ENGINEERING PRACTICE

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SPECIAL FEATURES

Digital Transformation Case Study in the Refining Industry – Building an Agile and Efficient Management System Through Integrated Data

A Quick Estimation Method to Determine Hot Recycle Requirements for Industrial Centrifugal Compressors

Produced Water Treatment Overview

Terrorism? Yea, it's still a thing!

IACPE
INTERNATIONAL ASSOCIATION OF
CERTIFIED PRACTICING ENGINEERS

ENGINEERING PRACTICE

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NETWORKING

IACPE INTERNATIONAL ASSOCIATION OF CERTIFIED PRACTICING ENGINEERS

ABOUT

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

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

HISTORY

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

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

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

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

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

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

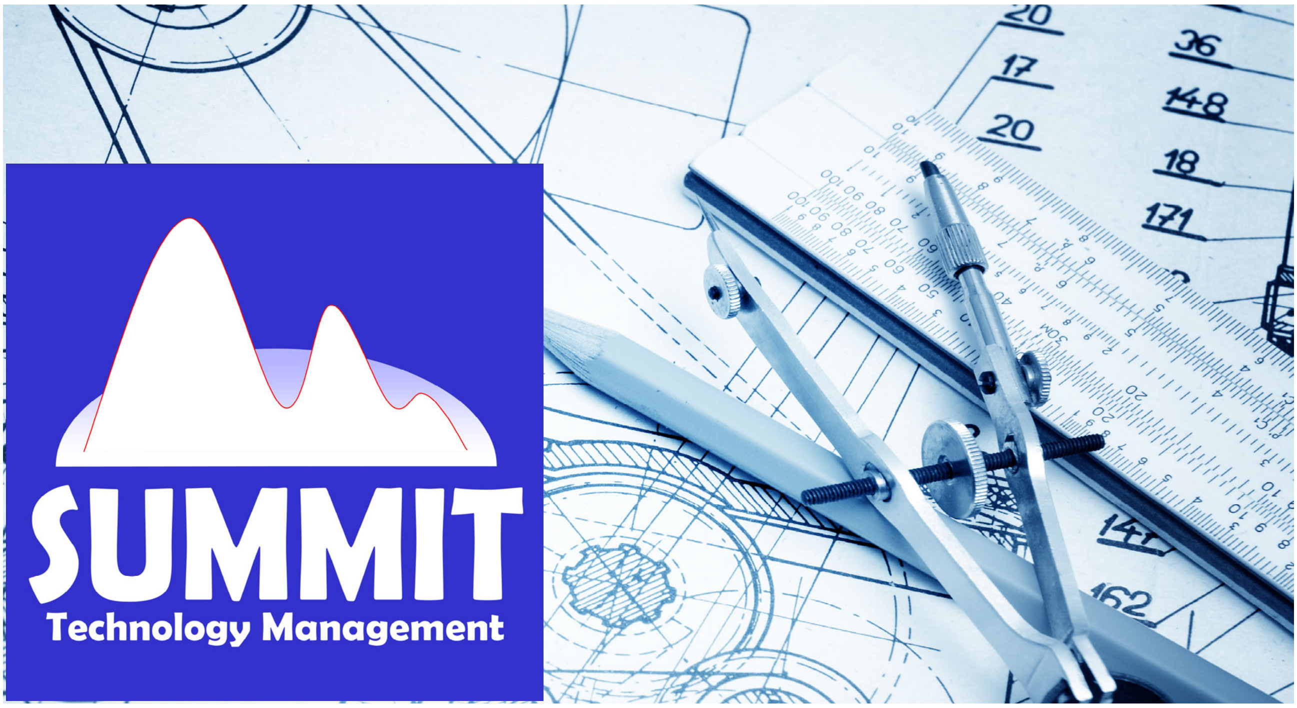
The IACPE took input from industry leaders, academic professors, and students from Indonesia, Malaysia, and the Philippines. The goal was to build an organization that would validate a candidates engineering fundamentals, prove their individuals skills, and enhance their networking ability. We wanted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

MISSION

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

VISION

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



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LETTER FROM THE PRESIDENT

KARL KOLMETZ

"The Odds Do Not Apply To ME"

Dear Friends,

I hope you are doing well. If you are, you have already beaten many of the odds in your life. Your birth, living though childhood and teenage years; you have already beaten many odds of your death. For many of us, how we drove a car or motorcycle as a teenager is proof we may have a guardian angel. In no way were many of us protecting our self.

From this fortunate luck we experienced we happen to be alive; we tend to believe the odds of an event happening to us is actually lower than the probability of the event happening. When we are young, we like to say, "That will not happen to me", because of our history of good luck. As we get older, we understand that the percentages of an event happening actually does apply to us. I spoke to a retired electrical line man and he said he was 40 years old before he began to understand how dangerous his work was. As a young person we have this prism of invincibility - "The Odds Do Not Apply To ME"

One large example of this belief that "The Odds Do Not Apply To Me" is the casino industry. The mathematical odds of winning are less than 2%, yet many people walk into a casino confident they will win. This is alright in a casino since you are not making life and death decisions, but far too many people still take this attitude into other areas of their life. Statistically, the most dangerous thing we do on a daily basis is drive a car. Our prism of invincibility leads to distracted driving, i.e. texting, drinking. And again, this tends to be a larger problem for younger drivers.

At home and on the job, we take unnecessary risk due to our prism of invincibility. We need to make a conscience effort to understand our prism and to take seriously the risk involved in our activities. Best to not depend on your guardian angel forever.

One of the best proactive safety strategies in a chemical plant is a Hazard and Operability Study (HAZOP). But the HAZOP is only as good as the team members. I have been in multiple HAZOPs where a credible event—one with a high probability of occurring—was identified, but the team decided that because it had never happened in this plant it was not a credible event. They were looking through their prism of invincibility. It is very important that we understand our prism when we are a HAZOP Team Member.

Many managers want to send the younger engineers to a HAZOP because it is a great learning tool. I agree HAZOP is a great learning opportunity, but the young engineers do not bring much value to the HAZOP if they have less than five years' experience. It is important to have a mix of senior engineers with the young engineers for multiple reasons:

1. The learning opportunity will be realized if senior engineers are present in the HAZOP to pass along their experience.
2. The senior engineers are starting to understand the prism of invincibility and accept that a credible event may have never happened here, but it is still a credible event and needs to be mitigated.
3. Many young engineers just see the HAZOP as a government requirement and they have the attitude let's just get the HAZOP done. A senior engineer is more likely to see a HAZOP as an opportunity to improve the safety of the plant.

A HAZOP with only young engineers and young operating personnel may be a great HAZOP, but the odds are low. As a manager if you are not putting some of your best senior people in the HAZOP, indirectly you are saying to your staff that you believe HAZOPs are not important and you have the attitude let's just get the HAZOP done.

As a senior engineer there is an amazing difference how I am treated in a HAZOP. In Asia where age is respected; I am treated as a senior advisor that can bring value to a HAZOP. Sometimes in the USA, I am treated as an unnecessary obstacle that is slowing down the HAZOP with an event that has never happened in our plant. I can list multiple examples of each as I have been involved with HAZOPs since 1993.

Example One of a Credible Event
A typical example is a HAZOP for a Plant that had a 75% Ethane Purity Steam in a carbon steel line. I suggested a credible event of low temperature embrittlement, where at low pressure the ethane could be at a lower temperature than the carbon steel metal rating. Carbon Steel is only rated for -20F or -29C. Pure ethane at low pressures can be -128F. Carbon Steel will become breakable like glass below minus 20F.

I was told by a young engineer that this was not a credible event and I was wasting the people's time in the HAZOP. Guess the county where this HAZOP was held? To prove me wrong the young engineer flashed the stream in an engineering program. Then the engineer got very quiet, where before was very argumentative. Finally, the engineer told me the steam flashed at -105F and agreed that this might be a credible event. This was a very good engineer who was blinded by the prism of invincibility and the prism of never happening in our plant. This plant was 30 years old and had been HAZOP-ed many times and this very credible event had been overlooked.

Example Two of a Credible Event
At one HAZOP an actual event happened in the same company at a similar plant and destroyed the plant with an explosion and fire. They were very fortunate that no lives were lost. The HAZOP team decided that the same issue at an adjacent plant was not a credible event and rated the event with low probability and low severity. This was an amazing example of prism blindness. Exact same scenario, just happed in an adjacent similar plant with catastrophic damage, but the team rated the very credible event low probability and low severity.

To have a good HAZOP we must understand our prism and have a list of credible events for our industry and other industries that apply to our unit operation. As a HAZOP Facilitator, I try to build a list of credible events for a particular industry and review the credible events that have happened in the industry before the HAZOP begins.

In addition, we need to understand that a mix of young and senior engineers needs to be present. The best senior engineers I have met have a mix of experience, some off shore, some midstream, some refining, some petrochemicals. If your senior engineer has only seen one industry, they may be great in designing that plant, but they may not be the best person for a HAZOP. This mix of experiences is very important in assessing hazards.

As a manager you may not be getting the full training value if you only send young engineers to your HAZOP. You also need to send some of your best people to the HAZOP to set the tone that the HAZOP is important.

Each of us have many biases and prejudices that we establish when we are young. As we mature, we need to understand our prism and adjust our vision.

All the best in Your Career and Life,
Karl Kolmetz

Digital Transformation Case Study in the Refining Industry – Building an Agile and Efficient Management System Through Integrated Data

Carina Pederiva Laidens e Dr. Marcio Wagner da Silva

Introduction

The expression "Data is the new Oil" had been widely applied in the crude oil transformation industry in the last years, mainly related with the evolution of technological means which allow quick and easy access to data. The compilation of these data and his conversion in integrated information aiming to ensure an agile and efficient decision-making is the focus of the called digital transformation in the scope of 4.0 Industry, the construction and incentive of interactions between teams

driven by two driving forces – One with the focus in to keep the reliability and profitability of the current operations that will sustain the development of planned future and the second with focus in the desired future, thus integrating incremental improvements and disruptive innovation.

Case Study—Henrique Lage Refinery (REVAP)

Henrique Lage Refinery (REVAP) is the third largest refinery in Brazil and is operated by the Brazilian National Oil Company, PETROBRAS. The refinery is capable to process 250.000 barrels of crude oil per day being focused to produce transportation fuels (Diesel, Gasoline, Jet Fuel, etc.), mainly to supply the national market. Figure 1 presents a simplified diagram of the refining scheme adopted by REVAP.

The program dedicated to integration of management and processes data in the refinery starts in 2018 with the objective to create a unique database aiming to initially integrate the data considered relevant by the refinery management areas, in order to convert this data in information and posteriorly in knowledge and, in a last stage in wisdom according to the evolutional cycle presented in Figure 2.

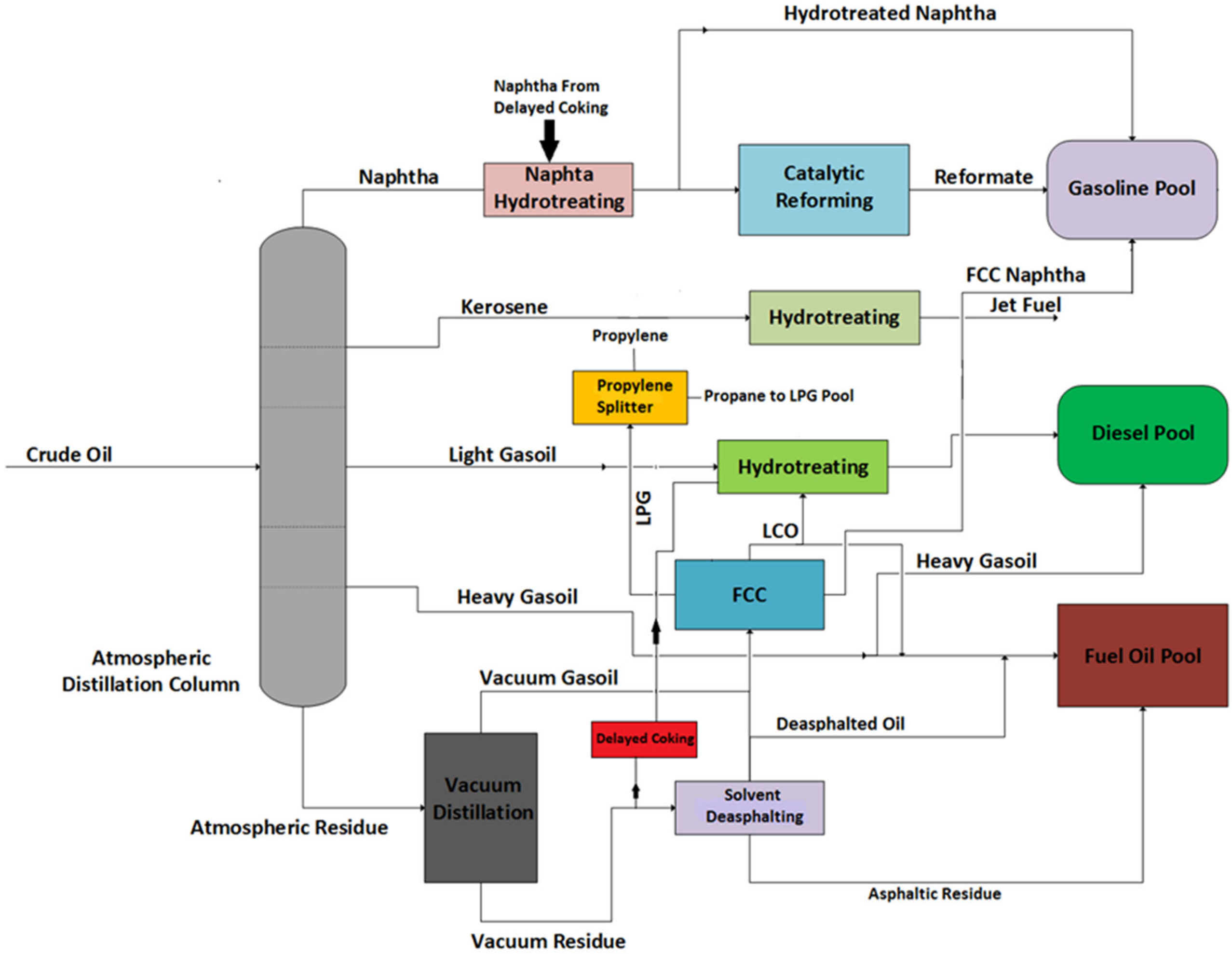

Figure 1 – Refining Scheme of Henrique Lage Refinery (REVAP)

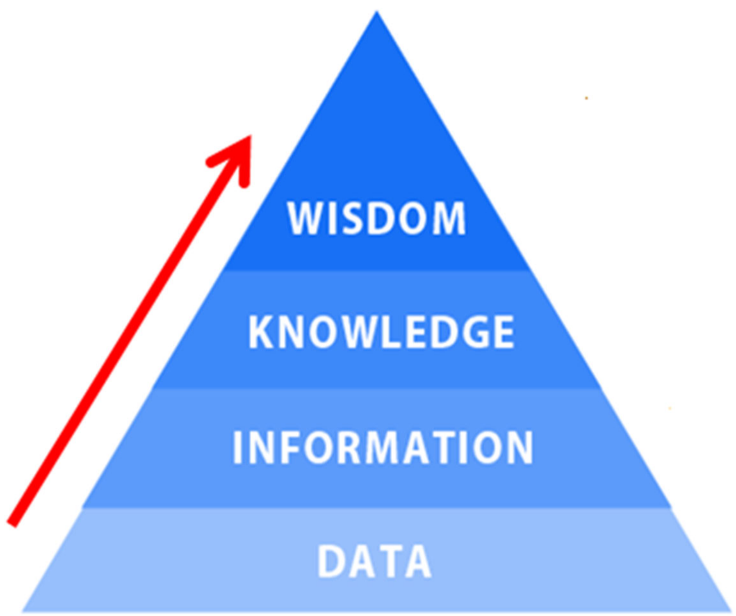

Figure 2 – Evolutionary Cycle of Digital Transformation

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It's important to highlight that the major challenge in the digital transformation is precisely to convert the data into useful information which support an agile and efficient decision-making system. It's a misconception face the digital transformation as purely technologic event, the technology allows the easy and quick access to large quantity of data, however, the real digital transformation consists in the change of mind map in the sense of integrate, make critical analysis, and finally to convert these data into actions that lead to improvement of decision-making process.

Presenting the data in a simple way, with agility of acquisition and space for the insertion of critical analysis, which should be treated as another integrated data, was the great advantage of the project implemented in the REVAP. Furthermore, no new acquisition or monitoring system was used once the refinery already had sufficient database to promote the desired transformation, leading to a reduced implementation cost given that wasn't need to acquire software or licenses. Another premise of the REVAP digital transformation

project was the integration of data from the original base, with the minimum change in the user routine. The data, presented in an integrated and easy reading way, together with the analysis carried out by the technical staff, are transformed in information that lead more clarity to the decision making process by the management staff, always respecting the concept to maintain the integrity of current operations, minimizing losses and developing the bases to the refinery strategic plan.

In the REVAP case, the initial goal was the integration of all opportunities of profitability gain already mapped in the operational routine in the same visualization aiming to achieve that the prioritization decisions of studies, operational maneuvers or maintenance were taken with more assertiveness. Figure 3 presents an example of the data presentation way adopted.

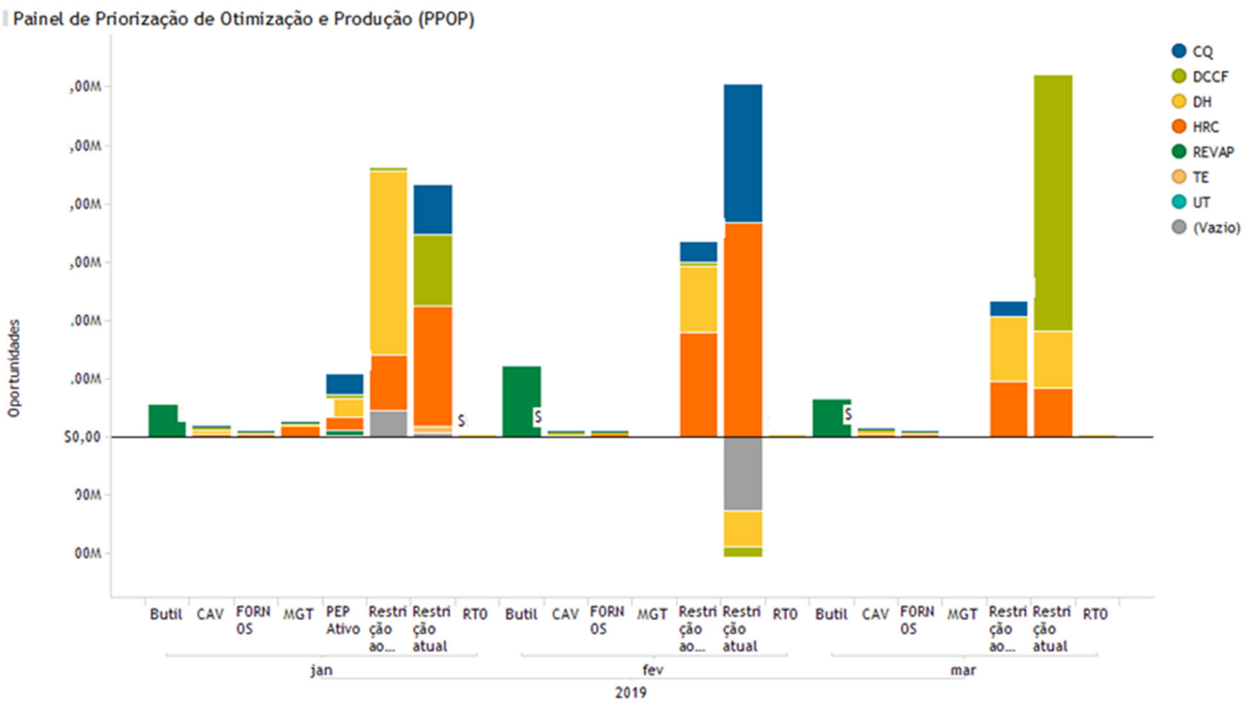

Figure 3 – Data Presentation Example REVAP (Data was suppressed by Information Security)

Through data integration, evaluations that previously were carried out in a isolated manner pass to be carry out in a jointly manner integrating different point of views of the areas of operational support, production and maintenance avoiding distortions in the analysis of strategic matters to the refinery reliability and consequently to the business profitability once focus is given in the actions that ensure higher security and financial results.

The utilization of the commercial software, JIRA™, allow the technical and management staffs carry out and register his analysis and expose the main threats to accomplish some actions, these analyses are treated as data leading to more agility and assertiveness to the decision-making process. Figure 4 shows the management flow adopted in REVAP after the implementation of the digital transformation project.

One of the key questions to achieve the desired results is an adequate asset management system, due to the limitation of maintenance resources, one of the main deliverables of the project is the prioritization of maintenance orders that need be accomplished keeping the focus on add security and profitability to process units. The combination of real-time monitoring of process data and the maintenance prioritization system allow faster identification of inefficiency points and higher agility to the solution, adding value to the business.

The main objective of the asset management in the scope of 4.0 Industry is to reach the concept of prescriptive maintenance, as presented in Figure 5.

The concept of prescriptive maintenance involves process and equipment analyzes in order to anticipate failure, minimizing

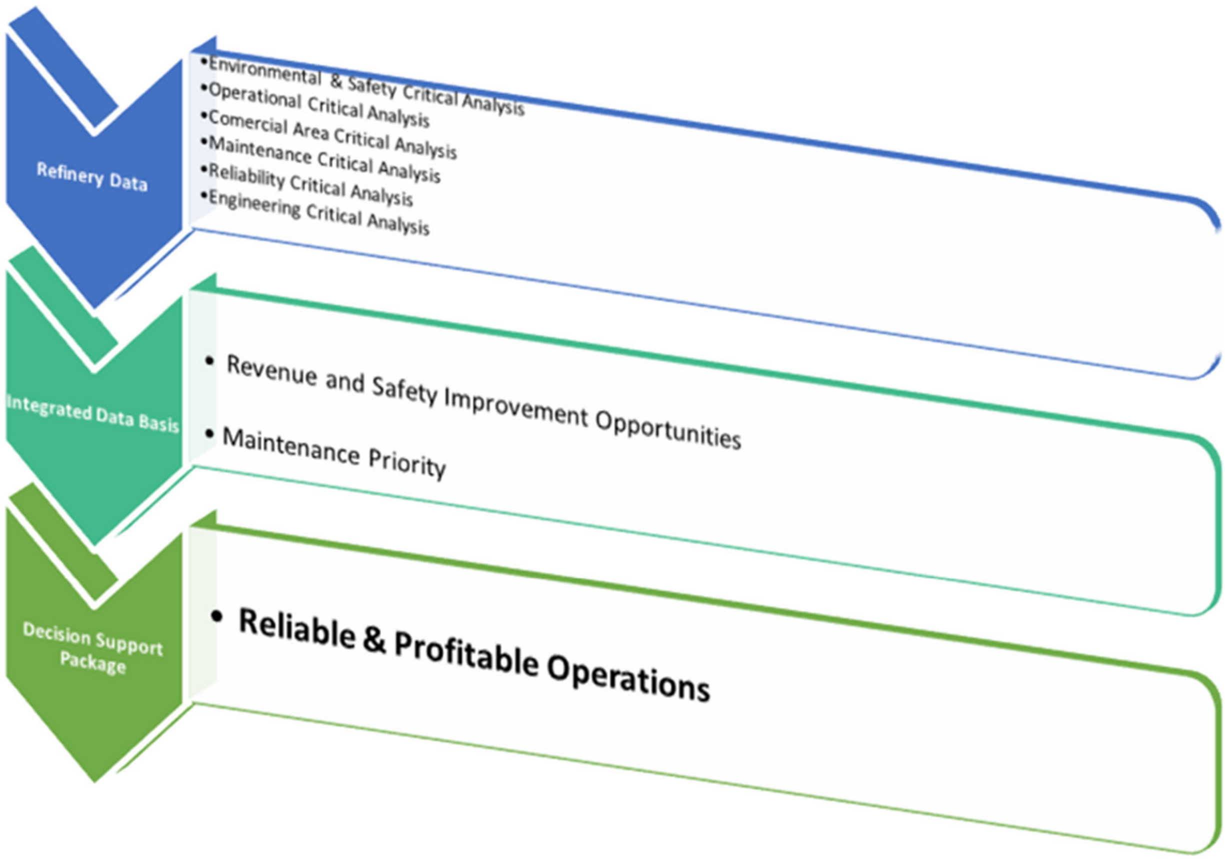

Figure 4 – Decision Flow adopted at REVAP after the Implementation of the Digital Transformation Project

production losses due to profit losses or inefficiencies. The implementation of prescriptive maintenance is a future step in the digital transformation program in Henrique Lage Refinery.

Conclusion

The implementation of digital transformation in the Henrique Lage Refinery (REVAP) is still in an initial stage, however, the adequate data exposure favored the creation of a more agile and effective decision-making process allowing ensuring safe, reliable and profitable operations, adding value to the refinery processes and better compliance with the production planning. It's important to highlight that not were produced new data during the project implementation, however, was adopted actions aiming higher integration and critical analysis of the existent data, ensuring higher information quality needed to better decisions.

As aforementioned, the main challenge in the digital transformation in the refining industry, that is a the consolidated industry, is the transformation of mind model of technical and management staffs to ensure an integrated and effective data analysis against punctual visions and interpretations, to achieve this is necessary transparency, clarity and quality in the data analysis. In the REVAP case, the great advances in the available data quality allowed the improvement in the information flow between management areas creating a decision package robust and reliable, allowing more agile and assertive decisions.

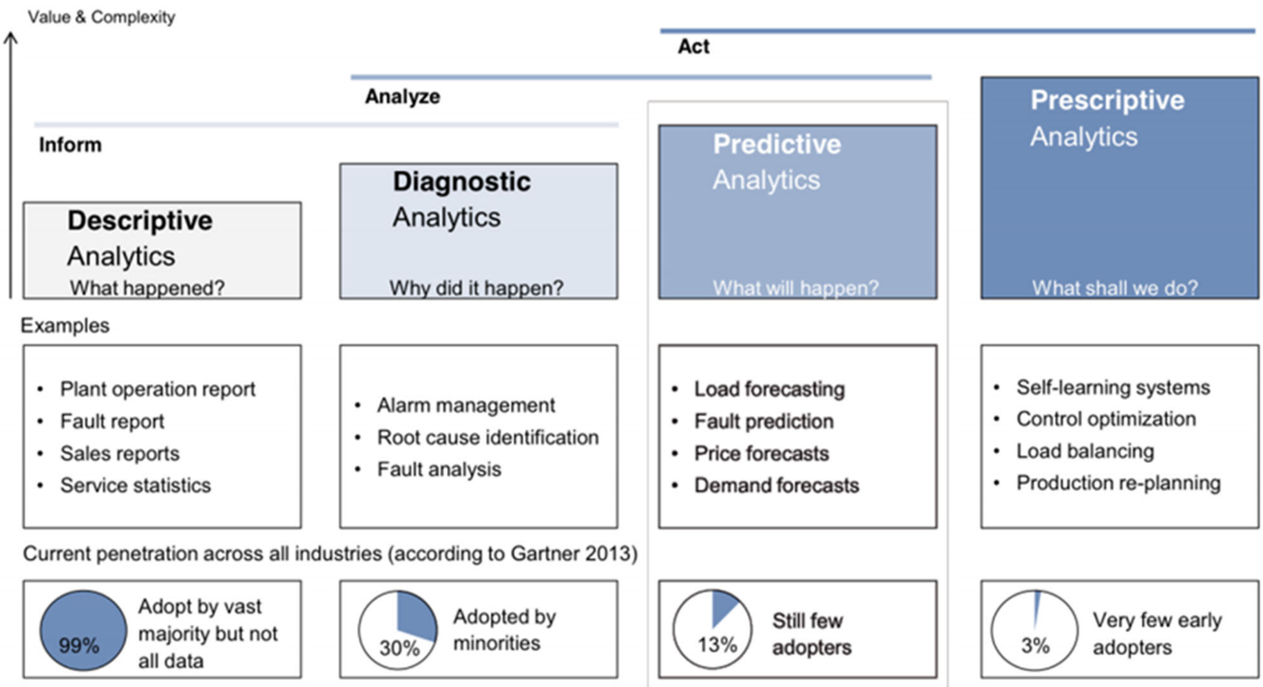

Figure 5 – Evolution of Asset Management System (MindIT Company, 2018)

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About the Authors

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Dr. Marcio Wagner da Silva is Process Engineer and Project Manager focusing on Crude Oil Refining Industry based in São José dos Campos, Brazil. Bachelor in Chemical Engineering from University of Maringa (UEM), Brazil and PhD. in Chemical Engineering from University of Campinas (UNICAMP), Brazil. Has extensive experience in research, design and construction to oil and gas industry including developing and coordinating projects to operational improvements and debottlenecking to bottom barrel units, moreover Dr. Marcio Wagner have MBA in Project Management from Federal University of Rio de Janeiro (UFRJ) and is certified in Business from Getulio Vargas Foundation (FGV).

A QUICK ESTIMATION METHOD TO DETERMINE HOT RECYCLE REQUIREMENTS FOR INDUSTRIAL CENTRIFUGAL COMPRESSORS

Jayanthi Vijay Sarathy, M.E, CEng

Abstract

Turbomachinery Engineers often conduct studies to determine if a hot gas bypass is required for a given centrifugal compressor system in addition to a cold recycle valve to avoid a compressor surge during operations. This would mean building a process model and simulating it for Emergency Shutdown conditions (ESD) & Normal Shutdown conditions (NSD) to check if the compressor operating point crosses the surge limit line (SLL). A quick estimation method prior to FEED using a dimensionless number (Ref [1, 2]) called inertia number can be used to check, if a Hot gas bypass (a.k.a. Hot Recycle) is required in addition to an Anti-surge line (ASV or a.k.a Cold Recycle).

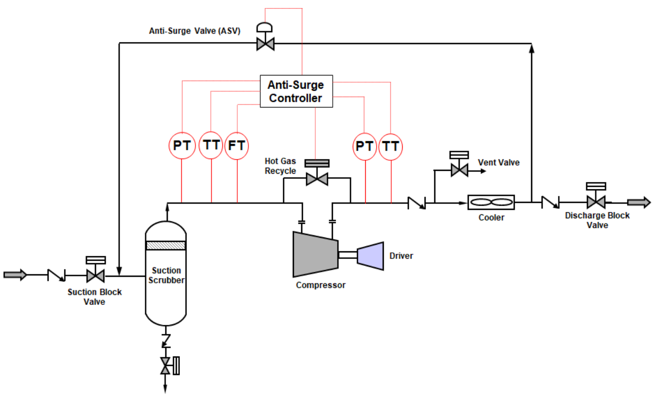

Figure 1. Typical Compressor Loop with HGB

The decision to employ a short recycle around the compressor unit during ESD depends on,

1. Effective compressor/driver rotor inertia defined at the compressor end (I) (kg.m2)

2. The delay time before the first crack-opening of the recycle valve opening stroke plus time taken for the first pressure wave to arrive at the compressor outlet or inlet (t) (milliseconds)

3. The maximum fluid energy extracted from the power train & the compressor speed which can be approximated by the product . Subscript 's' refers to the surge point at max speed (N) (rpm).

Hot Recycle Valves Considerations

A hot recycle valve is also sometimes refers to a hot gas bypass considering that a bypass line is provided to the hot discharge gas to flow back to the compressor suction. Some of the design considerations are as follows,

1. The Hot Gas Recycle System consists of an On-Off Valve which is either pneumatic or motor operated depending on the opening times (Typically Pneumatic valves with full opening time of 2 sec for valves between 4" to 16" and motor operated valves (MOV) for above 16" with an opening time of about 3 sec).

2. The piping is laid as short as possible between the discharge line and suction line to have a fast response time during ESD.

3. During an ESD scenario such as sudden power loss to CC driver, it takes ~0.1 sec for the signal to reach the DCS & another ~0.1 sec from the DCS to reach the hot recycle valve.

4. As a thumb rule, the HGB is sized for 50% (max) during FEED stage. However this needs to be checked with a dynamic simulation since over sizing the HGB system can cause the gas compressor to overheat with temperatures degradation the mechanical components such as lube oil systems and seal oil systems.

5. During operation, fluids velocities must be kept less than 0.3 Mach which otherwise causes erosional damage to the valve and piping. A noise limit of 110 dB is also placed and operating at around 85 dB is acceptable.

6. As per API 617 (7th Edition, 2002), Clause 2.7.1.3, it states, 'As a design criteria, bearing metal temperatures shall not exceed 100°C (212°F) at specified operating conditions with a maximum inlet oil temperature of 50°C (120°F). Vendors shall provide bearing temperature alarm and shutdown limits on the datasheets.' However clause No. 2.7.1.3.1 of the said document also says, 'In the event that the above design criteria cannot be met, purchaser and vendor shall mutually agree on acceptable bearing metal temperatures.

In reality, the Author has seen cases, where this deviation was taken up to ~1350C depending on the manufacturer and that this is due to a variation of operating conditions between string test conditions and actual conditions. Nevertheless, compressor operating temperatures must never exceed the stipulated or mutually agreed values in order to protect the compressor's internals.

7. The cold recycle valve is typically sized for either 2 times the surge flow (2 x Cv, surge) for a given speed or 2 times the flow corresponding to the operating flow (2 x Cv, operating flow). The latter is more conservative therefore the selection must be made to avoid choke flow.

Inertia Number

During an ESD level shutdown, as the driver speed decays to zero, the aim of the cold & hot recycle lines is to recycle enough gas back to the suction to avoid operating in the surge region. For conditions where the volumetric flow and discharge pressure is high, the recycle valves must not only respond as quickly as possible but also sufficient gas flow must be recycled.

During detailed design stage, a detailed dynamic simulation is conducted with all the piping elements such as pipes, valves, equipment, instrumentation based on the isometrics, piping & instrumentation diagrams, etc. But during FEED stage it becomes necessary to predict well in advance if a hot recycle valve is required since it also affects the control philosophy and thereby avoiding re-work of detailed drawings. In order to save time, at the FEED stage of a project, a dimensionless number called the 'Inertia Number as proposed by Botros K.K and Ganesan S.T (Ref [1, 2]) can be used to determine if a hot recycle in tandem with a cold recycle is required.

From Ref [1, 2], Inertia number in 'SI' units is termed as,

$$InertiaNumber(N_I) = \frac{(2\pi)^2 J \times N^2}{3600 \times m H_s \tau} \left(\frac{kg.m^2 \times (rpm)^2}{\frac{kg}{\sec} \times \frac{J}{kg} \times \sec} \right) \quad \text{(A)}$$

From Ref [1, 2], it is reported that, an inertia number of < ~30 would require a hot gas recycle to prevent the compressor unit from experiencing surge, while for > ~100 would mean the conventional recycle system (Anti-Surge system) would be adequate. For, a detailed dynamic simulation is required to check if a hot recycle is necessary. Based on industrial data obtained for 24 industrial centrifugal compression systems

(*Ref [1, 2]*) as described in Table 1, whether only a cold recycle or a combination of both hot & cold recycle is required can be estimated.

It can be inferred from the Inertia number that for a given compressor speed, high discharge pressure & volume flow compressors whose cold recycle valve's opening time is higher, are more prone to quickly experience surge & are likely contenders for a Hot Recycle in addition to Cold Recycle.

Mathematical Modelling Assumptions

1. The gearbox and coupling inertia do contribute to the inertia of the system but in comparison to the Driver and Compressor inertia, they are much smaller & hence neglected in deriving the relationship for inertia number.

2. The compressor polytropic efficiency & driver mechanical efficiency though contributes during operating point migration; they are neglected considering the short duration of the cold recycle delay time in opening.

3. It is assumed that the driver power was set to zero instantaneously at the instant of ESD. This is applicable for electric motors but not absolutely correct for gas turbines since there is residual fuel in the supply manifold that causes the compressor to run for a few hundreds of milliseconds and also the gas generator's rotor inertia will continue to provide hot gas to the power turbine even at a decreasing temperature (Ref [2]).

Derivation of Inertia Number

The inertia number is calculated from the total energy balance by neglecting the windage & frictional losses,

$$mH_S = -\left((2\pi)^2 J_C N_C \frac{dN_C}{dt}\right) - \left((2\pi)^2 J_M N_M \frac{dN_M}{dt}\right) \quad (1)$$

m = Mass Flow at Surge point [kg/s]

J_M = EM Inertia [kg-m^2]

J_C = Compressor Inertia [kg-m^2]

N = Rotational speed [rps]

H_S = Head at Surge [J/kg]

Using the gear ratio (GR) relationship between the electric motor & the centrifugal compressor,

$$Gear\ Ratio(GR) = \frac{N_C}{N_M} \Rightarrow N_C = GR \times N_M \quad (2)$$

Substituting Eq. (2) in Eq. (1) & rewriting,

$$mH_s + (2\pi)^2 \left[\left(J_C N_C \frac{dN_C}{dt} \right) + \left(J_M \frac{N_C}{(GR)^2} \frac{dN_C}{dt} \right) \right] = 0 \quad (3)$$

$$mH_s + (2\pi)^2 \left(J_C + \frac{J_M}{(GR)^2} \right) N_C \frac{dN_C}{dt} = 0 \quad (4)$$

Taking,

$$\left(J_C + \frac{J_M}{(GR)^2} \right) = J \quad (5)$$

Where, = Total Inertia [kg-m2]

Substituting Eq. (5) in Eq. (4) & taking,

$$mH_s + (2\pi)^2 JN \frac{dN}{dt} = 0 \quad (6)$$

$$mH_s = -(2\pi)^2 JN \frac{dN}{dt} \Rightarrow -\frac{mH_s}{(2\pi)^2 J} dt = NdN \quad (7)$$

As the operating point traverses towards the surge point at max flow, the delay time of the cold recycle () during ESD is taken as 't'.

$$-dt = t_0 - t_1 = \tau \qquad (8)$$

Here speed decay is approximated to begin when the cold recycle valve cracks open while the operating point reaches the surge flow point along the same operating speed. Therefore,

At steady state, $NdN \approx N^2$ (9)

Substituting Eq. (8) & Eq. (9) in Eq. (7), the ratio termed as inertia number is arrived as,

$$\frac{mH_s\tau}{(2\pi)^2 J} = N^2 \quad \Rightarrow N_I = \frac{(2\pi)^2 JN^2}{mH_s\tau} \qquad (10)$$

Converting back to 'rpm', we get,

$$Inertia\ Number\,(N_I) = \frac{(2\pi)^2 J \times N^2}{3600 \times mH_s\tau}\left(\frac{kg.m^2 \times (rpm)^2}{\frac{kg}{\sec} \times \frac{J}{kg} \times \sec}\right) \qquad (11)$$

Sr. No.	J [kg.m2]	N [rpm]	m [kg/s]	H [J/kg]	τ [msec]	Inertia Number	Remarks
1	36.1	6,800	250	28,000	200	13.1	Delay in Fuel Gas by 100msec
2	33.7	8,856	143	80,600	200	12.6	Hot & Cold Recycle
3	32.2	7,780	125	64,500	200	13.3	Hot & Cold Recycle
4	56.5	6,500	180	52,000	200	14.0	Hot & Cold Recycle
5	41.5	6,671	150	40,000	200	16.9	Hot & Cold Recycle
6	243.6	6,100	299	68,772	200	24.2	Hot & Cold Recycle
7	259.6	4,250	380	26,220	200	25.8	Hot & Cold Recycle
8	116.8	6,500	244	52,625	200	21.1	Hot & Cold Recycle
9	102.5	6,000	35	160,000	215	33.6	Hot & Cold Recycle
10	113.5	6,825	420	31,000	588	7.6	Hot & Cold Recycle
11	3.9	11,967	3	117,000	337	51.8	Hot & Cold Recycle
12	6.1	11,970	9	124,386	324	26.4	Hot & Cold Recycle
13	104.8	7,850	51	160,612	368	23.5	Hot & Cold Recycle
14	94.3	8,311	50	152,825	368	25.4	Hot & Cold Recycle
15	0.2	20,000	20	32,000	185	7.4	Hot Recycle
16	128.6	5,194	480	32,000	200	12.4	Hot Recycle
17	870	5,775	350	39,000	200	116.6	Only Cold Recycle
18	1.885	14,000	5	154,000	260.29	20.2	Hot & Cold Recycle
19	29.86	8,000	104.9	58,400	200	17.1	Hot & Cold Recycle
20	29.86	8,000	58	59,200	200	30.5	Hot & Cold Recycle
21	24.6	9,053	154	52,130	190	14.5	Hot & Cold Recycle
22	24.6	9,500	155	56,948	200	13.8	Hot & Cold Recycle
23	147.3	5,000	550	36,400	200	10.1	Hot & Cold Recycle
24	80.9	6,400	550	25,471	200	13.0	Hot & Cold Recycle

Table 1. Inertia Numbers for Various Industrial Compression Systems [Ref 1, 2]

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About the Author

Vijay Sarathy holds a Master's Degree in Chemical Engineering from Birla Institute of Technology & Science (BITS), Pilani, India and is a Chartered Engineer from the Institution of Chemical Engineers, UK. His expertise over 10 years of professional experience covers Front End Engineering, Process Dynamic Simulation and Subsea/Onshore pipeline flow assurance in the Oil and Gas industry. Vijay has worked as an Upstream Process Engineer with major conglomerates of General Electric, ENI Saipem and Shell.

Produced Water Treatment Overview

Robert Thomas

Introduction

A number of produced water treatment options should be investigated in order to determine the optimum configuration to process the water production expected. Most determinations are that the produced water treatment system should consist of hydrocyclones, a mechanically induced gas flotation cell, and possibly a polishing filter skid. Depending on the severity of the application.

Some operators may experience, as the field ages, unsatisfactory performance from their traditional produced water treatment arrangement consisting of hydrocyclones followed by a gas flotation unit. Investigate all possible alternatives and make suggestions to insure that you satisfy the project requirements and all local discharge regulations.

Goal of Produced Water Treatment

The produced water treatment system must be designed to treat the water to less than either 15 mg/l or 29 mg/l oil and grease. This stringent limit is in place to account for the inevitable presence of water-soluble organic (WSO) compounds which cannot be removed by enhanced gravity separation methods, yet still contribute to the total oil-in-water content that Environmental Protection Agency limits to 29 mg/l for overboard produced water disposal in the Gulf of Mexico.

Assumptions

Equipment separation efficiencies are assumed to be:

- FWKO: 5% Water in Oil Outlet; 2% Oil in Water Outlet
- BOT: 500 ppm Water in Oil Outlet; 1000 ppm Oil in Water Outlet
- Hydrocyclone: 2.5% Reject Rate, 50 ppm Oil in Water Outlet
- GFU: 15 mg/l Oil in Water Outlet
- Polishing Filter Skid: 5-10 mg/l Oil in Water Outlet

Recent Project Experience

The primary issue with hydrocyclones' is their inflexibility when it comes to varying flow rates. If the incoming fluid velocity is not maintained, the separation mechanism loses its driving force.

Equipment Analysis and Design Recommendations

A traditional produced water treatment train consists of hydrocyclones, gas flotation, and a polishing skid. The following sections analyze different types of equipment and alternative options for produced water treatment.

Primary Produced Water Treatment

In an offshore oil-producing facility, the primary treatment of produced water is typically performed by one of three types of equipment; a skim vessel, plate separator, or hydrocyclone.

Skim Vessel

Skim tanks are used for free oil and solids removal. They are designed to provide long residence times (up to 30 minutes) for drop coalescence and gravity separation, and therefore are very large.

Plate Separator (CPI/PPI)

Plate separators work on the same basic principle as skim vessels; however, they enhance the coalescence of the oil droplets by routing the flow through a series of specially designed plates where coalescence occurs. This increased efficiency allows plate separators to decrease their footprint, resulting in a size and weight advantage over skim tanks. If the amount of solids in the water is significant, the coalescing packs can become clogged as oily particles adhere to the plates. This problem can be mitigated by using a steeper plate angle.

Hydrocyclone

The hydrocyclone vessel is a device that separates oil from produced water by means of centrifugal force. It consists of individual hydrocyclone liners contained within a pressure-retaining outer shell. The separation mechanism inside a hydrocyclone is governed by Stoke's Law. However, in a hydrocyclone, the gravitational force can reach up to 3000 g's, far higher than that available in conventional gravity-based separation equipment. After entering through a specially designed tangential inlet, the fluid is accelerated in the concentric reducing sections of the cyclone where the lighter oil droplets migrate towards the lower-pressure central core, where an axial reversal of flow occurs. The oil-enriched phase is rejected through an orifice in the center of the inlet head, while the cleaned water stream exits from the downstream end.

Recommendations

Due to the emphasis on size and weight reduction, a skim vessel is unsuitable as the primary produced water treatment offshore. In addition, skim vessels have the lowest removal efficiency, and are the least tolerant of wave motion.

Although representing an improvement over skim tanks, plate separators are still relatively large, and have the second lowest removal efficiency of the three options. Therefore, plate separators are an undesirable choice offshore

Hydrocyclones have the lowest size and weight by far compared to other treatment options, as well as the highest removal efficiency, and immunity to the effects of wave motion. Therefore, the hydrocyclone is the most advantageous equipment choice.

Secondary Produced Water Treatment

Gas flotation technology is the industry standard for offshore secondary produced water treatment. There are however several different types of GFUs, which are discussed in the following sections.

Gas flotation works on the principle of attaching oil droplets or other suspended impurities to gas bubbles as a result of interfacial surface tension forces. The gas bubbles, along with the attached oil and particulates, rise to the vapor/liquid interface as an oily foam which can then be skimmed from the water interface, recovered, and recycled for further processing. Gas flotation technologies on the market today fall into four categories: sparge gas flotation, dissolved gas flotation, hydraulically induced gas flotation, and mechanically induced gas flotation.

Sparge Gas Flotation

Sparge gas flotation uses the simplest method to commingle the gas and liquid streams, usually by bubbling an external, high pressure gas source through a porous sintered metal sparger. This method utilizes roughly 1 scf gas per barrel of water treated; however, it results in only 60-80% removal efficiency due to the inconsistent and larger than ideal bubble sizes produced by the sparger.

Dissolved Gas Flotation

Dissolved gas flotation (DGF) units utilize a pump with a dual-sided impeller that pulls both liquid and gas into the pump volute, thereby dissolving gas into the liquid stream. When a pressure drop is taken downstream (usually at a globe valve just before entering a vertical separation vessel), micro-fine gas bubbles break out of solution, producing the desired flotation effect.

Hydraulically Induced Gas Flotation

Hydraulically induced gas flotation (HIGF) units utilize eductors, which exploit the venturi effect, to induce gas into the liquid stream. The eductors are designed to incorporate consistent and ideally-sized gas bubbles into the liquid stream. The liquid stream used to drive the eductor will typically come from either a small dedicated recirculation pump, or a partial recycle from a larger downstream pump. HIGF has a typical removal efficiency of 80-90% for single-cell vertical units. Multi-cell horizontal units can achieve removal efficiencies of up to 98%.

Mechanically Induced Gas Flotation

Mechanically induced gas flotation (MIGF) units utilize a motor-driven rotor assembly to incorporate blanket gas into the liquid, forming an oily froth that can be recovered by skimming. MIGF typically achieves removal efficiency of 90-98%. MIGF vessels are oriented horizontally and are typically divided into two or more cells where the flotation process is repeated in series.

Recommendation

A sparge gas unit is not recommended due to the very low removal efficiency. With DGF and vertical HIGF, the removal efficiency is limited to approximately 90%. With horizontal HIGF and MIGF units, efficiencies can approach 98%. Since discharging overboard is the only option for the disposal of produced water, it is best to install the most efficient unit possible. While horizontal HIGF units are smaller and lighter than MIGF units due to the absence of the rotor assemblies, they are almost exclusively designed for onshore use, with vertical HIGF being preferred offshore. MIGF units are typically designed for onshore service as well.

Tertiary Produced Water Treatment

A produced water polishing skid should be installed such that it can be operated in series or parallel with other produced water treatment equipment. The polishing skid can be used as a third stage of treatment if the water out of the GFU is off-spec due to high levels of WSOs, or to provide temporary surge capacity during periods of increased water production.

The polishing skid could contain a number of different types of filters.

Media Filters

Media filters incorporate deep bed designs which can have total thicknesses of four to eight feet of layered media material. Commonly used media materials include sand, garnet, anthracite, and walnut or pecan nut shells. Media material size is selected based upon an analysis of the suspended solids particle size distribution contained in the water feeding the filter. Some designs may

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incorporate more than one type of media within the same filter. Filters of this type will run back-flush cycles at preset time intervals to clean the filter media.

Coalescing Filters

Coalescing filters use filter media (usually in cartridge form) to assist in the coalescence of oil droplets. As oily water flows through the filter cartridge, the oil droplets coalesce and upon exiting the cartridge, rise to the top of the vessel where they are periodically skimmed off.

Adsorption Filters

Adsorption filters are usually used as secondary filtration as they excel at removing minute amounts of impurities from a process stream. They are typically composed of activated carbon. They foul easily given overly dirty inlet streams and can require frequent media replacement.

Recommendation

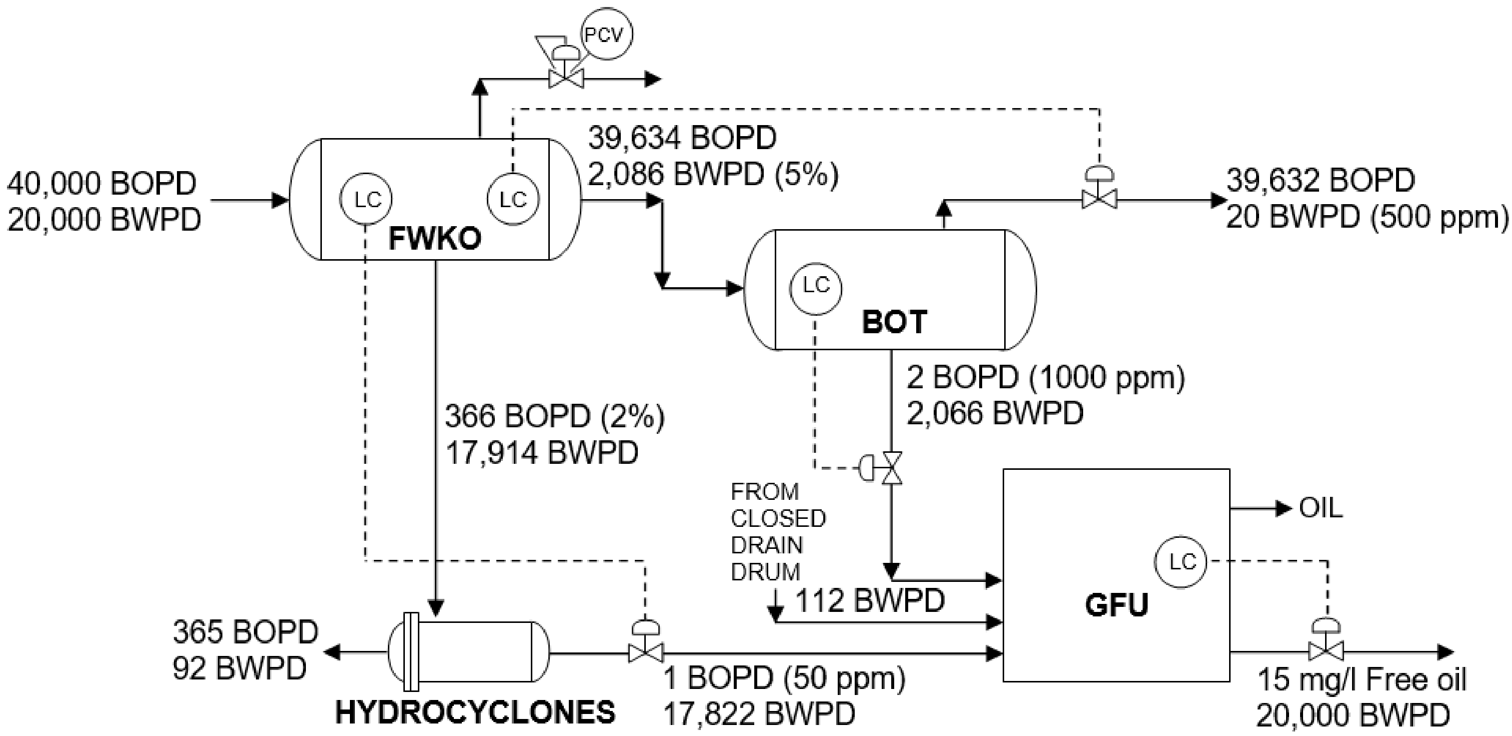
Since the goal of the polishing skid is to be able to treat both bulk separation water and post-processed water, the skid will have to contain several stages of filtration.

A media filter will be required to remove the bulk of the free oil and any solids that could plug downstream filters. Then a secondary media or coalescing filter would be used to further remove free oil. Finally, an activated carbon adsorption filter would be used to remove WSOs and any other impurities.

Capacity

Since not all the produced water travels through the hydrocyclone, it does not need to be sized for the full flow of water throughput. Using the assumed separation efficiencies from Section 4.1, the design oil and water flow rates for the relevant produced water treatment streams will be as in Figure 5.4.1 below.

Figure 5.4.1 – Design Oil/Water Stream Flow Rates EXAMPLE



The appropriate design capacity of the produced water polishing skid depends on its two functions: providing surge capacity and reprocessing high OIW content water.

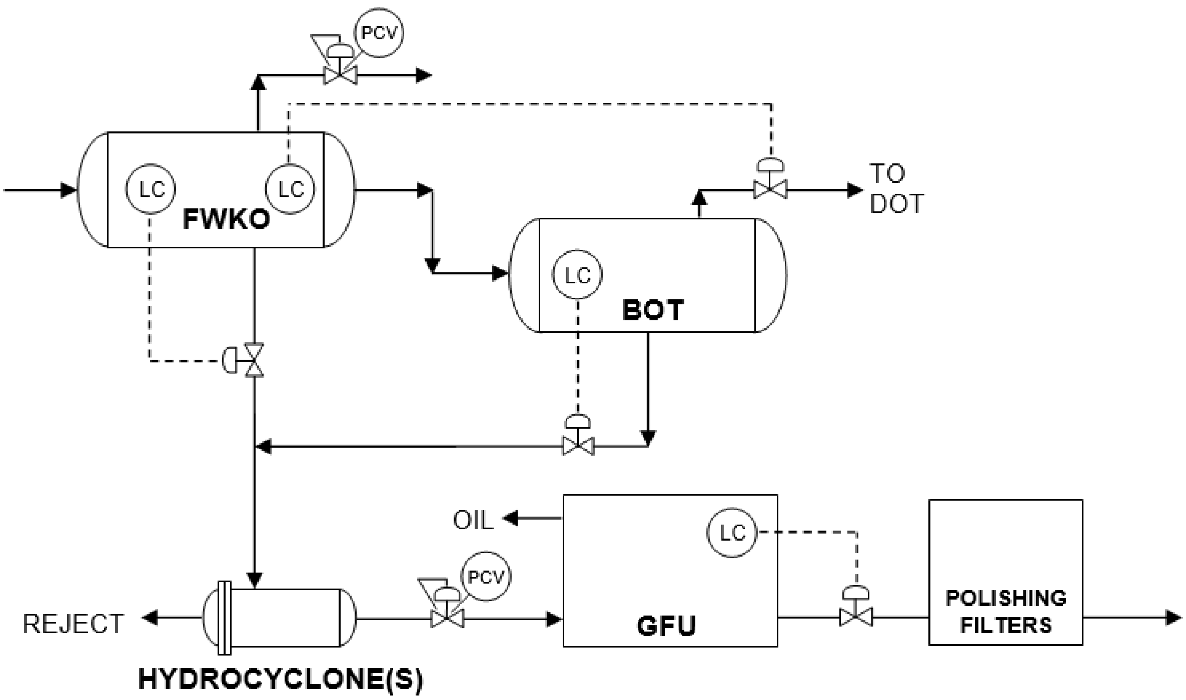
A surge capacity of approximately 50% would be appropriate for scenarios such as cold start-up or other unusual conditions where water cut is temporarily increased.

The required reprocessing capacity can be calculated using assumptions about the water quality and equipment capabilities. If the produced water treatment system is working as designed, the effluent water for overboard disposal will consist of up to 15 mg/l free-oil and usually no more than 14 mg/l WSOs, for a maximum total of 29 mg/l OIW. If we assume that the level of WSOs increases to 30 mg/l, then the total OIW content could be up to 45 mg/l, even with the hydrocyclone and GFU functioning normally.

The polishing skid should be able to produce clean water at 5-10 mg/l OIW. Assuming a 45 mg/l outlet stream from the GFU (including WSOs), the polishing skid would have to reprocess 40-46% of the water in order for the total overboard stream to meet the 29 mg/l specification. At design rates, this corresponds to 8,000-9,140 BWPD.

The design capacity of the produced water treating equipment should be as follows:

- Hydrocyclone – 18,280 BPD
- GFU – 20,000 BPD
- Polishing Skid – 8,000-10,000 BPD (depending on available standard capacities)



Hydrocyclone Control Scheme Optimization Example

In this configuration, the water outlets from the FWKO and BOT are regulated by level control before being combined upstream of the hydrocyclone, whose outlets are regulated by pressure control.

There are two problems with this configuration. The first is that the control valves upstream of the hydrocyclone will shear the oil droplets making them too small for the hydrocyclone to effectively separate from the water stream. The second is that combining the two level-controlled streams results in a fluctuating feed stream to the hydrocyclone, again reducing its ability to perform as designed.

The proposed produced water treatment configuration intended to remedy the hydrocyclone problems is shown below in Figure 5.5.2.

This configuration eliminates the control valves upstream of the hydrocyclone, thereby preserving the oil droplet size distribution out of the FWKO. With this type of control scheme, the hydrocyclone can only receive flow from one vessel, therefore the BOT water must be sent elsewhere. Since the water leaving the treater has had the benefit of extra residence time, it should be clean enough to be sent directly to the GFU.

Hydrocyclones have a range of operating flow rates over which the separation efficiency is essentially constant. Outside of this range, the efficiency drops sharply. In order to address the issue of flow turndown, the configuration in Figure 5.5.3 is proposed:

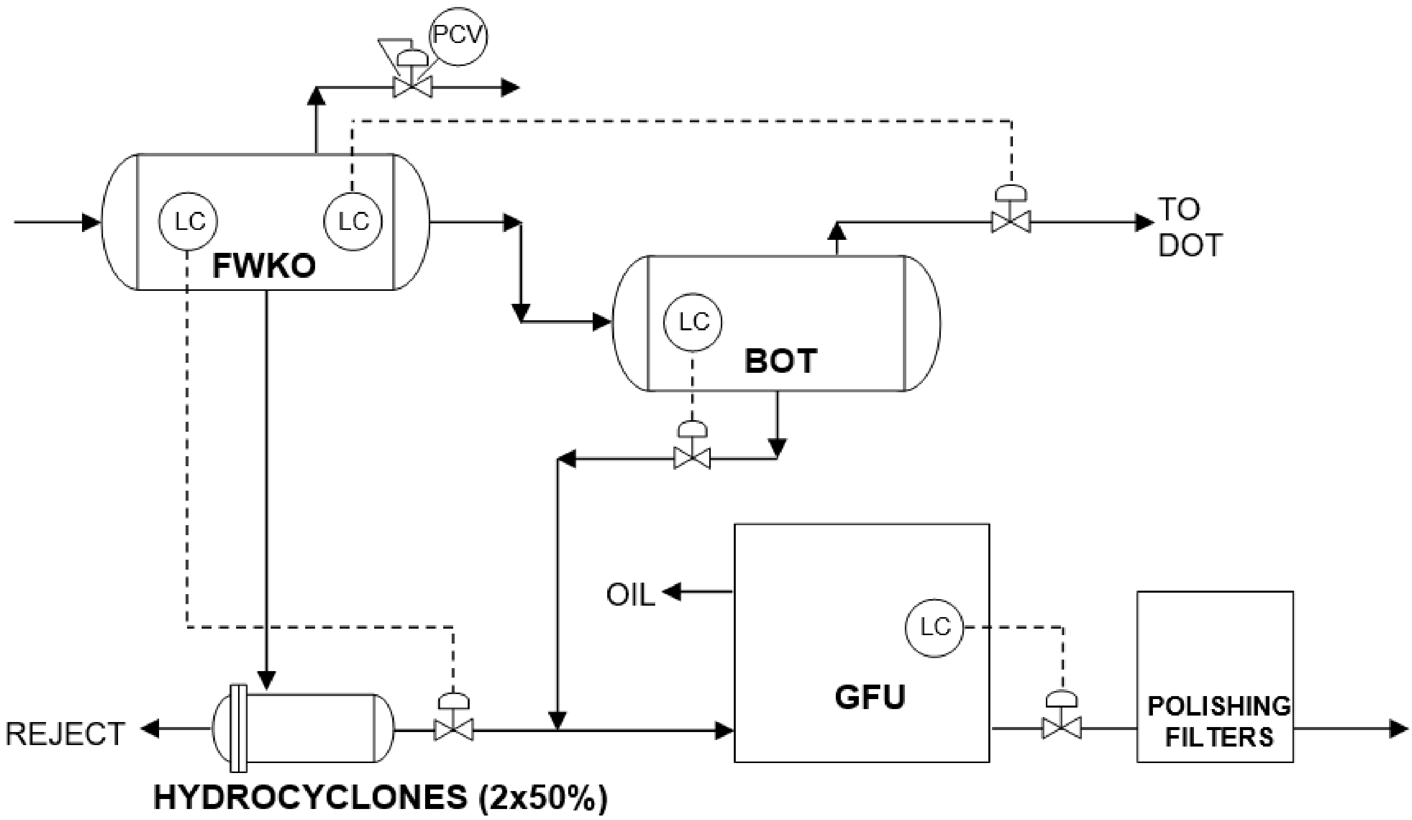
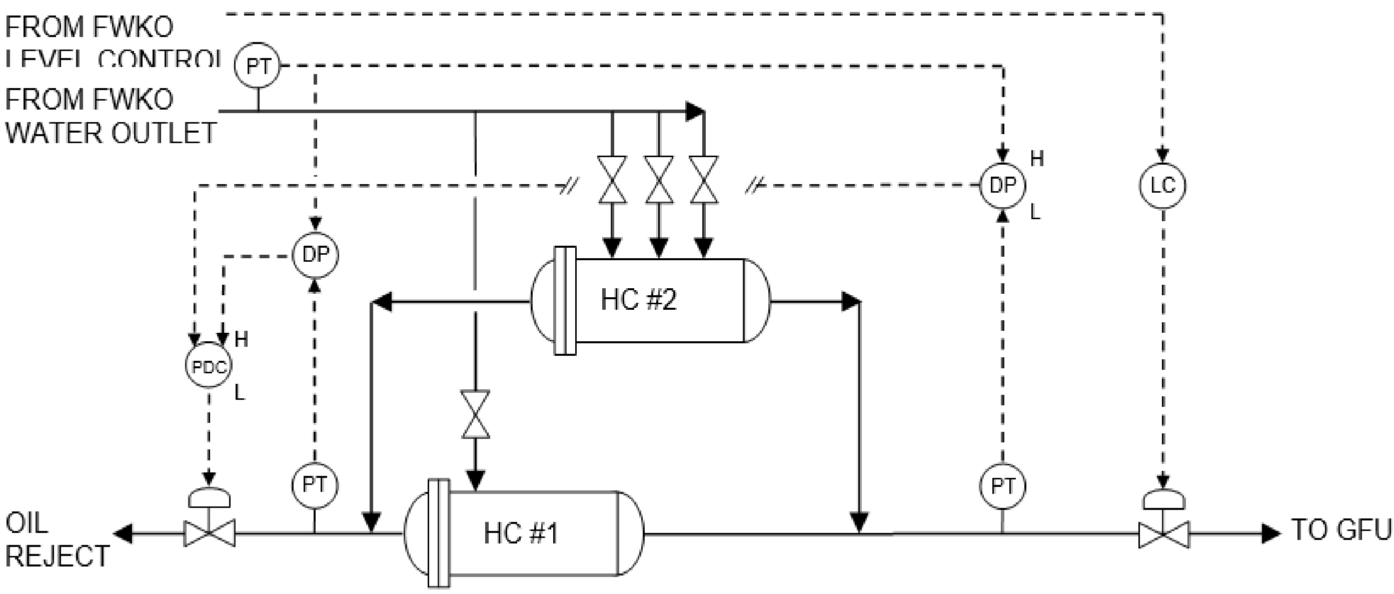


Figure 5.5.2 – Proposed Produced Water Treatment Arrangement EXAMPLE

FIGURE 5.5.3 – 2X50% HYDROCYCLONE DETAIL



Two 50% hydrocyclones would be used in parallel. "HC #1" would be a typical hydrocyclone, and "HC #2" would be the compartmental type with multiple inlets each associated with a certain number of liners. This allows flow turndown to be accomplished at the turn of a valve, eliminating the need to bypass and open up the equipment to blind off liners.

Since the opening and closing of liner sections is still a manual operation, the operator would be alerted to do so by high and low differential pressure alarms.

The turndown that can be achieved with various combinations of the two hydrocyclones is shown below in Table 5-1 (assuming HC #2 is a three compartment hydrocyclone).

Because compartmental hydrocyclones are heavier and larger due to the increased piping and valves, it is advantageous to have only one of the two be this type. Although designing both as compartmental would allow for finer incremental turndown, the level of flexibility provided by one (as shown in Table 5-1) should be sufficient to mitigate the problems experienced due to variable flow rates.

Overall Design Capacity	HC #1 Capacity	HC #2 Capacity
100%	100%	100%
83.3%	100%	66.7%
66.7%	100%	33.3%
50%	100%	0%
33.3%	0%	66.7%
16.7%	0%	33.3%

Conclusions

The produced water treatment system example shown here should consist of 2x50% hydrocyclones, a gas flotation unit, and a polishing filter skid. The control system around the hydrocyclones should be as shown in Figure 5.5.3, and the equipment design capacities should be as discussed in Section 5.4.

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Surface Production Operations Volume 1: Design of Oil-Handling Systems and Facilities, Ken Arnold and Maurice Stewart, 1989

About the Author

Bob Thomas has been in the water treatment business since 1967. He attended Widener University. He has been Vice President of several companies, most notably Modular Production Equipment where he was not only the V.P of Business Development but also the engineering manager, President of his own companies, and worked for and as a consultant to many OEM Water Treatment companies, EPC's and major oil companies. Fluid Technologies will be pleased to help you solve any water treatment problems you may have, whether Boiler Feedwater Systems, Produced Water Systems, Sea Water Injection Systems, Sulphate Removal Systems or Injection Systems which require Low Salinity effluent for EOR. We hope you find this article interesting and we look forward to publishing more articles on all types of water treatment systems as well as design information on both the systems and their specific equipment.

Quarterly Safety Connector

For Engineers; Because Safety Is Part Of The Process!

By: Chris Palmisano, MESH, IFSAC April 2019

Terrorism? Yea, it's still a thing!

Here's five elements to better prepare yourself for the unthinkable.

Terrorism: The unlawful use of violence and intimidation, primarily against organizations and/or civilians, in the pursuit of political or religious aims. The threats of domestic and foreign terrorism hasn't gone away. If you are a large operation with a dangerous inventory of Hazardous Materials, your operation can be a target, no matter where you operate in the world. It's time to ask yourself, "what if it happens here"?

PLANNING

Conducting a vulnerability assessment is the first part of planning. The assessment should cover not only potential acts of terrorism but also active shooter, cybercrimes, arson, rail accidents, earthquakes, floods, storms, power outages and other types of man-made and natural disasters. If any of these things occur, how prepared is your organization to respond to these incidents, in a way that will protect your employees, the public and the environment?

Good planning means assessing the likelihood of an attack and your ability to respond, given your staff's capability and that of your equipment and resources. If you have an emergency response team on your site, you should assure that your team and your emergency response equipment is ready to go.

Is your team trained in First Aid, AED and CPR? Acts of terror aim to create vast amounts of mass casualties. Your team and your equipment should be inspected regularly to make sure it's ready to go into service to save lives. Practical exercises are critical in honing your team's skills in life safety, evacuation, restoring power, spill mitigation, zoning, plugging, patching, diking, diverting and decontamination, as well as mass casualty triage and management.

SECURITY

We've all heard it before, "if you see something say something". Training for all levels of staff on how to recognize suspicious activity and potential acts of terror is paramount in assuring that everyone is keeping a watchful eye on the safety of your operation.

There are two basic components of security, passive and active. Having sound vehicle barriers, fencing, video surveillance, motion detection, lighting or other forms of passive protection is your first layer of defense.

Armed security service and emergency response teams are an active form of protection and can be placed in layers as well, with the first layer starting at the security entrance points. Using a layered response approach for threats such as an active shooter event, can be a good defense strategy.

MASS CASUALTY TRIAGE AND MANAGEMENT

When I was a Fire Lieutenant in the Philadelphia Fire Department, a Chief whom I had great respect for once told me, “Never risk your life or the lives of your firefighters to save a dead body”. That sounds horrible, and it was a tough pill to swallow, but it is the harsh reality of terrorism. In private industry it’s best for emergency response teams to establish a defensive posture and protect immediate exposures, with life being you’re number one concern. Offensive operations can and do put your people in harm’s way, presenting a costly potential toll on lives. It’s best to let professional emergency first responders handle offensive operations. Your people sharing their expertise on your operation, will be critical to the Incident Commander and the success of emergency responders while operating on your site.

A critical component of mass casualty management, may be evacuation and possibly the need for decontamination. Be sure you can get your people out quickly and up wind, and that your decon equipment is dusted off and tested regularly, in the event of a deliberate or unintended release of hazardous chemicals.

COMMUNICATION

Communication is paramount at an emergency scene, not just between your team members but also in informing authorities promptly and communicating with them on scene. It goes without saying that radio batteries should be charged and tested often. It’s not a bad idea to have a redundant form of communication through the use of cell phones, PA systems, warning tones and other methods.

TRAINING AND EVALUATION

Rarely does a sports team, without training and regular practice win a game. The site safety and security team should practice often, train often and evaluate their effectiveness often. There’s no replacement for good training and upgrading your standards as you learn.

Collaborate with local law-enforcement, fire protection, hospitals and military/government organizations that you rely on in your jurisdiction in the event of an emergency. These organizations train often and may have current and valuable information to share with your team. Invite them to your operation and try to include them in your exercises. They can help you determine how effective your team is and how well you will all work together in the event of an emergency.

On September 11, 2001, I spent some time working in New York City at the World Trade Center site, a.k.a. Ground Zero. Still today, what I saw at that fire ground, runs through my head like a PowerPoint slideshow. Seeing something like that changes you. In my 35 years of safety and public service, I have learned that it is human nature to be complacent when faced with preparing for the unthinkable. We tend to avoid preparing for things we think can never happen here. We live in a different world now. Terrorism can come in many forms and it lurks within our own borders and is no longer just a foreign threat. If we leave ourselves vulnerable to acts of terrorism, it’s not a question of if, it’s a question of when?*

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