ENGINEERING PRACTICE

VOLUME 3 NUMBER 11

OCTOBER 2017

DISTINGUISHED PRACTICING ENGINEERS

IACPE
INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS

WWW.IACPE.COM

ENGINEERING PRACTICE

VOLUME 3
NUMBER 11
OCTOBER 2017

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 available 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

IACPE
INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS

LETTER FROM THE PRESIDENT

KARL KOLMETZ

Distinguished Practicing Engineers

Dear Friends,

I hope you are doing great. This month we are pleased to honor the International Association of Certified Practicing Engineers 2017 Distinguished Practicing Engineers. We have a great group of people that has assisted and mentored their friends and colleagues.

The IACPE will annually recognize the outstanding accomplishments of engineering education and engineering technology through the "Distinguished Practicing Engineer" awards program. By their commitment to their profession, desire to further the Association's Mission, and participation in civic and community affairs, IACPE award winners exemplify the best in engineering education and engineering technology.

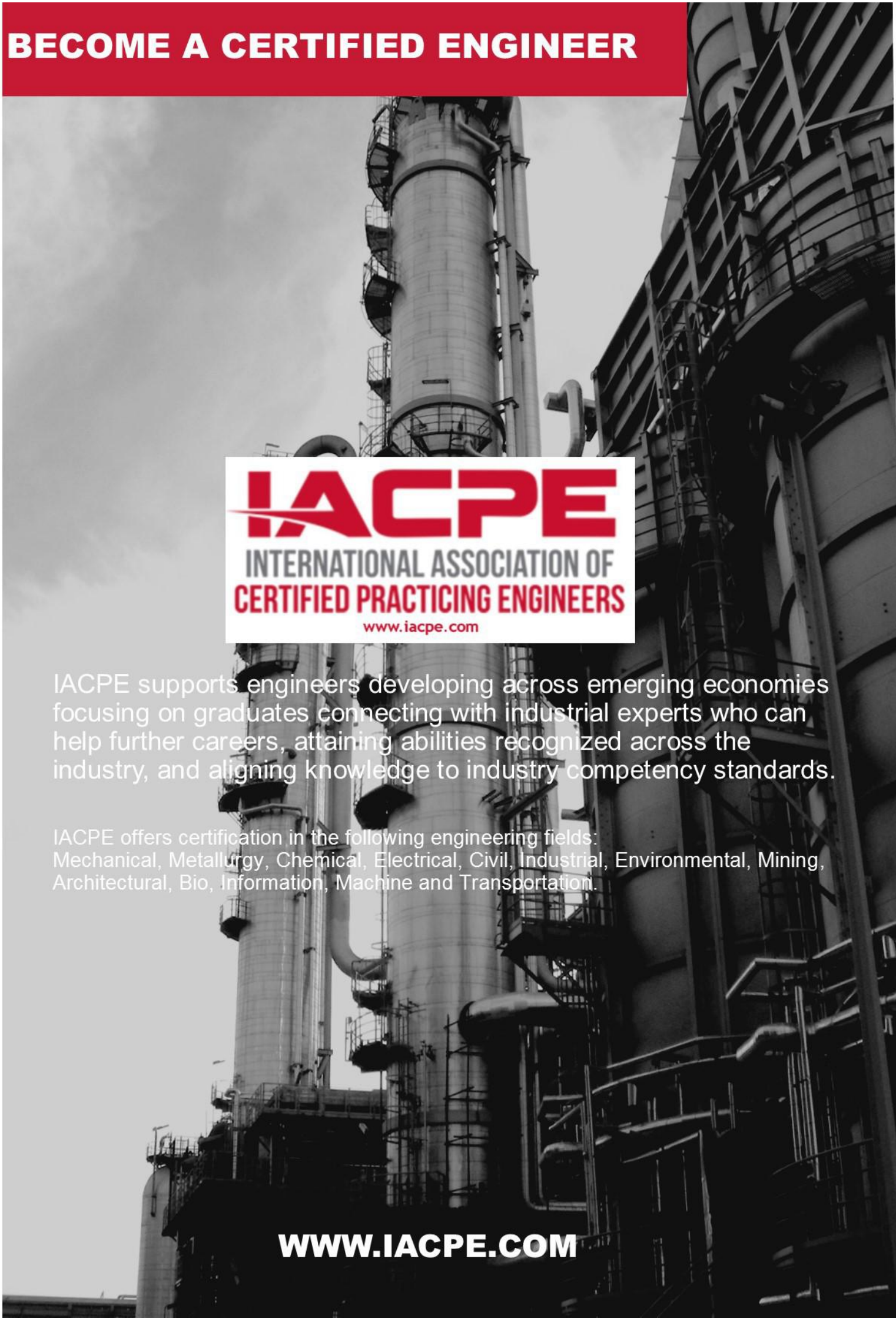
This award will salute leaders in engineering for their dedication to their field and their commitment to advancing the human condition through great engineering achievement and/or through innovation in engineering education and technology. We will have an Academic Division, Technology Division, and Young Engineer Divisions. In the July Engineering Practice Magazine, we will pick the top three from each division and in the October Engineering Practice Magazine we will recognize the 2017 group of awardees.

This year we are honoring Dr. James T. Richardson, from the University of Houston with our Lifetime Achievement Award. Dr. Richardson assisted me at the University of Houston and has been a great friend. He has multiple awards and was voted teacher of the year by the students multiple times.

All the best to you and IACPE award winners,

Karl

BECOME A CERTIFIED ENGINEER



IACPE
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www.iacpe.com

IACPE supports engineers developing across emerging economies focusing on graduates connecting with industrial experts who can help further careers, attaining abilities recognized across the industry, and aligning knowledge to industry competency standards.

IACPE offers certification in the following engineering fields:
Mechanical, Metallurgy, Chemical, Electrical, Civil, Industrial, Environmental, Mining, Architectural, Bio, Information, Machine and Transportation.

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NEWS

RECENT IACPE ACTIVITIES

IACPE President Karl Kolmetz presented "What is Success"

Institute Technology Indonesia - Serpong, Banten
September 11, 2017

Sekolah Tinggi Teknologi Fatahillah - Cilegon, Banten
September 11, 2017

IACPE Networking Meeting-Cilegon Chapter
September 12, 2017
Amaris Hotel-Cilegon, Banten

Universitas Wahid Hasyim-Semarang,Central Java
September 14, 2017

Universitas 17 Agustus 1945-Semarang, Central Java
September 16, 2017

Universitas Sultan Ageng Tirtayasa - Cilegon, Banten
September 19, 2017

Universitas W.R Supratman-Surabaya,East Java
September 20, 2017

Industrial Technic Faculty of Universitas Muslim Indonesia - Makassar, South Sulawesi
October 3, 2017

MOA sign, among
IACPE
Industrial Technic Faculty of Universitas Muslim Indonesia - Makassar, South Sulawesi
ISTMI - Ikatan Sarjana Teknik Industri & Manajemen Industri Indonesia
October 2, 2017

Five Aspects of High Productivity Teams and Companies
at The declaration of the National movement to increase the productivity and competitivene
Grand Clarion, Makassar, South Sulawesi
October 2, 2

IKATAN SARJANA
TEKNIK INDUSTRI
DAN MANAJEMEN INDUSTRI
INDONESIA

Distinguished Practicing Engineer Award

Each year IACPE recognizes the outstanding accomplishments of engineering education and engineering technology through the "Distinguished Practicing Engineer" awards program. By their commitment to their profession, desire to further the Association's Mission, and participation in civic and community affairs, IACPE award winners exemplify the best in engineering education and engineering technology.

This award salutes leaders in engineering for their dedication to their field and their commitment to advancing the human condition through great engineering achievement and/or through innovation in engineering education and technology. There are three divisions: Academic Division, Technology Division, Young Engineer and Student Divisions.

Academic Division

ARCHITECTURAL ENGINEERING
Dr.Ir.Retno Hastijanti, MT

CHEMICAL ENGINEERING
Ery Fatarina, ST.,MT.,IPM, CPE

ELECTRICAL ENGINEERING
Ir.drs.Muradi Suwargina, MT

ENVIRONMENTAL / GREEN ENGINEERING
Ir. Dr. Dominic Foo, CPE

INDUSTRIAL ENGINEERING
Dr.Ir.Muslimin Abdulrahim, MSIE

INFORMATION ENGINEERING
Dr.Ir.Muaffaq A.Jani, M.Eng, CPE

MECHANICAL ENGINEERING
Ir. Masriel Djamaloes MBA.,MM.,CPE

Technology Division

SEPERATIONS
Michael Resetarits

HEAT TRANSFER
Ir.Gatot Boedhi Tjahjono, MSME, MSIE

ETHYLENE TECHNOLOGY
Helmilus Moesa, CPE

PETROCHEMICALS
Lee Pheng

REFINING
Andrew Sloley

MECHANICAL ENGINEERING
Erebert Caracas

CHEMICAL ENGINEERING
Supriyanto

PROCESS SAFETY
Stephen Wallace

INFORMATION TECHNOLOGY
Randy Conley PE PMP

POLYMERS
Mohd Rohizat Abdul

Students

Sekolah Tinggi Technology Fatahillah, Cilegon-Banten
Maulana Ainul Yakin, ST.,CPE I

Institute Technology Indonesia, Tangerang, Banten
Choirul Anam, ST.,CPEI

17 Agustus 1945 University, Semarang, Central Java
Achika Augusti Ramanitya, CPE I

17 Agustus 1945 University, Surabaya, East Java
Riki Setyawan, CPE I

Wahid Hasyim University, Semarang, Central Java
Windi arum mukti CPE EIT

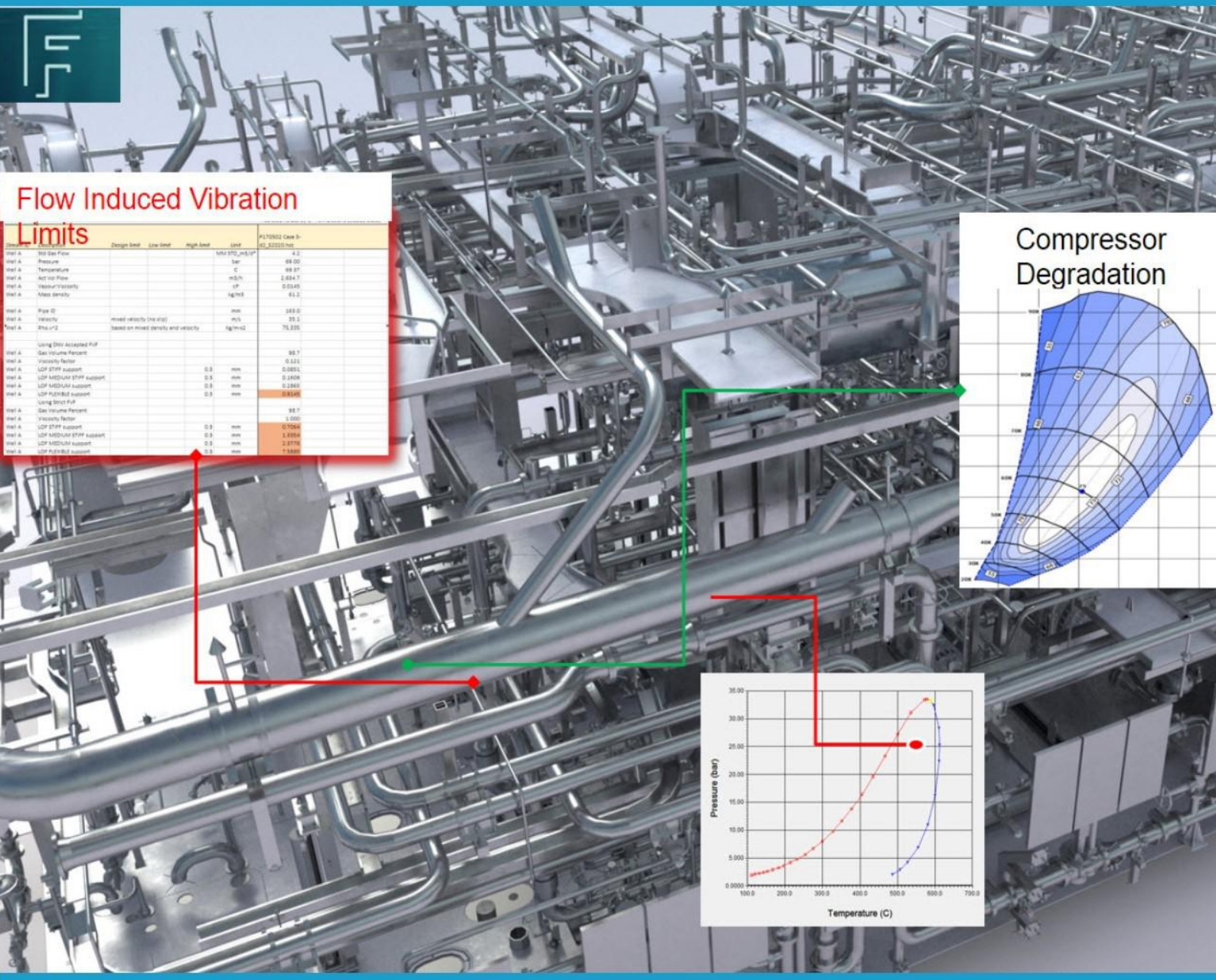
Serang Raya University, Serang, Banten
Naimi, ST.,CPE I

Sultan Ageng Tirtayasa, Cilegon, Banten
Wahab Arrie Rachman

Lifetime Achement Award

Dr, James T, Richardson

Over 200+ Successful Offshore Projects



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Technology Review 2017 Steady State Process Simulation of Distillation Columns

Karl Kolmetz CPE, KLM Technology Group
Contributing Authors: Timothy M Zygula, Prathamesh Deshpande, Dominic C Y Foo , Mark Brantana, and Tushar Madhukar Kamerkar

Introduction

This 2017 Technology Review will address Steady State Process Simulation of Distillation Columns. We would like to thank all of those who assisted in this technology review. A questionnaire was developed and sent to some of the major process simulation companies. The completed questionnaire was then utilized to develop this Technology Review.

A distinguish board of independent reviewers were asked to volunteer. They also answered the same questionnaire and gave a ranking from 1 to 10 on each question with comments.

We posted our idea to publish this paper on Linked In. That post received over 45,000 views, 62 comments and 132 likes. We know there is a great deal of interest in this area. Several of the board of independent reviewers commented on this post.

A great thank you goes to each person who helped in this technology review; The board of reviewers and the simulation companies. With their help this idea has become a great paper.

Questionnaire

Here are the questions from the Questionnaire

1. Ease of Software Utilization

To determine ease of software utilization, the same simulation case will be solved by an advanced and intermediate user. The chosen case is a benzene and toluene tower.

We are estimating it will take ten minutes to understand the problem and then an additional 20 to 40 minutes to solve the problem based on the expertise of the user. Please include the 10 minutes study time in your answers. Please provide the times for Advance and Intermediate users and their simulation outputs.

2. Iterative or Batch Run Program

There are two types of Simulation Software run styles. The first is iterative, which solves each unit operation when the degrees of freedom are met. The second is a batch type program which requires the user to input the data and then start the program to run. Please provide which type of program your software utilizes

3. Heat Transfer Limitations

Most simulations are mass transfer limited. How does your process simulation tool address heat transfer limitations as compared to mass transfer limitations?

4. Natural Gas Processing Polar Solvents

How does your process simulation tool address Natural

Gas Sweeting Processes such as amines, glycols and other polar solvents?

5. Recycle Steams Clamping

How does your process simulation tool address recycle streams? Some programs have no clamping on the recycle streams allowing them to cycle to very large numbers. Some programs have recycle models and other programs allow any stream to be designated as a recycle stream and clamped.

6. Equipment Sizing Interface

How does your process simulation tool address tray and packing ratings? How does your process simulation tool address heat exchangers? Does your tool build equipment data sheets?

7. Best Unit Operation - Unique Advantage - User Valued Feature

What is your process simulation tools best unit operation / process? What is your best area of utilization? What is your process simulation tool industry advantage? What features of your software do your users find most valuable, compared to other software?

8. Technical Support and Training

How do you add value in technical support and training?

9. Third Party Applications

How does your software utilize third party applications?

10. Graphical User Interface

Rate the software Graphical User Interface – rate one to ten. Send a picture of your Graphical Interface for ranking of volunteers.

Board Member Comments on the Questions

1. Ease of Software Utilization

To determine ease of software utilization, the same simulation case will be solved by an advanced and intermediate user. The chosen case is a benzene and toluene tower.

We are estimating it will take ten minutes to understand the problem and then an additional 20 to 40 minutes to solve the problem based on the expertise of the user. Please include the 10 minutes study time in your answers. Please provide the times for Advance and Intermediate users and their simulation outputs.

Member 2: In my opinion, ease of software utilization should not be limited to simulation runs only. As per my understanding, we can categorize this section into three sub sections.

1 Ease of software utilization: when simulations are performed for the design a new distillation column.

2. Ease of software utilization: when simulations are performed for retrofitting, troubleshooting or debottlenecking of existing distillation column.

3. Ease software utilization: for post processing and extraction of results in desired format for both above mentioned cases.

I believe currently we are considering ease of software utilization pertaining to design of a new distillation column. However, I feel the remaining two aspects also need to be considered within technical review.

Member 3: Basically, I am an intermediate to advance user (the "between" category) when it comes to simulation. There are two aspects/ approaches of solving any case.

A. Creating complete case from scratch and then solve the case.

B. Load a previous case (if similar or exact case been run previously) from database, make necessary changes and then solve the case.

Time taken for option A is lesser than that of option B to create and solve the case. Reason is I take complete clean approach (generally as default settings of software for any new case).

Whereas in option B, I have to look all the constraints which I (or somebody else) had set for that previous case. I have to check the applicability of such all constraints, validate them, discard some of them and then finally solve the case.

I took total 10 (study, conceptualizing, preparing for the activity) +18 (doing actual work in simulation software) +5 (to check input and output parameters) = 33 minutes for option A in Hysys.

I took total 10 (study, conceptualizing, preparing for the activity)) +28 (doing actual work in simulation software) +15 (to check input and output parameters) = 53 minutes for option B in Hysys.

However, this is only 50% of total simulation scenario. Because in reality when any case is raised to simulators, there are certain guarantee parameters (performance guarantee) which have to be satisfied. The question does not take "time required for to complete 100% accurate and acceptable

output" into the consideration. Every process (even though steady state assumption for simplification) comes with certain uncertainty in process parameters and as simulation engineer, I have to satisfy such uncertainties. Result of which I have to run case with added constraints and/or off design parameters.

So, from outputs point of view, option B has given most satisfactory results. Because output of option A has got lesser or no constraints.

2. Iterative or Batch Run Program

There are two types of Simulation Software run styles. The first is iterative, which solves each unit operation when the degrees of freedom are met. The second is a batch type program which requires the user to input the data and then start the program to run. Please provide which type of program your software utilizes

3. Heat Transfer Limitations

Most simulations are mass transfer limited. How does your process simulation tool address heat transfer limitations as compared to mass transfer limitations?

Member 2: As per my experience, during design of a new distillation column NTS based approach is recommended as actual tray efficiencies are unknown. During this approach vapor and liquid on each tray are considered to be in complete equilibrium with each other. However, in reality there exists non-equilibrium between the phases which also results in slightly different temperature profile within distillation column. Only few simulation software (like Pro-Treat) considers actual tray/ packing height during design phase. PRO-II gives separate temperatures for gas and liquid leaving that particular tray.

I feel we should also mention about the solver algorithm used to converge distillation columns. Various solver algorithms are available in different simulation software.

Another aspect that affects the simulation accuracy is the data incorporated within thermos-physical property package and frequency of data update based on experimental/ plant data.

4. Natural Gas Processing Polar Solvents

How does your process simulation tool address Natural Gas Sweeting Processes such as amines, glycols and other polar solvents?

Member 3: Since most of the simulators are developed for petroleum/petrochemical industries. Simulation of processing of polar solvents, you will get similar results from different software. The real deal is how the software company is using actual onsite data to increase accuracy of the model.

5. Recycle Steams Clamping

How does your process simulation tool address recycle streams? Some programs have no clamping on the recycle streams allowing them to cycle to very large numbers. Some programs have recycle models and other programs allow any stream to be designated as a recycle stream and clamped.

Member 3: Recycle stream is generally added to increase yield of the reaction process. In actual, the degrees of freedom analysis of recycle stream is necessary and simulator does that. However, it cannot understand why a splitting point is added by the user and a joining point. It will go on iterating and solving give you the results. This is basic approach. Simulator using recycle as "Function" has different story. Sensitivity of process parameters has to be decided based on which iterations are done. I believe results of recycle stream calculation without

sensitivity will be different than recycle using sensitivity.

Member 6: Most simulation software have recycle models to help the convergence of recycle streams. Software like Aspen HYSYS and UniSim Design have dedicated unit model to facilitate recycle stream convergence, which is an added
bonus.

6. Equipment Sizing Interface

How does your process simulation tool address tray and packing ratings? How does your process simulation tool address heat exchangers? Does your tool build equipment data sheets?

Member 3: Today most simulation software includes equipment sizing. If any one does not, it should not be called assimulator. However, many details a PDS (process data sheet) may have a question to be solved by simulation software developer company. For example; column specification parameters (based on which you can plan a layout), condenser profiles, tray wise purity chart, tray section details, vessels (reboiler, condenser) details, column pressure profiles, stream properties, and composition of all streams.

7. Best Unit Operation - Unique Advantage - User Valued Feature

What is your process simulation tools best unit operation / process? What is your best area of utilization? What is your process simulation tool industry advantage? What features of your software do your users find most valuable, compared to other software?

8. Technical Support and Training

How do you add value in technical support and training?

9. Third Party Applications

How does your software utilize third party applications?

10. Graphical User Interface

Rate the software Graphical User Interface – rate one to ten. Send a picture of your Graphical Interface for ranking of volunteers.

Companies that were invited to participate

From the Linked In post many people proposed companies to invite for the 2017 Technology Review. Attached is a list of companies that were invited to participate. Each company was sent an email inviting them to participate. In alphabetical order;

1. Aspen / Hysys
2. BRE ProMax
3. CHEMCAD
4. ProSim
5. ProTreat
6. PRO II
7. PSE - gProms
8. UniSim
9. VMGSim

We wish to thank those who responded to the questionnaire. Their valuable input greatly increased the technical value of this review.

CHEMCAD Response

1. Ease of Software Utilization

Intermediate User: 25 minutes, including the 10 minutes to understand the problem Advanced User: 30 minutes total because they ran multiple thermodynamic model scenarios

2. Iterative or Batch Run Program

CHEMCAD is a batch type program that calculates on-command, not automatically.

3. Heat Transfer Limitations

CHEMCAD has the capability to model mass-transfer limited distillation for trayed or packed columns. When using one of the mass-transfer distillation models, the heat transfer calculations allow for liquid and vapor to be different temperatures in any theoretical stage.

4. Natural Gas Processing Polar Solvents

CHEMCAD has two thermodynamics models specifically focused on these type of systems – the Amine and Sour Water models. There are also several other thermodynamic models that could work well for these systems, for example: rigorous e-NRTL for electrolytes or PSRK.

5. Recycle Steams Clamping

CHEMCAD has multiple algorithms to handle recycles, as well as an algorithm to select better recycle streams for improved convergence. The program also allows for simultaneous modular or sequential calculation modes for recycle calculations. The recycle algorithms in CHEMCAD allow our users to quickly and easily converge recycle streams, even nested recycles.

6. Equipment Sizing Interface

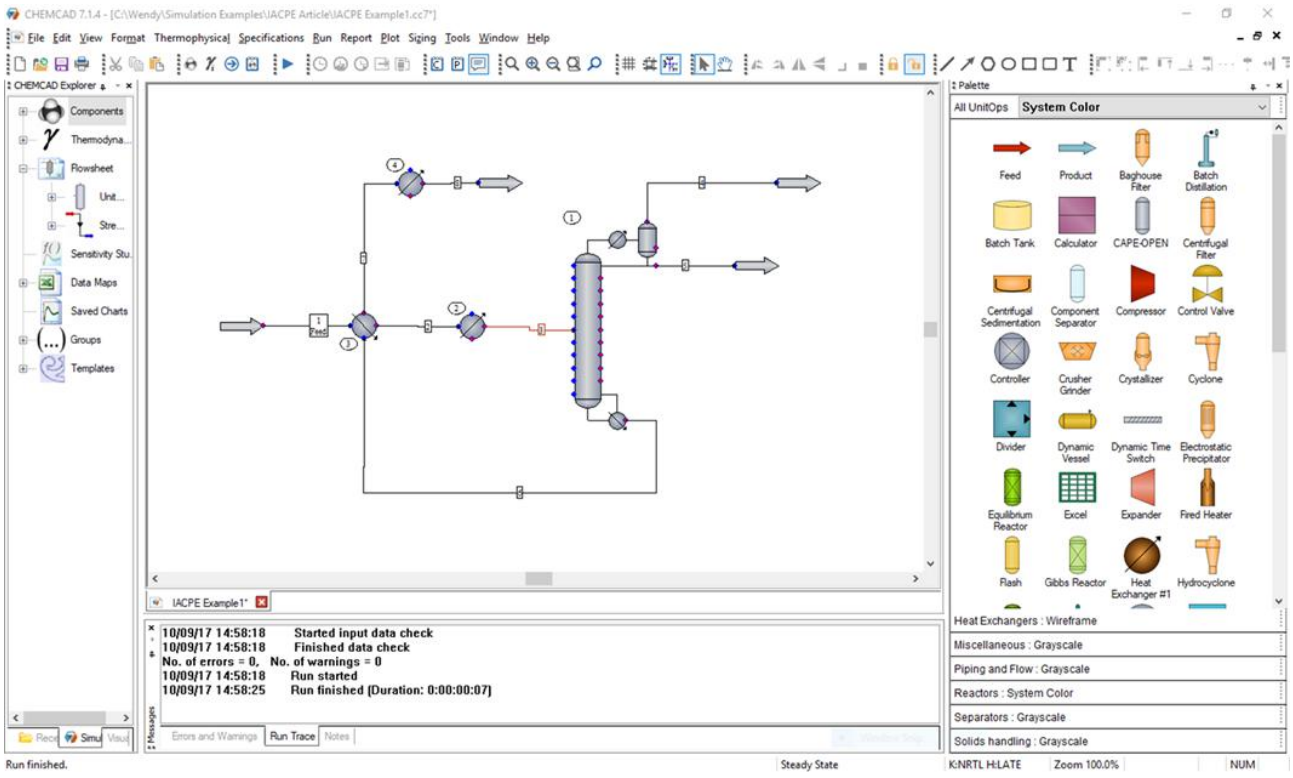
CHEMCAD uses industry-standard methods to address tray and packing ratings as well as partnering with Jaeger Raschig to deliver their best practice methods. For heat exchangers, CHEMCAD is capable of rigorous design or rating of heat exchangers based on heat transfer and geometry and includes this capability as part of overall flowsheet calculations. Equipment datasheets are built along with many other desired report formats.

7. Best Unit Operation - Unique Advantage - User Valued Feature

Distillation convergence in CHEMCAD is very good due to special algorithms implemented. The software is utilized by a very broad user base in petrochemicals, specialty chemicals, food, fragrances, pharmaceuticals, etc. The biggest industry advantage of CHEMCAD is reduced cost versus other software with the same capabilities. The ease of learning and using CHEMCAD is continuously listed by users.

8. Technical Support and Training

All of Chemstations' technical support team are



chemical engineers. Support is available at any time through support teams in Houston or Germany. There is no cost for a user with a current license to obtain support. In addition to accessing the support teams through phone or email, documentation and other resources are available on-line.

Training courses are held in-person in various locations throughout the world as well as on-demand through webinars and demos on-line.

9. Third Party Applications

CHEMCAD interfaces directly with Excel, VisualBasic, C programs, Matlab, and OPC.

10 Graphical User Interface

CHEMCAD's graphical interface is key to the ease of learning and use of the software and was completely updated in 2016. So, we would rate it a 10. Unit operation symbols are available in the default grayscale, system color, or wireframe (P&ID-style). The windows surrounding the flowsheet can be custom-sized or minimized completely to allow for a larger area to build models.

PRO/II Response

1. Ease of Software Utilization

PRO/II

Intermediate User 10 + 30 = 40 minutes

Advanced User 10 + 20 = 30 minutes

SimCentral

Intermediate User 10 + 20 = 30 minutes

Advanced User 10 + 10 = 20 minutes

2. Iterative or Batch Run Program

PRO/II

PRO/II is a batch program. User enters stream and unit operation data then runs. User evaluates results and continues adding equipment and runs again. Columns are easily converged with default specs on reflux ratio and product estimates to fill internal column estimates. A second pass can be used to column at specs. In the provided case there are more specs than variables, PRO/II allows for variables to be quickly activated/deactivated so that user can decide which additional spec is not the limiting.

Sim Central

SimCentral has an equation oriented solver that is closer to iterative than batch. Its numerical solver is set up to break down and solve blocks of equations either consecutively or simultaneously. For Example,

- SimCentral can solve each unit operation consecutively when it is placed on the flowsheet like the IACPE definition of an iterative simulation.

SimCentral can immediately solve the entire simulation simultaneously based on the way the user specifies the simulation. For example, SimCentral can solve the feed composition

- given a product composition specification without the user having to create any special solution order controls to iterate on the feed conditions.

3. Heat Transfer Limitations

PRO/II

PRO/II has a reactive distillation option available in the solving methods of Chemdist Liquid liquid extraction. We also offer an add-on RATEFRAC from KochGlitsch to solve these types of problems where heat and mass balance is carefully achieved accounting for vapor/liquid or liquid/liquid equilibrium with mass and heat transfer as well as reaction parameters.

4. Natural Gas Processing Polar Solvents

PRO/II

PRO/II has a database of Glycol interaction parameters with other hydrocarbons, in addition it provides

a proprietary correlation to predict the interaction parameters of glycol components and petro or pseudo-components usually encountered in refinery applications. It also has a database of Amine interaction parameters for single amines and includes the AMSIM from Schlumberger capabilities for single and mixed amines. In addition, PRO/II provides access to the OLI Electrolytic Engine for additional solvents, single and mixed. PRO/II also has a large Alcohol database and a proprietary correlation between Methanol and hydrocarbons.

SimCentral

SimCentral will acquire the thermodynamic methods of PRO/II in later versions.

5. Recycle Steams Clamping

PRO/II

PRO/II allows the user to provide initial estimate on streams, if user provides such information, it is taken in consideration when recycle streams are automatically assigned. However, it is not necessary in many situations and it can start without recycles. As the simulation evolves, PRO/II may decide to change the recycle streams to achieve the minimum number of recycle streams. User has the capability to limit or expand recycle convergence criteria and even select solution algorithm.

SimCentral

SimCentral is an equation oriented program which can solve recycles without the need for iteration. For almost all systems, SimCentral does not need the user to identify dedicated recycle streams. The robust solver solves very quickly. For rare difficult cases, any steam can be designated as a recycle to use an iterative rather than a simultaneous approach. SimCentral's equation oriented approach is ideal for systems with large numbers of recycles.

6. Equipment Sizing Interface

PRO/II

PRO/II includes Tray and Packing data provided by Sulzer and Koch-Glitsch. Both Sulzer and Koch-Glitsch also have programs that read PRO/II results and completes a tower design. In addition, PRO/II provides output that can be used as input in the FRI proprietary program.

PRO/II has a rigorous heat exchanger for which it creates a TEMA type report. However, most users use the PRO/II interface to HTRI, which can be used instead or on in addition to the PRO/II exchangers and with it they can simulate and design all types of exchangers.

Datasheets are often very specific for some customers and diverse from customer to customer. PRO/II provides an add-on, SIM4ME Portal, which is an Excel link to PRO/II, that allows users to create their own datasheets. In addition, PRO/II provides all variables calculated via a COM interface so that users can link PRO/II to any in-house application or 3rd party application for equipment data sheets.

SimCentral

SimCentral's distillation column is to be introduced near the end of 2017. The first version includes tray and tray rating. Future versions over the next year will include packing and packing rating. Since SimCentral has three modes, Process (design), Fluid Flow (rating), and Dynamics. Rating calculations are a fundamental part of Fluid Flow and Dynamics. SimCentral has an Excel reporting tool for users to link any SimCentral live or snapshot variable to equipment data sheets.

7. Best Unit Operation - Unique Advantage - User Valued Feature

PRO/II

Best Unit Operation

PRO/II distillation column has been used reliably for 30 years in refinery columns simulation. The column is unique for handling free water.

PRO/II advantage

Although not widely known, the thermodynamics capabilities and accuracy of PRO/II are praised by those in the know. PRO/II correlations for heavy crude characterization and viscosity is based on experimental data collected by PRO/II customers and analyzed by PRO/II. The recent PPR78 fill on EOS allows a much more accurate VLE prediction. The proprietary correlations for glycol and water in petro or pseudo-components provide accurate and reliable results.

The comment that we heard the most from our users is that they can reproduce plant data much better than other software. The other comment most heard is how good our support team is. No matter what the question is, our support team finds the answer and assist the engineer all the way until the question is completely solved and the simulation is called final.

SimCentral

Best Unit Operation

SimCentral's best unit operation is the distillation column. It is a complete rethinking of how to create and specify this model.

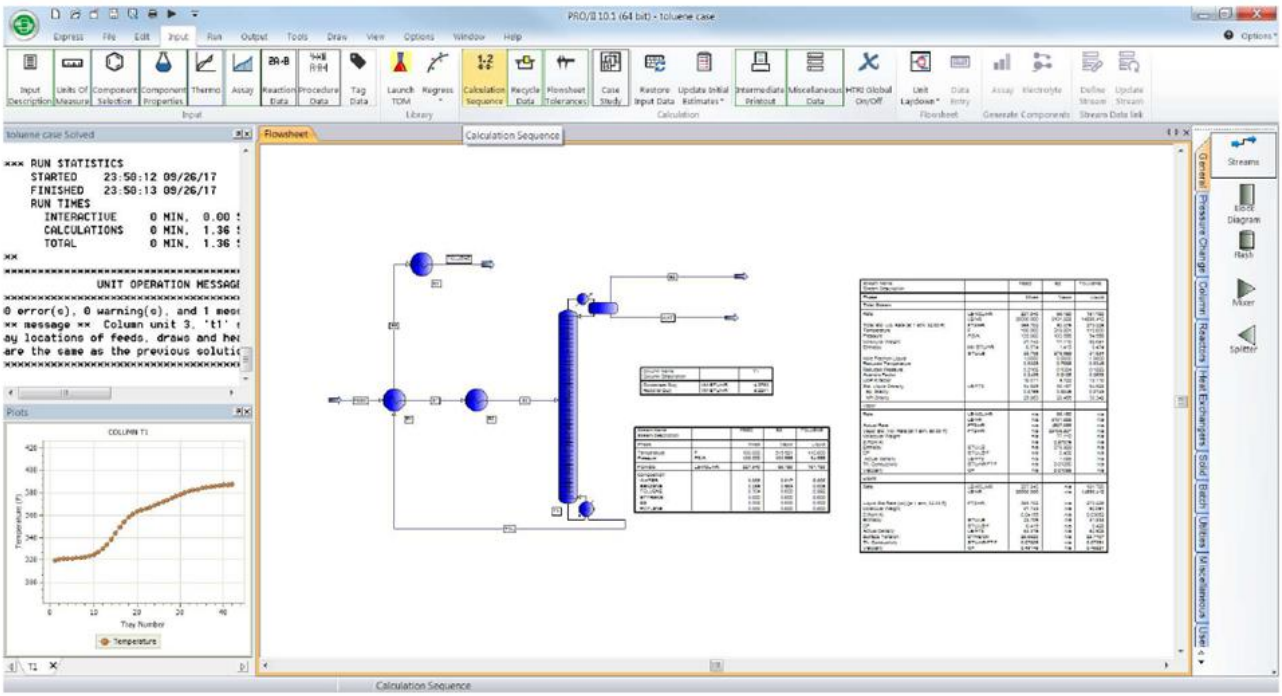
- Can solve for pressure given a condenser temperature specification.
- Can solve with dry trays to help new engineers diagnose convergence problems and match operational data.

SimCentral Advantages

- SimCentral has a platform approach to simulation. The SimCentral Simulation Platform also has library modules for cooling water and flow network design, steam balances, flare systems, and water hammer. This platform design uses one unified user interface which greatly reduces the time to learn a new application.

SimCentral employs a Lifecycle Engineering approach allowing users to start with simple conceptual models that they evolve into detailed engineering models capable of both steady state,

- fluid flow, and dynamics simulation.



PRO/II

- SimCentral Snapshots can save the multiple process conditions for a single simulation greatly reducing simulation engineering maintenance and allowing users to go forth and back from dynamic to steady state simulation with a single simulation file.
- SimCentral has a powerful model writing capability where users can write their own models in a high-level language.

8. Technical Support and Training

PRO/II SimCentral

Both PRO/II and SimCentral are supported by the Schneider-Electric / SimSci technical support teams. We are a global company with support and training facilities all over the world. Our support team is staffed with engineers ranging from 10 to 40 years in the industry. They understand all type of processes and can help the engineers not only on how to use

our software but on guiding younger engineers in the customer base to understand the process that they are simulating.

9. Third Party Applications

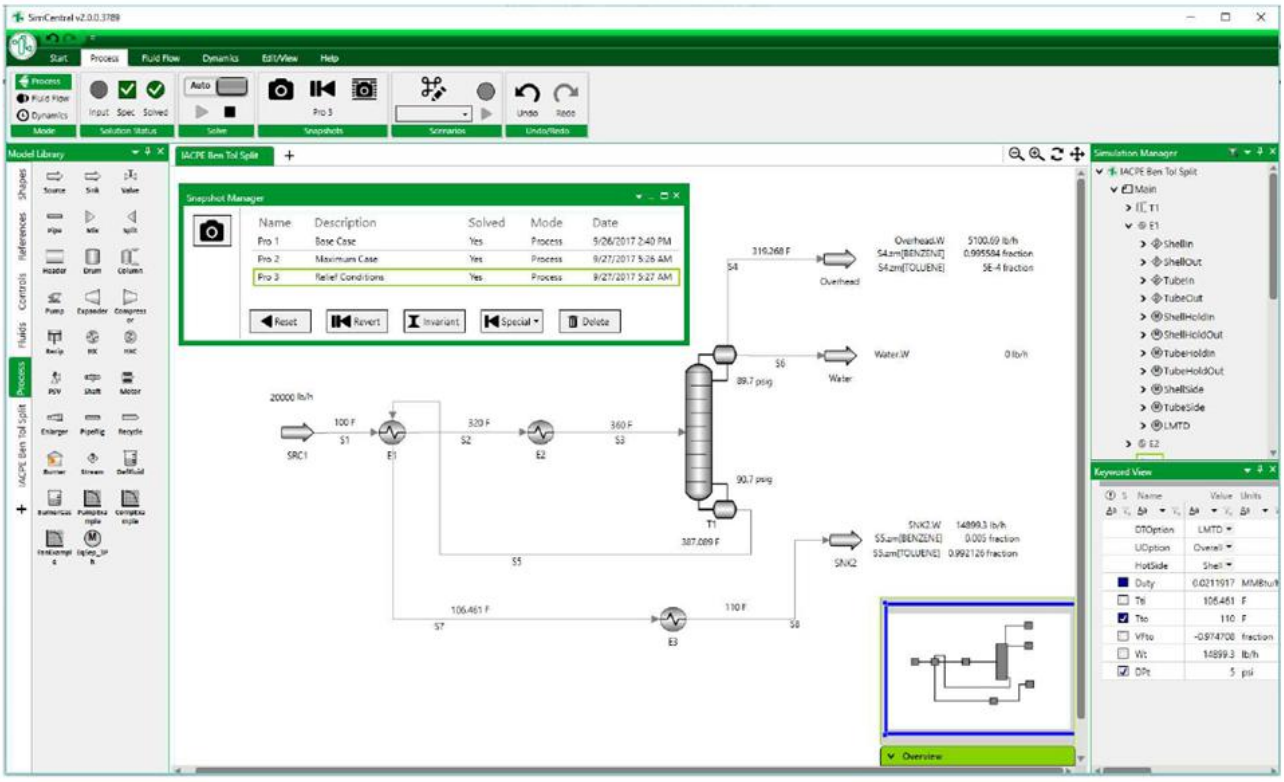
PRO/II

PRO/II has an extensive COM layer to allow third party applications to retrieve data from PRO/II or to set even set data and even run functions of PRO/II externally. In the same way PRO/II interacts with 3rd party applications that provide COM interface and in some cases it looks like native PRO/II. For instance, AMSIM is fully embedded into PRO/II. HTRI can be accessed from within a Heat Exchanger of PRO/II. OLI MSE Electrolytes and NIST look like direct thermodynamics of PRO/II while they are third party add-ons.

PRO/II has an Excel Unit Operation so that the user can create via Excel any unit operation that PRO/II may not have like a specialty reactor. PRO/II also has an Excel calculator. Not a spreadsheet like unit operation, it is Excel embedded inside PRO/II. Users can also add thermodynamics or other unit opera tions of their liking using CAPE OPEN interface.

SimCentral

SimCentral has a very flexible Excel report writing



SimCentral

engine that allows users to use Excel functions to create stream and equipment summary reports. SimCentral is based on a powerful Schneider Electric ArchestrA service bus that will provide interfaces to online systems and controls, including OPC, in future versions.

10. Graphical User Interface

PRO/II

PRO/II has an Office type of look. Similar ribbon, same way to customize it. This gives customer some familiarity with the look and field. Tabs are organized by functionality and each has a reasonable number of functions. The most used functions are collected on a "Express tab" It has easy ways to find unit operations and quickly navigate to them.

PRO/II is color coded and the aim is to remove all the colors and leave the PFD only blue. User with vision imparities can select their own colors or box-thickness to identify warnings vs input requirement or everything is solved. In an overall one to ten being 1 the best, I would say PRO/II is a 3, it does not have an Undo button, plots are a new feature, but it has not been completed for all available plots in PRO/II. But it has very flexible reporting to suit almost any requirement.

SimCentral

SimCentral graphical user interface has the following features:

- Undo button to immediately undo previous steps to return the values to the previous solved condition.
- Continuously solved so users can immediately see the impact of the change that they made.
- Unit operation design that can duplicate either a PFD / P&ID appearance.
- Badges next to the location of an error so users know where to look.
- Results can be dragged from the unit operation directly to the canvas to be able to view key results without looking inside the model.
- Graphical pump and compressor curves which can be created by importing a scanned pump curve and placing markers directly on the scanned performance curve.

Process Systems Enterprise Response

1. Ease of Software Utilization

The simulation was completed within about 40 minutes by an Intermediate user. It solved automatically without the need for any recycle or initial guesses. The simulation was completed within about 30 minutes by an advanced user.

2. Iterative or Batch Run Program

All gPROMS models solve in the following way:

1. Built-in unique Model and Flowsheet Initialization Procedures (MIPs and FIPs) are applied to ensure that individual unit models, no matter how complex, and then the entire flowsheet, initialize from scratch with minimum user intervention in the form of initial guesses etc. This step combines sequential and simultaneous solution.
2. Following initialization, pure equation-oriented solution is used to ensure rapid convergence and then re-convergence on change, irrespective of the number of recycles, which variables are specified, and which are calculated, and whether the solution is steady-state or dynamic.

3. Heat Transfer Limitations

gPROMS libraries contain models of a wide-range of fidelities, from mass balance models to high-fidelity, multi-scale catalytic reactors. A range of models are available for dealing with complex mass transfer limitations (e.g. rate-

based distillation and adsorption, rate-limited catalytic reaction, etc.) using Fick's and Maxwell -Stefan representations as appropriate.
For distillation columns, both equilibrium and thermal balances are performed. gPROMS ·ProcessBuilder is equation-based, so the environment does allow for additional modelling equations to be included to cover specific situations where heat transfer is more important.

4. Natural Gas Processing Polar Solvents

It is straightforward to model natural gas sweetening processes in gPROMS using PSE's gSAFT physical property package. This is based on the SAFT (Statistical Associating Fluid Theory) equation of state, and provides highly predictive, physically-realistic models of molecules and their interactions with other molecules, taking reaction into account where necessary.

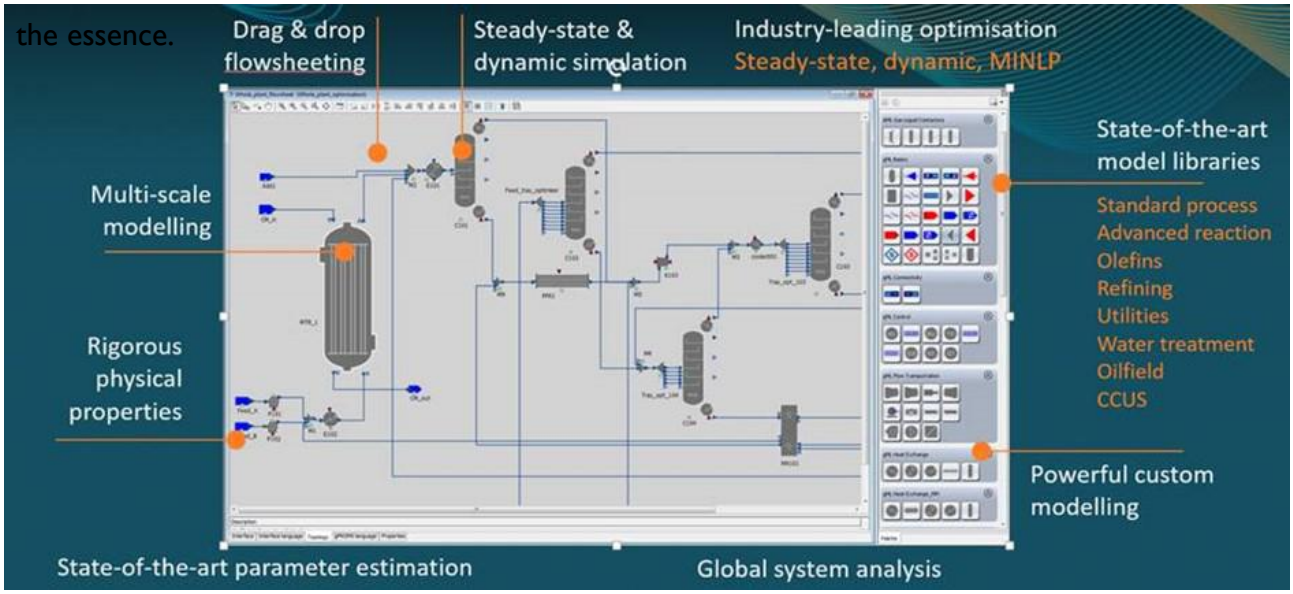
The SAFT-γ Mie equation of state in gSAFT is a group contribution method that can predict pure component properties and behavior of complex mixtures, including VLE and LLE, accurately using little or no data. This means that it can effectively model behavior of polar fluids, strongly associating/hydrogen bonding, are of the essence.

polymers, and a wide range of solvents.

5. Recycle Steams Clamping

gPROMS' equation-oriented architecture means that a recycle is simply another equation, to be solved simultaneously with all the others. Coupled with the built-in flowsheet initialization, this means that simulation and optimization solution is straightforward for complex flowsheets with a number of recycles.

For example, a complex air separation unit (ASU) with multiple recycles, multi-stream heat exchanger, inter-connected distillation columns and purity specifications takes about half a minute for the initial solution (including all initialization procedures) with no initial guesses; subsequent executions (e.g. following a change in specified variables) are of the order of 0.5 seconds on a standard laptop computer. This makes possible large-scale optimization, global sensitivity analysis, online applications and any other applications where robustness and speed



6. Equipment Sizing Interface

The distillation column models available in gPROMS allow for the specification of the sizing of both trays (weir length, hole area fraction, hole diameter,…) and packings (random or structured). Ultimately, the design of the column in terms of diameter and height can be calculated based on available correlations (for example, minimum column diameter required to avoid flooding).

Heat exchangers can be modeled in gPROMS using either simplified models (cooler, heater or heat exchanger) or detailed models (double pipe or shell-and-tube). Detailed sizing can be, of course, considered for all heat exchanger models.

For heat exchangers, gPROMS ProcessBuilder models heat transfer in detail, including such elements as metal thermal conductivity and predictions of thermal resistance due to heat exchanger fouling layers.

In some of these models, heat exchange limitations are critical and modelled in significant details. Examples are trickle-bed reactor models, where both heat and mass transfer are complex yet essential to achieving an accurate model of the reactor behavior. The software also calculates reactor temperature profiles both radially and axially.

gPROMS does not automatically build equipment data sheets, but can instead provide the relevant data via one of its output channels (e.g. via MS Excel) for use in company-standard data sheets.

7. Best Unit Operation - Unique Advantage - User Valued Feature

The major / unique advantages are as follows:

Best unit operation / process

- high-fidelity, state-of-the art models including multi-scale catalytic reactor models for detailed reactor design and operational analysis within a flow sheeting environment
- o robust pressure-swing adsorption (PSA) models that take advantage of gPROMS' fast dynamic solvers
- o furnace reactor models for most cracking furnace geometries, for olefins plant operational optimization (and design)
- o wide range of industry-leading active ingredient / formulated product and product performance models for optimizing formulation and manufacture of pharmaceuticals and other formulated products.

Best area of utilization:

- catalytic reactor and catalyst design and operational optimization
- PSA systems

gPROMS's key advantages (and the reason for its use in large petrochemical companies in particular) derive from its 'native' equation-oriented architecture. Some of these are: ·

- Ability to perform large-scale optimization calculations with many tens of decision variables (including integer/discrete decisions) and taking into account many process and equipment constraints, all based on high-fidelity predictive models.

- Unique Global System Analysis capability that enables modelers to explore the process design and operational decision space rapidly and effectively, using a systematic approach rather than considering point solutions.
- Powerful custom modeling capabilities of gPROMS ProcessBuilder that allow model developers to develop models of any complexity (e.g. for polymer applications) while focusing on the relevant physics and chemistry rather than computer programming, since gPROMS automatically takes care of the mathematical solution. Custom models can be incorporated into libraries then used in process flowsheets in the same way as any other library models.

gPROMS custom modeling is well known to provide far better capabilities and robustness of solution than other similar tools, and has shown to be orders of magnitude faster in some cases.

The ability to deploy high-fidelity models online as part of plant automation systems. PSE provide an OPC client and a Dynamic State Estimator in addition to the optimization technology, enabling deployment of plant models in online monitoring and optimization.

8. Technical Support and Training

PSE provides frequent standard public software training courses in locations including the UK, USA, Korea and Japan, as well as a range of tailored on-site training and workshops and courses aimed at specific technologies such as catalytic reaction. These are conducted by experienced practitioners from within PSE's Applications Engineering team. PSE also has a range of 'How to' videos, accessed through its website.

gPROMS comes with installation and bug-fix support as standard. Beyond this, we provide a number of options for standard software support, plus the PSE ModelCare program for expert modeling support and project execution.

9. Third Party Applications

gPROMS has extensive APIs that are used to connect to external software – for example, CFD applications for co-simulation including mixing effects, MATLAB, CAPE-OPEN physical property packages, Plant Automation Systems, and so on. It can make direct calls to plant data via OPC, and can seamlessly work with dashboard technologies to make its results available through web-based dashboards.

10. Graphical User Interface

The GUI for gPROMS ProcessBuilder, on a 1(poor) to 10 (extremely good) scale is judged to be 9. The GUI is a drag-and-drop flow sheeting environment. The model won't run until the correct degrees of freedom have been specified.

Some diagnostics are present to advise the user on missing information. A screenshot from the main page is shown below. The user selects the unit operations from a Palette on the right-hand side of the screen.

Details for each unit operation are input by double-clicking on the unit operation icon and then entering data into the dialogue box(es) that then appear.

VMGSim Response

1. Ease of Software Utilization

Time for advanced users to understand problem, build and solve model – 15 minutes

Time for intermediate users to understand problem, build and solve model – 20 minutes

America in the midstream oil and gas processing

2. Iterative or Batch Run Program

VMGSim is an iterative style simulation software. It has a non-sequential modular solver, bi-directional information propagation and automatic degrees of freedom monitoring. This style of simulation software is faster than the batch run programs.

3. Heat Transfer Limitations

VMGSim can handle mass transfer effects in columns, but at the moment, cannot handle heat transfer limitations in distillation towers.

4. Natural Gas Processing Polar Solvents

VMGSim can handle all natural gas processing polar solvents, as our biggest customer base in North industry. Our rigorously validated Advanced Peng-Robinson for Natural Gas 2 thermodynamic property package has been compared with all available GPA Research Reports (validation document attached), and is used for glycol dehydration, methanol injection, etc.

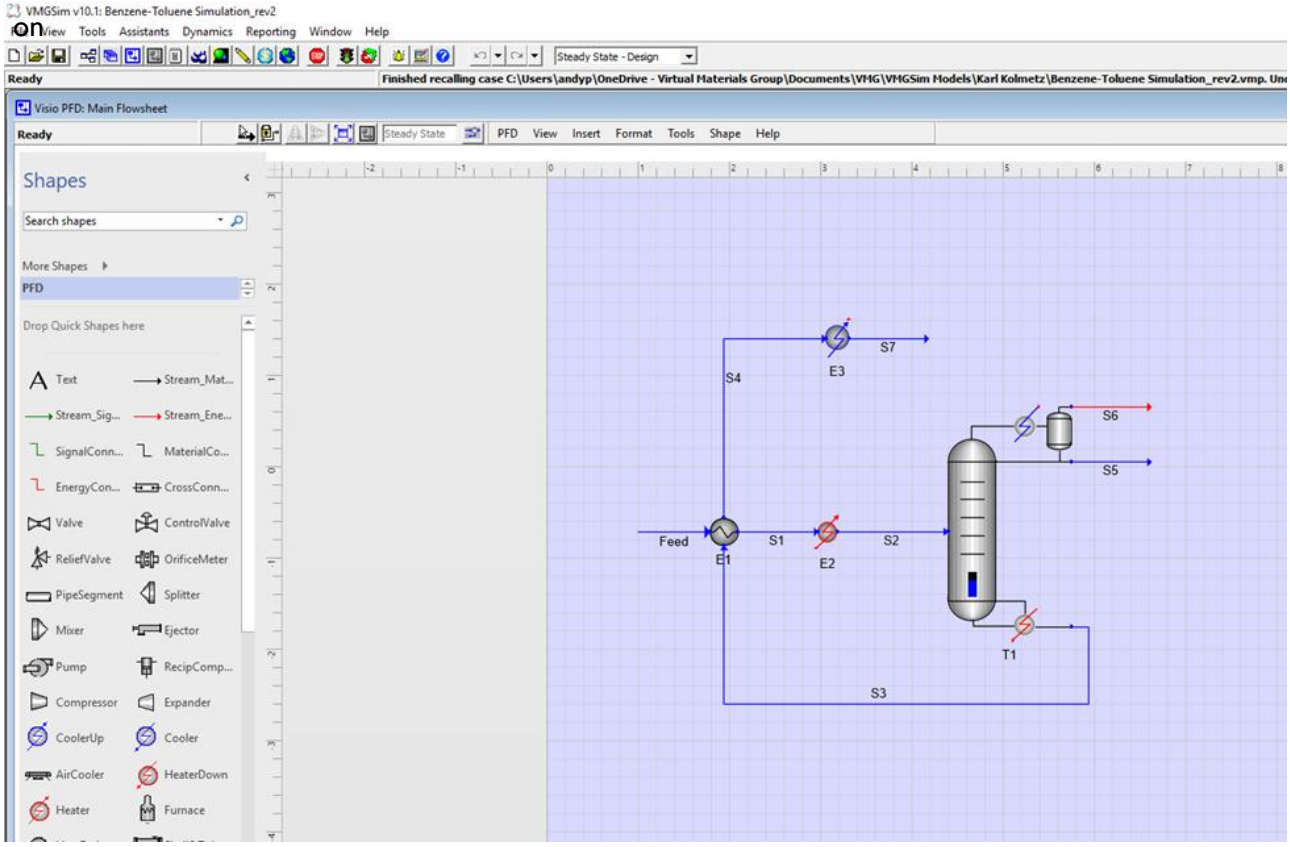
We also have a validated amine package to handle primary, secondary and tertiary amines, as well as mixtures of amines, with the ability to handle piperazine. In addition, we also have a Physical Solvents package that can handle Selexol, Rectisol, NMP and DEPG units.

5. Recycle Steams Clamping

VMGSim is unique in that it has no recycle unit operation. Any material stream can be turned into a recycle stream, thus a user is not placing additional artificial blocks on the flowsheet. Recycles can be clamped and every recycle stream can be set with a particular tolerance or can use the global tolerance

6. Equipment Sizing Interface

VMGSim has built in separator sizing, heat exchanger rating and tower design/rating that can handle both trayed and packed towers. Unlike other tools, this is part of the basic package and not an add-on cost.



7. Best Unit Operation - Unique Advantage - User Valued Feature

VMGSim is the only software that provides comprehensive steady state and dynamic process simulation, integrated with multiphase pipeline and network modeling. Its highly validated, proprietary thermo-physical property packages cover the upstream, midstream and downstream hydrocarbon industries.

Area of focus Focus/applications are:

Oil & gas processing including inlet separation, compression, gas plants, hydrate inhibition, methanol injection, mercury partitioning, glycol dehydration, amine & physical solvent treating, membrane units and sulfur recovery

- Refinery-wide modeling including crude towers, sour treating, sulfur recovery and rigorous reactors such as catalytic reformers (CCR), fluidized catalytic crackers (FCC), hydrotreaters (HT), hydrocrackers (HC) and delayed cokers (DC).
- Petrochemical reactor units, including ethylene and heavier feed crackers and vinyl chloride monomer (VCM) units
- Syngas, ammonia, hydrogen, urea, methanol and Fischer-Tropsch gas-to-liquids (GTL) plants
- Gasification units with various feeds including coal, biomass, municipal waste, etc.
- Multiphase steady state and transient pipeline modeling that can solve networks, branches and loops, including pigging, slugging, surge analysis, etc. and their impact on facilities
- Safety modeling for flare networks, emergency relief and blowdown systems
  Environmental flash and tank emissions
- Budgetary economics/cost estimation for CAPEX and OPEX calculations
- Control system analysis, operational studies, virtual plant startups & shutdowns, malfunctions, scenarios and operator training via dynamic plant models

8. Technical Support and Training

We place a very high emphasis and priority on both technical support and training. Our technical support engineers all have chemical engineering backgrounds with advanced degrees, and there is no call center or multiple levels of support, as we do not hire non-chemical engineers to work on our Support team. the flowsheet.

When you call or email someone at VMG, you are communicating with an experienced engineer familiar with process simulation, that can solve both IT/computer issues, as well as engineering/thermodynamics questions.

With regard to training, unlike most other providers, we offer all our courses (both Introductory and Advanced classes) free of charge. This can greatly reduce organizational training costs. We also conduct onsite and offsite training for both clients and non-clients who want to learn how to use VMGSim, and have numerous training videos that can be viewed at any time on our website or YouTube page.

9. Third Party Applications

In terms of 3rd party applications, we typically link to them directly through a dll (such as HTRI's Xchanger Suite) or through COM or OPC.

10. Graphical User Interface

Our graphical user interface is modern and flexible. We would rate it a 10. We utilize Microsoft Visio as the PFD engine, and it can support multi-flowsheets, multi-property packages (even on the same sheet), with a fully integrated Dynamics engine.

There is full Microsoft Excel functionality at the unit/stream level and engineering grade equipment datasheets built into every Unit Op that are updated live.
In addition, there are built-in advanced tools such as the Case Study, Optimizer and Model Regression, and our OPC Client/Server can connect live with control systems, historians and databases.

Independent Review Board Answers to the Questionnaire

We were very fortunate to develop a great group of people to rate the software. We rated the software and provided some additional comments. We wanted to rate each software that we invited, but we limited the ratings to companies where we had two or more board member ratings.

Aspen / HYSYS

1. Ease of Software Utilization

Member One Rating - 4 Stars
Aspen is a very powerful tool. Very good property packages and applications. The length of time to run the Benzene / Toluene Tower example might be 25 to 30 minutes for an advanced user and 45 minutes for an intermediate user.
Member Two Rating – 5 Stars
Addition of new components can only be done in terms of pseudo components only. Aspen Plus is good for chemicals simulation.
Member Three Rating - 4 Stars
10 + 18 + 5 + 33 minutes
Member Four Rating – 5 Starts.
I have utilized Aspen / Hysys for over twenty years. I would be considered an advanced user. Time to solve the Benzene / Toluene Tower for an advanced user might be 25 to 30 minutes
Member Five Rating – 5 Stars
Member Six Rating - 5 Stars

2. Iterative or Batch Run Program

Member One Rating – 4 Stars
Aspen is a Batch Run Program.
Member Two Rating – 5 Stars
Member Three Rating – 5 Stars
Member Four Rating – 4 Stars
Member Five Rating – 4 Stars
Member Six Rating – 5 Stars

3. Heat Transfer Limitations

Member One Rating – 6 Stars
Aspen has special applications that address heat transfer limitations

Member Two Rating- 7 Stars
Member Three Rating – 5 Stars
Member Four Rating – 5 Stars
Member Five Rating – 5 Stars
Member Six Rating - 5 Stars

4. Natural Gas Processing Polar Solvents

Member One Rating – 6 Stars
Aspen has special application that address polar solvents

Member Two Rating - 5 Stars
Good for natural gas processing. However, specialized applications like gas sweetening, dehydrations can be further improved.

Member Three Rating – 6 Stars
Since most of the simulators are developed for petroleum/petrochemical industries. Simulation of processing of polar solvents, you will get similar results from different software. The real deal is how the software company is using actual onsite data to increase accuracy of the model.

Member Four Rating – 6 Stars

Aspen's physical property packages allow user to obtain good results when simulating with polar solvents.

Member Five Rating – 6 Stars

Member Six Ratings – 4 Stars

5. Recycle Steams Clamping

Member One Rating – 4 Stars

Member Two Rating – 6 Stars

Member Three Rating – 5 Stars

Member Four Rating – 5 Stars

Member Five Rating – 5 Stars

Member Six Rating - 5 Stars

6. Equipment Sizing Interface

Member One Rating – 6 stars

Aspen has tray rating, sizing and costing applications

Member Two Rating- 5 Stars

Hysys is good for preliminary equipment sizing. Detailed sizing can be performed with the help of Hysys simulation results.

Member Three Rating – 6 Stars

Member Four Rating – 6 Stars

Aspen's heat exchanger design software does a good job solving and sizing exchangers. This application can do pinch analysis and well as mechanical design analysis.

Member Five Rating – 6 Stars

Member 6 Rating - 5 Stars

7. Best Unit Operation - Unique Advantage - User Valued Feature

Member One Rating – 5 Stars

Aspen tends to be the simulator of choice for operating companies.

Member Two Rating- 5 Stars

Depends on the application for which it is to be used. However, it is good that, thermodynamic models from Aspen Plus are also available now in Hysys.

Member Three Rating – 6 Stars

Member Four Rating – 6 Stars

Aspen has very good VLE Packages

Member Five Rating – 5 Stars

Member Six Rating – 5 Stars

8. Technical Support and Training

Member One Rating – 4 Stars

Aspen tends to charge for all their trainings and sometimes the trainer has a language barrier making it harder to present the material.

Member Two Rating- 6 Stars

Member Three Rating – 6 Stars

Member Four Rating – 5 Stars

Member Five Rating – 5 Stars

Member Six Rating – 6 Stars

9. Third Party Applications

Member One Rating – 5 Stars

Aspen will interface with excel and other programs.

Member Two Rating – 8 Stars

Good connectivity with other third-party programs/ software.

Member Three Rating – 5 Stars

Member Four Rating – 5 Stars

Member Five Rating - 5 Stars

Member Six Rating – 5 Stars

10. Graphical User Interface

Member One Rating – 4 Stars

Aspen has an older style GUI

Member Two Rating - 6 Stars

Previous Hysys version prior to V8 seems to be more user friendly.

Member Three Rating – 6 Stars

Member Four Rating – 5 Stars

Member Five Rating – 5 Stars

Member Six Rating - 4 Stars.

They get slower in the new interface, after v8.

BRE ProMax

1. Ease of Software Utilization
Member One Rating – 5 Stars
Member Two Rating – 5 Stars
ProMax is a specialized software. Brayan Research has done extensive work and came up with the data values which gives some of the most accurate results for gas treatment simulations

2. Iterative or Batch Run Program
Member One Rating – 5 Stars
Member Two Rating – 5 Stars

3. Heat Transfer Limitations
Member One Rating – 6 Stars
Member Two Rating – 7 Stars

4. Natural Gas Processing Polar Solvents
Member One Rating – 7 Stars
ProMax has highly rated applications that address polar solvents
Member Two Rating- 9 Stars

5. Recycle Steams Clamping
Member One Rating – 5 Stars
Member Two Rating – 6 Stars

6. Equipment Sizing Interface
Member One Rating – 5 Stars
Member Two Rating – 4 Stars

7. Best Unit Operation - Unique Advantage - User Valued Feature
Member One Rating – 6 Stars
ProMax is one of the simulators of choice for natural gas operating companies.
Member Two Rating – 7 Stars
Excellent for gas sweetening, dehydration applications.

8. Technical Support and Training
Member One Rating – 7 Stars
Promax has great free training
Member Two Rating – 7 Stars

9. Third Party Applications
Member One Rating – 5 Stars
Member Two Rating – 5 Stars

10. Graphical User Interface
Member One Rating – 5 Stars
Member Two Rating – 5 Stars

ChemCad

1. Ease of Software Utilization
Member One Rating - 5 Stars
Member Two Rating – 5 Stars

2. Iterative or Batch Run Program
Member One Rating – 5 Stars
Member Two Rating – 6 Stars

3. Heat Transfer Limitations
Member One Rating – 5 Stars
Member Two Rating – 7 Stars

4. Natural Gas Processing Polar Solvents
Member One Rating – 6 Stars
Member Two Rating – 5 Stars

5. Recycle Steams Clamping
Member One Rating – 6 Stars
Member Two Rating – 5 Stars

6. Equipment Sizing Interface
Member One Rating – 5 Stars
Member Two Rating – 6 Stars

7. Best Unit Operation - Unique Advantage - User Valued Feature
Member One Rating – 6 Stars
Member Two Rating – 6 Stars

8. Technical Support and Training
Member One Rating – 6 Stars
Member Two Rating- 6 Stars

9. Third Party Applications
Member One Rating – 5 Stars
Member Two Rating – 5 Stars

10. Graphical User Interface
Member One Rating – 6 Stars
Member Two Rating- 6 Stars

PRO/II

1. Ease of Software Utilization
Member One Rating – 5 Stars
PROII is a very powerful tool. Very good property packages and applications. The length of time to run the Benzene / Toluene Tower example might be 20 to 25 minutes for an advanced user and 40 minutes for an intermediate user.
Member Two Rating – 7
Column convergence is faster. Molecular structure for new components can be inputted and other thermos-physical properties can be estimated using standard estimation methods within software. Detailed crude characterization can be performed including PONA analysis. Very good tool for data regression. PRO-II is preferred for Refinery application

Member Four Rating – 5 Stars
Intermediate User – 35 to 40 minutes
Advanced User – 25 to 30 minutes
Member Five Rating – 5 Stars

Intermediate User – 35 to 40 minutes
Advanced User – 25 to 30 minutes

2. Iterative or Batch Run Program
Member One Rating - 4 Stars
PROII is a batch run program
Member Two Rating – 5 Stars
Member Four Rating – 4 Starts
Member Five Rating - 4 Stars

3. Heat Transfer Limitations
Member One Rating – 6 Stars
PROII has good applications for heat transfer limitations
Member Two Rating – 7 Stars
Member Four Rating – 6 Stars
Member Five Rating – 6 Stars

4. Natural Gas Processing Polar Solvents
Member One Rating – 6 Stars
PROII has good add on applications for Polar Solvents
Member Two Rating – 6 Stars
Member Four Rating – 6 Stars
Member Five Rating – 6 Stars

5. Recycle Steams Clamping
Member One Rating – 4 Starts
Member Two Rating – 4 Stars
Member Four Rating – 5 Stars
Member Five Rating – 5 Stars

6. Equipment Sizing Interface
Member One Rating – 5 Stars
PROII has tray rating and sizing applications
Member Two Rating – 4 Stars
Member Four Rating – 6 Stars
Pro II interfaces with HTRI heat exchanger sizing software.
Member Five Rating – 5 Stars

7. Best Unit Operation - Unique Advantage - User Valued Feature
Member One Rating – 5 Stars
PROII is the program of choice for the engineering design companies.
Member Two Rating - 6 Stars
More suited for refinery applications
Member Four Rating – 6 Stars
Member Five Rating – 6 Stars

8. Technical Support and Training
Member One Rating – 6 Stars
PROII has good training
Member Two Rating – 7 Stars
Member Four Rating – 6 Stars
Member Five Rating – 6 Stars

9. Third Party Applications
Member One Rating – 6 Stars
PROII will interface to excel and 3rd party programs
Member Two Rating – 7 Stars
Member Four Rating – 6 Stars
Member Five Rating – 6 Stars

10. Graphical User Interface
Member One Rating – 5 Stars
PROII has older style GUI
Member Two Rating – 8 Stars
Member Four Rating – 6 Stars
Member Five Rating – 6 Stars

UniSim

1. Ease of Software Utilization
Member One Rating – 6 Stars
UniSim is a very powerful tool. Very good property packages and applications. The length of time to run the Benzene / Toluene Tower example might be 20 to 25 minutes for an advanced user and 40 minutes for an intermediate user.
Member Two Rating – 7 Stars
Member Six Rating – 5 Stars

2. Iterative or Batch Run Program
Member One Rating - 6 Stars
UniSim is an iterative run program
Member Two Rating – 6 Stars
Member Six Rating – 5 Stars

3. Heat Transfer Limitations
UniSim will interface to excel and 3rd party
pMember One Rating – 5 Stars
Member Two Rating- 7 Stars
Member Six Rating – 5 Stars

4. Natural Gas Processing Polar Solvents
Member One Rating – 5 Stars
UniSim has good applications for Polar Solvents
Member Two Rating – 5 Stars
Member Six Rating – 5 Stars

5. Recycle Steams Clamping
Member One Rating – 6 Stars
UniSim has an Icon that sets the recycle streams clamping
Member Two Rating – 6 Stars
Member Six Rating – 5 Stars

6. Equipment Sizing Interface
Member One Rating – 5 Stars
Member Two Rating – 5 Stars
Member Six Ratings – 5 Stars

7. Best Unit Operation - Unique Advantage - User Valued Feature
Member One – 6 Stars
UniSim is becoming well received
Member Two Rating – 5 Stars
Member Six Ratings – 5 Stars

8. Technical Support and Training

Member One Rating – 5 Stars

Member Two Rating – 6 Stars

Member Six Rating – 5 Stars

9. Third Party Applications

Member One Rating – 6 Stars

rograms

Member Two Rating – 8 Stars

Member Six Rating – 5 Stars

10. Graphical User Interface

Member One Rating – 6 Stars

UniSim has updated style GUI

Member Two Rating – 6 Stars

Member Six Rating – 5 Stars

The previous interface was very fast.

Conclusions

The simulation companies seem to be like distillation equipment. In distillation equipment there are trays, random packing and structured packing. No one size fits all. In the simulation companies again, no one size seems to fit all cases. Each has its advantage. Trays for high pressure, packing for low pressure.

We wanted to rate all the invited companies, but unfortunately, we were only able to rate five of the companies with two or more board members. The board rated the simulation programs almost equal in average, but if you look at the induvial ratings many of the simulation companies had a distinct specific advantage. From the answers provide by the simulation companies, you again can notice that each has its advantage.

Our highest thanks go out to the companies that responded to the questionnaire, and the board members that volunteered to assist in this technology review.

Company	Avg Score	Advantage (Highest Rated Question)
Aspen / Hysys	5.20	Question 6 – Equipment Sizing
BRE ProMax	5.80	Question 4 – Gas Processing
CHEMCAD	5.60	Question 8 – Technical Support
PRO II	5.60	Question 8 – Technical Support
UniSim	5.57	Question 9 – Third Party App

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Quarterly Safety Connector

For Engineers; Because Safety Is Part Of The Process! By: Chris Palmisano, MESH, IFSAC **October 2017**

Countdown to Disaster!

The top five reasons employees get injured.

Over the years, like in any profession, there are many things we see as Safety Professionals that become realities for us. After a career of nearly 40 years, serving in some sort of safety capacity and as a former OSHA Compliance Officer, I've learned that accidents don't just happen and there is always a root causal factor that leads to the incident. Some of the more common causes can be summed up as follows:

1. **Complacency** - Often caused by task repetition, where employees fail to take important safety procedures seriously because they've preformed the same tasks over and over for a long period of time. Complacency is normally fueled by a few things, such as; repetition, over confidence and in some cases; poor morale, which can be sparked by a variety factors, such as pay, overburden from workload or even a lackluster company safety culture.

The best way to address complacency is with positive reinforcement, cross training and an across the floor staff rotation program. Changing employee's job tasks with a rotation program helps to stimulate their minds. The program can reduce the potential for ergonomic injuries caused by repetitive movement and creates a more efficient work force

2. **Training Deficiencies** - One of the principal foundations to worker safety is formalized training. When we put "Tribal Knowledge" over formal training we expose our employees to greater risk. While it makes sense to put your best worker with a new person, he/she may be great at the job tasks, however lack skills in adult training methodologies. Just because a worker is seasoned, doesn't mean they can properly train an adult. Effective training goes well beyond story telling.

Adult learners require auditory, visual and practical stimulation in a repetitive manner, in order to retain information in their long term memory. Sensory information is stored only long enough to be transferred to short-

term memory; therefore, adult learners need their five basic senses stimulated: sight, hearing, taste, smell and touch. By repeating information using a variety of modalities in a cyclic manner employees are better able to retain information in their long term memory.

Another thing to remember is that at best, learners devote about 80% of themselves to training. They are not bad people; it's just how the human mind works. So, as trainers, we have to be enthusiastic and give 110% to our training sessions and never show a propensity for short cuts. Just like we are what we eat, we are what we learn. Never skimp on new employee orientation and always implement ongoing training programs.

3. **Failure to conduct (JSAs) or Job Safety Analysis for all job tasks** - A job safety analysis (JSA) is a procedure which is used to integrate accepted safety and health principles into a particular job task or operation. The JSA process is multi-layered and broken into three parts:

1 - The Job Tasks

2 - Potential Hazard Exposures

3 - Recommended Safe Procedures

Employers are often cited by OSHA for failing to conduct JSAs, because they are an OSHA requirement under the (PPE) Personal Protective Equipment Standards. It is important to remember however, that PPE should be your last form of employee protection. You will have a lower exposure to risks and fewer injuries by implementing engineering and administrative controls before opting for a suit of armor.

JSA work studies must be documented and signed by all stakeholders in the process, which can include the President of the company, Management, HR, Safety as well as the Employee. The goal being to assure that everyone is on the same page and trained on the study results.

4. **Failure to conduct frequent and regular inspections** - Supervisors should conduct frequent and regular inspections and job task observations to assure employees are working safety and document findings. Deficiencies should be noted and may even include pictures.

Observations, both good and bad can be highly valuable. Formal topics of your findings should be part of your regular Safety Committee meetings. Always make observations in a kind and helpful manner and provide coaching, positive feedback and encouragement, otherwise you are just viewed as the safety police. I cannot think of a single employee that was ever happy after a safety manager barked at them for making a mistake or violating a safety rule. The kinder gentler approach, serving as their trusted adviser always yields more productive results than the barking dog.

5. **The Safety Department is integrated into the disciplinary process** - Stay with me and be aware of what I'm saying. You certainly need a discipline program to enforce safety. I'm in fact, a firm believer that observation of the company safety rules should be a <u>condition of employment</u>. It is important however to implement discipline <u>progressively and in a fair manner.</u> The point is that the safety department should never be sitting in the room during discipline nor should they dish out punishments or the issuance of warning letters.

That is the role of management, the supervisor and/or the HR department. Once safety is used in the discipline process, employees view you and your rules in a very negative way.

In closing I will say that safety is a very complex and dynamic arena and over the years, I've learned that, I keep learning. We need to build trust and relationships with our employees. Buy-in doesn't come from rewards, incentives, punishment or a sign that displays how many days you've gone without an accident. If your safety program is grounded upon a number on a sign, you are doing very little to promote safety.

have a positive safety culture, where employees have the "Permission" to inherently say to anyone in the company, without ridicule, **"Hey STOP, let's see if there's a safer way to do this job"!***

Chris is a Professional Risk Management Consultant, a former Philadelphia Fire Department Lieutenant and former OSHA Compliance Officer. He is the creator of the InSite GHS Hazcom Workplace Labeling System for Secondary Chemical Containers. For questions about this article or his workplace chemical labeling system to meet the OSHA GHS June 2016 requirement, you can reach Chris at: ChrisAPal@aol.com or at LinkedIn https://www.linkedin.com/in/chris-palmisano-696b3b6/

Hydrocracking Technologies: Upgrading the Refining Margins and Derivates

Dr. Marcio Wagner da Silva, MBA
Process Engineer and Project Manager at Petrobras

Introduction

One of the biggest challenges for the oil refining industry is raise the profitability or the so-called refining margin face to a scenario with environmental legislations increasingly restrictive, which requires high costly processes and the volatility of the crude barrel price.

Nowadays, is increasingly difficult the access light crude oil reserves and the conventional refining processes generate a high quantity of low added value products like fuel oil that have a restricted market. Aim to face these challenges the refiners needs to install deep conversion units in his refining scheme.

Deep conversion processes are dedicated to produce high added value products (LPG, Gasoline, Diesel and Jet Fuel) from residue streams, these units are commonly called "bottom barrel" process units. Available technologies to processing bottom barrel streams involve processes that aim to raise the H/C relation in the molecule, either through reducing the carbon quantity (processes based on carbon rejection) or through hydrogen addition. Technologies that involve hydrogen addition encompass hydrotreating and hydrocracking processes while technologies based on carbon rejection refers to thermal cracking processes like Visbreaking, Delayed Coking and Fluid Coking, catalytic cracking processes like Fluid Catalytic Cracking (FCC) and physical separation processes like Solvent Deasphalting units.

Despite the high investment for hydrocracking units construction, this technology is what gives more flexibility to refineries to processing heavy oils producing high-quality products. When the technology is compared with thermal cracking technologies, for example, once the products produced in these units need downstream hydrotreating steps to attend the commercial and environmental requirements.

Hydrocracking Process

The hydrocracking process is normally conducted under severe reaction conditions with temperatures that vary to 300 to 480°C and pressures between 35 to 260 bar. Due to process severity, hydrocracking units can process a large variety of feed streams, which can vary from gas oils to residues that can be converted into light and medium derivates, with high value added.

Among the feed streams normally processed in hydrocracking units are the vacuum gas oils, Light Cycle Oil (LCO), decanted oil, coke gas oils, etc. Some of these streams would be hard to process in Fluid Catalytic Cracking Units (FCCU) because of the high contaminants content and the higher carbon residue, which quickly deactivates the catalyst, in the hydrocracking process the presence of hydrogen minimize these effects.

According to the catalyst applied in the process and the reaction conditions, the hydrocracking can maximize the feed stream conversion in middle derivates (Diesel and Kerosene), high-quality lubricant production (lower severity processes).

Catalysts applied in hydrocracking processes can be amorphous (alumina and silica-alumina) and crystallines (zeolites) and have bifunctional characteristics, once the cracking reactions (in the acid sites) and hydrogenation (in the metals sites) occurs simultaneously. The active metals used to this process are normally Ni, Co, Mo and W in combination with noble metals like Pt and Pd.

It is a necessary a synergic effect between the catalyst and the hydrogen because the cracking reactions are exothermic and the hydrogenation reactions are endothermic, so the reaction is conducted under high partial hydrogen pressures and the temperature is controlled in the minimum necessary to convert the feed stream. Despite these characteristic, the hydrocracking global process is exothermic and the reaction temperature control is normally made through cold hydrogen injection between the catalytic beds.

Process Arrangements

Depending on feed stream characteristics (mainly contaminants content) and the process objective (maximize middle distillates or lubricant production) the hydrocracking units can assume different configurations.

Figure 1 shows a typical arrangement for hydrocracking process unit with two reactions stages, dedicated to producing medium distilled products (diesel and kerosene).

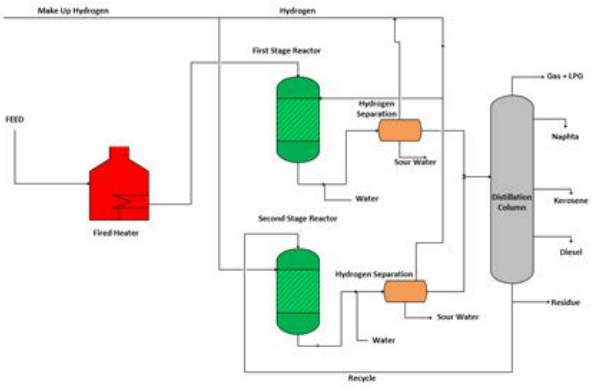

Figure 1 – Basic Process Flow Diagram for Two stages Hydrocracking Units

According to the feed stream quality (contaminant content), is necessary hydrotreating reactors installation upstream of the hydrocracking reactors, these reactors act like guard bed to protect the hydrocracking catalyst.

The principal contaminant of hydrocracking catalyst is nitrogen, which can be present in two forms: Ammonia and organic nitrogen.

Ammonia (NH_3), produced during the hydrotreating step, have temporary effect reducing the activity of the acid sites, mainly damaging the cracking reactions. In some cases, the increase of ammonia concentration in the catalytic bed is used like an operational variable to control the hydrocracking catalyst activity. The organic nitrogen has permanent effect blocking the catalytic sites and leading to coke deposits on the catalyst.

As in the hydrotreating cases (HDS, HDN, etc.), the most important operational variables are temperature, hydrogen partial pressure, space velocity and hydrogen/feed ratio.

For feed streams with low nitrogen content where the objective is to produce lubricants (partial conversion) is possible adopt a single stage configuration and without the intermediate gas separation, produced during the hydrotreating step, this configuration is presented in Figure 2. The main disadvantage of this configuration is the reduction of the hydrocracking catalyst activity caused by the high concentration of ammonia in the reactor, but this configuration requires lower capital investment.

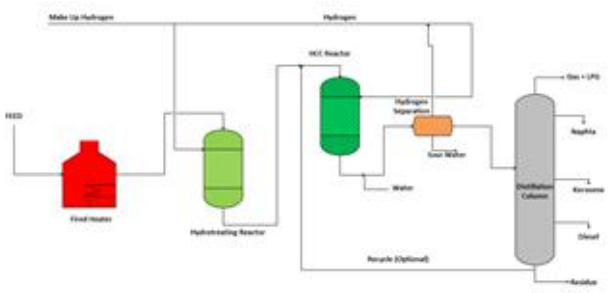

Figure 2 - Typical Arrangement for Single Stage Hydrocracking Units without Intermediate Gas Separation

Normally, for feed streams with low nitrogen content where the objective is to produce middle distillates (diesel and kerosene), the configuration with two reaction stages without intermediate gas separation is the most common. This configuration is showed in Figure 3.

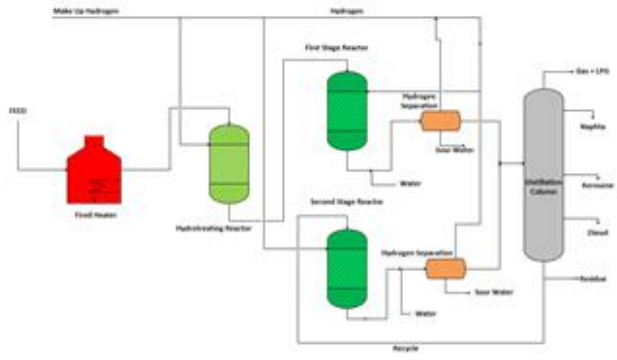

Figure 3 – Typical Arrangement for Two Stage Hydrocracking Units without Intermediate Gas Separation

Like aforementioned, the disadvantage, in this case, is the high concentration of ammonia and H_2S in the hydrocracking reactors, which reduces the catalyst activity.

The higher costly units are the plants with double stages and intermediate gas separation. These units are employed when the feed stream has high contaminant content (mainly nitrogen) and the refinery looks for the total conversion (to produce middle distillates), this configuration is presented in Figure 4.

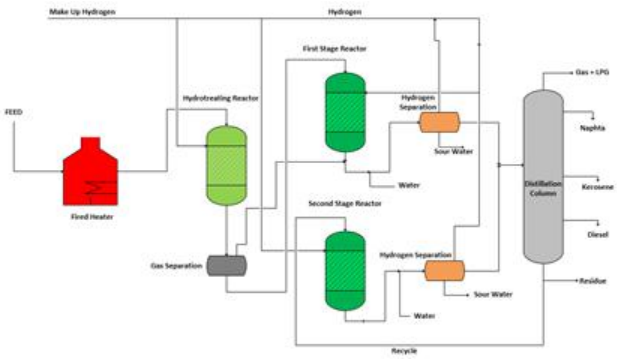

Figure 4 – Typical Arrangement for Two Stage Hydrocracking Units with Intermediate Gas Separation

In this case, the catalytic deactivation process is minimized by the reduction in the NH_3 and H_2S concentration in the hydrocracking reactor.

Like cited earlier, the hydrocracking units demand high capital investments, mainly to operate under high hydrogen partial pressures, it's necessary to install larger hydrogen production units, which is another high costly process. However, face of the crescent demand for high-quality derivates, the investment can be economically attractive.

The Residue Hydrocracking Units have severity even greater than units dedicated to treating lighter feed streams (gas oils). These units aim to improve the residues quality either by reducing the contaminant content (mainly metals) like an upstream step to other processes, as

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Residue Fluid Catalytic Cracking (RFCC) or to produce derivates like fuel oil with low sulfur content.

Residue hydrocracking demand even greater capital investment than gas oils hydrocrackers because these units operate under more severe conditions and furthermore, the operational costs are so higher, mainly due to the high hydrogen consumption and the frequent catalyst replacement.

Available Technologies

Hydrocracking technologies have been widely studied over the years, mainly by countries with large heavy oil reserves like Mexico and Venezuela. The main difference between the available technologies is the reactor characteristics.

Among the hydrocracking Technologies which applies fixed bed reactors, it can be highlighted the RHU technology, licensed by Shell company, Hyvahl technology developed by Axens and the UnionFining Process, developed by UOP. These processes normally operate with low conversion rates with temperatures higher than 400°C and pressures above 150 bar.

Technologies that use ebullated bed reactors and continuum catalyst replacement allow higher campaign period and higher conversion rates, among these technologies the most known are the H-Oil technology developed by Axens and the LC-Fining Process by Chevron-Lummus. These reactors operate at temperatures above of 450 °C and pressures until 250 bar.

An improvement in relation of ebullated bed technologies is the slurry phase reactors, which can achieve conversions higher than 95 %. In this case, the main available technologies are the HDH process (Hydrocracking-Distillation-Hydrotreatment), developed by PDVSA-Intevep, VEBA-Combicracking Process (VCC) developed by VEBA oil and the EST process (Eni Slurry Technology) developed by Italian state oil company ENI.

Conclusion

Despite the high capital investment and the high operational cost, hydrocracking Technologies produces high-quality derivates and can make feasible the production of added value product from residues, which is extremely attractive, mainly for countries that have difficult access to light oils with low contaminants.

In countries, with a high dependency of middle distillates like Brazil (because his dimensions and the high dependency for road transport), the high-quality middle distillate production from oils with high nitrogen content, indicate that the hydrocracking technology can be a good way to reduce the external dependency of these products.

Biography

Over 8 years experience in project management and Process Engineering. Experienced in downstream projects/programs implementation for the oil industry. Passionate for oil refining technologies and to learn more and more. Always available to talk about new good opportunities.

Bachelor in Chemical Engineering - UEM, Master in Process Engineering - UNICAMP, Doctor in Chemical Engineering - UNICAMP, MBA in Project Management - UFRJ, Specialist in Business Administration - FGV.

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Best Practices for Verification of Overpressure Scenarios

WIM VAN WASSENHOVE, BPT VP Software Development

Overpressure protection covers the integrity of inflow into the well, pipelines, risers, inlet arrangements, separators, primary and secondary safety systems including the flare system. This is the most critical safety aspect of any upstream oil and gas installation. BPT has executed over fifty overpressure protection studies and we have seen multiple examples where the overpressure protection analysis was based on PSV capacity calculations not in agreement with API Std 520 /2/. In many cases, it requires linking a multiphase simulation tool to a transient process simulator to capture the highly transient loads from a realistic "worst case normal operating condition". Will you be able to confidently state that best practice methods have been used when an incident happens? Below is what we consider to be the best practices. We do not keep this to ourselves, we are open to train your engineers and to supply the tools needed to do the studies yourselves or have them done by your contractor.

About BPT

As an independent third party service provider since 1998, BPT mainly specializes in performing verifications for the operator companies. Since 2007, BPT has developed a specialized overpressure protection service whereby transient flow assurance and engineering simulators are used interlinked. To date some 50 design and verification studies have been executed. The service has been provided to the major operators on the Norwegian and UK continental shelf; see Appendix A for a list of references.

BPT has over the years identified improvement to the standard software applications to effectively execute these studies. We have therefore developed software bridging the technologies and complementing their capabilities. These additional programs are commercially available globally and to all participants in the process and energy industries. For overpressure protection efforts, we specifically use BPT-OLX®, BPT-PSX™ , BPT-FSG™ and BPT-EXT™ alongside a transient process simulator and a transient flow assurance simulator.

We believe we are providing the best available technology and methods by integrating a transient process simulator and a transient flow assurance simulator and by using software such as the BPT-

PSX™ for PSV rating calculations, which fully complies with the pressure relief requirements of API Standard 520 9ed. The high fidelity of our methodology allows for study conclusions that fulfil all the requirements for overpressure protection whilst maintaining a maximal production utilization of the facility.

Best practices for verification of overpressure scenarios

BPT refers to state of the art process safety methods and the underlying international standard API Std 521/1 /. We specifically refer to the overpressure scenarios "choke collapse" and "inadvertent valve opening" as described in chapters 4.4.8.6 and 4.4.9.2 of that standard. Our methods adhere to the standard and use accepted technology to obtain an as realistic as possible simulation of this type of incidents

Key benefits are:

From experience, an integrated work methodology provides significant time savings. The integrated approach eliminates the need for extensive use of a time and labour-intensive iterative work processes needed to compensate for the lack of functionality and rigour of existing tools. The integrated prediction tool using the BPT software resembles the physical plant on a one-to-on at piping isometric level. This is making documentation and reporting easy to produce as well as understand.

Our experience also shows that previous overpressure protection studies based on either steady state consideration only or flow assurance tools only may contain "hidden" plant integrity limitations due to the simplifications made in these types of studies.

Modelling Aspect	Steady State	FA(*) tool	Linked FA(*) & Process model
Prediction of slug phenomena	-	+++	+++
Integrated approach; "forced" coupling of multiphase and process diciplines	-	+	+++
Account for volume accumulation	-	++	+++
Dynamic response from other flowlines/feeds	-	++	+++
Prediction of separator performance	-	+	+++
Prediction of PSV capacity	-	+	+++
Dynamic response from flare system and other downstream systems	-	+	+++
User friendliness with regard to interpretation of process results	+	+	+++
HIPPS Solutions	-	+	+++
Primary Safety Protection requirements	-	+	+++

(*) FA = Flow Assurance

Our methodology relies on:

Model tools that are rigorous and offer the possibility of one-to-one representation of all the elements, including wells, pipelines, risers, topside piping, block/wing/master valves, choke valves, control valves, by-pass valves, safety valves, blowdown restrictions, separators, flare, flare knock out drums, flare tip, as well as PSD and control system details. This means that the various elements are modelled rigorously and with considerably fewer or no use of simplifications. Every single item in our work methodology and tools used, can be verified against the acceptance criteria and provide full traceability.

For multiphase flow in wells, pipelines and risers we use globally recognized multiphase simulation software (OLGA® from Schlumberger)

For topside processing equipment / facility we use recognized process simulation software (Aspen HYSYS Dynamics®, Aspen Flare System Analyzer®). BPT-OLX® is used to link the transient multiphase simulation software tool with the transient process simulation software

- Topside piping is calculated in accordance with detailed isometrics. The piping upstream and downstream safety valves can be modelled per "as-built" piping and segments can be documented individually.

- Safety valves are calculated per as-built data using the calculation methodology described in underlying international standard API Std 520 /2/ (BPT-PSX™ unit operation available for HYSYS, UniSim and Petro-SIM).

- The flare system is calculated with tail pipes, manifold, header pipes per piping isometrics, flare knock out drum, flare stack and flare tip in the transient model. This enables to model transient behaviour from "well to flare tip". Subsequent verification is performed using the results from the transient simulations in a "steady state" design tool like Aspen Flare System Analyzer, based on rates and fluid compositions from the different sources defined by the transient model. BPT-FSG™ (Flare Scenario Generator) is one of the BPT Apps which

automatically capture the individual relief rates allowing workflow integration with the flare design tools such as the Aspen Flare System Analyzer. Although current dynamic simulators lack the ability to represent the velocity/pressure correctly, an automatic dynamic flare model builder is part of our BPT-EXT solution. This functionality transfers the Aspen Flare System Analyzer topology into a dynamic HYSYS flare network model.

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Example applications

Choke sizing, a multidiscipline collaboration taskMany parties are involved in the sizing of the choke valve.

—Reservoir Engineers: they have a say in the desired depletion rate of the reservoir

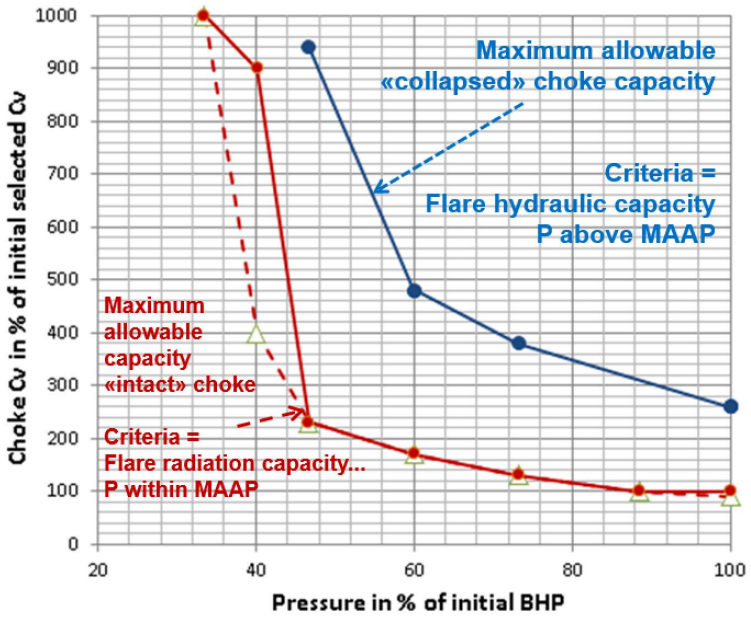
—Flow Assurance: flow through the choke valve needs to flow nicely in the flow lines

—Process: flow needs to be process-able into products that satisfy the product specs

—Process Safety: a choke valve incident should not put the plant in danger

—Choke valve supplier: requested choke valve may not exactly match the supplied one

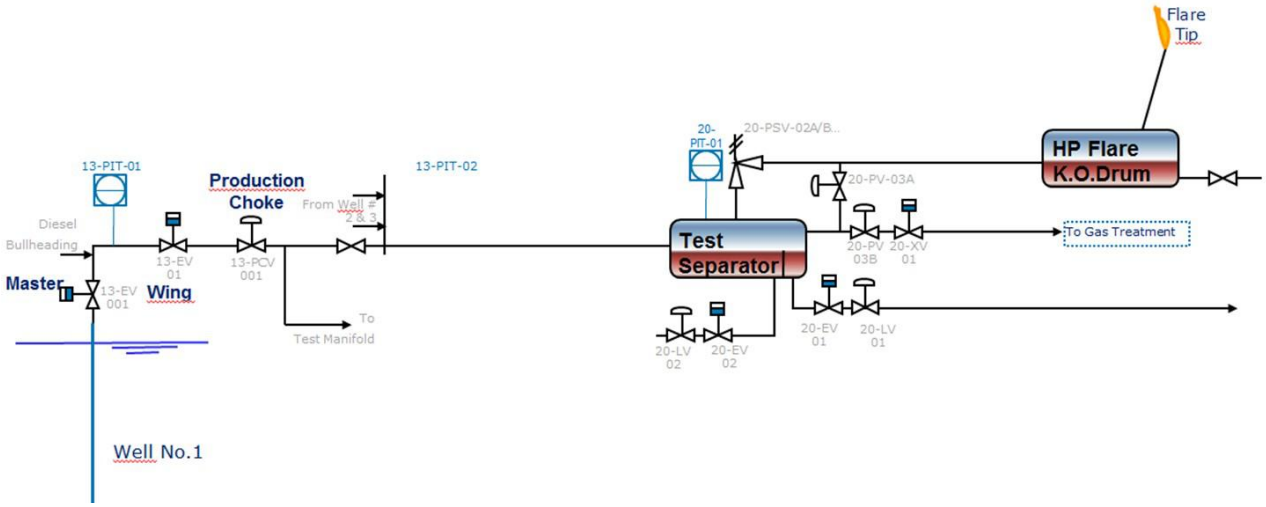
The production strategy would like to dictate a maximum choke Cv and control reservoir depletion by manipulating the choke valve opening. The task of the team is to find the maximum allowable choke capacities across the field life. They are shown in a graph as a function of declining Bottom Hole Pressure (BHP).



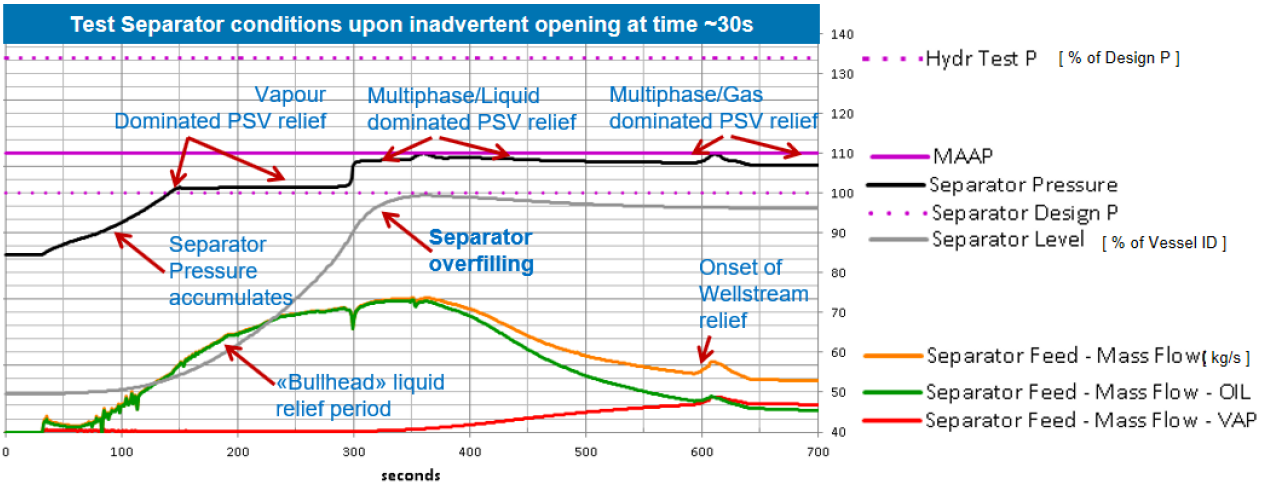
Dimensioning scenarios are often the inadvertent valve opening of Wing Valve with Choke wide open (first error) and the inadvertent valve opening of Wing Valve with Choke wide open (first error) AND "collapsed". Although this study can be done with a flow assurance tool alone, that approach ignores details concerning the downstream process that cannot be modelled with a flow assurance tool.

Start-up of "Bullheaded" High GOR well

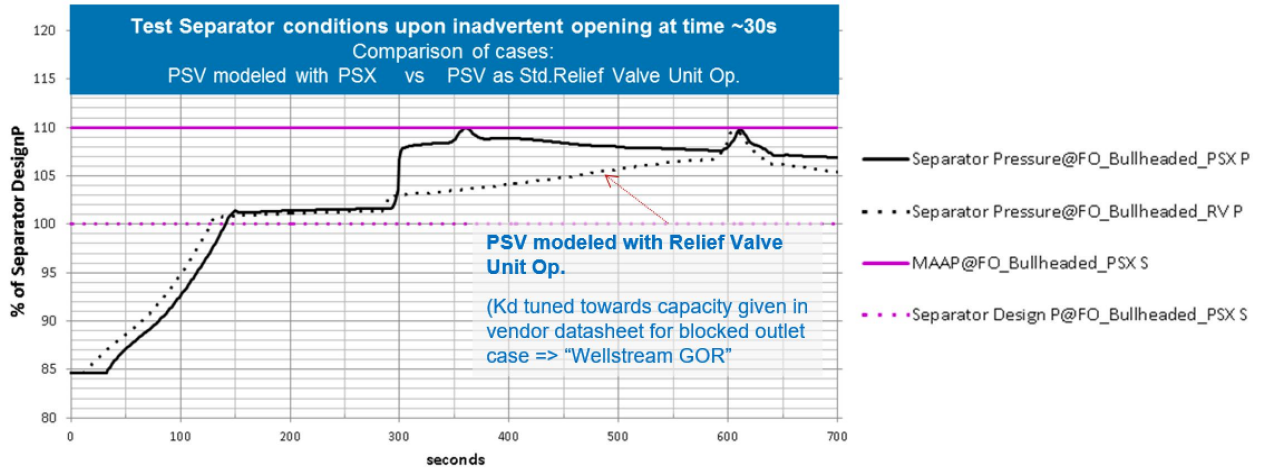
During the start-up of a bullheaded well, diesel is used to fill up the riser to reduce the topside arrival pressure below acceptable limits and to avoid hydrate formation. The incident considers the inadvertent opening of the wing valve while the choke valve is wide open.



The figure below shows the evolution of a series of parameters over time after the incident happened. The key parameter is the separator pressure which should not exceed the MAAWP.



The results obtained using PSX for PSV rating calculations, predict a higher separator pressure from the onset of overfilling than when using the built-in relief valve from the simulator. The difference is due to the more accurate calculation of PSV capacity for multiphase or liquid dominate flow since the derating coefficients are adjusted automatically for each time step based on compositional changes in the inflow.



Conclusions

The use of flow assurance tools linked to dynamic process simulators and the use of more accurate relief valve models clearly makes a difference when assessing overpressure incidents. Higher accuracy translates into safer designs. The high fidelity of this methodology allows for study conclusions that fulfil all the requirements for overpressure protection whilst maintaining a maximal production utilization of the facility. This reduces CAPEX and OPEX for field development and tie-back projects.

Ref / 1 / API STD 521 - Pressure Relieving and Depressuring Systems - (6th Edition, January 2014)

Ref / 2 / API STD 520 Part I - Sizing, Selection, and Installation of Pressure-relieving Devices - Sizing and selection - (9th Edition July 2014)

Biography

As VP of Software Development Wim heads up the development of software solutions for BPT. Wim joined BPT after 20 years at Hyprotech / AspenTech where he was initially the Hyprotech agent for Benelux and France. Later he took the role of Business Consultant for the HYSYS suite of products with a strong focus on helping users and prospective users to find a solution to their problem. With over 20 years experience in the Oil & Gas industry Wim has a thorough understanding of what engineers are struggling with every day and how to make their life easier. Prior to AspenTech Wim worked at Solvay as a Process Engineer. Wim holds a Master in Chemical Engineering from the University of Gent Belgium and is fluent in English French Dutch and German.

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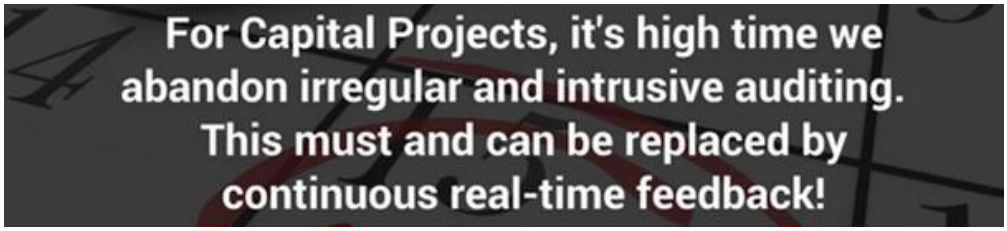
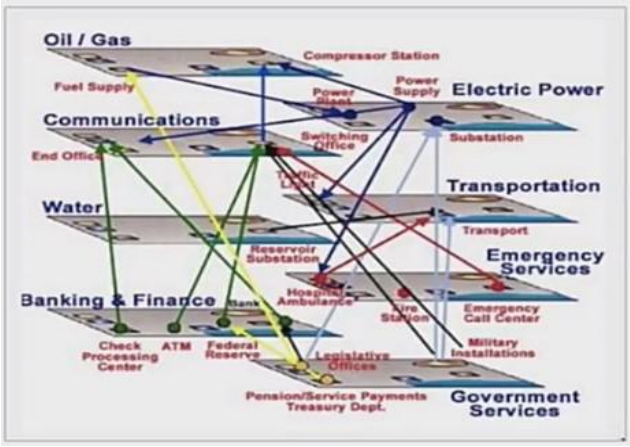
Resolving the Megaproject Paradox

John Noonan
Complex Organisation and Megaprojects Change Agent | Author of "The Megaproject Paradox"



Owners of Megaprojects invest US$ Billions in the Preparation Phase of the Megaproject Life Cycle. This investment is designed to secure expert estimates about predictable simultaneous Schedule and Cost of Execution or Construction for Final Investment Decision. Paradoxically, these estimates and predictions are almost always wrong. The consequence is NPV losses measured in the US$ Billions. The Megaproject Paradox articles identify a simple method to turn massive NPV losses into massive NPV Profits.

Megaprojects are typically the largest of Capital Projects in all industry disciplines. Megaprojects form infrastructure foundations and intricate infrastructure links that traverse all aspects of life in the modern world. Megaprojects are defined by their type and the complexity associated with many different factors that make up a Megaproject across its "*Life Cycle*".



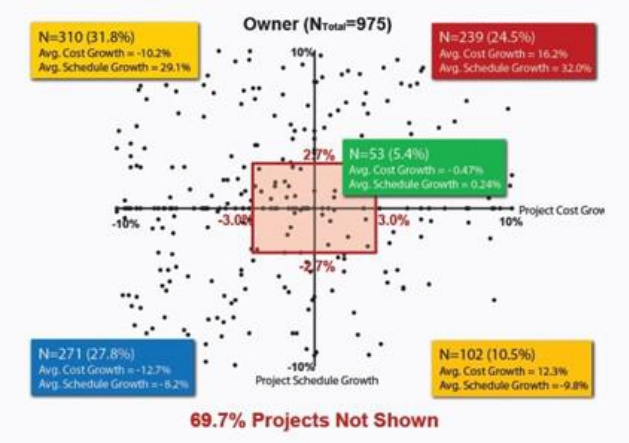
The "*Megaproject Paradox*" articles introduce the counter intuitive Paradox, explore the consequences of the Paradox across three key Phases of the Megaproject "*Life Cycle*", and propose a simple solution to resolve the Paradox. People are notoriously bad at making predictions or giving estimates, even expert professionals who are paid to make such estimates across the Megaproject "*Life Cycle*". When complexity involved in an estimate increases, predictability gets tougher and accuracy suffers. Inaccurate estimates lead to lack of predictability and consequential NPV losses measured in the US$ Billions in three key Phases of the "*Life Cycle*". The "*Megaproject Paradox*" articles introduce a simple method, the "*Noonan Method for Megaproject Risk Mitigation*", for identifying and avoiding or

negotiating and overcoming the Paradox wherever it occurs across the three "*Life Cycle*" Phases.

What is the Paradox?

Megaprojects valued in the US$ Deca-Billion and above range, are only attempted by the most experienced, wealthiest "*Owners*" usually in Joint Venture or appropriate other contracted teams. "*Owners*" employ the most experienced non-owner supply chain in each of the three key Phases, (i) Preparation, (ii) Execution or Construction and (iii) Asset Management or Operations and Maintenance. The teams employed in each Megaproject "*Life Cycle*" Phase are required to achieve appropriate deliverable outcomes during and at the end of each Phase.

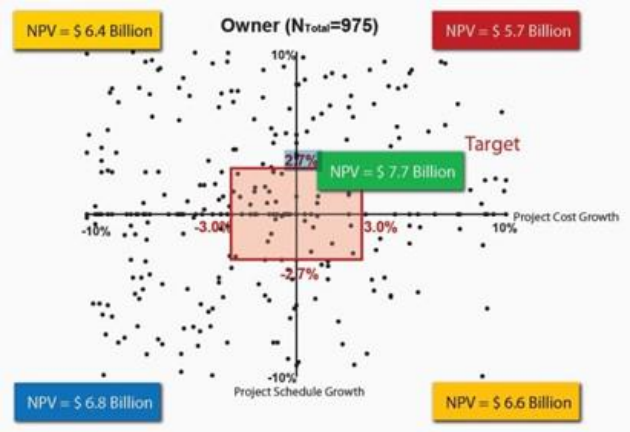
Typically the most complex and least predictable Phase of the Megaproject "*Life Cycle*" is the Execution or Construction Phase. The Execution or Construction Phase is broadly highlighted by the Project Procurement, Construction and Hook-up and Commissioning stage gates in the diagram above. To prepare appropriately for Megaproject Execution or Construction, "*Owners*" invest significant time and sums of money in the Preparation Phase of the "*Life Cycle*". The Preparation Phase is identified by the Project Definition and Engineering Design stage gates in the diagram above. Investment in the Preparation Phase is at times measured in US$ Billions over a period lasting decades. The objective of the Preparation Phase is to produce accurate estimates of "*predictable simultaneous achievement of Megaproject Cost and Megaproject Schedule*" in the Execution or Construction Phase to enable the "*Owner*" to achieve Final Investment Decision (FID). Only after FID is achieved, can a Megaproject proceed to the Execution or Construction Phase of the "*Life Cycle*".



The CII 2012 Performance Assessment Report identifies 95% of Megaprojects missed the Execution Phase predictability level required by "*Owner's*" estimates at FID. The predicted accuracy of Preparation Phase estimates required by "*Owners*" is bounded by the pink bulls-eye on the CII chart. The bulls-eye is bounded by limits of +/-2.7% for Project Schedule Growth and +/-3% for Project Cost Growth.

The Paradox is defined by the 95% lack of predictability for Megaprojects to hit the pink bulls-eye in the CII chart. If the biggest and best Megaproject "*Owners*" in the world, are armed with the biggest budgets in the world, and given lengthy "*Life Cycles*" sometimes measured in decades or even in centuries, why do 95% of

Megaprojects miss predicted FID estimates in the Execution Phase? The consequence of missing the pink bulls-eye in the CII graph is NPV losses for the "*Owner*" measured in the US$ Billions.



There are four modes of Execution Phase failure making up the Paradox, the failed 95% of the 975 Megaprojects in the CII chart, as follows:

1. Simultaneous over Budget and over Schedule 24.5% (Most people expect all failed Projects end here, but not so)
2. Simultaneous over Budget and on or under Schedule 10.5% (Schedule Driven Projects)
3. Simultaneous on or under Budget and over Schedule 31.8% (Cost Driven Projects)

Simultaneous under Budget and under Schedule 27.8% (Counter intuitively these Projects too are considered failures)

Each of these modes of failure incurs NPV losses for the "*Owner*". The CII 2012 Performance Assessment Report provides a detailed analysis of the consequences of the "*Megaproject Paradox*" occurring in the Execution Phase for 975 different Megaprojects. However, the "*Megaproject Paradox*" may occur in any of the three key Phases of a Mega project "*Life Cycle*", including (i) Preparation Phase, (ii) Execution Phase and (iii) Asset Management or Operations and Maintenance Phase. The consequences of the Paradox are similar in the Preparation and Execution Phases, and even more severe in the Asset Management or Operations and Maintenance Phase.

Most "*Megaproject Paradox*" articles explore consequences of poor FID estimates when the Paradox arises in the Execution Phase of the "*Life Cycle*". Consequences of the "*Megaproject Paradox*" in the Asset Management or Operations and Maintenance Phase of the "*Life Cycle*" are more severe than in the Execution or Preparation Phases. Severity of "*Megaproject Paradox*" consequences in the Preparation Phase are a similar order of magnitude NPV losses to the Execution Phase.

Why the Paradox? Managing Execution or Construction Phase Complexity

Managing simultaneous achievement of Megaproject Execution or Construction Phase "*Cost*" and Schedule is a complex task. Expecting Preparation Phase Teams to estimate predictable Management in the Execution Phase is even more complex. Management of key factors include (i) Execution "*Strategy*", (ii) "*Scope Complexity*", (iii) the complicated nature of the "*Contract*" binding the "*Owner*" to the Non Owner Supply Chain and Contract operation across the Megaproject Execution Phase of the "*Life Cycle*", (iv) the size, "*Culture*", "*Structure*" and "*Behaviour*" of the "*Organisation*" involved in the

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Execution Phase, (v) the "*Geolocation*" of the "*Organisation*" used in the Execution Phase, and (vi) managing the combined Financial and Engineering "*Risk*" associated with historical poor performance of Global Megaprojects in the Execution Phase of the Megaproject "*Life Cycle*".

Mitigating "*Risk*" of poor performance in the Execution Phase of a Megaproject's "*Life Cycle*" requires financial backers to make careful preparations of their own. Financial backers require that Megaproject "*Owners*" are appropriately contracted consortia of Government and/or Private Owner "*Organisations*" capable of carrying the "*Risk*" of poor performance in the Execution Phase of the "*Life Cycle*". This introduces a level of "*Contract*" complexity at the "*Owner*" level. Financial backers of Megaprojects understand that most Megaprojects historically fail to achieve the "*Owner's*" objectives in the Execution Phase of the "*Life Cycle*". "*Owner*" expectations and requirements often change during the Execution Phase. For example, the "*Owner*" JV Team often evolves and changes formation through ownership JVP shareholding sales or acquisitions and mergers of JVP companies during the Execution Phase. This may result in "*Strategy*" change for the Megaproject during the Execution Phase.

The complexity of the management task in the Execution Phase commences its evolution in the Preparation Phase of the "*Life Cycle*". The "*Owner*" team has historically struggled to find an appropriate method in the Preparation Phase of the Megaproject to make its estimates for FID more predictable.

The "*Noonan Method*" is proposed to resolve the Paradox.

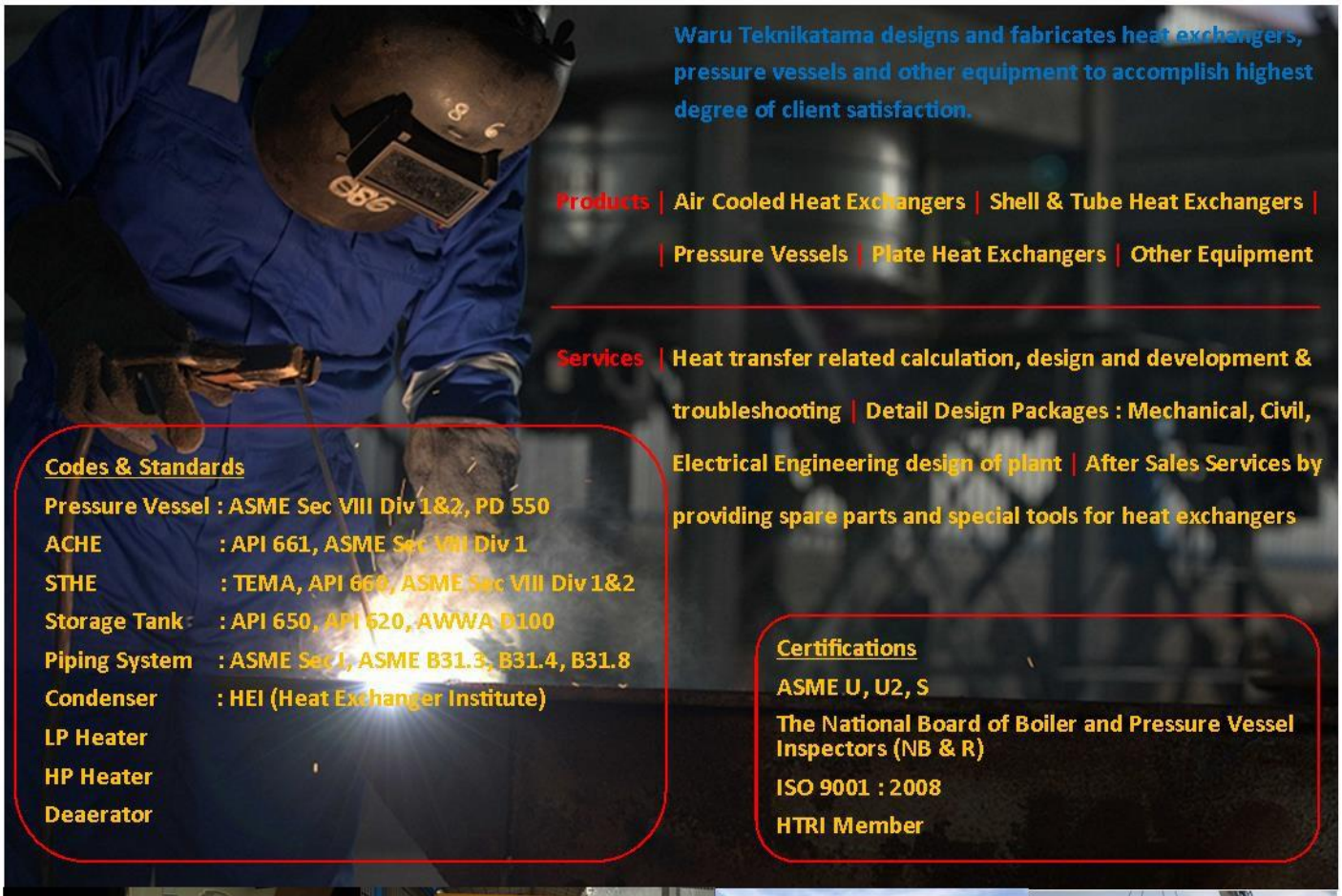
Resolving the Paradox

A new and simple method for dealing with the "*Megaproject Paradox*", the "*Noonan Method for Megaproject Risk Mitigation*" The "*Noonan Method*" identifies 12 generic factors impacting complexity in Megaprojects, independent of Megaproject type. The 12 factors define eight "*Noonan Megaproject Descriptive Parameters*" or "*Horizontal Parameters*" and four "*Noonan Megaproject Rule Parameters*" or "*Vertical Parameters*". The parameters are used as input to Monte Carlo based Design, Modelling, Simulation, Analysis and Verification tools. Using the 12 "*Noonan Parameters*" a Digital Twin Model of the Megaproject "*Organisation*" can be developed.

The Digital Twin "*Organisation*" Model is used as a tool to provide 20/20 Foresight scenario planning of "*Organisation*" development across the Megaproject "*Life Cycle*". The Digital Twin Model of the "*Organisation*" is designed to mitigate the "*Risk*" of managing Megaproject complexity. The Digital Twin "*Organisation*" Model empowers Megaproject "*Owners*" to capture 20/20 Hindsight Lessons Learned and integrate them into the "*Organisation*" Model. Scenario planning of "*Organisation*" development can then identify undesirable consequences of inappropriate estimates in advance so that the "*Megaproject Paradox*" can be avoided and not repeated during "*Organisation*" deployment and engagement.

PT. WARU TEKNIKATAMA

HEAT TRANSFER TECHNOLOGY



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The "*Noonan Method*" proposes a Digital Twin "*Organisation*" Model as a living tool, that must be kept synchronised with the Megaproject "*Organisation*" as it evolves across each of the three key Phases of the Megaproject "*Life Cycle*". As a Megaproject Transitions through the stage gates between Phases of its "*Life Cycle*", the Transition Team must make sure that the Digital Twin "*Organisation*" Model is current and complete to the end of the previous stage, and ready for the next stage in the "*Life Cycle*".

The "*Organisation*" Model is a new artifact that must be a part of the transition package throughout the Megaproject "*Life Cycle*"

The "*Noonan Method*" presents a simple and innovative way of moving predictable Megaproject Execution from the current 5% towards 100%. The "*Noonan Method*" empowers "*Owners*" to specifically deal with Megaproject complexity in a structured way and focus on avoiding or overcoming the "*Megaproject Paradox*" and hitting the pink bulls-eye in the CII chart every time.

Noonan Descriptive or Horizontal Parameters

1. OWNERSHIP
2. LIFE CYCLE
3. COST
4. SCOPE COMPLEXITY
5. CONTRACT
6. ORGANISATION
7. GEOGRAPHIC LOCATION
8. RISK

Noonan Rule or Vertical Parameters

1. STRATEGY
2. CULTURE
3. STRUCTURE
4. BEHAVIOUR

Conclusion

Megaproject Return on Investment (ROI) reflects the complex nature of the scale of investment in the Execution Phase of a Megaproject's "*Life Cycle*". Typically in the Execution Phase of the "*Life Cycle*" Megaproject "*Cost*" is measured in the US$ Billion or US$ Deca-Billion range. The most complex Megaprojects in 2017 have budgets in excess of US$1 Trillion.. Consequences of not managing "*Megaproject Paradox*" issues are NPV losses for the "*Owner*" measured in US$ Billions in the Preparation and Execution Phases. NPV losses in the Operations and Maintenance or Asset Management Phase are even greater. Execution of Megaprojects therefore are only ever attempted by the biggest, best funded Private and Government "*Owners*" globally.

Massive investment is made in the Preparation Phase of Megaprojects around the globe by the biggest, best funded, most experienced Megaproject "*Owner*" and Non-owner supply chains. Despite this investment, 95% of Megaprojects miss the bulls-eye of "*predictable simultaneous achievement of Megaproject Cost and Megaproject Schedule*" in the Execution Phase.

Companies such as IPA, CII, McKinsey, PWC, KPMG, Ernst and Young, and Deloitte Touche Tomhatsu among others, develop and employ well documented "*Man in the Loop*" Auditing techniques in an effort to deal with Megaproject Management. These traditional "*Man in the Loop*" methods of auditing and managing

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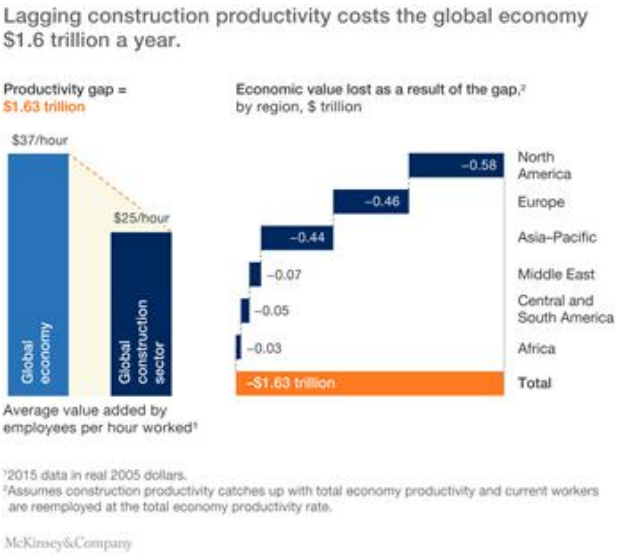
Megaprojects have proven only that expert professionals are notoriously bad at estimates. The fact that 95% of Megaprojects miss the pink bulls-eye identified by CII, defines the "*Megaproject Paradox*". Despite massive investment in the Preparation Phase, and the most extensive due diligence behind "*Owner*" FID, the "*Megaproject Paradox*" is alive and well.



The Megaproject Paradox is alive and well

The "*Megaproject Paradox*" series of articles uses detailed statistical evidence to define the counter intuitive Paradox that exists with Megaprojects. The articles explore a Big Data Method using Digital Twin Modeling of Megaproject "*Organisation*". The refined use of a Digital Twin Model of "*Organisation*" is fundamental for "*Owners*" to manage Megaproject Complexity across the "*Life Cycle*". The Digital Twin Model captures 20/20 Hindsight "*Organisation*" Lessons Learned and integrates them into the Digital Twin Modeling of Megaproject "*Organisation*". The refined use of a Digital Twin Model of "*Organisation*" is fundamental for "*Owners*" to manage Megaproject Complexity across the "*Life Cycle*".

The Digital Twin Model captures 20/20 Hindsight "*Organisation*" Lessons Learned and integrates them into the Digital Twin Model to provide 20/20 Foresight using Scenario Planning to identify and avoid "*Megaproject Paradox*" issues before they occur. The "*Organisation*" Model can also be used for identifying, negotiating and resolving the "*Megaproject Paradox*" should it arise due to Black Swan or other unforeseen and unknown events.

The "*Megaproject Paradox*" series introduce the "*Noonan Method for Megaproject Risk Mitigation*". The "*Noonan Method*" proposes a Digital Twin "*Organisation*" Model as a simple, structured method empowering "*Owners*" to hit the CII bulls-eye and move the needle of successful Megaproject Execution from the current 5% towards 100%. The "*Megaproject Paradox*" series identify a lack of Productivity in Major Capital Projects, and propose a Big Data Resolution to that lack of Productivity. New techniques involving the addition of "*Organisation*" Design, Modelling, Simulation, Analysis and Verification prior to deployment of the "*Organisation*", are the only way to resolve the issue. Acting with a digital mindset and introducing and using agile, real time Big Data to the Major Capital Projects Industry in the Execution or Construction Phase is mandatory for resolving productivity issues. Benefits are also realised in Megaproject Preparation and Asset Management or Operations and Management Phases. Turning around declining productivity across the Megaproject "*Life Cycle*" requires development of a new field of Information Modelling called

Organisation Information Modelling (OIM). Only when OIM is effectively merged with BIM can the "*Megaproject Paradox*" be fully resolved and productivity in Execution/Construction, and more broadly across the whole Major Capital Project "Life Cycle" be restored to appropriate levels.

The "*Noonan Method for Megaproject Risk Mitigation*", "*Noonan Megaproject Parameters*" and "*Megaproject Paradox*" series of articles are copyright of JNC Pty Ltd.

John consults to Mega corporations with deca billion dollar annual revenues or "*Owners*" of deca billion dollar Megaprojects. John speaks publicly and consults to clients dealing with "*Megaproject Paradox*" issues. Typically issues are related to corporate "*Strategy*", "*Culture*", "*Structure*" and "*Behaviour*".

John assists ELT's achieve financial and schedule goals. Some information in the articles is sourced from the CII 2012 Performance Assessment Report, Internet based information including Wikipedia, and News and Television articles. Some references are quoted in the articles, or directly linked to as video or other internet links. Reference information is public domain. "*Noonan Method*" innovation proposes a Digital Twin Model of Megaproject "*Organisation*" for analysis of key issues using scenario planning techniques.

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