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Improve Your Distillation Operations Through Procedural Automation

A White Paper

YOKOGAWA

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Abstract

This paper shows how to improve distillation operations by focusing on procedure automation. It will review the importance of using procedures in distillation operations and highlights the collaboration work underway between Fractionation Research Inc. (FRI) and Yokogawa Corporation to improve procedural operations. Additionally, it will review efforts on building a standard around procedural operations and review two examples of how automating the procedures made significant improvements in distillation operations.

Challenges Affecting Distillation Operations

Distillation is the most widely used separation process in the chemical process industries. In the US manufacturing sector, distillation uses 24% of the total energy. Refineries, in particular, rely heavily on distillation to separate the complex mixture of compounds present in crude oil into the products that are for sale or that become feedstock for downstream units. Distillation consumes approximately 40% of all the energy used in refineries.

First, the distillation process is viewed from a steady state perspective with most of the initial attention focused on achieving an optimal steady state to ensure the process remains within safe operating limits. Those who run and manage continuous process units understand that procedural activities are critical to safe and efficient operations. Often this procedural information is not well documented, not readily available, or is only stored in an experienced operator's head.

Procedural activities in a distillation process are most prevalent and critical at certain times of the process operation.

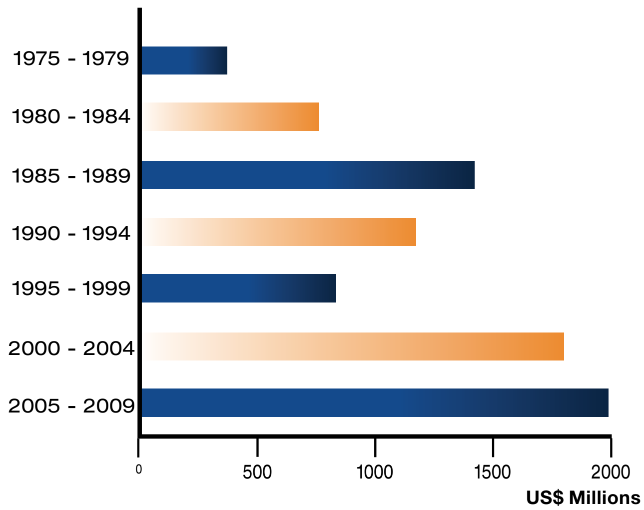
- Startup – Safe and efficient startup of a distillation unit is critical to the overall operation of the unit. Startup frequency may vary, from once every day to once every five years. If startups occur often, they can occur on different shifts and the time and skill of the operator on duty can determine the efficiency of the startup. If startups occur at a longer interval, companies run the risk of not having experienced personnel available to run and oversee the startup. There have been cases where companies have had to bring operators out of retirement to restart a unit after a shutdown.

- Shutdown – Orderly and safe shutdown of a distillation unit is just as critical as a startup. One key item in shutdown procedures is recognizing that a shutdown might not be scheduled. System problems or severe weather such as approaching hurricanes might require a shutdown of distillation operations on very short notice. As with startups, the "on shift" operating personnel might not have the most experience shutting down a system.

- Feedstock and product output transitions – Many chemical processing units regularly operate at more than one optimum steady state. In refineries for example, many refiners purchase crude oil of different types in tankers. As they run out of one type of oil, they must adjust operation to correctly process the next type of oil. Similarly, in chemical plants a single plant will often make a variety of products in a "campaign fashion" by changing operation to meet the new product specification.

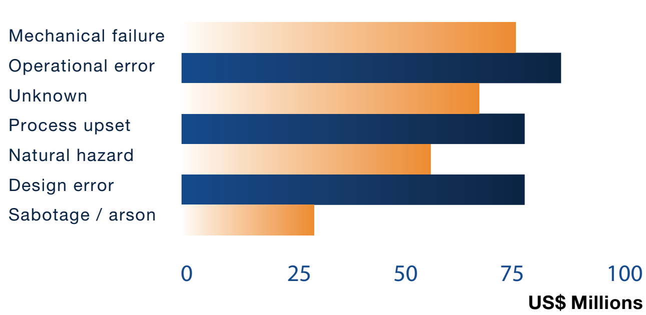
Transitions inherently increase the risk of disruptions that can lead to incidents. According to a report by J &H Marsh and McLennan Ltd., The 100 Largest Losses 1972-2009 –Large Property Damage Losses in the Hydrocarbon Industries, the 5-year loss rate (adjusted for inflation) in the refinery industry continues to rise. Incidents that occur during startup and shutdowns continue to be a major factor.

Figure 1: Refinery losses in five year periods



Five year loss totals in the refinery industry have continued to trend upwards over the last few years. Piping failures or leaks (corrosion or incorrect metallurgy) and startup and shutdown events continue to be significant causes.

Figure 2: Average dollar loss per major incident by cause
Source: J & H Marsh & McLennan, Inc.



An additional study, by Marsh Ltd., shows that in an examination of major incidents by the average loss per incident that operational error is the largest average dollar loss.

From a process efficiency perspective, distillation operations consume a large amount of the energy requirements in a refining or petrochemical application. Efficient production is a key to meeting product specifications and producing the best possible yields of valuable products. Performing procedural operations in an inefficient or time-consuming manor will have a significant economic impact on the complete operation.

Fractionation Research Inc.

FRI™ is a non-profit corporation founded in 1952. FRI is a consortium of 72 global member companies. Technical representatives from the member companies established the research program, which the FRI Staff administers. FRI employs approximately 20 people, in Oklahoma, with an annual research budget around $3MM.

FRI's membership is global, with about 25% from Asia, 35% from Europe and 40% from the Americas. The membership is composed of refiners, chemical companies, and engineering companies. The refiners include ExxonMobil, Shell, Chevron, Petrobras, BP, Marathon, and ConocoPhillips. The chemical companies include Dow, DuPont, BASF, Praxair, Air Products, Eastman, Mitsubishi, and Mitsui. The engineering companies include Fluor, Lummus, Toyo, EIL, Technip, and Lurgi.

FRI conducts experimental work in a large pilot plant located on the campus of Oklahoma State University. The pilot plant contains a low-pressure column that has a four-foot (1.2 m) section topped by an eight-foot (2.4 m) section. The low-pressure column can operate from high vacuum conditions up to 175 psig. The pilot plant also contains a four foot diameter high-pressure column that can operate from atmospheric conditions up to 525 psig.

Procedural Automation Goals at FRI

FRI has several reasons to be interested in procedural automation:

- Process Safety – Due to its operating plan and the need to revamp the experimental distillation columns frequently, FRI shuts down and starts up their equipment around 20 times per year. In addition, the nature of experimentation requires that the column transitions from one data point to another several times a day. Transition periods typically represent the greatest risk of a process safety incident. While written procedures in a notebook next to the operator console help, different operators can interpret the procedures differently.

- Incorporating the best operator practices into an automated procedure will result in a reduction of process safety incidents.

- Productivity – FRI measures productivity by the amount of experimentation completed in a year. Quicker startups and faster transitions from one data point to another are the best solutions to improve productivity and to reduce the cost of learning something new. Procedural automation reduces the number of control moves required to reach steady state during startup and transition. It will also help to bring all operators closer to the operating practices of the best operator, which will again improve productivity.

- Member benefits – Testing procedural automation on the FRI pilot plant generates real world experience that will greatly benefit FRI members as they operate production scale refineries and chemical plants.

In November 2010, recognizing that improvements in procedural operations would benefit the industry, FRI and Yokogawa started collaborating on automating procedural operations at the FRI research facility. The FRI staff has worked closely with Yokogawa consultants and engineers to standardize, automate, and optimize procedures used in the startup, shutdown, and transition of the distillation columns at the facility. These optimized procedures were a result of lessons learned by Yokogawa in applying procedural automation in continuous applications and by referencing ISA standards.

Yokogawa

Yokogawa Corporation of America is the North American division of the four billion dollar a year Yokogawa Electric Corporation (YEC™). YEC is the global leader in the manufacturing and supply of instrumentation, process control, and automation solutions. Yokogawa Corporation of America (YCA™) headquarters is located in Sugar Land, Texas. YCA offers clients a variety of state of the art products such as analyzers, flow meters, transmitters, controllers, recorders, data acquisition products, measuring instruments, and distributed control systems.

One of Yokogawa's primary industry focuses is on refining operations and developing and delivering control systems that enables the safe and efficient plant operation. Over the past 15 years, Yokogawa has helped clients to improve their procedural operations using experienced and skilled engineers combined with excellent procedural tools.

Early Efforts in Procedural Standardization

In the process industries, a standard, ISA-88, was developed starting in 1988 and approved in 1995 that focused on a common problem: procedural automation in batch processes. The standard revolutionized batch control introducing new products and practices into the marketplace. Numerous manufacturers in food, pharmaceutical, and specialty chemical realized significant benefits in safety, production flexibility, and project engineering costs reductions. Many practitioners of ISA-88 began to implement the principals behind ISA-88 to continuous process applications.

The WBF (the organization for production technology) has had several papers presented focusing on the ISA-88 standard on continuous processes such as:

- Application of ISA-88 Model in the Control of Continuous Distillation Facilities by Franjo Kralj of PLIVA 2003
- Using ISA-88 Batch Techniques to Manage and Control Continuous Processes by Dave Chappel of P&G 2003
- Applying NS 88 to "Non Stop" Continuous Production by Dennis Brandl of BR&L Consulting, Inc*

Application of the ISA-88 standard did not catch on to the "continuous" user community in spite of early efforts to apply the standard to continuous process applications. It was often felt that there were too many differences in batch applications and continuous processing to adapt the same standard. In January 2010, the ISA Standards and Practices Board proposed a new standard that became ISA-106.

* Dennis Brandl expands on his ideas on applying ISA-88 models and terminology to continuous processes in what he terms NS (NonStop) 88 in his book Design Patterns for Flexible Manufacturing, 2007, ISA Press

Procedural Automation Standard for the Continuous Process Industries ISA-106

ISA approved the formation of a new standards committee in April 2010, and adopted the title Procedural Automation for Process Operation. The purpose for the committee in June 2010 was to develop a standard, recommended practices, and technical reports on the lifecycle of automated procedures for process operations.

Topics considered for the standard are:

- Models and terminology
- Modularization of procedural steps to foster re-use and lower TCO
- State models for procedural logic
- Process unit orientation with operational perspective

- Exception handling of abnormal process situations
- Implementation of startup, shutdown, abnormal situations, hold states, and transition logic
- Recommended target platform (i.e. control system vs. safety system) for different types of procedures
- Training and certification best practices

(So far these topics have the input and support from 39 manufacturers and suppliers including many companies that run distillation operations)

A 2008 survey by the ARC Advisory Group™ indicates that continuous process manufacturers are now seeing effective and repeatable transition management, along with the use of sequence-based operator procedures, as a competitive advantage. The safety aspect of automating procedures should be a high priority. The cause of some recent industrial accidents has been attributed, in part, to the lack of good emergency shutdown procedures during an abnormal situation. This put too much pressure on operators, in a crisis, causing improper procedural operations that resulted in disastrous consequences. Process industries have used semi-automated and automated procedures in the process industries for years, especially in batch processes. These procedures, when implemented in recipes, use a modular approach in accordance with the ISA-88 batch control standard.

Semi-automated and automated procedures are typically a rarity in continuous processes, due to the lack of general industry expectations and standards. Increased operational excellence has put more focus on business drivers that require increased safety, improved throughput, reduced cost, and knowledge capture, to retain years of operational experience that will soon be lost due to retirement.

Automating procedures for continuous processes in the past has typically been implemented using outdated designs and programming techniques. These older techniques usually result in difficult to maintain code. While this can provide short-term operational benefits, the total cost of ownership of these procedures is higher than necessary. This is due to the increased implementation costs to change and update successive procedures over time due to the lack of re-usable software code.

Implementing a modular approach could also provide companies the ability to standardize functions across plants, sites, and the enterprise achieving corporate-wide repeatability and reproducibility. This would help reduce engineering labor cost, provide consistent operation, and lower the Total Cost of Ownership (TCO).

Modular Procedural Automation (MPA)

Yokogawa introduced an integrated solution called Modular Procedural Automation to address industry needs to improve operating procedures, and to apply a uniform approach to the standard using different technology tools. MPA is a consultative methodology whose purpose is to document and automate procedural operations in continuous processes. A modular design approach facilitates standardized implementation within sites and across companies. This approach optimizes user acceptance and reduces deployment costs.

Using a modular approach as offered by MPA provides a number of benefits such as:

1. Hierarchy of Procedures: MPA breaks large and complex procedures into smaller modules and organizes them into a hierarchy. This modularization provides easier documentation, verification, and implementation of the discrete pieces of procedural logic and knowledge.

2. Re-use of Procedural Logic: Whether implemented with manual, prompted, or automated procedures, MPA can help re-use the same procedures and logic in different parts of the plant and with different products. When procedural logic (that is portions or modules of procedures) is re-used, the business gains repeatability, reliability, and it lowers the cost of developing duplicate procedures.

3. Multi-site Consistency: Companies with multiple production sites can experience an efficiency gain and product improvement by standardizing procedural knowledge between plants. Without modular procedural automation techniques, this level of standardization would be very cumbersome to maintain. Modular procedures, both prompted and automated, allow easy sharing of procedural knowledge between facilities.

4. Scalable Approach: MPA provides a flexible and scalable approach to automation; it avoids the "one size fits all" approach. Different types of procedure implementations contain scalability for manual, prompted, and automated control. The hierarchy of modular procedures is easily adjusted to fit the application requirements. Application requirements can vary the level of complexity (e.g. normal sequencing only or complex exception handling).

MPA has been used in many types of unit operations across many industries. Below are two examples in which the MPA methodology has been applied to refining and distillation operations.

Case Study #1

An oil refinery in Japan in normal operations underwent crude oil feedstock switches two or three times a week. The efficiency of the crude oil switch operation was very dependent on the experience and skill of the board operator running the distillation unit. With a skilled operator, the time to reach normal steady state operations was typically 5 hours. A junior, less experienced operator could take over 8 hours to reach the same normal steady state operations. These long transition times had an impact on product quality and production efficiency. It also caused the inefficient use of utilities such as fuel gas, power, and cooling. Additionally, with junior or less experienced operators there was a higher incident of operational errors resulting in abnormal conditions and "off-spec" product.

Yokogawa's engineers familiar with MPA methodology practices worked with the operational staff at the refinery. They interviewed the board operators from different shifts and were able to uncover and document their best practices. For instance, when ramping up feed temperatures, junior operators would typically ramp feed temperatures at a linear rate throughout the temperature zones. The veteran operators had the operational experience to change the temperature ramp at different rates depending on the temperature zone of the column. It was also uncovered that operators typically had to make over 100 adjustments to the process through the DCS system during the switch over. This was in addition to responding to false alarms that were set for normal operating conditions.

Implementing MPA methodology and automation allowed the refiner to make significant improvements in the operations switchover time to a predictable 4-1/2 hours regardless of what operator was on shift. During crude switchover, operator workload was reduced significantly with over 100 control system adjustments reduced to 10 and over 2000 process alarms reduced by configuring the system to be operationally aware of process conditions. Additionally, there was increased process knowledge sharing, a significant reduction in operator errors, and reduced operator training.

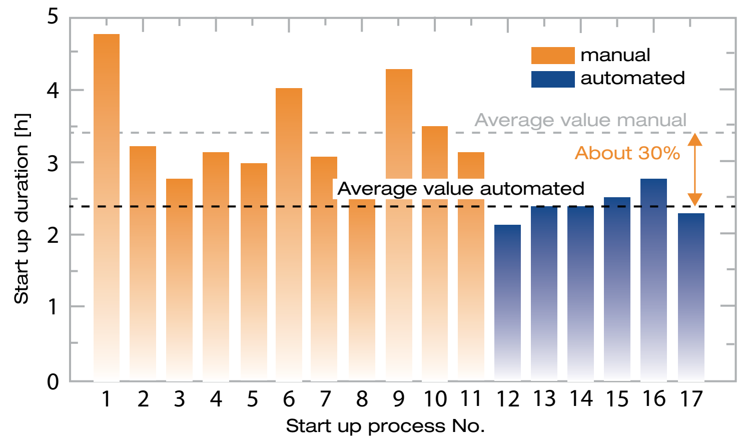
Case Study #2

Evonik Industries has an Acrylic Acid production facility in Germany that has integrated into the process two reactors, four distillation columns, and a crystallizer for the manufacturing process. A regular system shutdown of the production of Acrylic Acid is required for cleaning and maintenance. The startup procedure for Acrylic Acid manufacturing required the skills of experienced operators to bring the process up to steady state. Any additional time to bring the process to full production resulted in unnecessary rework and waste of production utilities.

Evonik worked with Yokogawa engineers on their requirements and determined the correct procedures and technology to automate the process. The results were:

1. Process operators were able to startup their distillation columns 30% faster
2. Reactors were able to come on stream 70% faster
3. Process safety margins, of explosive conditions during startup, were increased significantly

Figure 3: Startup procedure of a column



Procedural Automation Collaboration between Yokogawa and FRI

Since November 2010, FRI process supervisors and technicians have been working closely with Yokogawa consultants and engineers in implementing procedural automation utilizing the MPA methodology. Currently, procedures that automate the frequent startup and shutdown of the fractionation columns are in successful operation.

In analyzing requirements, it was determined to automate certain steps in both the startup and shutdown procedures. All procedure steps are converted into automated prompted procedures, but not all procedure steps require interface with the process control system (PCS). In the case of non-interfacing steps, prompted actions are programmed into the electronic procedure without requiring communication with the PCS. In the two cases at FRI, the startup and shutdown procedures contain a mixture of PCS interfacing and non-interfacing steps. For example, isolating and blocking in a component may not require PCS input—only manual manipulation. However, placing a control value in manual and opening it requires interfacing with the PCS. These types of actions can be automated and modularized. Modularization is the process of creating one electronic sub-procedure that may be used repeatedly within multiple procedures. In the above example, a general sub-procedure was developed for FRI to place a controller into automatic, manual, or cascade and set the setpoint value or manipulated value for a dummy tag. The only actions required of the electronic procedure writer are to drag and drop the user-defined sub-procedure to the workspace and replace the dummy tag and values with the actual tag name and values. This prevents re-writing these steps in each procedure.

MPA methodology begins with an examination of the procedures chosen for automation. At FRI, during the first step of the MPA methodology, the procedure evaluation process uncovered that many of the procedures were not actually written down, in logical order, or correct with regard to values. The common practice was to use the procedure as more of a guideline than an actual procedure. This allowed for variations in actual startup and shutdown efficiency. The automated procedures captured the best practices of the senior operators for use by all the operators.

Procedural flow diagrams for the startup and shutdown procedures were created in order to capture the evaluation results—completeness, logical order, correctness, steps to be automated, and sub-procedures to be modularized. The procedural flow diagrams were converted into automated procedures. The FRI subject matter expert and the Yokogawa consultant reviewed the automated procedures to validate logic and completeness. Testing on the procedures was performed in Offline Mode (disconnected from the process control system), in Trial Mode (read only from the process control system), and Normal Mode (read from and write to the process control system). The testing allowed for final adjustments of the procedures before they were placed into operation.

Future of Procedural Automation

Increased demand for improved distillation operations will expand the need for better automation procedures. This will increase of number of examples and published case studies that will grow the expertise and best practices.

The ongoing work of the ISA-106 standards development will develop models, terminology, and best practices for procedural control. Yokogawa will continue to participate and drive this along with end users and other participating companies. FRI and Yokogawa will continue their collaboration to investigate and develop MPA methodology best practices and document results of its benefits. MPA will continue to benefit FRI in researching fractionation technology more efficiently through evaluation runs of fractionation packing and column configurations, while increasing safety margins.

A Yokogawa Commitment to Industry

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