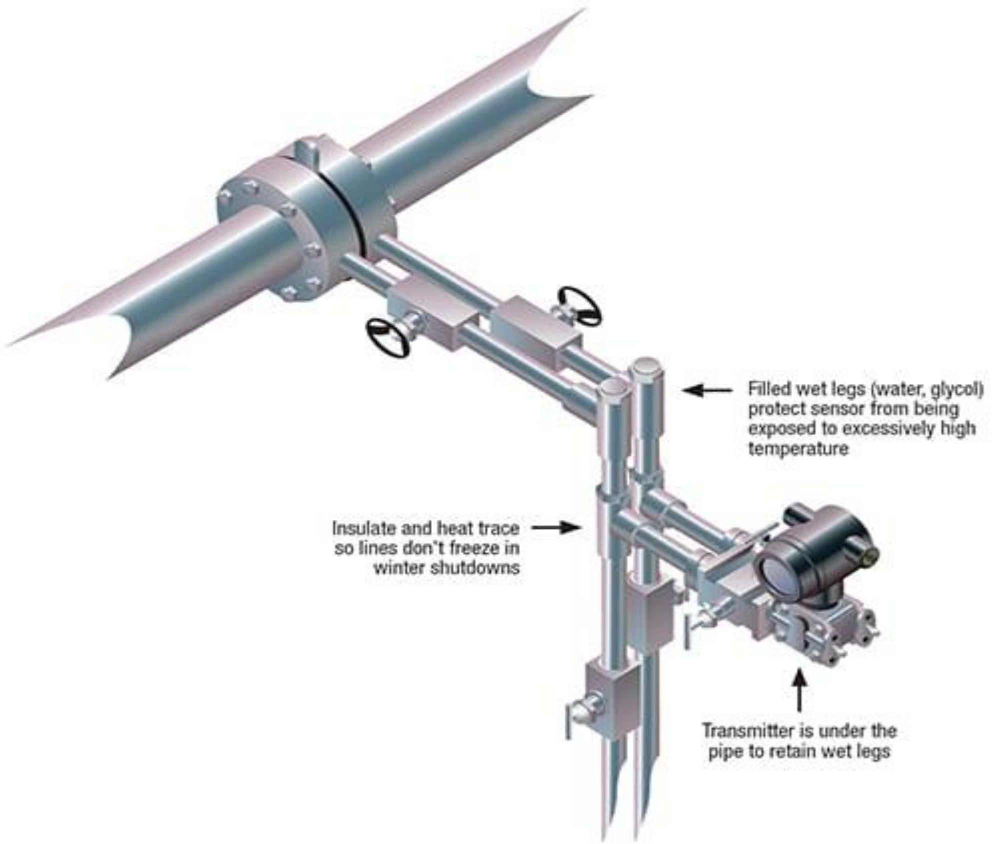


Figure 4: This a typical DP flowmeters installation with impulse lines, including typical practices to fill wet legs with a fluid able to withstand wide temperature swings

Additionally, in either wet- or dry-leg installations, mounting best practices can help eliminate measurement challenges. By mounting a pressure device with a liquid leg below the process connection, gas bubbles that form can work their way out to the process, keeping the wet leg filled. Mounting the pressure transmitter above a gas line can also help liquids flow out of the impulse lines.

Either type of line can become clogged either through sediment or frozen liquid. Bleeding can clear the line, or at least confirm the clog exists. But having wet legs filled with process fluid has drawbacks. The fluid's hazardous nature may make it dangerous, its characteristics outside of the process may change, and it may be subject to viscosity changes at different temperatures. Where wet legs have challenges, remote seals can often be used as an alternative to solve some of these problems.

A remote seal can be added at the process tap point(s), with fill fluid added to the line and permanently sealed in the space next to the actual measuring sensor diaphragm. It is important to select the correct fill fluid suitable for the specific application. As is the case with most fluids, characteristics change as a function of temperature. Viscosity increases as temperature decreases, and if it gets too hot, the fill fluid can flash into vapour. If the fill-fluid line is long, the temperature difference between a hot process and a sensor some distance away in a cold climate could easily be 200°F or more. Some heat will be transmitted down the line, but even with stainless steel tubing, it dissipates quickly. A good rule of thumb is that a fill fluid can lose 100°F for every foot, though this can be significantly more depending on installations and ambient conditions. Figure 5 highlights this rapid heat loss in relation to installed distance [1]. One end can be hot while the other is cool, causing slow measurement response. Heat tracing is one solution, but it is expensive and maintenance-intensive. Another approach uses an integral enclosure to protect the impulse lines and minimize heat transfer problems (Figure 6).

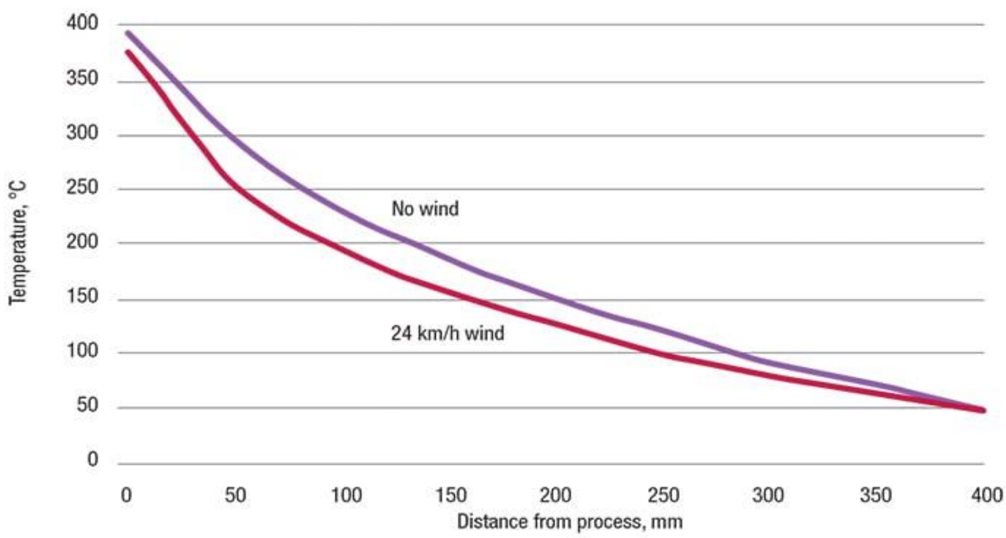


Figure 5: This graph shows process heat dissipation versus distance from transmitter curve

Figure 6. In some hot applications, it is required to add additional separation from the process heat to the transmitter. This shows an example cut-away view where the oil fill lines extend to the sensor and protect the temperature of the transmitter

In tough applications where process temperatures are extreme or ambient temperatures swing significantly throughout the year, dual seals with multiple fill fluids can help. In some instances, electronic remote sensors can eliminate several of the traditional challenges. This approach eliminates the need for a long capillary by connecting the two transmitters electronically, one at each tap point, rather than using a single device and long impulse lines or capillaries. Electronic remote sensors also eliminate heat tracing and associated maintenance challenges. Using systems with closed fill fluids or electronic remote sensors can overcome many challenging combinations of temperatures likely to be encountered in process plants and facilities.

Differential Pressure Challenges

DP measurements are made in all kinds of process plant areas. Examples include measuring level in tanks, flows through pipes, clogging in strainers, and many more applications. Since DP installations need connections to two process points, and those points could be some distance apart, they may call for the longest impulse lines. Consider this example: measuring level in a large pressurized tank (Figure 7, left panel). The pressure instrument is mounted near the tank with an impulse line from a spud near the bottom connected to the high side of the DP manifold. The low side is a line running to the top of the tank, say 10-m high, to measure the pressure in the headspace above the liquid. This dry leg comes down the side of the tank and is connected to the low side of the manifold. The two sides may present significantly different temperatures depending on the contents of the tank. But as long as everything works properly, the level measurement will be correct within the accuracy limits of the process connections. However, there is a risk that the dry leg could collect liquid or the wet leg could trap some gas, in either case introducing potential problems.

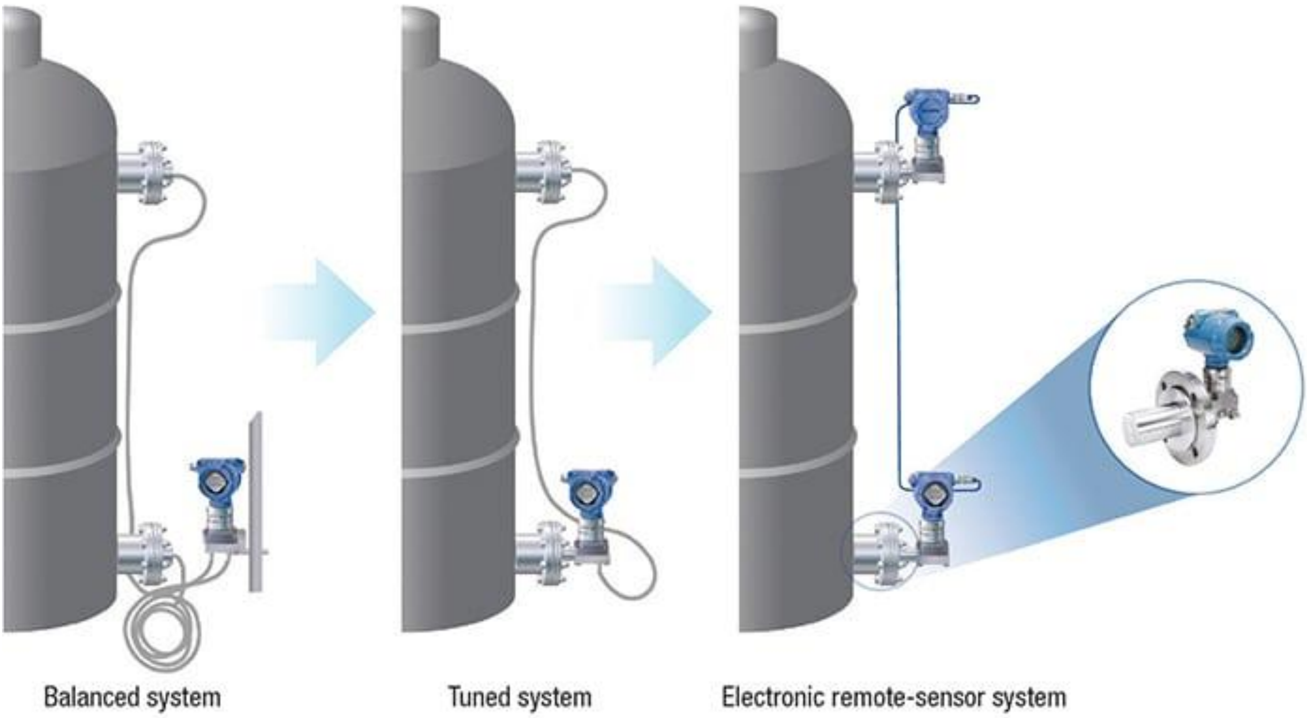


Figure 7. These illustrations show three typical level measuring approaches each providing measurement benefits in different applications

A different approach is to utilize a tuned remote seal on the lower connection (Figure 7, center and right) instead of an impulse line. This avoids any potential for clogging of the wet leg. Of course it is still important to select the correct capillary fill fluid for optimal temperature performance. A third alternative, if static pressure isn't too high, is to mount a second pressure instrument on top of the tank instead of using an impulse line (Figure 7, right panel). For optimal performance, an electrical connection between the two instruments provides a means to synchronize the measurements. This configuration removes the capillary piping and significantly reduces temperature effects. This pressure measurement system can be configured as a single instrument, with the DP reading sent to the automation system as the primary variable, and the two static pressure measurements sent to the automation system as secondary variables. This approach eliminates many of the challenges inherent to impulse lines and capillaries.

Challenges within the CPI

Many chemical manufacturing processes involve a variety of toxic, flammable or corrosive products at a huge range of possible temperatures. While conventional stainless-steel construction is well suited to most chemical environments, special materials may be necessary in particularly difficult situations. High-nickel alloys (for example, various grades of Hastelloy, Inconel and so on) are common, along with zirconium in applications such as urea production. These special materials are higher cost, so they should be used strategically in appropriate applications where they perform significantly better than traditional materials. Using the right material not only extends the life of the instrument, but reduces the probability of failure with consequent leak points and possible shutdowns. Applications where special materials are required need careful design to avoid becoming overly expensive and complex. For example, using conventional impulse line configurations requires the use of special tubing and fittings along with the non-standard instrument manifold. If a transmitter can be selected with a remote seal, the special impulse line can be eliminated, and only the single wetted part needs to be made from the special material.

New Devices, Old Environments

Many chemical plants were built decades ago. Compared to current practices, plant designs of those times had sparse instrumentation and automation. Older automation platforms usually support only simple analog field instruments, with no built-in support for digital instruments. Adding communication from today's digital instruments can be challenging, but when applied properly and coupled with suitable work practices, it is well worth the effort. Communication from existing HART instruments can be added using three basic approaches:

- Replacing analog input cards with HART input cards. These upgraded I/O cards enable digital communications with field equipment, but must be supported by the automation control system
- In the case where the automation system doesn't support HART, multiplexers can tap into the existing I/O and extract the HART data, and transmit these data via discrete or 4–20-mA signals
- If the need is to access specific field instruments for strategic information, external wireless adapters can be added. These adapters send digital data to a gateway, with the gateway hard-wired to the automation system. These devices do not interfere with normal operation of the analog loop, but are powered by the loop. They act just as if the device was hooked up to a modem, and provide access to valuable data along with instrument configuration capabilities

Adding new field instruments where cable trays are crowded and automation system I/O panels are filled to the maximum is difficult and expensive. Wireless instruments avoid these infrastructure problems and can be deployed throughout a plant without extra cabling or conduit. Most wireless instruments are entirely self-contained with internal power supplies capable of operating for many years. They can also be placed in most hazardous environments without the usual concerns related to conventional wiring infrastructure installation and maintenance.

Weather & Environmental Issues

Chemical plants are not always located in temperate hospitable environments. Those sited with petroleum-production facilities can be very hot or very cold. Temperatures in the Middle East can routinely reach 50°C with daily swings of 15°C. The Athabasca oil sands in Canada can go the opposite direction, requiring field instruments to operate at –55°C and even lower. This can play havoc with impulse lines by causing blockages due to frozen fill fluids, measurement latency caused by high viscosity of fill fluids at low temperatures, or low-molecular-weight fill fluids being vaporized by heat. Sensitive electronics can also be affected by ambient conditions. Where temperatures are extreme but steady, finding a solution is usually manageable. Bigger problems occur where temperatures fluctuate from very cold to very hot. With a continuous process, the process temperature stays stable, but batch processes change as they start up and shut down. If appropriate compensation is not included, the same batch process starting at 5:00 a.m. in Saudi Arabia can perform differently when starting at 5:00 p.m. due to significant ambient environment temperature swings. By selecting fill fluids and appropriately rated devices, accommodations can be made to deal with these issues. In addition, modern instruments monitor the transmitter temperature and therefore know when it is outside of its reliable operating range. These instruments can warn operators via diagnostics of potential problems with the readings so that corrective measures can be taken.

Listening to the Diagnostics

A surprise failure of a smart pressure instrument (short of it receiving damage from an external source) should be a rare event. Many failures are not immediate, nor are they difficult for the transmitter's own diagnostic routines to detect. If a plant is monitoring the rich diagnostic data available from a modern digital pressure instrument, warnings of a growing device problem often become evident well in advance of failure. Some pressure instruments can monitor for subtle process changes. Sensors can function as a process diagnostic tool by analysing noise signatures. Since good modern transmitters sample data in excess of 20 times per second, additional process insights can be identified. Over time, normal operation creates a specific noise signature, and signature changes can warn operators of an impending problem. For example, if the amplitude of the process noise falls, it may be due to an impulse line clogging. Of course, diagnostics depend on automation systems and operators. For plants where field instruments communicate via a fieldbus or with native HART-enabled I/O, this is a simple matter to implement. Older systems using analog I/O will need to use a HART multiplexer or wireless solution to benefit from this enhanced available information.

Flow Measurements

DP instruments are at the heart of many flow-measuring techniques, using disruptions in moving process media streams caused by an obstruction, such as an orifice plate (Figure 8). The characteristics of these technologies have been the topic of many articles, but some difficulties are caused when the pressure instrument is not performing optimally due to a mounting or maintenance issue.

Figure 8. Example of an orifice plate utilized in flow applications

Most flowmeters are designed to minimize the amount of pressure loss they create since this is a waste of energy. Therefore, the pressure instrument has to be very sensitive and precise when measuring what might be a very small differential, even though the line pressure could be very high. Impulse lines should be kept as short as possible since even a small obstruction can affect a low level measurement. Some newer flowmeters designs eliminate impulse lines entirely, building the flow-disruption device and pressure sensor into one integrated unit (Figure 9). This simplifies installation and maintenance, particularly in situations where special materials are needed. Situations with high line pressures but a low differential can be difficult, especially when it comes to maintenance. Anyone installing or working on such an installation should be careful not to pressurize only one side of the pressure instrument, as this would subject the sensor to full line pressure. If the sensor can't withstand this overpressure, damage or even a leak could result.

Figure 9. Newer DP-based flowmeters use an integrated design, simplifying the construction and reducing potential maintenance problems

Reference

1. Brown, Stephen R., and Menezes, Mark, Measurement Best Practices for Safety Instrumented Systems, Chem. Eng., September 2006, pp. 66–72.

2. Wally Baker, marketing manager for the Worldwide Pressure Product group of Emerson Automation Solutions

PUMP SIZING AND SELECTION MADE EASY

Sruthy C Nair (TKM15CH062, 2015 – 2019)

Viscosity, power consumption, commercial availability and lifecycle cost analysis are all important considerations in pump sizing. An automated spreadsheet method helps engineers take those factors into account in centrifugal pump selection

Many aspiring chemical engineers enter industry after university study without sufficient practical knowledge about how to properly size pumps. A number of recent articles provide useful guidelines for sizing and selecting pumps, but these articles focus on certain specific aspects of proper pump sizing, while leaving out others [*1–4*]. Chemical engineering literature does not fully cover other essential aspects of pump sizing and selection — including the viscosity correction, power consumption, commercial availability and lifecycle cost analysis. In industrial operations, pumping alone can account for between 25 and 50% of the total energy usage of the process, depending on the application [*5*]. The initial purchase price of a pump is only a small fraction of the total lifecycle cost. There are situations in which purchasing a less expensive pump actually leads to greater energy-usage costs. This results in a higher lifecycle cost (see Example 1, below). Without a proper understanding of the pump selection process, engineers cannot effectively make both economic and practical decisions. This article aims to fill in some of the gaps in understanding and provide a straightforward method for pump sizing and selection. Along with this article, we have created a useful Microsoft Excel spreadsheet to assist with centrifugal pump sizing. The automated Excel spreadsheet assists in calculating the key parameters for pump sizing and selection. Since the majority of the pumps used in the chemical process industries (CPI) are centrifugal pumps, this article focuses on that equipment category, rather than the other general classes of pumps, such as rotary and positive displacement pumps.

EXAMPLE 1. PUMP SIZING AND SELECTION: The following is a pump sizing problem to illustrate the calculations in this article. You are told to purchase a pump for your manufacturing facility that will carry water to the top of a tower at your facility. The pump is a centrifugal pump that will need to pump 800 gal/min when in normal operation. Assume BHP is 32 and 16 horsepower for the 3,500-

rpm and 2,850-rpm pumps, respectively, for all pump choices in the composite curve. The pump operates for 8,000 h/yr. assume all of the pumps are viable for your required flow rate. The suction-side pipe and discharge-side pipe diameters are 4 and 3 in., respectively. The suction tank elevation (*S*) is 12 ft., and the discharge tank elevation (*D*) is 150 ft. Pressure on the suction side is atmospheric pressure (1 atm = 14.696 psi) and the pressure on the discharge side is 1.1 atm. Assume that both $HD_{,f}$ and $h_{s,f}$ are roughly 10 ft. Based on a five-year life, the objective of the problem is to calculate the lifecycle cost to operate each pump (that is, the costs of installation, maintenance and electricity, which is $0.18/kW), and to choose the pump with the lowest lifecycle cost (depreciation is assumed to be negligible for this example). The pump curves in Figure 3 illustrate the following pump options to choose.

Option 1: 4 × 3 – 13 3,500 rpm Installed cost of pump and motor: $20,000 for 3,500 rpm Maintenance cost: 10% of installed cost per year Motor efficiency: 65% (assumed)	**Option 2**: 4 × 3 – 13 2,850 rpm Installed cost of pump and motor: $40,000 for 2,850 rpm Maintenance cost: 8% of installed cost per year Motor efficiency: 80% (assumed)
Option 3: 4 × 3 – 10 3,500 rpm Installed cost of pump and motor: $10,000 for 3,500 rpm Maintenance cost: 10% of installed cost per year Motor efficiency: 65% (assumed)	**Option 4**: 4 × 3 – 10 2,850 rpm Installed cost of pump and motor: $20,000 for 2,850 rpm

$$\text{Flow rate}\left(\frac{gallons}{minute}\right)\cdot\frac{1\,ft^3}{448.83\,gpm}(conversion)\cdot\frac{1}{pipe\ area\ (ft^2)}\cdot\frac{1\ minute}{60\ seconds}$$

$$\text{Suction Side Velocity}: 800\,gpm\cdot\frac{1\,ft^3}{448.83\,gpm}\cdot\frac{1}{\left(\frac{2}{12}\right)^2\pi}\cdot\frac{1}{60}=0.340\,ft/s$$

$$\text{Discharge Side Velocity}: 800\,gpm\cdot\frac{1\,ft^3}{448.83\,gpm}\cdot\frac{1}{\left(\frac{1.5}{12}\right)^2\pi}\cdot\frac{1}{60}=0.605\,ft/s$$

$$h_d = D + \frac{v_d^2}{2 \times g} + h_{d,f} + P_d$$

$$h_d = 150ft + \frac{(0.605\ \frac{ft}{s})^2}{2 \times 32.2\ \frac{ft}{s^2}} + 10ft + 16.166\ psi \times \frac{2.31}{1.0}\ (ft)$$

$$h_s = S + \frac{v_s^2}{2 \times g} + h_{s,f} + P_s$$

$$h_s = 12\ ft + \frac{(0.340\ \frac{ft}{s})^2}{2 \times 32.2\ \frac{ft}{s^2}} + 10 + 14.696\ psi \times \frac{2.31}{1.0}\ (ft)$$

$$TDH = h_D - h_S$$

$$TDH = 153\text{ ft}$$

$$Power\ [kW] = \left(\frac{BHP}{E_m}\right) \cdot 0.7457\ \frac{kW}{hP}$$

$$Power\ [kW](Option\ 1) = \left(\frac{BHP}{E_m}\right) \cdot 0.7457\ \frac{kW}{hP} = \left(\frac{32}{0.65}\right) \cdot 0.7457 = 36.71\ kW$$

$$Power\ [kW](Option\ 2) = \left(\frac{BHP}{E_m}\right) \cdot 0.7457\ \frac{kW}{hP} = \left(\frac{16}{0.80}\right) \cdot 0.7457 = 14.914\ kW$$

$$Cost[\$] = (Power) \cdot (Operating\ Hours) \cdot \left(\frac{Cost}{kWH}\right)$$

$$Cost[\$] = (36.71kW) \cdot (8000\ hours) \cdot \left(\frac{\$0.18}{kWH}\right) = \$52{,}862$$

$$Cost[\$] = (14.914\ kW) \cdot (8000\ hours) \cdot \left(\frac{\$0.18}{kWH}\right) = \$21{,}476$$

$$NPSH_a = h_s - P_{vp} = 50\ ft - 13.93\ mmHg \times \frac{14.696\ psi}{760\ mmHg} \times \frac{1}{1.20} \times 2.31 \frac{ft}{psi} = 49.5\ ft$$

Year	Option 1			Option 2		
Cost	Purchasing	Maintenance	Electricity	Purchasing	Maintenance	Electricity
0	20,000			40,000		
1		2,000	52,862		3,200	21,476
2		2,000	52,862		3,200	21,476
3		2,000	52,862		3,200	21,476
4		2,000	52,862		3,200	21,476
5		2,000	52,862		3,200	21,476
	Total cost		$294,310	Total cost		$163,380

FACTS AT YOUR FINGERTIPS

(DRISHYA R PILLAI, 14403023, 2014 – 2018)

HIGH-SHEAR MIXING: High-shear, high-speed mixing equipment supplies the mechanical energy necessary to reduce the size of solid particles and liquid droplets in emulsions and dispersions. Emulsions are mixtures of two normally immiscible liquids in which tiny particles of one liquid are suspended in another. Dispersions refer to solid particles distributed uniformly throughout a continuous medium. High-shear mixing processes are common across the chemical process industries (CPI), including in foods, cosmetics, pharmaceuticals, greases and lubricants, specialty chemicals, paints, inks and others. This one-page reference provides information on high-shear mixing operations and equipment. Rotor-stator mixers Rotor-stator mixers are standard workhorses used throughout the CPI for preparing fine dispersions and emulsions. The traditional design features a four-blade rotor running at tip speeds in the range of 3,000–4,000 ft. /min within a close-tolerance fixed stator. The mixer creates mechanical and hydraulic shear by continuously drawing product components into the rotor and expelling them radially through the openings in the stator.

FERMENTATION: For intermediate and specialty chemicals, the incorporation of biotechnology-based processes has become a viable option for the chemical process industries (CPI). This one-page reference discusses some of the benefits and challenges of fermentation-based processes. The potential advantages of fermentation processes over conventional processes are the following: Improved selectivity. Bioengineering techniques generally allow the elimination of by-products from the outset, by designing a microorganism to carry out the fermentation so that by-products are not produced. Reduced costs. Fermentation can dramatically reduce the number of process steps, as well as operational costs. Because the single unit operation of fermentation can replace multiple unit operations in conventional chemical processes, the cost per ton may be significantly lower (sometimes 20–40% lower) for bio-based process technologies. Also, capital equipment for fermentation-based processes may be less expensive because fermentation runs at near-ambient temperature and pressure and near-neutral pH, compared to more challenging conditions often required in a conventional chemical process.

REFINERIES EXPLORE IIOT TOOLS TO MAXIMIZE PROFITS

(KIRAN R, 14403037, 2014 – 2018)

New IIoT- and cloud-enabled digital tools and services give petroleum refiners new avenues to increase profitability and safety, but also require greater attention to cybersecurity

While several forces are creating conditions in which Indian petroleum refiners can thrive in 2017 and beyond, success and profitability are not guaranteed. Refiners must address changing supply and demand for individual refined products, fluctuations in crude oil prices and dynamic geopolitical factors, all while pursuing the industry's ever-present imperative for efficient and safe operations. And refinery operations are taking place in an environment where the retirement of experienced workers is ongoing and the industry infrastructure is aging. The sum of these forces makes for a challenging environment for the nation's 139 active petroleum refineries. To strengthen their chances of success, refiners are increasingly exploring digital tools that take advantage of the emerging Industrial Internet of Things (IIoT), as well as advanced software for data analysis that can optimize process operations and reduce downtime. A host of new offerings are becoming available, and several were discussed at the annual meeting of the American Fuel and Petrochemical, which took place in San Antonio, Tex. in late March.

WHAT IS THE DIGITAL TRANSFORMATION?

Today, technological advances are being made and implemented at an accelerated pace that is quickly changing the way we live and work. In our day-to-day environments we encounter "smart" objects, including our phones, cars and devices throughout our homes. And, these devices are being connected to each other. This trend is also taking place in industry, and while perhaps not as rapidly as with our personal devices, changes are occurring quickly. More and more, smart sensors and equipment that contain smart diagnostic features are being used in industry to generate large volumes of data. Advanced computing technologies are allowing these devices to be connected to each other, and to use the data in a variety of ways. This growing interconnectedness of industrial operations is what is meant by the now familiar term, the Industrial Internet of Things (IIoT). As Marcelo Carugo, senior director Chemical and Refining Solutions, Emerson Automation Solutions, states, "IIoT is partly about how we make data accessible and then get the right data to the right person, in the right format, at the right time — to make a decision. It's about transferring digital data into digital intelligence by using the thousands of touch and sensing points in your plant and advanced analytics to help you recognize patterns and make decisions based on patterns instead of individual measurements."

Industry 4.0 is another familiar term, perhaps more so in Europe than elsewhere, because it has its origins in Germany. The term refers to this interconnectedness and related concepts in the digital transformation as a fourth industrial revolution, with the first three including mechanization, mass production and automation. Digitization, digitalization and "smart industry" are additional terms associated with the current movement toward the implementation of IIoT and the newest digital technologies. These terms are used interchangeably by some, and defined more rigorously by others, but in general they all refer to the same trend that goes beyond connecting things, and often refers, in a broader sense, to connecting the process to the business as well (Figure 1).

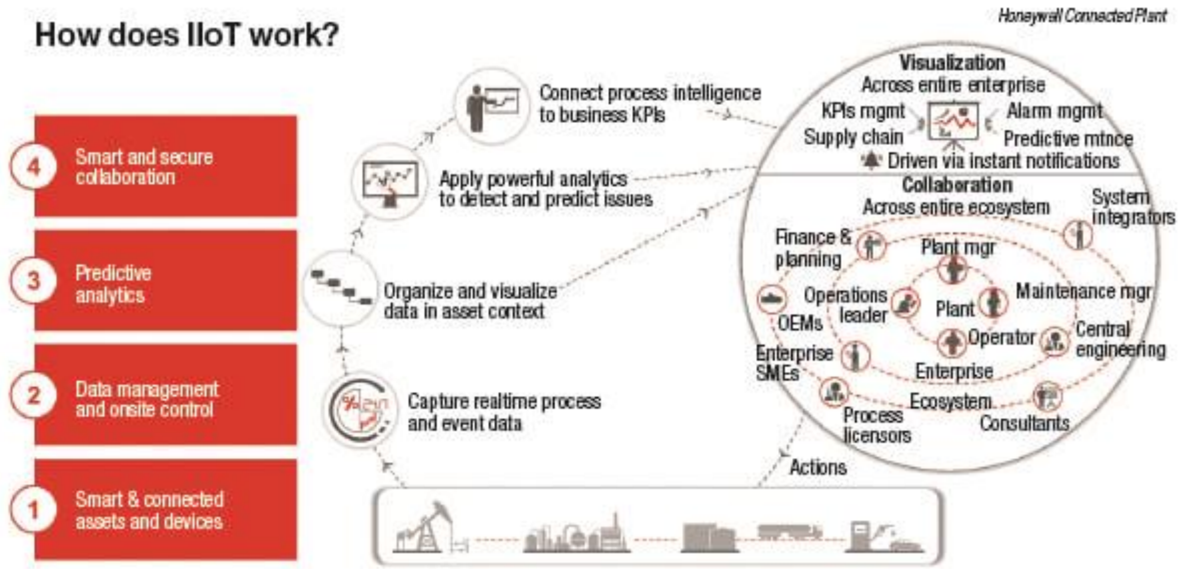


Figure 1. The Industrial Internet of Things (IIoT) can connect assets across a company to create a powerful interconnected enterprise as depicted in this graphic

Advances in sensors, data analytics, computing networks (the "cloud"), software, additive manufacturing, unmanned aerial vehicles (UAVs or drones) and more, are enabling this fourth industrial revolution. While the chemical process industries (CPI) may be slower to adopt some of these technologies than the consumer market, the CPI are very familiar with the use of sensors and automation and are well poised to take advantage of the newer technologies. As Billy Bardin, Global Operations Technology Center director for The Dow Chemical states, "In general, the process industries have been slower to adopt these new technologies than the consumer and service sectors, but the process industries do have an advantage with the installed instrumentation base that has been a mainstay of our technology for decades. We have significant amounts of data from our instrumentation and process sensors to use with the new analytics and deep-learning technologies."

INSIGHTS FROM INDUSTRY LEADERS

A key driver for the digital transformation in the CPI is maintaining a competitive edge. Global competition, immediate communications and technological advances are creating an environment where businesses need to respond with increasing speed. Aligning production and business through the tools available with digitalization offers new possibilities for business models. John Cate, commercial director for Surface Chemistry at Akzo Nobel N.V. says, "We've been driving digitalization across our entire business. It's all about efficiency and optimization. The digital world delivers more comprehensible and actionable data than we have ever had before. By replacing gut-feeling with comprehensive, real-time data, we are able to make better decisions. Whether this is about plant utilization, selecting R&D projects to fund, or sales accounts to focus on, we now have data work for us instead of the other way around." He further explains that IIoT can help combine supply and demand intelligence and that it is essential in today's environment, "Forget about getting ahead — just to ensure survival in today's chemical industry, this [IIoT] should be high up on top management's agenda. And the earlier you start understanding the IIoT and implementing digitalization, the more effective you'll be in execution over time."

Dow's Bardin also expects digitalization to affect all aspects of business and production. "We are connecting data streams from R&D, marketing, supply chain and manufacturing to better serve our markets," he says. And he also sees applications in safety and sustainability, "We can use robotics, augmented reality, big data, the digital twins and other aspects of Industry 4.0 to help achieve Dow's 2025 sustainability goals and to continue to improve our safety performance. Safety, as well as cybersecurity, remain paramount as our industry continues to evolve." Earlier this year, Evonik Industries AG confirmed its commitment to the digital transformation by establishing a digitalization subsidiary, Evonik Digital GmbH (Figure 2). The group is building digital expertise and developing digital business models under the guidance of Henrik Hahn, who holds the newly created position of chief digital officer (CDO). Evonik is also the first chemical company to join the Industrial Internet Consortium, which is a global organization formed to promote the growth of the IIoT. Hahn says that it will become more and more common to realize truly personalized customer experiences, and in the future, there may be more competition between business models rather than between products or process technology. “Therefore we believe strategy, not technology, drives digital transformation,” he says.

TECHNOLOGICAL ADVANCES

Technology, however, is an enabler for digital transformation. There is much going on in this area, and new developments are occurring quickly. Several key developing areas are the following:

Sensors have been ubiquitous in the CPI for decades. In recent years, however, advances in smart sensor technology and implementation have helped to make sensors one of the powerful enablers of the IIoT. Automation vendors, such as Siemens AG, Endress+Hauser, Honeywell Process Solutions, Emerson and many others offer a wide variety of sensors. Regarding sensors, Jeroen Pul, marketing manager and digital lead for AkzoNobel Surface Chemistry says, “More sensors equals more data. More data equals better decisions. In general, and at AkzoNobel, we’re employing more creative use of sensors to measure all aspects that impact our business.”

In addition to developing new sensors, research is also going on to optimize placement of sensors — where do you best locate them in a plant? Stephen E. Zitney, at the Research & Innovation Center, U.S. Dept. of Energy, National Energy Technology Laboratory is studying underlying technologies for optimal sensor network design in a digitalization framework. Four key applications for optimization-based sensor placement technology include: better disturbance rejection in plants; better state estimation (using data from other sensors to estimate process variables that are not directly measurable, perhaps due to harsh operating environments); condition monitoring (the "health" of equipment); and fault diagnosis.

Augmented and virtual reality are familiar to some from the gaming industry. Advances in virtual reality software and more readily available hardware are enabling the use of these techniques in the CPI. Two of the targeted application areas are training and asset management.

One example of a dynamic simulator enhanced by a 3-D virtual plant is one that was developed and deployed at the Advanced Virtual Energy Simulation Training and Research (AVESTAR) Center at West Virginia University in collaboration with the NETL. The simulator is for an IGCC (integrated gasification combined cycle) system with carbon dioxide capture (Figure 3). NETL's Zitney, who led the project, explains that it provides a very realistic, immersive training system for operators, engineers and students. It is currently being used at the university to educate chemical engineering students in process dynamics, operations and control. Vendors, such as Schneider Electric and others, offer software for augmented and virtual reality simulations.

Figure 3. This virtual reality environment for an IGCC plant offers realistic training opportunities

Another application where 3-D reality modelling has great potential is in asset management. Bentley Systems, Inc., for example, offers software that can combine photos taken from the ground, from drones and from laser scans to create 3-D reconstructions of facilities. These reality models can be used for planning maintenance, construction, training and more.

Process modelling and simulation capabilities are increasing as software becomes more advanced and more readily available. One of the areas gaining momentum is in moving from steady-state process optimization that is run periodically, to continuous dynamics optimization and control. So called "digital twins" are real-time dynamic models that run alongside a functioning plant. These dynamic models can use data from sensors installed in the plant to match its real-time status and condition, and to carry out off-line dynamic studies to help optimize its performance. These digital twins can also be used to train operators. Vendors such as Honeywell Process Solutions and others offer digital twin technology.

CONVERGENCE OF IT, OT AND ET

To draw the full benefits of the digital transformation, cultural changes are needed in addition to technological ones. A better working relationship between operational technology (OT), information technology (IT) and engineering technology (ET) has been cited as an important step. Greg Gorbach, vice president of the ARC Advisory Group says, "Chemical companies are revisiting their own business processes and technology approaches as competitors and partners start to employ 'digitalized' business processes and exploit the increasing convergence between OT and IT on the plant floor, to connect the enterprise as a whole to the extended supply chain and throughout the ecosystem."

One of the areas where this convergence is most needed is in cybersecurity. While cybersecurity on enterprise IT has been well defined with firewalls, routers, anti-virus software and more, the needs on the OT side are less well defined. Eddie Habibi, CEO and founder of PAS Inc. Says "Operational technology used to be thought of as 'cyber-immune,' but we've come to know that OT is also vulnerable." Because "we cannot know what the cyber hackers are thinking or will be doing next," Habibi sees cybersecurity as a compelling need for IIoT. On the OT side, he says that there are a tremendous number of assets that are unprotected, and part of the problem is that owners are often not aware of what cyber assets they have. Taking an inventory is a first step that he recommends. And on the cultural side, training employees in cybersecurity — even the most basic steps — is much needed.

The new technologies and advanced computing that are now available with the dawn of the digital transformation offer amazing possibilities. To put it into perspective, Dow's Bardin offers the following insight: "A key in this environment is to determine what makes sense for your business, develop a concise strategy that will achieve the desired objectives, and stick to the principles of that strategy to screen out the hype in order to find the nuggets of technology that can provide true, long-term benefit."

THIS TANK-CONTAINER FLEET IS BECOMING SMARTER
(NAGASWARUPINI S, 14403047, 2014 – 2018)

This logistics company has begun fitting a new telematic system to its tank container fleet (photo), enabling seamless monitoring of goods transported in tank containers at any defined point in time. This includes monitoring not only position, as in the general cargo sector, but also the status of the transported goods with regard to their pressure, temperature, filling level and density parameters. A non-invasive filling-level measuring system solves a large number of technical challenges. Full ATEX certification for all the components completes the range of services offered. Users have access to these data, together with the transport order data, on a web platform that includes automatic monitoring and an alert if there are any discrepancies. Of the 37,000 tank containers in the company's fleet, 5,000 have already been upgraded, and around 8,000 tank containers per year will follow in each of the next few years. — *Hoyer GmbH, Hamburg, Germany*

APJAKTU Exam Corner

(Dr. K. B. Radhakrishnan)

Fluid and Particle Mechanics and Particle Technology

1. What is continuous fluidization? Explain how continuous fluidization help in slurry transport and pneumatic conveying.
2. The pressure drop through a particle bed can be used to determine the external surface area and the average particle size. Data for a bed of crushed ore particles show ΔP/L = 84lb_f/ (in^2) ft. for airflow at a superficial velocity of 0.025 ft. /s. The measured void fraction is 0.5, and the estimated sphericity is 0.8. Calculate the average particle size and the surface area per unit mass if the solid has a density of 4.1g/cm^3 and viscosity of 0.672 cP
3. In a packed bed explain how the pressure drop per unit length of column depend on sphericity and nominal diameter of particle, viscosity of the fluid, superficial velocity, and the porosity of the bed for both laminar and turbulent flow.
4. With the help of a plot explain the pump performance curve. Using it explain shut off and free delivery condition, BEP, operating point and efficiency of a pump.
5. Explain the concept of NPSH for pumps. How can it be used to avoid cavitation? Explain the different types of NPSH?
6. It is proposed to pump 10,000 kg/h of toluene at 114^0C and 1.1 atm absolute pressure from the reboiler of a distillation tower to a second distillation unit without cooling the toluene before it enters the pump. If the friction loss in the line between the reboiler and the pump is 7 kN/m^2 and the density of toluene is 866 kg/m^3, how far above the pump must the liquid level in the reboiler be maintained to give a net positive suction head of 2.5 m. Also calculate the power required to drive the pump, if the pump is to elevate the toluene 10 m, the pressure in the second unit is atmospheric and the friction loss in the discharge line is 35 kN/m^2. The velocity in the pump discharge line is 2 m/s. Assume a pump efficiency of 0.6.
7. What are different types of pneumatic conveying systems? Explain the working of any two in detail. Point out their applications also.
8. Write short notes on (a) fans (b) blowers(c) compressors. Mention the applications of each.
9. The general theory of filtration was studied by Herman and Breed. They developed the general equations for studying both constant rate and constant pressure filtration. When n = 1.5 they represent cake filtration where the cake is incompressible

   (i) $\log(\frac{d^2t}{dV^2}) = \log(k_1) + n\log(\frac{dt}{dV})$

   (ii) $\frac{d(\Delta P)}{dt} = k_2(\Delta P)^n$

   Identify the equation that represents constant rate and the one that represents constant pressure. Validate your answer mathematically.

10. A slurry containing 40 per cent by mass solid is to be filtered on a rotary drum filter 2 m diameter and 2 m long which normally operates with 40 per cent of its surface immersed in the slurry and under a pressure of 17 kN/m^2. A laboratory test on a sample of the slurry using a leaf filter of area200 cm^2 and covered with a similar cloth to that on the drum

produced 300 $cm^3$of filtrate in the first 60 s and 140 cm^3 in the next 60 s, when the leaf was under an absolute pressure of 17 kN/m^2.The bulk density of the dry cake was 1500 kg/m^3 and the density of the filtrate was 1000 kg/m^3.The minimum thickness of cake which could be readily removed from the cloth was 5 mm. At what speed should the drum rotate for maximum throughput and what is this throughout in terms of the mass of the slurry fed to the unit per unit time?

11. Write a short note on the role of filter aids in filtration.
12. With the help of a sketch briefly explain the different types of filters.
13. Briefly explain the features of aggregative fluidization.
14. What are advantages of positive displacement pumps over dynamic pumps?
15. What is mixing index at zero time? Draw and explain the graph of mixing index v/s mixing time for blending salt and sand in a small tumbling mixer.
16. With the help of figures explain the two types of tumbling mixers.
17. With the help of flow chart differentiate between open circuit and closed circuit grinding.
18. Do material balance on a theoretical screen and obtain an expression for screen effectiveness. State all the assumptions involve. Using the generated equation solve It is desired to separate a mixture of crystals into three fractions, a coarse fraction retained on an 8-mesh screen, a middle fraction passing an 8 mesh but retained on a 14 mesh screen, and a fine fraction passing the 14-mesh screen. Two screens in series are used, an 8-mesh and a 14-mesh conforming to the Tyler standard. Screen analyses of feed, coarse, medium and fine fractions are given below. Assuming the analyses are accurate, what do they show about the ratio by weight of each of the three fractions actually obtained? What is the overall efficiency of each screen?

Screen	**Feed**	**Coarse fraction**	**Middle fraction**	**Fine fraction**
3 /4	3.5	14.0		
4/6	15.0	50.0	4.2	
6/8	27.5	24.0	35.8	
8/10	23.5	8.0	30.8	20.0
10/14	16.0	4.0	18.3	26.7
14/20	9.1		10.2	20.2
20/28	3.4		0.7	19.6
28/35	1.3			8.9
35/48	0.7			4.6
Total	100	100	100	100

19. Sketch the various motions of screen and give example of equipment based on each type.
20. State all the three laws of crushing and grinding. Starting from the following basic equation derive all the three laws.
    a. $\frac{dE}{dL} = -K\, L^n$
21. Where, E is the energy required for crushing unit mass of material, L is the size of particle, K and n are empirical constants that vary with the law under consideration. Using the laws solve the following
22. A material is crushed in a Blake jaw crusher such that the average size of particle is reduced from 50 mm to 10 mm with the consumption of energy of 13.0 kW/ (kg/s). What would be

the consumption of energy needed to crush the same material of average size 75 mm to an average size of 25 mm? (i) Assuming Rittinger's law applies (ii) Assuming Kick's law applies? (iii) Assuming Bond's law applies? Also find the work index of the material. (iv) Which of these results would be regarded as being more reliable and why?

23. With the help of graph and a neat labelled diagram explain the various stages of batch sedimentation and the rate of sedimentation.
24. Explain the working principle of any one open channel flow meter.
25. For the following size reduction equipment's tabulate the feed size range, the product size range, action used for size reduction and any one application: i) knife cutters ii)hammer mill iii) tooth roll crusher iv)fluid energy mills v) rod mill
26. Explain the working principle of a colloidal mill with the help of a neat sketch
27. In a ball mill of diameter 2000 mm, 100 mm diameter steel balls are being used for grinding. Presently, for the material being ground, the mill is run at 15 rpm. At what speed will the mill have to be run if the 100 mm balls are replaced by 50 mm balls when (i) all other conditions remain same (ii) if the mill is operated at 20rpm instead of 15rpm (iii) if the mill is operated at 35rpm instead of 15rpm
28. Compare the working of a Pitot Static Probe and a venturi meter
29. Define the following terms: (i) Water horsepower and Brake horsepower (for pumps) (ii) Ideal crusher (iii) Electrostatic precipitator (iv) Flotation (v)Grizzlies and disintegrator (vi)Thickeners and Clarifying filters (vii)Cyclones and Hydro clones (viii)Crushing Efficiency (ix)Bucket Elevators and screw conveyors (x) Compressible and incompressible filter cake
30. Answer the following briefly
    - (i)What are the factors affecting the efficiency of screens?
    - (ii)What are screens? Explain the notation 14/20 with respect to screens.
    - (iii)What is the separation principle in flotation? What are the types of flotation?
    - (iv)What is the advantage of wet grinding over dry grinding?
    - (v) Suggest the sequence of crushing units to produce 0.5 mm size product from 1 m size rock.
    - (vi)Name four mixers for dry powders and thin paste.
    - (vii)Calculate the sphericity for a small cylinder with L = Dp =D
    - (viii) An equipment works on the following principle "A fluid pushes into a closed volume, where it turns a shaft or displaces a reciprocating rod". Identify the equipment and give its applications.
    - (ix)Why pressure filters are discontinuous?
    - (x)Human heart is a natural pump. Which type is it and why?

GATE Corner

(Prof. Manikandan P. M.)

Q1 **Surface tension is due to**

a)	Cohesion only	b)	Difference in magnitude between the forces due to adhesion and cohesion	c)	Adhesion between liquid and solid molecules	d)	Frictional forces

Q2 **The law similar to Newton's law of viscosity used in solid mechanics is called**

a)	Newton's second law of motion	b)	Archimedes principle	c)	Hook's law	d)	Newton's third law of motion

Q3 **The prandtl mixing length is**

a)	Zero at the pipe wall	b)	A universal constant	c)	Useful for the analysing laminar flow problems	d)	All of the above

Q4 **For the crushed coal particles, the sphericity is**

a)	Less than 1	b)	Equal to 1	c)	Greater than 1	d)	Infinity

Q 5 **The molecular weight of air is**

a) 16 b) 28.84 c) 32 d) 24

Q6 **The thermal conductivity of a perfect heat insulator is**

a)	Zero	b)	Infinity	c)	One	d)	between zero and infinity

Q7 **Log-mean heat transfer area for the two heat transfer areas A_1 and A_2 is given by**

a)	(A1 – A2)/ln (A2/A1)	b)	(A1 – A2)/ln (A1/A2)	c)	(A1 – A2)ln (A1/A2)	d)	ln(A1/A2)/(A1 - A2)

Q8 **The coefficient of volume expansion for an ideal gas is**

a)	P/RT	b)	R/P	c)	R^2T/P^2	d)	1/T

Q9 **The colburn analogy state that**

a)	$N_{st} = f/2$	b)	$N_{st} N_{pr} = f/2$	c)	$N_{st} N_{pr}^{2/3} = f/2$	d)	$Nst\ N_{pr}^{2/3} = f/8$

Q10 **Which tube configuration in a heat exchanger would result in the highest heat transfer rate?**

a)	square pitch	b)	Diagonal square pitch	c)	Triangular pitch	d)	

Q11 **Oleum is**

a)	a mixture of conc. H2SO4 and oil	b)	sulphuric acid which gives fumes of sulphur dioxide	c)	sulphuric acid saturated with sulphur trioxide	d)	a mixture of sulphuric and nitric acid

Q12 **Producer gas is obtained by**

a)	thermal cracking of naphtha	b)	passing steam and air through red hot cake	c)	passing air through red hot cake	d)	passing steam through red hot cake

Q14 **The vapour pressure of water at 100°C is**

a) 13.6 cm of Hg b) 100 cm of Hg c) 76 cm of Hg d) 100 N/cm^2

Q14 **The gradual cooling of glass product is called**

a) tempering b) Annealing c) quenching d) Galvanising

Q 15 **Stoke (St) is the unit kinematic viscosity and one stoke is equal to**

a) 1 m^2/s b) 1 ft^2/s c) 1 cm^2/s d) 1mm^2/s

Q16 **Which of the following is a state function?**

a) Temperature b) Pressure c) specific volume d) Work

Q17 **When the temperature of an ideal gas is increased from 27^0C to 927^0C the kinetic energy will be**

a) same b) Twice c) Eight times d) Four times

Q18 **At the critical point of a substance**

a) $(\partial P/\partial V)_T = 0$, $(\partial^2 P/\partial V^2)_T \neq 0$ b) $(\partial P/\partial V)_T \neq 0$ $(\partial^2 P/\partial V^2)_T = 0$ c) $(\partial P/\partial V)_T = 0$ $(\partial^2 P/\partial V^2)_T = 0$ d) $(\partial P/\partial V)_T \neq 0$ $(\partial^2 P/\partial V^2)_T \neq 0$

Q19 **The relation PV^γ = constant, hold only for those processes which are**

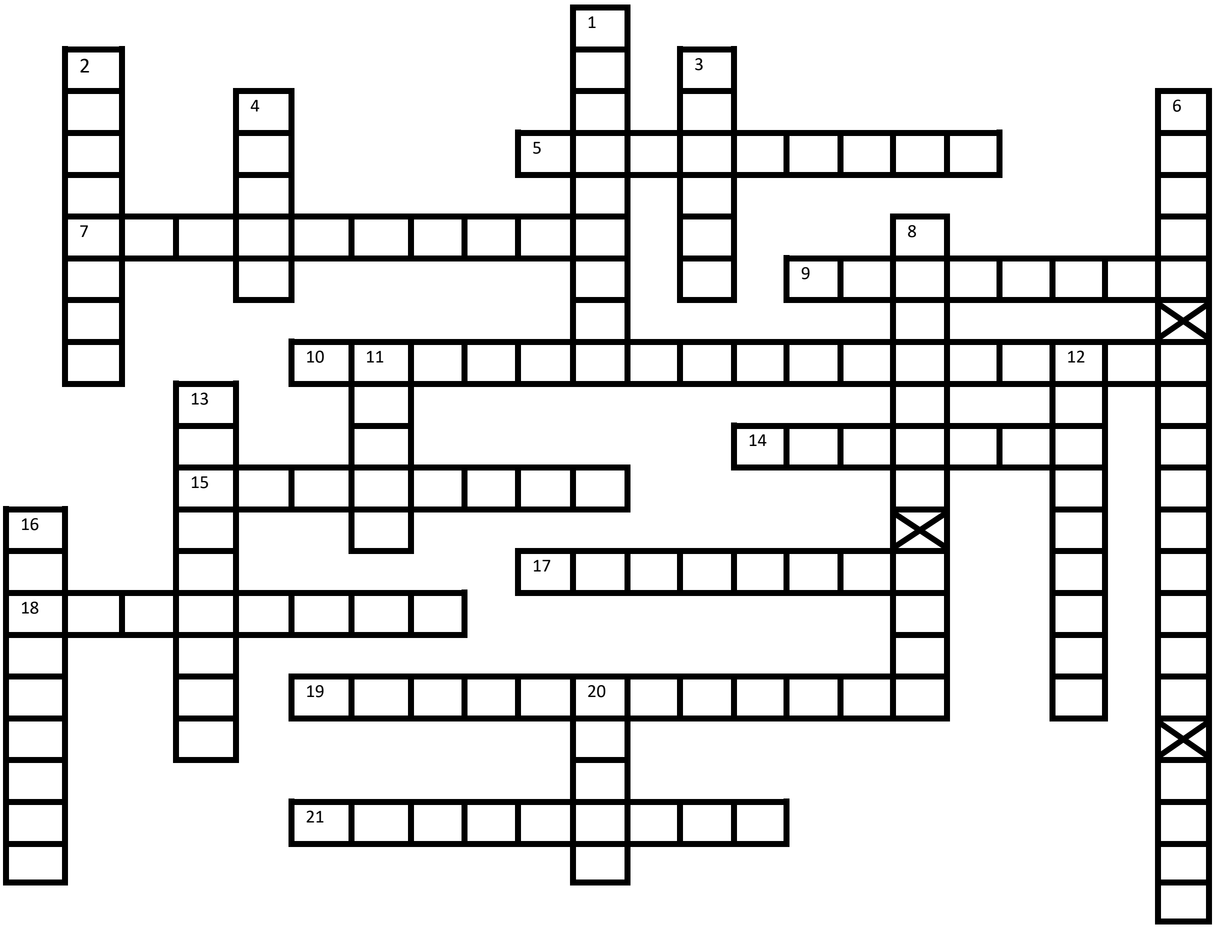
a) Isentropic b) Irreversible adiabatic c) Reversible polytrophic d) All of these answer

Q20 **Entropy of a substance is that quantity which remains constant during**

a) a reversible isothermal change b) a reversible adiabatic change c) an irreversible adiabatic change d) an irreversible isothermal change

Fluid and Particle Mechanics Cross Words

(Prof. Shan S)



Across

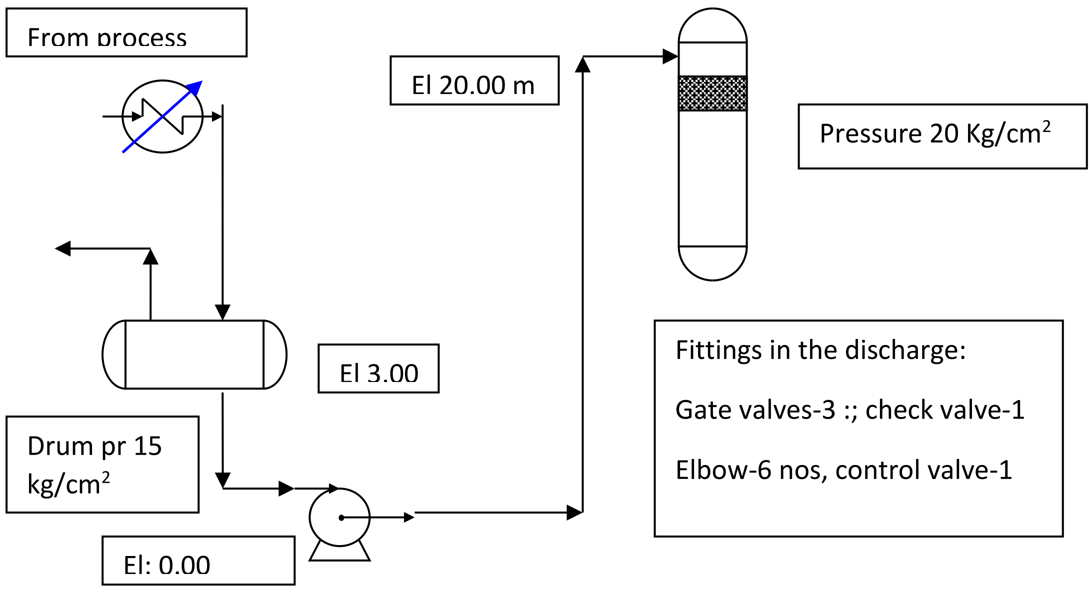
6. Incompressible flow with no shear
7. Types of liquids separated by decanters
9. Fraction of the voids
10. Type of pump employing check valves
14. Flow with no lateral mixing
15. Flow observed in case of small objects moving in viscous fluids
17. Type of fluid if flow behaviour index is greater than 1
18. Dimensionless number: ratio of inertial to viscous forces
19. Density is not constant
21. Diameter = flow crass sectional area / wetted perimeter

Down

1. Used to measure pressure difference
2. Velocity of an object falling in air, with no acceleration
3. Independent of time
4. Substance that does not resist distortion permanently
5. Constant velocity profile (3 words; space between words)
8. Type of non-invasive flow meter (2 words)
11. Equation of motion for inviscid and incompressible flow
12. The principle of conservation of mechanical energy
13. Physics of the behaviour of objects under application of force
16. Velocity profile of Newtonian fluids in laminar flow in circular pipe
20. Mathematical model for packed bed

Industry Corner: Time to smoke your brains…

(Prof Fazil A.)



Centrifugal pump of the recovery plant was not delivering the required flow. The plant manager told that the impeller had worn off. The maintenance Manager says it is an NPSH problem. The schematic is given above.

Analyse whether it is case of NPSH problem; The NPSH requirement as per the pump vendor's data sheet is 2 metres. If the pump discharge pressure is 22 Kg/cm^2 and the head developed as per pump data sheet is 18 metres.


THANGAL KUNJU MUSALIAR
COLLEGE OF ENGINEERING
CYBER SECURITY