It's Time to Use AI and IOT in Upstream Oilfield Facilities

In a December 22, 2017 E&P Magazine published article titled, *"Insight: Data-driven Energy Industry Is Ripe For Growth"*, author Michael O'Connell touted the reality that the oil and gas industry stands to save billions of dollars annually by getting on the IOT and AI bandwagon. And in the December 2017 issue of Automation World in an article titled, *"Oil and Gas Hunker Down"*, author Lauren Gibbons Paul asked, *"After weathering storms both economic and meteorological, will the industry stick to the hard-won lessons it has learned about the importance of optimization and process improvement?"*

Ms. Paul's question is provocative, and there is little doubt that Mr. O'Connell's conclusions are correct … though in an industry traditionally mired in the muck of diminished oil prices and long-standing paradigms where the by-word has always been, "We're doing it this way because we've always done it this way", only time will tell.

It seems the upstream industry has a particularly tough time of getting out of its own way as regards embracing advancements. There are exceptions; exceptions like the transition from cable tool drilling to rotary drilling, and from vertical completions to long multi-stage fracked laterals, and others of course. These advancements, and the others like them, are sprinkled throughout the long history of an otherwise slow-to-change industry, but only sparsely.

And even now, faced with a panacea of electronic marvels, too little consideration is given to the use of the Internet of Things and Artificial Intelligence in the upstream sector where all fluids are processed and oil and gas are sent to market. The upstream sector has an amazing, even if heretofore overlooked, opportunity!

At 76, I take pride in the fact that I have walked through hundreds, perhaps thousands of your tank batteries. These are places where oil and gas are separated and shipped off to market; the literal cash register of all E&P companies. Yet, I have NEVER been in even one such facility, simple as most are, that has not had a tank overflow.

Wading through a pool of crude oil sticks in your mind! It's not hard to imagine the waste an oil spill represents … and chilling to realize the dangers as you go step by step through it … wondering, "Is this "it"? Will it ignite?" Eventually, we simply must ask, "Could this spill have been avoided, and if so, how?" Decades ago, before man walked on the moon, even before Microsoft developed Windows 97, the answer was unclear. There were too many variables; combinations of human error, lack of experience and oversight. But today? We have the tools, and they're affordable. There's simply no excuse!

SCADA AND INFORMATION OVERLOAD

We now live in a marvelous age where nearly anything we can conceive can be affordably achieved! We can measure anything, sense anything, communicate anything, anywhere … all in the twinkling of an eye. Accurately too, if we do it right! We've been doing it with SCADA (supervisory control and data acquisition) for some time. But when we do, we find ourselves engulfed in a wave of information overload!

What we are struggling with now is how to properly collect and then to manage all of this information! Instrumentation has taken a quantum leap forward, becoming accurate and affordable. What falls behind is our ability to use this information in real time, to automatically make intelligent decisions with it so our upstream facilities manage themselves via analytics applied through AI … using AI as a self-managing tool to control facilities to a here-to-fore unachievable level of performance, efficiency, optimization that ultimately generates increased profits.

We do this on a smaller scale in the more obvious levels in upstream operations; with ESPs for instance, and in many cases with pumping units. But instrumenting and automating a tank battery so it manages itself still seems simply too "out there"! Why is this? Perhaps it's because none of us have the unrelated skill sets necessary to do it right. The code author has never walked through a tank battery after a tank runs over; through a pool of spilled crude oil. And, the lease operator who does this daily, and knows the analytics backwards and forwards, lacks the software code writing skills to fix it through AI.

Then there's the reality that every time the price of crude drops $10/barrel we, the industry, lay off the higher paid, more experienced people we employ … robbing the industry of those with developed skill sets and experience we need to develop new AI analytics. We handcuff our field operations this way every time the price of oil drops. It's costly! How costly?

Late in 2015 the domestic oil and gas industry was proud to enjoy production from 1,666,715 wells! Imagine, if each one spilled only 10 barrels per year, the industry would lose nearly 11 million barrels of oil annually … these barrels worth over half-a-billion dollars. And this is a conservative estimate … very conservative! After all, when a 500-barrel oil tank overflows overnight, while the operations staff is sleeping snugly in their beds, we could lose hundreds of barrels. It happens in every tank battery … year after year!!

So why don't take greater advantage of our IOT and develop our own AI?

One big reason is that we are very short sighted. Our morning meetings focus on the activities of the last 24 hours. There's no room, no time, for a far reaching long-term futuristic approach! Budgets stay focused on the micro level rather than the long-term macro level. We install $300 pressure transmitters on the bottom of our storage tanks to transmit their liquid levels to us remotely, but don't know whether to calibrate them for oil density, water density, or some average of both … so when we accumulate a layer of typical oilfield muck (iron sulfide, solids, and emulsion) inside those tanks the pressure transmitter lies to us. We think the tank is only 65% full when in reality it is overflowing because the transmitter is transmitting a muck fluid density which is completely out of whack with the API gravity of the crude in the tank. Yet, look at all the money we saved! We spent $300 for the transmitter when we could have spent $1400 on a density-compensated ultrasonic level transmitter located safely out of the muck in the roof of the tank!

Decisions like this look good on paper. They get raises for the project manager who saved $1100 per tank by installing the pressure transmitters. And by the time the muck accumulates, and the tank overflows, he's spent his raise and is long gone … leaving the facility operator to try to figure out how to placate his supervisor who is really upset because he ran his tanks over!

Another reason is that we are stuck in the past. Our paradigms force us to accept things the way they are because "we've always done it this way". We simply must overcome both!

But perhaps the best reason is that we are starting from scratch! We have never done it before!

What's clearly needed here is innovation; a meeting of the minds! A commitment to break the constraints of the past, and a mind meld between the best of a future staff of analytics development code writers, and our best lease operators and their supervisors who can coach these software gurus until they get it right!

In reality few code authors have any idea what should happen in a tank battery, so they are handcuffed when asked to write an AI program that completely automates a tank battery. On the other hand, most lease operators and their supervisors have a good idea what should happen minute-by-minute, event-by-event, and what to do about it. However, they have no idea what instruments to select to sense it or how to write the code needed to detect it and make the right moves automatically to correct it, or to divert it, or to stop it completely. But as a team, they do!

We often use this team approach as we practice HAZOP/PSM, gathering our most knowledgeable field and professional folks together to play the "what if" game … but usually only after the facility design is on the drawing board. We almost never ask them to take this approach in the design phase of a new production facility, so it has the possibility of managing itself!

But, the time has come!!

GETTING IT DONE

Let's see how this might take place!
Imagine a facility design where the production is from a long lateral shale formation completed with a multi-stage frac job using 150,000 pounds of proppant. The new well makes 8,500 BWPD, 1500 BOPD 3.5 MMSCFD and about 100#/day of frac sand during IP. The oil is 48°API, the water is 1.065 specific gravity, and the gas is 1350 BTU.

With light oil like this it is unlikely that we'll have any difficulty separating the water and BS from it, so the only reasons we'd design the facility to include a new heater treater is 1) because we've always done it that way (a reason showing how locked in the paradigms of the past we are), and 2) because we might accumulate tank bottoms over time and it would be good to be able to process them as they accumulate.

But to get properly implement AI based on the IOT we choose, we need the analytics only presently available from the operations staff and interpreted through our code authors.

It might go something like this …

OIL-WATER-GAS-SAND SEPARATION

First, we need is a properly sized FWKO to do the job of separating the majority of the water, if not all of the water, from the oil. Using the rule of thumb for light oil (100B/D per square foot of interface area) we can see that the FWKO needs to have about 100 square feet of interface area. Using the standard length to diameter ratio of 2-4 L/D, and sticking to standard nominal diameters, the FWKO could be a 6' x 16'-8" or a 5' x 20'. Too small and it will carry over. Too large and it will have very poor hydraulics and the flows with short-circuit reducing retention time and separation. The smaller diameter vessel will cost less, so we pick it. Being almost 2-1/2 times as heavy as the produced water and 3.3 times heavier than the oil, we know the sand will separate so we have the FWKO designed with sand pans.

In the past, we'd probably stop there, but today we can install a sand sensing probe to alert us electronically when and as the sand accumulates. We do, but rather than simply alarming a sand build-up so the operator can drain it out, we trigger quick open valves under the sand pans to remove the sand automatically. We operate the FWKO at 100 PSIG and route the sandy water through hydro-cyclones which dump the sand with less than 20% water into hopper bags or roll-off boxes for disposal or re-use. We cycle the sand dumps in short bursts to minimize the effect of rapid vessel draining on the overall separation process, so the water and oil actually separate. If the sand sensor senses more sand accumulating than is being removed the new operating software (AI) adjusts the dump valves (IOT) cycle intervals and durations until an equilibrium is reached. The hopper bag or roll-off box are monitored with load cells so as they approach about one day's holding capacity the operator or designated contractor is alerted to change them out for new ones. And finally, we protect the FWO with a normally closed automatic ESD valve, help open by a signal from the AI when operations are normal, and closed during periods of power outrages or in critical alarm conditions.

With the sand removed the produced water and oil volumes can be accurately measured using lesser expensive turbine flow meters (about 1/5th the cost of Coriolis meters). Flows are monitored in real time. A 10% deviation in oil or water flow from one eight-hour period to the next triggers a text message to the operator so he knows a well is down, or a line is leaking somewhere. A 20% deviation alerts remote staff to check the tank battery security cameras looking for leaks (more AI). Sump pumps, installed within containment confines to move spills and rainwater to storage, are monitored for run time and duration. If a production deviation and an extended sump pump event occur at the same time the AI starts an event timer. If the event timer signals (more AI) a sequential repeat of the same event an ESD is triggered and all wells feeding the battery are shut in until the operator remedies the issue.

Our new FWKO is fitted with a pressure, high and low-level transmitters. Each can trigger a shutdown event.

Produced gas is efficiently separated from entrained liquids by a serpentine vane demister located near the outlet end of the FWKO, and leaves the vessel to flow first through a conventional orifice plate meter run, a back-pressure valve, and on to its gas sales line.

Produced water is sent from the FWKO to a HWSB® Skim Tank, described in more detail below, for final oil-water separation. Oil from the Skim Tank flows to a dedicated oil treating tank. This tank is fitted with a side-wall mixer (Jensen Int'l, Tulsa) and three Chromalox LTFX totally enclosed electric immersion heaters. A density compensated ultra-sonic liquid level transmitter (LT) monitors the tank level and feeds the AI with this data. When the tank is 80% full the tank heaters are switched on and the sidewall mixer and a demulsifier feed pump are started. The demulsifier is added through a sidewall dip tube feeding the emulsion breaking chemical into the impeller intake of the mixer to assure thorough mixing. The oil temperature is monitored by a sidewall temperature element installed in a 24" long thermowell so it monitors a representative sample of the moving oil. As the oil temperature reaches its preset set point the heaters cycle on and off, but the mixer continues to run for a pre-set time. When that time elapses the mixer and chemical feed pump are shut off, and the heaters remain active. This heated oil is left static for at least eight hours to allow all of the water of emulsion to settle out. After eight hours a bottom circulating gear pump is started and the tank bottoms are recycled into the inlet of the FWKO.

The oil leaving the FWKO is sent to additional oil storage tanks, each fitted with a normally closed automatic inlet valve, held open by a signal from the AI when operations are normal, a bottom circulating pump, and a pair of density compensated ultrasonic LT. As each tank reaches 80% of its capacity the LTs signal the bottom circulating pump to start, comparing level measurements, and left it stay on until the tank reaches 95% full, assuming the output from the two transmitters is within preset tight tolerances. If not, a text message is sent to the instrument tech alerting him of the drift so he can recalibrate or replace the faulty sensor. If the drift exceeds a wider tolerance, the AI switches all inflow to the next tank to avoid the possibility of a tank overflow. When the LTs are in agreement the bottom circulating pump continues to pump until the tank level is down to 90% full, at which point the AI shut it down. This shutdown alerts the operator and/or the oil purchaser to move this tank load of oil to sales. The LTs monitor the tank level changes over time during the transfer, and the AI records the number of barrels of oil transferred out of the heated tank and each of the other oil storage tanks. The duration of level change is recorded. The time of each nominal volumetric increment a cross-check against custody transfer, giving the owner an accounting of oil sales in real time.

Where oil is sold via a LACT Unit the tank level AI monitoring serves as a cross-check against the LACT meter to confirm accurate and proper oil sales, thereby avoiding inaccuracies or potential oil thefts (for instance, if the LACT Unit is not active but the oil tank levels are falling something is wrong! In this event the AI can trigger an alarm horn, focus all battery cameras on the oil tank area, start a recording, and trigger a remote alarm to owner headquarters, turn all battery lights on high, close the electric gate leading from the highway to the tank battery, etc.). If the LACT Unit rejects oil it is directed into the heated tank for emulsion resolution as previously described.

All water leaving the FWKO is sent to a dedicated Skim Tank known as the HWSB®. This tank is specifically designed to remove small amounts of oil from large volumes of water. It has successfully replaced conventional Gunbarrel tanks, never designed for high water cut applications, since the early 1990s, becoming a standard of the industry for high water cut separation applications. This tank is always taller than downstream water storage tanks and the oil tanks to allow for gravity flow, thereby eliminating the need for additional pumps. It fitted with one high level ESD LT identical to those used in the oil tanks. Its design precludes overflowing conditions unless an outlet valve is closed or an outlet line plugs, so high level ESDs are rare. Nevertheless, the ESD is installed to prevent an oil spill.

Water leaves the Skim Tank through a large diameter concentric pipe water adjustable leg, often 30" OD with a 20" concentric overflow pipe inside. Water flows into the annulus between the two rising to the top of the 20" pipe inside, and then overflows into that pipe. The top section of the 20" pipe is adjustable. Its elevation determines the elevation of the oil-water interface inside the Skim Tank, and is adjustable so the operator can manage the depth of the oil layer inside the Skim Tank, raising it in winter to allow for more oil retention time in the colder winter months, to minimize the degree of tank bottoms in the receiving oil tank. The water overflowing the 20" inside vertical pipe flows on to the next water storage/transfer tank.

This water storage/transfer tank is shorter than the Skim Tank, usually by about 8', to allow for gravity flow. It is also fitted with a pair of LTs identical to the others. One is dedicated to managing to outflow of water, often to an offsite water disposal plant. It does this by feeding levels via AI to the transfer pump's VFD (variable frequency drive) which increases or decreases the pumps motor-driver speed, thereby maintaining the water level in the storage/transfer tank. As in the oil tanks, the LTs check each other for consistence, and report any/all discrepancies to the Instrument Technician via text AI generated messages. The secondary LT is dedicated to a high/low level detection condition which can trigger a system ESD.

The water transfer pump is backed up by a stand-by pump, both feeding a mass-flow meter which is monitored by the AI. Any deviation above or below preset high and low flow rate conditions triggers an alarm which, in the case of high level starts the second transfer pump, or in the case of a low-low level results in an AI triggered ESD of the entire system should it exceed the low-level or high-level tank limits, and/or persist for more than a few minutes. In the event of a low-low level condition, the AI monitors the sump pump operations which could indicate a water leak inside the containment, and if so detected, triggers a full system ESD and sends out an automated cell phone call to the lease operator directing him/her to return the facility ASAP.

WHAT'S THE CAP-EX COST AND OP-EX ROI?

Once we realize that all of this is possible, and not so far-fetched after all, the operative question is, "Can we afford it?". It's the standard question for all IOT and AI related efforts!

Taken only on a micro view, from the perspective of a project manager in charge of building the new facility, the answer is almost always an emphatic, "NO!". However, if management has a longer-term view of its overall operational economics, the answer is always a resounding, "YES!". So, as always, the broader picture of long term economics must come from the top of the organization, or we focus only on today.

So, let's look at it both ways!

SHORT TERM COSTS – FWKO

The FWKO will be fitted with the following AI/IOT friendly instruments, valves, and controls which are over and above the traditional controls:

1. 3" x Class 600 88A-T40-xx Apollo SS Inlet ESD ball valve with electric actuator @ $1,784 + $1,376 = $3,160
2. Invalco ISM780 oil-water interface probe in lieu of pneumatic LLC @ $4,340 - $926 = $3414
3. Three sand pans, 2" x Class 100 full port ball valves with electric actuators @ 3 x $866/ea. = $2,598
4. One Ashcroft Model A2XBM0242C010000#G#high/low pressure transmitter @ $529
5. Two Rosemount #5081 high-low level transmitters @ $780/ea. = $1,560
6. AI Software program for FWKO @ $4,000
7. Labor, conduit, wiring @ $15,000

FWKO Total Cost Over and Above Normal = $29,732

SHORT TERM COSTS – TANK BATTERY

The tank battery will have four 1500-barrel oil storage/sales tanks, each fitted with dual LTs and one of them fitted with heating and mixing components:

1. Eleven density compensated ultrasonic level transmitters @ $1,160/ea. = $12,760
2. Four 2" Valworx SS 2" electrically actuated ball valves #565352 @ $505.44/ea. = $2,022
3. One Jensen Int'l tank mixer @ $3,150
4. Three Chromalox 15 Kw LTFX shrouded electric immersion heaters @ $8,600/ea. = $34,400 minus the cost of the normally purchased heater treater @ $22,000 replaced by these heaters = a net project cost of $12,400
5. One spare Goulds 3196 standby water transfer pump with VFD @ $13,850
6. Four oil/tank bottoms recycle gear pumps @ $820/ea. = $3,280
7. One AI integrated software program @ $25,000
8. Labor, conduit, and wiring @ $25,000

Tank Battery Total Costs Over and Above Normal = $97,062
Total AI/IOT adder for FWKO and Tank Battery = $126,794 plus $13,206 contingency
Short Term AI/IOT Grand Total Adder = $140,000

Adding $140,000 to any tank battery construction for automation seems extravagant on the surface. This is the main reason it is rarely proposed or seriously considered.

THE LONG-TERM APPROACH

When management considers the cost of operating a single oilfield tank battery facility they must consider all factors. One of the most expensive factors is the cost of lost production from unnecessary downtime and unforeseen upsets like tank overflow events. So, let's estimate the likely costs of both, as follows:

1. Assume three tank overflows for an average of 7 hours each = 21 hours of lost production. At 1,500 BOPD normal production we will lose $21/24^{th}$ of 1,500 barrels or 1,313 barrels. Today each barrel is worth about $52, so our annual loss from tank overflows is estimated at $68,250.

2. Assume this facility has four ESD's that shut it down for a total of 32 hours per year. The cost of this is clearly 32/24th x 1,500 BOPD x $52 or $104,000.
    a. The AI controlled self-managed system should reduce this downtime by at least 50%, cutting the cost to about $52,000 if the system were fully automated and self-managed.
3. When a tank battery is self-managed the operations staff is freed up from the daily visits normally necessary, so they can do more important chores like providing the maintenance necessary on other less automated facilities. If we reduce the overhead expense of operating this facility by 75% of the annual cost of the operator, we save approximately $60,000 in direct costs plus another 22% G&A costs per employee or $13,200 for a total of $73,200 per year.

When we add these probable costs together we see that operating as we have in the past is likely to cast us $68,250 plus $104,000 plus $73,200 for a grand total of $125,450 per year for each year of operation. In ten years this will total $1.25 million in lost revenue!

If we automate, the first year will cost us $140,00 in CAP-EX to build the facility. From the above, we will recover $125,450 in direct savings. After year one we will recover another $52,000/year in indirect savings from reduce overhead expenses, paying out all added CAP-EX costs in 9.46 net overall months. This is a first year ROI of 37% ... making it an investment hard to overlook!

CONCLUSIONS

Interest in artificial intelligence (AI), and in the internet of things (IOT), has been slow to gain popularity in the upstream sector of the oil and gas industry. While they seem to hold great promise, they are also in serious competition with other, higher profile technologies such as long lateral completions and multi-stage fracking, and rightly so! The higher profile technologies are inarguably the lowest hanging fruit of today's E&P sector.

Nevertheless, the application of today's AI and IOT technologies to existing and new upstream facilities has the opportunity of propelling those upstream process operations into the 21st century, streamlining operations, reducing wastes and inefficiencies, and adding significant profitability … all at a time when it's seriously needed.

ABOUT BREAKTHROUGH ENGENUITY

Breakthrough Engenuity was founded by Bill Ball. He has a distinguished history of oilfield separation system designs, and a comprehensive list of fourteen related patents. Bill's hands-on oilfield experience over the past five decades, and his career portfolio, make him an authority in facilities design.

After his university studies Bill launched his career in a 1,000,000 b/d waterflood operation where he was responsible for the selection, evaluation, performance, and improvement of all surface separation facilities. He sent most of his work days crawling through *the process equipment of the day, querying the designers, and making improvements wherever possible.*

This hands-on experience was the equivalent of a real-world PhD. In the early years Bill learned what works, and what didn't, by wrote! Bill needed this experience to develop and advance new technologies which have since become standards of the industry. Over time his accumulated separation experience and knowledge led to his many patents, each of which speaks for itself.

The result is Breakthrough Engenuity's unique approach; one where today, "engineering meets ingenuity!"

Bill's efforts to innovate have been well received. Consider "KOTREAT®", where it's patent describes the combining of free water knockout and a heater treater into a single vessel. This is the perfect vessel for today's high water cut wells whether in horizontally completed shale wells or waterfloods. KOTREAT® is a game changer!

Another example of ingenious innovation is the MorOil™ patented system. MorOil™ condenses valuable C4+ hydrocarbon liquids present in the natural gas stream, stabilizes them, and adds them to oil in storage to generate an increased cash flow stream.

These are just two of Breakthrough Engenuity's unique contributions.

Today, Breakthrough Engenuity is one of the industry's leading low-cost engineering and design firms. It specializes in developing designs for the industry's most efficient high and low pressure, two and three phase heated and unheated separators, as well as providing general engineering services geared to specialty subjects like:

- *Natural gas handling to optimize income and liquids recovery.*
- *Proper line sizing to avoid turbulence, erosion-corrosion, and mixing energies.*
- *Specialty vessel internals designed to maximize separation performance.*
- *The application optimization of oilfield chemicals geared to reduce cost and improve performance.*
- *3D modelling to avoid costly facility installation delays.*

Now, more than ever, Breakthrough Engenuity can be found in every sector of the oil and gas industry, adding efficiency and cash flow and efficiency to upstream operations. Breakthrough is a full-service consulting engineering firm, and pledges to exceed each client's expectations.

CONTACT

If all else fails, or even if you just have a question, don't hesitate to call Bill Ball at Breakthrough Engenuity for assistance. You can reach Bill at the office at 918-298-6841, or on his cell phone at 918-231-9698.