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SPECIAL FEATURES

Resolving Process Distillation Equipment Problems

IACPE

INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS

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IACPE
INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS

ABOUT

International Association of Certified Practicing Engineers provides a standard of professional competence and ethics. Identifies and recognizes those individuals that have meet the standard. And requires our members to participate in continuing education programs for personal and professional development.

In additional to insuring a professional level of competency and ethics the IACPE focuses on three major areas of development for our members: Personal, Professional, and Networking.

HISTORY

The International Association of Certified Practicing Engineers concept was formulated by the many young professionals and students we meet during our careers working in the field, running training courses, and lecturing at universities.

During question and answer sessions we found the single most common question was: What else can I do to further my career?

We found, depending on the persons avail able time and finances, and very often dependent on the country in which the person was from, the options to further ones career were not equal.

Many times we found the options available to our students in developing countries were too costly and or provided too little of value in an expanding global business environment.

The reality is that most of our founders come from countries that require rigorous academic standards at four year universities in order to achieve an engineering degree. Then, after obtaining this degree, they complete even stricter government and state examinations to obtain their professional licenses in order to join professional organizations. They have been afforded the opportunity to continue their personal and professional development with many affordable schools, programs, and professional organizations. The IACPE did not see those same opportunities for everyone in every country.

So we set out to design and build an association dedicated to supporting those engineers in developing in emerging economies.

The IACPE took input from industry leaders, academic professors, and students from Indonesia, Malaysia, and the Philippines. The goal was to build an organization that would validate a candidates engineering fundamentals, prove their individuals skills, and enhance their networking ability. We wanted to do this in a way that was cost effective, time conscience, and utilized the latest technologies.

MISSION

Based on engineering first principles and practical real world applications our curriculum has been vetted by academic and industry professionals. Through rigorous study and examination, candidates are able to prove their knowledge and experience. This body of certified professionals engineers will become a network of industry professionals leading continuous improvement and education with improved ethics.

VISION

To become a globally recognized association for certification of professional engineers.

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KNOWLEDGE. CERTIFICATION. NETWORKING

LETTER FROM THE PRESIDENT

KARL KOLMETZ

Honor Your Engineering Mentor and Friends

Dear Friends,

Far too many times we fail to honor those that have assisted our engineering careers and personal lives. I will never forget the kindness of Dr. James T. Richardson at the University of Houston who assisted me in obtaining my engineering degree.

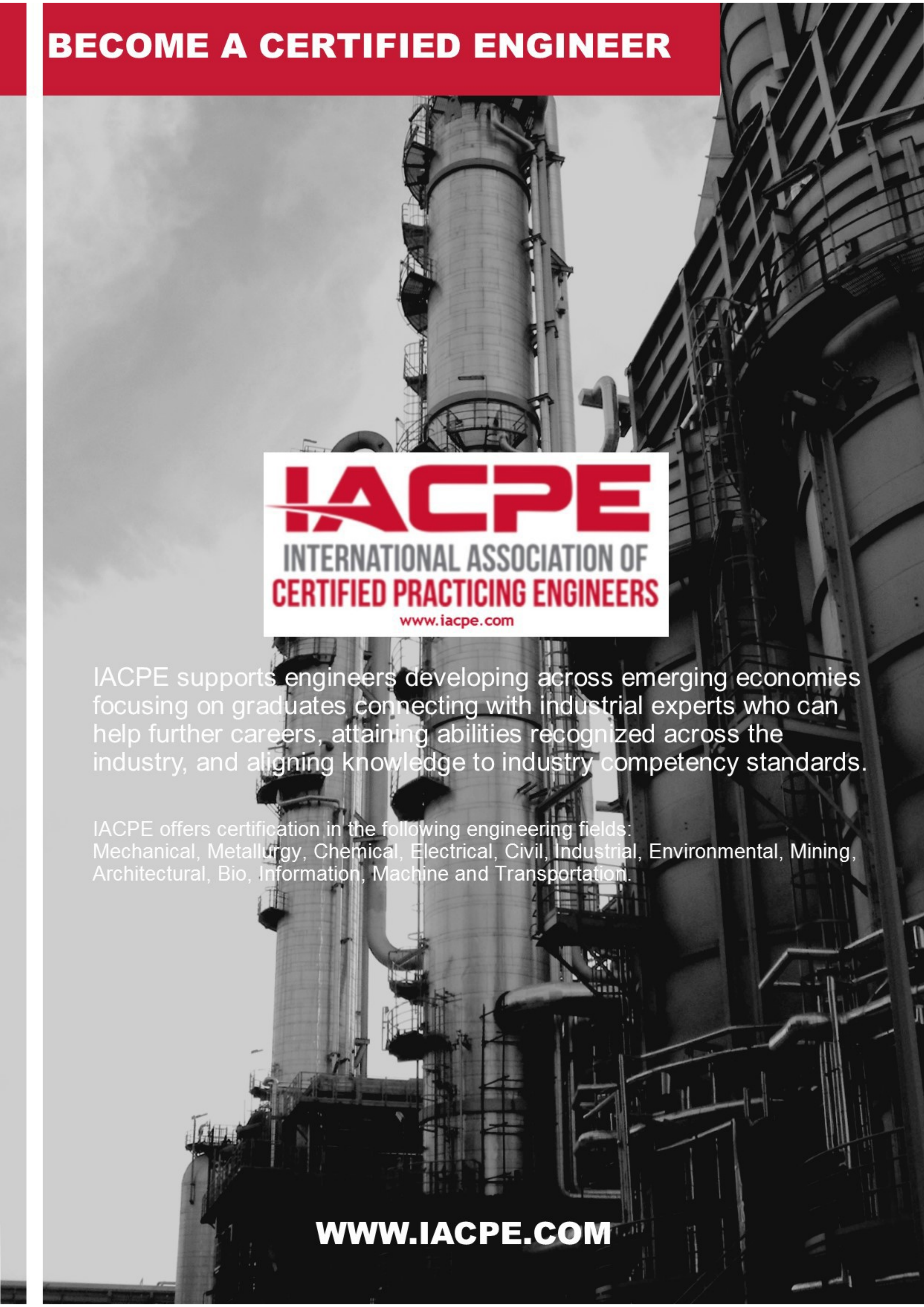
I have many friends and colleagues that have assisted my engineering career and personal life. I try to let them know that I appreciate their help.

In order to honor those great people who are impeccable mentors and cherished friends we are announcing the Distinguished Practicing Engineer Award. We ask you to submit nominations of people you believe embody this award.

In the July *Engineering Practice Magazine*, we will select the top three nominees from each division and in the October *Engineering Practice Magazine* we will recognize the 2017 group of awardees.

All the best in your career and life,

Karl Kolmetz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NEWS

RECENT IACPE ACTIVITIES

March

- MOU Sign between IACPE & ITI (Institute Technology Indonesia), Tangerang, Banten, Indonesia
- At ITI (Institute Technology Indonesia), Tangerang, Banten, Indonesia
- Safety Seminar & CPE EIT & CPE 1 Certificates Awarded
- At UNTAG (17 Agustus 1945 University), Surabaya, East Java, Indonesia
- Safety Seminar & CPE & CPE 1 Certificates Awarded
- At UNIPRA (W.R Supratman University), Surabaya, East Java, Indonesia
- Safety Seminar & CPE EIT Certificates Awarded
- At UNTAG (17 Agustus 1945 University), Semarang, Central Java, Indonesia
- Safety Seminar & CPE 1 Certificates Awarded
- At UNWAHAS (Wahid Hasyim University), Semarang, Central Java, Indonesia
- Safety Seminar & CPE EIT Certificates Awarded
- Campus visit - meet Board executives of UNPAND (Pandanaran University), Semarang, Central Java, Indonesia

April

- Campus Visit - Meet the Collaboration Dept. board member of STTNAS (National College of Technology) Yogyakarta, D.I Yogyakarta, Indonesia

MEMBER NEWS

CERTIFICATE CPE EIT, CPE 1 & CPE AWARDED

Member from ITI (Institute Technology Indonesia), Tangerang, Banten, Indonesia

CPE 1 certificates received:
Ade Sonjaya & Choirul Anam

CPE EIT certificates received:
Haudi Iknal Warid, Nabil Adliwafi, Japeth Nugraha Kristanto, Faiz Abyantoro, Anna Permatasary, Arief Lukman, Ario Wibowo, Armelia Purwaningrum, Bagus Maulana, Cecep Iwa Supriatna, Damiri Anwar, Dwi Ratna Mustafida, Edwin Franz Mandey, Febryan Ramadhan, Iqbal Ferdiansyah, Joni Arif, M.Ilham Pratama, Muhammad Aryzal Nuruzzaman, Muhammad Syahrul Rizal, Nana Suryatna, Sinta Lestari, Susanti Wahyuni, Syawkat Khalaf

Member from UNTAG (17 Agustus 1945 University), Surabaya, East Java, Indonesia

CPE certificates received:
Dr.Ir..Muaffaq A.Jani.,M.Eng
Dr.Ir.R.A Retno Hastijanti.,MT
Dr.Ir.Muslimin Abdulrahim, MSIE
Ir.Masriel Djamaloes, MM
Dr.Dwi Yuli Rakhmawati, S.Si.,M.Si.,Ph.D
Herlina ST.,MT
Dr.Ir.Achmad Daeng GS, SE.,MM

CPE 1 certificates received:
Riky Setiawan, Azhar Rasyid Firdausi, ST
Eko Doni Bagaswara
Member from UNIPRA (W.R Supratman University), Surabaya, East Java, Indonesia

CPE EIT certificates received:
Dewi Wulan Safitri, Wisnu Yudiantoro, Syaiful Anam, Rizky Angga Pradita, Buhadi, Mohammad Kharis Ubaidillah, R.Harnanda Satria Pratama, Tedo Risqi Anggarda, Adi Prasetyo, Weni Wulandari, Munirul Ikhwan, Nanda Luktinial Firial, Gregorius Kevin Oetomo

Member form UNTAG (17 Agustus 1945 University), Semarang, Central Java, Indonesia

CPE 1 certificates received:
Muhammad Teguh Prasetyo, Grania Vicelia Pinto Gaspar, Nur Riyati, Deka Dwi Shofiyan

Member from UNWAHAS (Wahid Hasyim University), Semarang, Central Java, Indonesia

CPE EIT certificates received:
Ninik Indah Hartati, Revy Andar Raesta, Windy Arum Mukti

Resolving Process Distillation Equipment Problems

Karl Kolmetz CPE
KLM Technology Group

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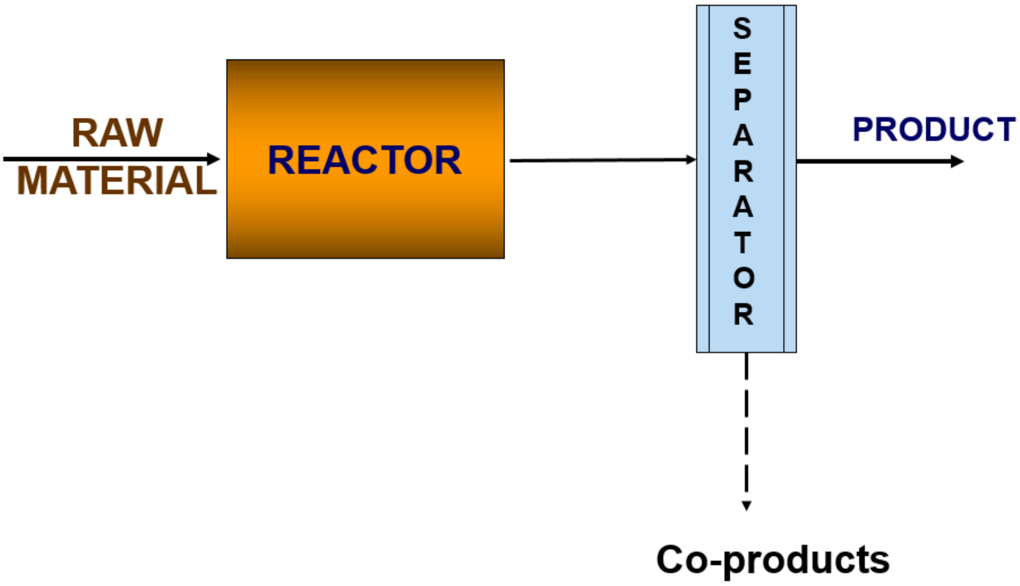
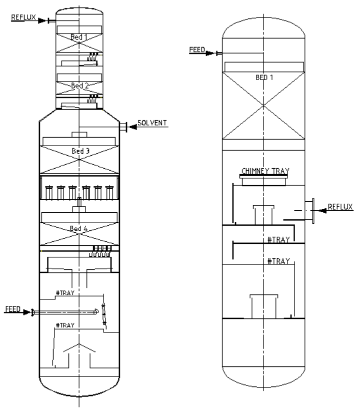
Contributing Author

Introduction

In most chemical processing systems two main unit operations dominate; chemical reaction followed by separation. The chemical reaction step is normally completed in a reactor. The reactor can be in numerous forms, from a plug flow reactor, to a CSTR (Continuously Stirred Tank Reactor), which can be in the form of a batch reactor, to a fixed or a fluidized catalytic bed reactor. From the reactor the reactants are then sent to a separation unit. The reactants are separated into desired products, unreacted products for recycle, and unwanted or co products.



Most Separation Units contain distillation equipment. Distillation Equipment was developed to separate ethanol from the by-products of fermentation. From the original batch stills, distillation equipment has progress to the type of trayed and packed columns used today. Today columns range from absorbers, extractors, strippers, and rectifying towers. They include vapor / liquid columns, liquid / liquid columns, and extractive distillation and reactive distillation columns. Vapor / liquid columns are designed to separate products by boiling point differences. Liquid / Liquid columns are designed to separate products by a physical property difference such as polarity. Extractive and reactive distillation columns shift equilibrium by removing one of the products to improve the equilibrium distribution.



Extractive Distillation Columns

General Distillation Equipment Design

The first step in resolving any distillation problem is to understand the operating and technical fundamentals of the column. Knowledge of how a column functions, hydraulic constraints, thermodynamic and equilibrium limits, and heat and material balances are required. This knowledge needs to be accumulated in advance of formulating any resolution of a problem.

At least three types of distillation equipment problems exist. The first problem is inappropriate design, the second problem is inappropriate operation, and the third is potential damage to internal equipment. Before a process is shut down for repairs the inappropriate design and damage to internal equipment should determined, and inappropriate operation should be eliminated.

Appropriate Stage Design

The design of stage operations has progressed from a trial and error basis to a computer-modeled system. The computer-modeled system came become an error-based system if operational feedback is not utilized. The computer model should match existing field data if the tower is operating properly, and if not, field data should be re-verified. If field data is accurate, the model should be adjusted to match existing data. The computer model can be verified by developing a McCabe-Thiele plot to verify the number of separation stages required. If you assume that the model is correct in all cases, you will soon have opportunities for new employment.

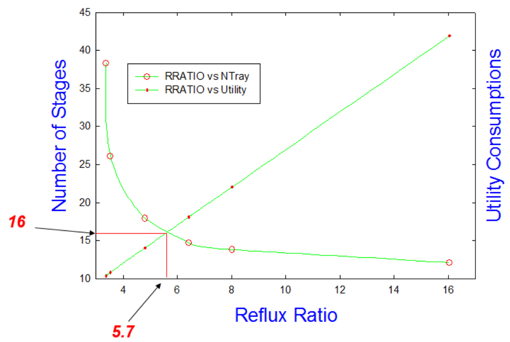
Trayed Columns utilize a pressure and temperature differential, to create a mass transfer gradient, to separate the products. Packed Columns generate a mass transfer area by providing a large surface area over which the liquid can transfer heat and mass to the vapor.

Pressure is a very important constraint in stage design. In low-pressure systems the vapor is considered the continuous phase and in high-pressure systems the liquid is considered the continuous phase. In low-pressure systems packing can be successfully utilized. In high-pressure systems packing can fail, due to a back mixing mechanism, therefore trays are the preferred system.

The temperature at which the reflux can be condensed usually determines the tower pressure. Normally the preferred temperature is that of cooling water. If cooling water cannot be used, the pressure is set using the best combination of variables. One variable is the increased cost of cooling at lower pressures. Often at lower pressure, refrigeration is needed equating to increased operating cost. A balance has to be constructed between capital cost and operating cost. This balance is also utilized in the determination of the amount of reflux verses the number of stages. This balance is between the energy requirement verses the cost of the additional stages. Computer based models has made this balance optimal.

Minimum Reflux Ratio and Minimum Number of Stages by use of Simulation

To determine the minimum reflux ratio and the minimum number of stages, one develops a reflux-stage plot and extrapolates from it. To develop this plot, simulation runs are performed at different number of stages while keeping the material balance, product compositions, and the ratio of the feed stage to the number of stages constant. The reflux ratio is allowed to vary. Then a plot of the number of stages versus reflux or reflux ratio is plotted. The curve is extrapolated asymptotically to an infinite number of stages to obtain the minimum reflux ratio and asymptotically to an infinite reflux ratio to obtain the minimum number of stages



Optimization of Feed Stage by Simulation

To determine the optimum feed stage, simulation runs can be performed at several different feed positions. In the simulation runs, the material balance, reflux ratio, and total number of stages need to be kept constant. Then two main plots can be created. One plot is the McCabe-Thiele diagram and the other is a concentration versus feed stage diagram. The McCabe-Thiele diagram is plotted using the mole fraction data calculated for each stage by the simulation. The equilibrium data and the operating lines are determined from this data. The McCabe-Thiele diagram then shows how an optimum feed stage versus a non-optimum feed stage looks when using the simulation data.

Pressure Choices

Many times when designing a distillation tower, the controlling factor in choosing the column pressure is the heating requirements of the reboiler or the condensing requirements of the overhead condenser. For example, a new column was being installed to separate benzene and toluene. For this design case the controlling factor in choosing the column pressure was the ability to use low-pressure boiler feed water as a condensation medium to produce low-pressure steam. This choice would mean that the column was going to operate under pressure. Performing this separation under pressure had a couple of advantages.

1. Increasing the column pressure would increase the vapor density and therefore the vapor handling capacity. This would lead to a reduction in the diameter of the column, which would reduce the overall cost of the project.
2. It would allow the possibility of having the benzene-toluene splitter share a condenser with a tower used to remove benzene from vent gas. Both columns' overhead products would go to the same location. The cost of installing a complete condenser system for this column would be considerably reduced.

However, in raising the column's operating pressure there are some unfavorable effects.

1. Raising the pressure also raises the reboiler temperature, thereby requiring a more expensive heating medium. A reboiler with a larger heat transfer area would be required.
2. Above 100 psig pressure, the columns shell thickness increases to handle the higher pressures. This will constitute an increase in capital costs.

Reboiler Design and Selection

Several types of reboilers can be selected based upon operational needs and reboiler duty requirements. For larger duty requirements forced circulating reboilers are required. The lowest in cost are the once through thermosyphon reboilers and they are preferred if the required duty can be delivered. If fouling due to low velocities or a higher duty is required a circulating thermosyphon reboilers or forced circulation reboilers may be preferred.

Most types of reboilers use condensing steam as a heating medium. Steam condensation may occur on the shell side or the tube side depending of the type of reboiler used. The steam flow may be horizontal or vertical. As with all condensing systems, it is very important to see that the system is regularly vented to prevent the build up of non-condensable gas in the system. Non-condensable gas in condensers is the most common reason why the condensation heat transfer coefficient is less than expected.

In industry many different types of reboilers are used. Overviews of three types used are given below.

1.Vertical Thermosyphon Reboiler

A vertical thermosyphon reboiler is very similar to a long tube evaporator and a climbing film evaporator. Liquid from the column sump flows through the inlet leg of the reboiler, enters the bottom channel, and is distributed uniformly to the tubes. A shell-side fluid, often condensing steam heats the tubes. Condensate flow in this type of reboiler is vertical. The process fluid entering the tubes is below its boiling point due to static head effects and must undergo sensible heating; for vacuum systems, such heating may consume a significant portion of the tube length.

Heat is transferred by both nucleate boiling and two-phase convective mechanisms. The two-phase mixture exiting from the heated zone returns to the column for disengagement of the phases, with the net vapor representing the needed boil-up for the distillation process and the liquid representing a recycle. Good design calls for vaporization per pass in the range of 10% to 30%; thus, there is a significant recycle flow.

The advantages of the vertical thermosyphon reboiler are the low residence time of the process liquid, the low liquid inventory of process fluid and, the low floor area required. Another advantage of this type of reboiler is the high heat transfer coefficients that are obtained. Vertical thermosyphon reboilers are usually the best value for the heat supplied. This type of reboiler can be used in fouling services because these exchangers are easy to clean.

The disadvantage of this type of exchanger is that they require extensive amounts of headroom. A distillation column may have to be raised off the ground in order to accommodate the reboiler. This may cause a mechanical design problem with the column. Stability of the column may become an issue.

2. Horizontal Thermosyphon Reboiler

This is perhaps the most common type of reboiler. A horizontal thermosyphon reboiler consists of a horizontal shell and tube exchanger with a single horizontal baffle. The process fluid flows along the shell-side along the length of the tube bundle from its point of entry midway along the shell to the ends. The fluid then turns 180° and flows back to the midpoint of the shell along the upper part of the shell. Boiling takes place over most of this flow path. The heating medium, usually steam, flows inside the tubes usually in two paths. The steam enters along the upper pass and leaves along the lower pass, allowing the condensate to drain naturally out of the bundle.

The flow of process fluid through the reboiler is governed by thermosyphon action, although a pump could be installed in the inlet pipe if necessary. The flow rate through this type of reboiler is controlled by density differences.

The main advantage of the horizontal thermosyphon reboiler is the ease of removing the tube bundle for cleaning. Also, the horizontal arrangement permits a lower elevation of the return line. This allows for a lower column elevation in relation to the reboiler elevation.

3. Kettle Type Reboiler

The kettle reboiler is similar to a shell-side evaporator. The heating fluid is usually condensing steam flows inside the tubes, which are commonly U-Tubes. The U-Tube bundle occupies the lower part of the K-Type shell. Liquid boiling is outside the tubes and the eccentric bundle arrangement makes available space for vapor-liquid disengagement. An internal weir controls the liquid level in the shell. The liquid level is such that the top of the bundle is only just submerged. The liquid enters the reboiler by gravity feed. A valve usually controls the feed. The overflow from the weir is the bottom product of the distillation column. If necessary a pump can be installed in the pipe between the distillation column and the reboiler. A properly designed kettle can produce a near-equilibrium vapor mixture and thus can provide an extra theoretical stage for the separation. It has an advantage of convenient bundle removal for tube inspection, and is relatively insensitive to varying loads of vapor production. It is comparatively expensive, however due to the type of shell design used for this type of reboiler.

Trayed Columns Design

One of the very first trays to be developed was the sieve tray. It is essentially a plate with holes punched into the plate. The number and size of the holes is based on the vapor flow up the tower. The liquid flow is transported down the tower by downcomers, a dam and overflow device on the side of the plate, which maintains a set liquid level on the tray. To maintain the liquid level on the tray a minimum amount of vapor traffic up the tower must be maintained, or the liquid level on the tray will weep down to the next tray through the holes punched on the plate. Typically sieve deck trays have a minimum capacity, or downturn, of approximately 70%.

One of the next developments was to add a variable valve opening to the tray deck. This valve would open in relation to the vapor flow. The advantage to this design was the ability to maintain the liquid level on the tray deck. Typically valve deck trays have a minimum capacity, or downturn, of approximately 60%.

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Some of the latest developments in tray design include changes to the downcomer and changes in the valve design. The downcomer requires a disengaging area to separate the liquid from the vapor. This area requires a minimum distance that normally sets the tray spacing. To use multiple downcomers reduces this distance and the total height of the tower. The liquid is required to travel across the deck to the next downcomer. If the valves are designed to help direct the liquid flow across the deck, by directing the vapor, the total time on the deck will be reduced leading to increased capacity. Trays are the most commonly selected type of tower internal. Generally trays perform well at high liquid and vapor loadings. At low flow parameters the capacity and efficiency of trays can be reduced.

Some other items to consider when deciding to use trays in a tower.

1. Trays have downcomer capacity problems in heavy foaming services.

2. Trays have a high resistance to corrosion.

3. Trays have higher pressure drop than structured packing or random packing.

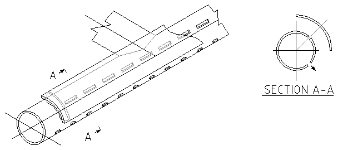
4. Entrainment is an issue with trays. Trays usually have more entrainment than packing. Excessive entrainment can lead to efficiency loss.

5. Excessive vapor and liquid mal-distribution can lead to a loss of efficiency in a tray tower.

Mal-distribution can be caused by the feed and reflux inlet design. A good feed and reflux design will affect the equilibrium on the feed tray and the adjacent trays slightly. A poor inlet design can affect several trays above and below the feed point. If a tower has 20 trays and a poor inlet feed design disrupts the equilibrium on 4 of the trays, the capacity and efficiency of the tower can be reduced by 20%. Installing better inlet designs is an efficient way to improve separation.

Good Reflux Inlet Feed Design

Not Good Reflux Inlet Feed Design



Good Feed Design

Trayed Columns Trouble Shooting

Trayed Columns utilize a pressure and temperature differential to separate the products. The weir holds a liquid level of each tray. The vapor must over come this liquid head to move up the column. On the tray the vapor and liquid are contacted and then above the tray they are separated. Any deviation that develops that restricts the vapor and liquid from contacting and then separating will deteriorate the column's ability to meet design specifications.

Deviations that will restrict the ability of a column to contact include, but are not restricted to;

1. Corroded, fouled, or eroded tray valves and feed devices,
2. restrictions in downcomers,
3. physical damage.

Deviations that will restrict the ability of a column to separate include, but are not restricted to;

1. **excessive rates,**
2. **contaminates that cause foaming,**
3. **improperly sized downcomer openings,**
4. **liquid entrainment**
5. **foaming**
6. **excessive liquid back-up in the downcomers**
7. **physical damage.**

Because a trayed column uses a pressure and temperature differential to separate the products, the pressure and temperature profile of a column is a key indicator of how the column is performing. The column temperature and pressure should gradually increase as one surveys down the column.

A calculation can be developed for what the column pressure drop should be, based on the number of stages and the height of the weir, or downcomer dam. If a column has twenty trays and a weir height of three inches the vapor has to over come a liquid height of sixty total inches. The equivalent height of one pound of water is 27.68 inches. Therefore sixty inches of water equates to 2.16 pounds of pressure drop. This calculation will need to be corrected by the specific gravity of the actual liquid on the tray.

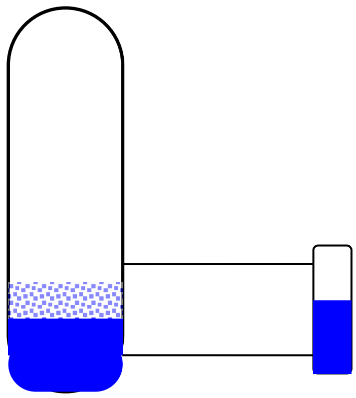
This pressure drop calculation is an essential tool in tower trouble shooting. If the pressure drop is low, tower may be weeping, internal tray man ways may be dislodged, or reflux flow may be inaccurate on the low side. If the pressure drop is high downcomers may be restricted, whole trays may be dislodged, or reflux flow rate may be inaccurate on the high side.

After a calculation of what the pressure drop should be, a pressure survey should be performed. It should be preformed with the same pre-calibrated gauge, if not by the engineer, under the supervision of the engineer. Gauges can be damaged in installation and care should be used in the installation of the gauge. Field mounted pressure gauges contain a high level of uncertainty and should not be used for trouble shooting.

A temperature profile will also provide valuable information as to the operations of the tower. If thermo-wells and thermocouples are not available at the desired points throughout the tower, an IR temperature scan gun can be used at the inspection ports through the insulation. If the temperature profile is not consistent several causes are possible, hydraulic tray flooding or weeping, potential tray damage and fouled or corroded trays or downcomers.

In distillation towers there are actually two accumulators. The first is normally obvious, the over head receiver, the second is the bottom section of the tower. These accumulators are used to stabilize the operation of the tower and down stream operations. This internal surge drum creates an inventory to act as a buffer. If this internal level is allowed to rise above the reboiler return, stripping inlet, or feed inlet flooding can occur.

There is an inherent error built into sight glass and level instrumentation. The sight glass and level instrumentation contain non aerated liquid, called clear liquid, which is not a true indication of the condition of the liquid within the tower. The liquid within the tower will have two levels, a clear liquid level below the aerated liquid level. Because the aerated level will have lower specific gravity than the clear liquid within the instrumentation, the tower level will be higher than the instrumentation indicates. If the level in the tower is higher than the feed or reboiler return entrained liquid can be carried to the next stage causing flooding.



Tower Level Errors

Synopsis of Tray Troubleshooting

Do simple checks first.

1. Assure that levels are accurate. Have operations move levels and view changes in the field.
2. Calculate column pressure drop and then measure pressure drop. Review survey pressure reading to operation's readings.
3. Survey column temperature profile. Review survey temperature reading to operation's readings.

Verify Tower Operations

Perform tower simulation to verify Tower Stage efficiency. Sometimes the feed compositions changes and tower is no longer able to meet desired specifications due to thermodynamic or equilibrium constraints. Needed to perform the simulation will be;

1. Accurate tower feed, Overhead, and Bottoms laboratory analysis
2. Accurate tower mass balance, within 2%.
3. Heating and cooling medium temperatures.

If the tower simulation confirms the limits are not beyond thermodynamic or equilibrium constraints and additional check may be to have the tower scanned to look for tray damage. This type of troubleshooting method can determine internal damage, vapor liquid mal-distribution, and packed and trayed tower fouling. Because of economic constraints, scanning should be chosen only after the simple checks and the limits are confirmed. Scanning can sometimes confirm the problem that was identified by the other checks.

Random and Structured Packed Columns Design

Random and Structured Packed Columns generate a mass transfer area by providing a large surface area over which the liquid can transfer heat and mass to the vapor. The packed column has several distinct advantages and some disadvantages.

A major advantage to packed columns is the reduction in pressure across the column. In high-pressure systems, this is not as important, but in low-pressure systems this can reduce the temperature, if polymerization is a concern as in a Styrene Monomer plant, or reduce the upstream pressure to help improve furnace yields, as in an ethylene plant.

Typically the column pressure drop for a packed column is less than that of a trayed column because of the percent open area. Typical percent open are of a trayed column is 8 to 12%, whereas a packed column can approach 50%. Liquid accumulation for a packed column is lower than that of a trayed column. This is important when degradation of products can occur at higher residence times.

Another advantage of packed column is reduced foaming. Packing generates thin films instead of fine droplets for mass and heat transfer, reducing entrainment when foaming agents are present. An additional advantage is that residence time within a packed column is shorter leading to less polymerization potential. Because the residence time is short, control systems may need to be modified to account for this difference. For example, the control of a tower bottoms may be based on temperature or boil-up rate verses level.

Here are some points when trying to decide if structured packing should be the application of choice. The vapor and liquid rates, or loadings, of the tower are important when considering structured packing. Generally structure packing performs well at low liquid and vapor loadings. At high flow parameters the capacity and efficiency of structured packings can be significantly reduced. Structured packing is generally most efficient in low-pressure distillation applications.

Some other items to consider when trying to decide to use packing in a tower.

1. Random packing does not perform well in heavy fouling applications.

2. Packing has a low resistance to corrosion due to thickness of packing.

3. Packing is a low-pressure drop device that provides high efficiency. This is why structured packing is extremely successful in low-pressure distillation applications.

4. Packing performs well in foaming applications.

The design of a packed column includes the packing, liquid distributors, and liquid collectors. After the packing the liquid distributor is the most important part of the tower internals. It can determine the success or failure of the column. Packed towers are more sensitive to liquid and vapor mal-distribution than trayed towers. Therefore, it is critical that vapor and liquid enter packing evenly distributed. The performance of the packing depends heavily on the initial vapor and liquid distribution entering the packing. Poor vapor and liquid distribution to a packed bed can result in a loss of efficiency.

The liquid inlet distributor is the device that diffuses the liquid across the mass transfer area. This device must be designed properly or the liquid will not create the surface area required for separation. Many times the liquid inlet distributor is the main problem area for random and structured packed column problems. The liquid distributor types include V-notched channel distributor and the pan or orifice distributor.

The V-notched channel distributor is mainly used in towers of greater than three feet in diameter and is the preferred choice. The V-notches allow high liquid turndown and can handle liquids that contain solids or that have fouling potential. The pan or orifice distributor is similar to a sieve tray in operation and is normally used in towers of less that three feet in diameter with clean services.

To avoid the loss of efficiency due to channeling, the liquid should be collected and re-distributed every 15 to 20 feet. Above twenty feet the channeling becomes high and the efficiency is greatly reduced. The liquid should be collected in a chevron type collector to evenly distribute the vapor to the next bed. The liquid should be taken and re-distributed with a V-notched type distributor.

Bed limiters or hold down grids are used to prevent expansion of the bed at high flow rates. They are attached to the tower wall by means of a support ring. Bed limiters or hold down grids should not be designed to produce a restriction in vapor flow and increase the tower pressure drop.

Tower internals must be installed taking particular care to insure levelness of parting boxed, troughs and similar equipment. In small columns moderate misalignments may be tolerated, but in large towers tolerances must be held to no more than +/- 1/8 inch (3 mm).

One of the great disadvantages of packing is the inability to properly inspect the installation. If the installers crush the packing during the installation the tower can flood because of reduced open area. A trayed tower is more controllable and the intermediate sections are inspectable.

Random and Structured Packed Columns Trouble shooting

Random and Structured Packed Columns generate a mass transfer area by providing a large surface area over which the liquid can transfer heat and mass to the vapor. Any deviation that develops that restricts the liquid from forming this large surface area will deteriorate the column's ability to meet design specifications.

Deviations that will restrict the ability of a column to generate this area include, but are not restricted to;

1. Packing damaged during installation,
2. incorrect distributor design or installation.
3. fouled packing,
4. **packing flooding**
5. **contaminates that cause foaming,**
6. liquid entrainment into a packed bed.
7. physical damage.

The pressure and temperature profile of a column is a key indicator of how the column is performing. The column temperature and pressure should gradually increase as one surveys down the column.

A calculation can be developed for what the column pressure drop should be, based on the height to the bed of the packing. For most packed beds the pressure drop should be between 0.1 to 0.8 inches of water per foot of packing. Below this rate the liquid may not be evenly spread across the packing and or the liquid rate may be inaccurate on the low side. Above this rate the packing may be fouled or damage not allowing the liquid to exit from the packing and / or the liquid rate may be inaccurate on the high side.

After a calculation of what the pressure drop should be, a pressure survey should be performed. It should be preformed with the same pre-calibrated gauge, if not by the engineer, under the supervision of the engineer. Gauges can be damaged in installation and care should be used in the installation of the gauge. Field mounted pressure gauges contain a high level of uncertainty and should not be used for trouble shooting.

A temperature profile will also provide valuable information as to the operations of the tower. If thermo wells and thermocouples are not available at the desired points throughout the tower, an IR temperature scan gun can be used at the inspection ports through the insulation. If the temperature profile is not consistent several causes are possible, hydraulic flooding, potential damage and fouled or corroded packing.

Synopsis of Packing Troubleshooting

Do simple checks first.

1. Assure that levels are accurate. Have operations move levels and view changes in the field.
2. Calculate column pressure drop and then measure pressure drop. Review survey pressure reading to operation's readings.
3. Survey column temperature profile. Review survey temperature reading to operation's readings.

Verify Tower Operations

Perform tower simulation to verify Tower Stage efficiency. Sometimes the feed compositions changes and tower is no longer able to meet desired specifications due to thermodynamic or equilibrium constraints. Needed to perform the simulation will be;

1. Accurate tower feed, Overhead, and Bottoms laboratory analysis
2. Accurate tower mass balance, within 2%.
3. Heating and cooling medium temperatures.

If the tower simulation confirms the limits are not beyond thermodynamic or equilibrium constraints and additional check may be to have the tower scanned to look for tray damage. Because of economic constraints, scanning should be chosen only after the simple checks and the limits are confirmed. Scanning can sometimes confirm the problem that was identified by the other checks.

Strategies for Field Work

1. Do not trip over the same obstacle twice.
2. Look out for other obstacles and prevent from tripping over them.
3. Arrange and time the obstacles to suit our purposes.
4. Monitor critical obstacles closely and clear them on time.
5. Do not assume there is only one critical obstacle.
6. Be wary of new obstacles and new untested techniques.

Conclusions

In column trouble shooing it is important to understand the fundamentals of distillation, the choice of tower internals and externals and how they interact. Several recommendations have been presented and should be evaluated for the best application. Keep in mind to always do the simple checks first, and use the available tools to verify that the separation that is desired is achievable.

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Pneumatic Pressure Testing of Piping

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Introduction

Strength testing is a technique used in the oil and gas industry to prove the mechanical strength and integrity of pressure containing components in a system. Chemical Plant equipment like pressure vessels, heat exchangers, towers, piping and others need to be tested for at various stages like; completion of fabrication, before commissioning and at regular intervals during plant operation to ensure adherence to statutory regulations and safe operation.

Normally employed methods of testing are Hydrostatic and Pneumatic tests. in addition to rarely used test like "Helium Test" etc. The purpose of pneumatic testing is to verify that a system may be safely subjected to its maximum operating pressure by testing it beyond its designed pressure limit. It is also useful to detect very fine leak paths which may not be found in Hydrostatic Test. However it is not as safe as hydrostatic tests if not done according to the specifications of pneumatic test.

Figure 1 : The explosion occurred during a pressure test of the equipment.

Pneumatic pressure testing can be a very hazardous operation due to the danger of explosive rupture if any mechanical failure occurs. It is therefore only to be carried out with the full agreement of the relevant management team. This paper will review some of the specifications that must be reviewed for success and to avoid an accident of pneumatic test.

Definition of Pneumatic Pressure Testing

Pneumatic pressure testing is to verify that a system may be safely subjected to its maximum operating pressure by testing it beyond its designed pressure limit. The pneumatic strength test uses air, or an inert gas medium such as nitrogen, to pressurize the system to 110% of its designed pressure limit. A holding period is then applied for a fixed amount of time and the results monitored to determine the safety and integrity of the system.

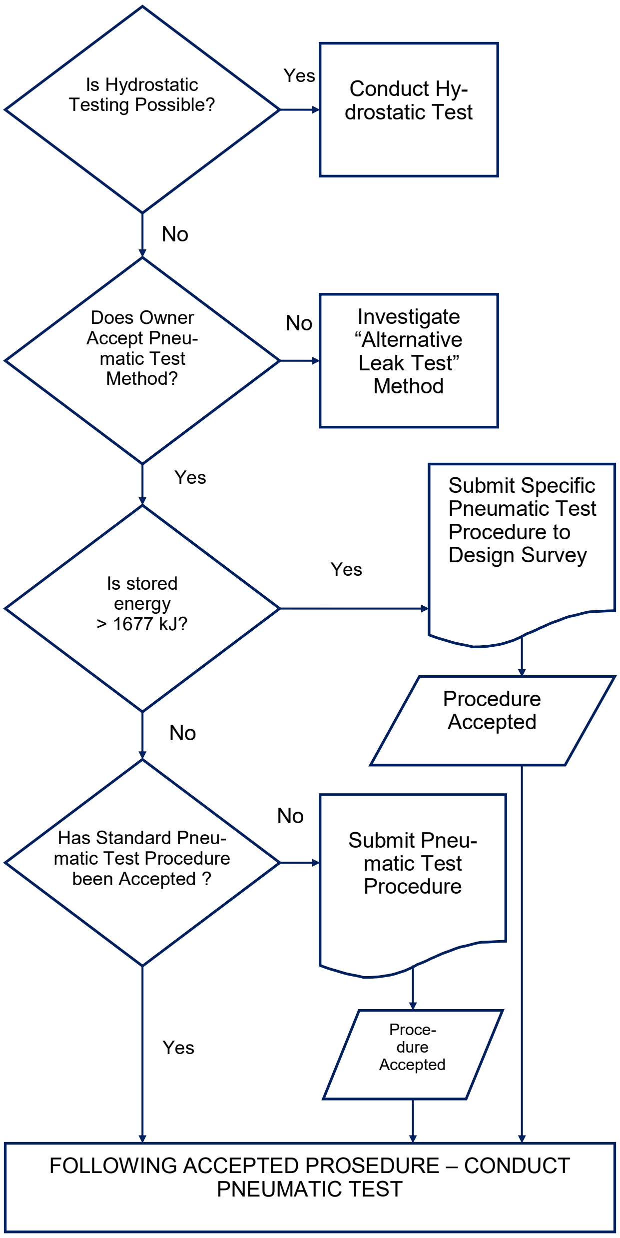

Figure 2
Pneumatic testing flowchart.

During the pressure test the total circuit shall be inspected and tested for any leaks. If any leaks are found on flanged, threaded, plugged or welded joints the system pressure shall be totally released prior to any rectification work starting. IT is not advisable to work on the pressurized system.

Requirements for Pneumatic Pressure Testing

For flanged joint testing during pneumatic testing of circuits the flange joints shall be hermetically sealed by means of adhesive paper tape and a pinhole made in the tape to permit easy detection of leaks.

The following equipment and components shall not be included in the piping system, and this equipment shall be isolated from the test section.

- Rotating equipment such as pumps, compressors and turbines.
- Safety valves rupture discs, flame arrestor, and stream traps.
- Pressure vessels with sophisticated internals.
- Equipment and piping lined with refractory.
- Storage tanks.
- Filters, if filter element (s) is not dismantled.
- Heat exchangers of which tube sheets and internals have been designed for differential pressure between tube side and shell side.
- Instrument such as control valves, pressure gages, level gages, and flow meter. (Excluding thermocouples).

The followings are excluded from the testing requirements of this specification :

- Any package unit previously tested by the vendor in accordance with the applicable codes.
- Plumbing systems, which are tested in accordance with the applicable plumbing codes.
- Lines and systems which are open to the atmosphere such as drain, vents, open discharge of relief valve, and atmospheric sewers.

The gas used as test medium shall use the nonflammable and nontoxic gas such as N_2 or inert gas, if not compressed air. Tests with CO_2 are very rare and very difficult because at elevated pressures the gas can change into a "dense phase" which behaves very differently from either a gas or a liquid.

Care must be exercised to minimize the chance of brittle failure during testing by initially assuring the system is suitable for pneumatic testing. Pneumatic tests could be performed only when at least one of the following conditions exists :

- When the systems are designed in such a way that it cannot be filled with water.
- When the systems are such that it is to be used in services where traces of the testing medium cannot be tolerated.

Equipment for Pneumatic Pressure Testing

- Equipment for testing are as following :
- Air Compressor
- Flexible hose
- Calibrated Pressure gauge
- Oil filter
- Temporary piping set
- N_2 cylinder, if required
- Safety valve

Note: Safety valve required for pneumatic testing, rapid opening or pop action of over pressure, should be installed and connected with an adequate system of piping not containing valve which can isolate tested system.

To conduct a pneumatic test of piping systems, complete the following steps:

- Identify the maximum test pressure to be used, as determined by the Project Engineer or Field Engineer.
- Identify the type of pipe system to be tested.
- Examine all connections prior to the test to ensure proper tightness.
- Determine the pressure rating for all connected fittings and devices to ensure they are rated for the maximum test pressure.
- Isolate any equipment that may be damaged by the test and indicate this isolation on the test form.
- Secure a blind flange or cap suitable for the system's rated pressure on all openings that are not closed off by valves.
- Plug all test, drain, and vent ports that are not required for the test.
- If the section of pipe being tested is isolated from other sections by in-line valves, ensure the portion not being tested is open to the atmosphere.
- Apply a preliminary test pressure of 25 psig, or as directed by the Project Engineer.

Note : This pressure should be held for a minimum of 10 minutes to allow for the location of any major leaks. If leaks are detected during this step, or at any time during the test, relieve the pressure and take appropriate action to correct the leak. If necessary, consult the Project Engineer for instruction.

- Apply the test pressure in increments of 25 psig, or as directed by the Project Engineer, until the maximum test pressure is reached. Hold pressure for 5 minutes at each 25 psig increment and inspect for leaks before adding more pressure.

Note : The maximum test pressure shall be 150% of the maximum system operating pressure. For systems that derive their pressure from hydrostatic pressure, the required test pressure will be verified prior to testing by the Project Engineer or the Field Engineer.

- Hold the maximum test pressure for 10 minutes.
- After the required 10 minutes, reduce the pressure to 100 psi or predetermined pressure.
- Hold this pressure for 24 hours.
- Remove the pressure, with caution to avoid escaping air stream, debris, and high decibel noise level

Preparations For Pneumatic Pressure Testing

All joints, including welds, shall be accessible and left uninstalled, unpainted and exposed for examination during the test joints previously tested in accordance with this specification may be insulated or covered.

There are some that should be prepared before testing as follow :

A. Piping systems shall have been completely checked for correctness.
B. All lines, vessels and equipment shall be checked to insure the entire system can be completely drained after testing.
C. Temporary gaskets may be used, which are not the same as permanent gaskets provided.
- Such use will not lead to damage of the flange faces.
- Temporary gaskets are removed immediately after completion of tests.

Lines containing check valves shall have the source of pressure located in the piping upstream of the check valve so that the pressure is applied under the seat. If this is possible, remove or jack open the check valve closure mechanism or remove check valve completely and provide necessary spool piece or blinds. A notation shall be included on the Punch List that check valve flapper has been removed. Subcontractor shall install a new gasket wherever the check valve bonnet has been disturbed. Where flappers have been removed, tagging shall mark valves.

Test equipment to be used during testing shall have suitable capacity for the range of test pressure required. The range of pressure gauges to be used shall be with a minimum span of 1.5 times pressure and maximum span of 2 times of test pressure.

All pressure gauges are to be calibrated. If gauges have been used previously on other projects or for other purposes, they shall be recalibrated. Validation of gauges and chart recorders shall be for a maximum of 90 days, however, recalibration shall be required if the calibrated gauge/recorder is damaged or strained.

Procedures For Pneumatic Pressure Testing

Prior testing start, Supervisor/Tester is to set up the exclusion zone, complete with signs, prior to pressure being raised on the system. Also marshals shall be positioned at all exclusion barriers to ensure no personnel enter the exclusion zone.

During pneumatic testing care must be exercised not to exceed the specified design pressure by more than ten (10) percent (maximum test pressure to ne marked on the Test pressure gauge, prior to pressurized the system).

The pressure shall be held at design pressure for 10 minutes prior to raising the pressure to the test pressure. At test pressure shall be held for 30 minutes during which time to access within the exclusion zone will be allowed.

After 30 mins the test pressure shall be reduced to design pressure at which point access within the exclusion zone will be allowed to the testing team only and the inspection of the joints shall be undertaken. All flange, threaded, welded joints and attachment shall be inspected with a proprietary testing solution. The design pressure shall be maintained until inspections of all joints are completed.

Test procedure limits are calculated using method 1 or method 2 below based on the design pressure and the volume of the system undergoing testing. The calculation outcome will result in relatively higher volume for lower pressure and conversely lower volume for higher pressure while maintaining the accumulated stored energy of 1677 kJ.

Step A : Define piping system Design Pressure (DP) and Volume (V) including volume of vessels that will be tested with this piping system.

Step B : Calculate piping system Test Pressure (TP) using the rules from the code of construction (for example: paragraph 345.5.4 of ASME B31.3).
Note : When the code of construction requires stress ratio correction, the allowable stress at test temperature vs. the allowable stress at the design temperature ratio shall be used in the test pressure calculations.

Step C : Use the value of TP defined in step 2 to calculate the volume limit (V) for the test applying one of the following two methods:

Method 1

If Imperial units are used, calculate V_1 using TP in psi

$$V_1 = \frac{3436}{(TP+14.7)\left[1-\left(\frac{14.7}{(TP+14.7)}\right)^{0.286}\right]} \quad (ft^3)$$

or, if SI units are used, calculate V_1 using TP in kPa

$$V_1 = \frac{670.8388}{(TP+100)\left[1-\left(\frac{100}{(TP+100)}\right)^{0.286}\right]} \quad (m^3)$$

Method 2

Calculate V_1 using values from table 1 and apply the following interpolation

$$V_1 = V_B + \frac{(V_A - V_B)\times(TP_B - TP)}{TP_B - TP_A} \quad (ft^3) \text{ or } (m^3)$$

Where :

DP	= Design Pressure (psi or kPa)
TP	= Test Pressure (psi or kPa)
V	= Total volume of the piping system including any vessels that form part of this system (ft^3 or m^3)
TP_A	= The first smaller pressure value in table 1 than the step B TP value
TP_B	= The first large pressure value in table 1 than the step B TP value
V_A	= The corresponding table 1 volume listed in same row as TP_A
V_B	= The corresponding table 1 volume listed in same row as TP_B
V_1	= Calculated volume limit (ft^3 or m^3)

For Volume Limit (V_1), Method 2 is showing from 0 to 3% lower value than method 1.

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- Reduced Installation Costs:
- Smaller Equipment Footprints
- Simplify Installation, Resulting in a Lower Total Invested capital (TIC), While I ImprovingPayback and ROI

Table 1: Test Pressure and Volume (TP_A & V_A).

Imperal Units		SI Units	
Test Pressure	Volume	Test Pressure	Volume
psi	*ft³*	*kPa*	*m³*
15	615.9	103	17.44
20	441	138	12.488
25	342.92	172	9.71
30	273.68	207	7.75
40	194.5	276	5.508
50	145.27	345	4.114
75	90.11	517	2.552
100	66.07	689	1.871
125	50.77	862	1.438
150	41.39	1034	1.172
175	34.21	1207	0.969
200	29.58	1379	0.838
225	25.8	1551	0.731
250	22.84	1724	0.647
275	20.47	1896	0.58
300	18.52	2068	0.524
315	18	2172	0.5
325	16.9	2241	0.478
350	15.52	2413	0.44
375	14.35	2586	0.406
400	13.33	2758	0.378
450	11.66	3103	0.33
500	10.35	3447	0.293
600	8.43	4137	0.239
700	7.1	4826	0.201
800	6.11	5516	0.173
900	5.37	6205	0.152
1000	4.73	6895	0.134
1500	2.97	10342	0.084
2000	2.21	13790	0.063

Using a pneumatic test instead of hydrostatic requires approval by the pressure systems program manager. In addition to a justification, a piping schematic for pneumatic pressure test is required. A recommended typical piping schematic for pneumatic test is shown in follows :

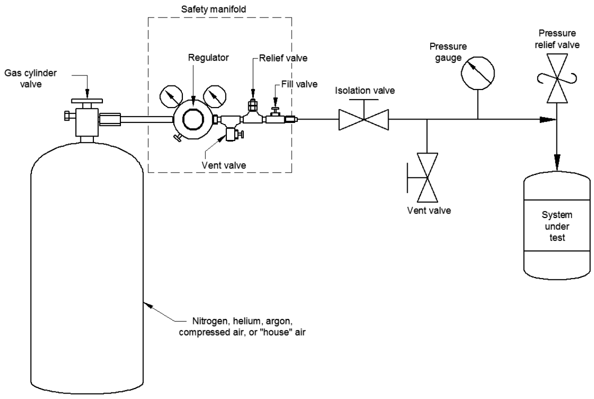

Figure 3 :
Piping Schematic for Pneumatic Pressure Testing.

Safety for Pneumatic Pressure Testing

Pneumatic pressure testing can be a very hazardous operation due to the danger of explosive rupture if any mechanical failure occurs. It is therefore only to be carried out with the full agreement of the relevant management.

All personnel concerned with pneumatic testing must be competent and familiar with the hazards associated with any gas used, e.g. the danger of asphyxiation in vessels not properly ventilated.

Pneumatic testing of vessels constructed of material liable to brittle fracture under test conditions must be avoided. Before testing, careful inspection of the vessel must be carried out. In the case of pressure vessels, the inspection must include radiographic or other non-destructive testing of welds

Figure 4 : Failure during Pneumatic Testing.

Management Responsibilities (includes all personnel with a supervisory role) as follows:

- Empower all personnel with the authority to "Stop Work" whenever hazardous conditions or potentially hazardous conditions are identified.

- Provide for and require that signs, barricades or other protective barriers are placed in a manner and at a distance sufficient to demarcate a safe zone to protect personnel and the public from unanticipated pressure release or equipment failure.
- Provide for and require the installation of devices that mark the limits of the exclusion zone.
- Keep unauthorized personnel out of the test area.
- Inform all affected site and community personnel of the planned test.
- Provide for and require that equipment and materials are arranged to give unobstructed access/egress during testing and in the event of an emergency.
- Establish lines of communication between the Owner/Facility, Contractor, and local authorities.
- Provide for and require the use of reliable transportation and communication systems during all aspects of the testing event.

In general, measures to minimize the risk of pneumatic testing is as follows :

- Appointment of Contractor's Test Controller who is in attendance and responsible throughout the testing and inspects the welding during testing.
- Appointment of the subcontractor's test controller who will be responsible for ensuring safe testing in accordance with the specification.
- Display of safety warning signs to alert workers in the vicinity of the pressure testing with line identification.
- Pressure test training and maintenance of a competency register as required by Contractor Safety plan.
- Pressure rating for the test manifold and the test equipment and the required inspection/ testing.
- The air in the subsystem shall be released slowly by means of opening the valves. The vent valves shall be left open until the pressure in the loop reaches zero.
- All of the Contractor and Piping Subcontractors Test Controllers must be cautious when approaching flange joints & listen for escaping air.

Strength testing can be performed safely by following the proper procedures.

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