DUE DILIGENCE PROJECTS - ADDITIONAL THOUGHTS

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Assessing Technical Matters in the Chemical and Energy Production Sectors

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Within the context of producing chemicals and useful forms of energy in the private sector, very little happens without a careful evaluation of many factors. This applies to common tasks such as acquiring a pump or a heat exchanger, and to less common, but more complex tasks such as acquiring an entire production facility or an entire company. Many of us who are involved with acquisitions share certain characteristics. Among these is a hatred of being surprised by technical problems with equipment, by higher-than-expected production costs, by legal problems and, worst of all, by serious injuries or fatalities resulting from equipment or operating problems. Prudent purchasers therefore diligently examine many aspects of their potential acquisition; a process generally referred to as *Due Diligence.*

Dynalytics' experience is that within the chemical production and energy sectors, each party in an acquisition project in the industrialized countries can be reasonably confident that deliberate fraud will not be encountered. Future disappointments are far more likely to result from honest misunderstandings, excessively optimistic extrapolations, and phenomena that could not have been reasonably anticipated. Disappointments arising from any factor are what a due diligence effort is meant to minimize.

This paper discusses typical items that must be examined, the resources needed, and the roles Chemical Engineers are uniquely qualified to undertake within a due diligence project. It is recognized that each company in the chemical and energy production sectors presents some unique issues. The following material is therefore focused on typical design and operational matters, based on actual due diligence assignments that have had high chemical engineering contents. Issues related to pricing, marketing, contracts and accounting practices are obviously important but are not addressed in detail herein.

The Acquirer's Needs

An external independent Due Diligence Team (DD Team) is often retained to evaluate aspects of a specific situation: Typically, will the process/plant work? Is it safe? Is it scalable to higher capacities? Does it have the Permits it needs? Are there any intellectual property problems? Although suggestions may be welcomed, it is not usually part of a due diligence assignment to develop a better process. Indeed since this would be a distraction that could introduce biases against the situation being considered, it is best handled as a separate effort.

A properly performed due diligence effort will identify significant risks and assess the likelihood that each will or will not materialize. These are then combined to help management answer two broad questions:

- Should we proceed with the acquisition essentially as-is?
- If not, which aspects of the opportunity must be improved, and to what extents?

The technical factors that influence the answers to these will vary from one project to another, but most often are related to process- and plant-design, operations and maintenance, intellectual property, safety, and environmental permits.

Meeting The Acquirer's Needs

Preliminaries

In order to help the Acquirer come to fact-based conclusions, the DD Team will need to obtain and review a great deal of information that each party believes must be held in confidence and used by the other party only for the purpose of evaluating the specific opportunity being considered. This is commonly handled by both parties by executing a *Non-Disclosure Agreement (NDA).* Assuming that the proposed NDA contains exclusions for information the parties already possess or is already in the public domain, or similar situations, defining exclusions is normally not a problem. A potentially serious problem is that parties frequently demand that all documents be returned to the provider either on-demand or at the end of the assignment. This could theoretically leave the DD Team members exposed to legal problems, but without documents that might be necessary for a successful defense. Dynalytics' position therefore is that this is not acceptable; reasonable compromises have usually been reached. The following assumes that a mutually acceptable NDA has been executed.

Access to valid data is critical. Regardless of how complete documents appear to be, there are always items that either are not shown or need to be clarified. It is therefore important throughout the due diligence process that the team be able to have "frank and candid" discussions with appropriate members of the staff of each party. We become very concerned when we encounter managers who have a stake in the status quo or have a preconceived course of action, or we have a feeling that information is being withheld. Restricted access to employees is a major issue, and is likely to lead to a due diligence report with qualifications that diminish its usefulness. We find that having a serious discussion with corporate managers usually overcomes this problem.

A clear understanding by all parties of the agreed upon *Scope-of-Work* for the assignment is essential so that a properly staffed team may be assembled and reasons for requesting information, documents and meetings with the plant staff will be clear. Equally important, aspects that are not to be addressed must be clear to all; care must be devoted to assuring that a potential issue has not been overlooked. And certainly DD Team members must have the listening and writing abilities required for producing a report that has clear conclusions and recommendations, is well-organized with information that is properly documented and is internally consistent.

As will be seen below, a DD Team for a technology-based project within the chemical and energy production sectors anywhere in the world must include members possessing very broad backgrounds and, as necessary, deep subject expertise gained through their education and many years of experience. Direct experiences in process and equipment design, and plant operations are virtually an absolute necessity. A DD assignment may involve evaluating and applying kinetic data for reactor design, as well as equilibrium, heat transfer and mass transfer data for the design of separation and other specialized equipment such as crystallizers, mixers and pneumatic conveyers. Depending on the nature of the assignment, additional expertise may be required for assessing materials-of-construction, environmental health and safety issues, Environmental Permitting, statistical analysis, electrical power generation & distribution, instrumentation & control systems, and intellectual property matters.

Assessment of Technology

A threshold issue for a DD Team is whether or not the facility can safely and consistently produce its products in the quantities and with the properties its customers expect. Dynalytics' starting point is therefore a review of the product and feedstock requirements, including purities and production rates. We pay particular attention to physical and thermodynamic properties, the analytical techniques used to measure them, and techniques used to extrapolate them to other conditions.

Many processes use raw materials that have noticeable variations in their properties. Examples include the contents of moisture and other impurities and, in a hydrocarbon mixture, the distribution of isomers. These, moreover, may change with time as they are stored and thus may need to be tested upon receipt and then again immediately prior to use. A DD Team will therefore assess the methods used to reduce the risks of using poor quality raw materials. Items commonly evaluated include the in-house inspection procedures, assignments of responsibility and documentation requirements. Additionally, the technical aspects of the contracts for the supply of raw materials are reviewed. Do they contain appropriate bounds for impurities? How are samples analyzed? How are unacceptable raw materials to be disposed of?

Variations in compositions and properties virtually always occur to some extent. It has therefore become common for purchasers to analyze small samples and then use statistical techniques to evaluate the probabilities that the concentration of an impurity in a much larger batch of material will be unacceptably high. Although a great many statistical distributions have been developed by mathematicians, the Gaussian (Normal) Distribution is by far the most commonly used because it has been highly developed, is mathematically simple, and its results are easy to understand. It, however, exhibits two properties that limit its application; it shows probabilities that are symmetrical around a mean value, and it shows positive probabilities that compositions (or other "X" values) will extend from minus infinity to plus infinity. As simple examples of problems that may arise from these, consider establishing the ambient air conditions to be used to design an air-cooled heat exchanger. Results of fitting a Normal Probability Distribution actual data to would show there is a finite probability that the minimum and maximum air temperature that might be encountered are -500^{O}F and +500^{O}F, respectively. Although the Normal Probability Distribution will predict that the probabilities of these arising may be very small, it will not predict they are zero. Since these ambient air temperatures simply never occur in our real world, a different more appropriate Probability Distribution must be used. Similarly, the wind directions that will be encountered at a given site vary throughout the day and season. They however have a predominant direction; they are not symmetrical around a centerline so again a different more appropriate Probability Distribution must be used. Recognizing these deficiencies, other probability distributions have been more useful in due diligence assignments, including the

- Poisson (Considers the *number of events within a fixed time or space*) Example: Based on utility companies availability data for previous years, what is the probability that an emergency generator will need to operate 25 times in a year?
- Binomial (*Counts the number of successes (or failures) in a fixed number of trials*) Example: What is the probability that the emergency generator will successfully operate only 10 times out of 25 tries?
- Geometric (*Counts the number of events within a fixed time or space until a "Success" (or "Failure") is reached*) Example: What is the probability that the emergency generator will successfully operate 20 times before it first fails to do so?
- Gumbel (For *Extreme Value extrapolations* from sample data; *Focuses on the highest (or lowest)values encountered in periodic trials*) Example: Based on historical weather data, what is the maximum ambient air temperature that is likely be encountered, with a 95-percent confidence level, each week at a given site?
- Weibull (*Similar to but broader than the Geometric Distribution; widely used in reliability analysis because it can show early "Infant Mortality' failures, Uniform failures, or increasing frequent failures caused by increased aging*) Example: What is the probability that a specific pump assembly last for at least 50,000 hours of operation from its first start?

A reality is that situations often arise within which the collection, interpretation and use of data involve many subtleties. A Chemical Engineer with a strong background in statistics, including the design of experiments and interpretation of results, is therefore often an important member of a DD Team.

Statistical methods have been developed to help design a testing program that will produce valid useful results on a time- and cost-efficient basis. Our broad generalization is that results of an analysis of fewer than ~25 data points are probably not useful for any important purpose. For some applications such as the production of pharmaceuticals, many parameters, each with dozens or even hundreds of physical property tests per parameter may be required. Three major concerns that we always have about how statistics are used are whether:

- the most appropriate statistical distribution was used
- <u>all</u> of the test data were considered; "cherry-picking" and subconscious biases that eliminate unwelcome, but valid, data have been responsible for misleading results in many technical fields.
- situational-specific limits were used for concluding that an item is or is not "statistically significant." The 95-percent confidence level is very commonly used but is often not appropriate. It may be unnecessarily restrictive when calculating, as an example, the amount of a low-cost acid to use for neutralizing a waste stream whose pH can be readily measured prior to discharge and adjusted as necessary; a 75-percent confidence level is frequently appropriate. Conversely a 95-percent level may be insufficiently restrictive when establishing health- and safety-related requirements such as the quantity of toxic or flammable materials formed as byproducts in a reactor, or the sizing of a relief valve and venting system; appropriate confidence levels for these may be in the 99.0- to 99.9-percent level.

Although often not considered to be a raw material, water for either process, cooling, or fire protection uses can be a vital part of a plant's operation. Its reliable availability for industrial uses throughout the world is, however, becoming increasingly problematical due to droughts and competition from agricultural users. Assessing the situations that might arise requires an evaluation of economic, political and historical availability records. Situations have indeed been identified within a due diligence project that led to the use of air-cooled heat exchangers, accepting their efficiency penalties as the cost of increased plant reliability.

After reviewing physical property requirements and their supporting data, we then examine *Process Flow Diagrams (PFDs)* to obtain a clear understanding of the chemical and physical processes used for production, separations and purifications, disposal of solid and liquid wastes, and control of emissions to the environment and final packaging, which may range from vials to tank trucks or railroad tank cars, for delivery to customers. Due diligence concerns include the

- presence of recycle streams in the process that may cause problems of unintentional buildup of concentrations of impurities or dangerously reactive compounds

- large pressure reductions that may lead to substantial temperature reductions that, in turn, may lead to phase changes, plugged equipment, and possible brittleness in piping and vessel materials
- use of complex heat recovery networks that reduce process flexibility and complicate startup and shutdown operations
- methods and equipment relied upon for adequately removing thermal energy from exothermic reactions under all conditions that might be encountered.

It has now become common for process-designers to use highly developed commercially available computer programs to establish flow rates, compositions, temperatures and pressures for production of products from specified raw materials. This is normally acceptable to a DD Team. Assuming the computer program is identified, has been used by experienced engineers for the specific process being considered, and its limitations are understood, the process review can focus on examining input and output documents, as well as the options selected; it is unusual to request more than this.

Information shown on the PFDs is then used by the facilities process design engineers to prepare *Piping and Instrumentation Diagrams (P&IDs)* that illustrate the ways the production equipment are controlled, and presents piping and valve specifications. *Equipment Data Sheets* for each piece of major equipment are also prepared using the information shown on the PFDs. The latter are used by the mechanical designers and fabricators to produce the equipment that should meet the process requirements in a safe and dependable way.

A DD Team will examine the PFDs and the Equipment Data Sheets for consistency with all foreseeable operating scenarios, including startup, normal and emergency shutdowns. This is a valuable step because they will contain critical information that may appear to be reasonable or may be unusual and must be explained. Examples of information that we will review are:

- Catalyst specifications and operating conditions
- Maximum working temperatures and/or pressures
- Selections of materials-of-construction and corrosion allowances
- Major dimensions and critical tolerances
- Provisions for process data measurements and safety devices
- An identification of the Design Code, Standards, or Recommended Practices used for the mechanical design of the device
- Fabrication and inspection techniques

Many companies, associations and institutes have developed standard Equipment Data Sheets for equipment such as heat exchangers, pumps and compressors, mixers and storage tanks. Using these is advantageous since they usually request all the critical technical information necessary for designing the equipment they cover. They, moreover, were developed by groups of knowledgeable experienced people and were subjected to a critical review process prior to being accepted and recommended by the relevant organization. It is unlikely that important considerations have been overlooked.

The selection of specific equipment automatically imposes various constraints on the operation of the plant. Typical technology-related ones are maximum or minimum allowable and/or attainable temperatures, heat transfer rates, pump/fan/compressor flow maps, ramp-up and shutdown rates, relief valve sizes and emergency venting requirements, provisions for normal purging and cleaning, and inspection/maintenance requirements. It is therefore important for a DD Team to identify operations or equipment, if any, that are were specified by using generalizations or past experience that are not applicable to the process or equipment actually specified. Dynalytics has indeed encountered numerous cases of inadequate inspection/ maintenance practices that were not sufficiently process or equipment-specific. One example of this is the use of inappropriate sampling valves and filters in systems with streams whose viscosities increase to unusual extents as their temperatures decrease, leading to erratic performance. Another example frequently encountered is the reliance on inspection/maintenance intervals developed for other processes before sufficient experience is gathered for a new process. This is exacerbated when new materials such as nano-based ones are being handled.

In many cases equipment will be tested to determine compliance with performance requirements. Professional institutes and association have helped by developing testing and data reduction procedures. Examples include the AIChE's procedures for testing centrifugal compressors and pumps, mixing equipment, particle size classifiers, spray driers and trayed and packed columns for absorption and distillation processes. Additional testing and data reduction procedures have been developed by many other organizations.

Due diligence efforts can be reduced by focusing on the design information contained on the Equipment Data Sheets and their attachments, and results of tests that followed appropriate protocols, without necessarily verifying that each calculation was properly performed.

Many chemical engineers work in fields that are quite innovative and advancing rapidly such as the production of high-density batteries, other energy storage systems, carbon capture and storage systems, and those related to the production of nano-based and bio-based materials. The benefits are that equipment and plant performances are constantly improving, and materials with previously unavailable properties may now be obtained in reasonable quantities and at reasonable costs. Examples of this include nanomaterials with remarkable optical, thermal, electrical, strength and flexibility properties. They also may be functionalized to have specific catalytic, hydrophilic or hydrophobic properties and are thus (slowly) entering the broader chemical production field. Similarly, as processing conditions become more severe with respect to temperatures, pressures, and corrosive environments, many new plastics, composites, metals and ceramics such as those used for high temperature ethylene production furnaces and steam-hydrocarbon reformer tubes are constantly introduced to the marketplace.

We, however, always have a due diligence concern about advancements in newly available materials. Although laboratory and pilot plant investigations often show promising results, there is, precisely because they are new, limited experience with the long-term stability of the materials themselves, and the components or solutions in which they are used. The DD Team must therefore be able to understand and evaluate the test methods and correlations used for extrapolations to plant operating conditions and over long times. It is also important to assess follow-up and monitoring protocols that may lead to revisions to initial estimates.

Still another issue is that many groups of smart talented chemical engineers, chemists and other professionals apply for patents throughout the world, and many are indeed issued. It has now become an absolute necessity for Patent Attorneys to review the potential production process and uses of new materials to determine whether there may be infringements on others' patent claims, and whether or not the developer of a "new" material may be granted patent protection for its composition or use. This intellectual property issue has become more worrisome since the *U.S. Patent and Trademark Office* now relies on "first-to-file" rather than the previous "first-to-invent" timing. And having a patent issued is not an absolute guarantee that others will not successfully challenge it. Ominously for those who rely on patent protection, as of September 11, 2014 the *Patent Trial and Appeal Board* cancelled all claims in 65-percent of the cases brought before it. Because of the ever-increasing complexities, many Patent Attorneys have Chemical Engineering degrees themselves or retain Chemical Engineers to provide the necessary technical expertise.

Assessment of an existing Plant

In the event that acquisition of an existing operational facility is being considered, many additional factors related to the physical plant and its operation must be evaluated. One major set are those necessary for assessing the likelihood of critical equipment failures that might lead to fatalities or injuries, major damage, and a curtailment of the plant's ability to produce products.

An experienced DD Team will therefore normally review the plant's *Piping & Instrumentation Diagrams (P&IDs)* and characterize the failure situation for each piece of the plant's equipment, including piping and control instruments used for normal operation as well as for startup/shutdown. The probability of a failure may be quantified or simply described as "High", "Medium" or "Low", and the consequences may be "Disastrous," "Noticeable Impact on Financial Performance" or "Minor Inconvenience." Thus the mechanical failure of a storage tank or pressure vessel for poisonous or flammable materials is likely to be a "Low Probability - High Consequence" event. Mechanical failures of piping systems designed, fabricated and installed in accordance with the contents of codes, standards or recommended practices promulgated within the last ten years or so are likely to be low probability events, while failures of older vintage piping systems, depending on their age, are likely to be medium or even high probability events. Regardless of their probabilities of failure, consequences will be situation-specific. Dynalytics will normally first focus on the high-consequence events first and then the lesser ones. Others may, not unreasonably, first evaluate the high-probability events. The important consideration using either approach is that the design, construction and operation of the entire plant be evaluated.

Time-to-Failure of any component in an industrial setting depends on its precise composition, its fabrication methods and inspection history and of course the exact conditions to which it has been exposed. This includes physical failures such as the rupture of a tank, or operational failures such as that of an engine not starting when required. Failure times cannot be predicted with a high accuracy, but with this caveat in mind, realistic data for the probability that a type of equipment will fail within a specified time are available from various sources, such as:

- Governmental publications, including those of the:
  - International Atomic Energy Agency (IAEA)
  - Military (particularly MIL Std HDK-217)
  - National Aeronautics and Space Administration (NASA)
  - National Oceanic and Atmospheric Administration (NOAA)
- Associations' and Institutes' publications, including those of:
  - The American Institute of Chemical Engineers (AIChE)
  - The American Petroleum Institute (API)
  - The American Society of Mechanical Engineers (ASME)
  - Electric Power Research Institute (EPRI)
  - Society for Industrial and Technological Research (Norway)

Publicly available data are usually suitable for due diligence projects. In-house experience may be helpful and should not be ignored, but there is rarely a sufficient amount of detailed information within a single company to be very useful. Process licensors and equipment vendors may provide insights and guidance but appear to be reluctant to share data, perhaps for perceived competitive or liability-related reasons.

A DD Team will always devote much effort to assessing *maintenance practices* both for their obvious importance, and also as an indication of the long range views management may or may not have taken. Much has been documented and published, for example, about the short sightedness of following a lowest first-cost philosophy that often leads to future high cost replacement and maintenance needs. In any case, high-quality maintenance practices always reduce the frequencies and impacts of equipment failures, so typically we hope to see:

- a written *Maintenance Procedures and Schedule Manual* for each piece of critical equipment. These should incorporate, directly or by reference, recommendations of the equipment suppliers.
- accurate records being kept of inspection and maintenance activities, certainly including dates, actions, and the signature of the responsible employee
- the use of Predictive Maintenance techniques, particularly for rotating equipment and equipment subject to vibrations; these include online real-time monitoring and data analysis. Considering the impact of a failure, their costs are usually justifiable

We are particularly concerned that a dangerous catastrophic failure will occur, leading to a fire, explosion or releases of dangerous chemicals. Therefore we will always evaluate how mechanical integrity concerns are addressed by the company. Our specific concerns include the presence of:

- <u>Corrosion Under Insulation (CUI):</u> This is a frequently occurring, potentially dangerous phenomenon that is difficult to detect. Techniques that may be tried include conventional radiography, pulsed eddy current and ultrasonic methods; their effectiveness is not extremely high. Detecting corrosion defects by removing sections of the overlaying insulation is also an imperfect solution since it depends on the removed area being located directly on the corrosion site. If almost complete certainty of locating CUI is important, all of the insulation must be removed. This is a difficult expensive effort, particularly for older asbestos-containing insulations.
- <u>Abrasion or Corrosion</u> of piping and critical components: This may be detected by measuring wall thicknesses and comparing them to original design and, if available, more recent values. These are relatively simple straightforward tasks. Reasons for significant wall thickness reductions would need to be determined and properly addressed, which may be complicated, expensive, but necessary.
- <u>Surface Defects</u> that may have arisen from long-term stresses, from changes in the metal's structure or from the scouring action of abrasive particles in moving components. These defects may be detected by various nondestructive examination (NDE) techniques such as using liquid penetrants and eddy current arrays.
- S<u>ubsurface (Volumetric) Defects</u> such as voids and cracks that may be present within the equipment walls and internals. These defects typically grow with time because of cyclic temperature and pressure changes and their gradients. Locating and assessing subsurface defects, unfortunately, are costly efforts, but should be considered in the absence of sound reasons that they do not exist, and if a failure would be catastrophic.

A DD Team will certainly examine reports of mechanical integrity tests that were performed by or for the company, and come to a conclusion about the condition of the equipment. If adequate testing has not been performed in the recent past, an examination of maintenance and operating records will help decide whether to ask that adequate testing be performed. Mechanical integrity testing, moreover, deserves special attention because of its abilities to detect equipment deterioration to extremely dangerous levels. They, moreover, are legally required by various governmental agencies' regulations such as the U.S. Environmental Protection Agency's *Spill Prevention, Control and Countermeasure* requirements, and those of the U.S. Occupational Safety and Health Administration (OSHA)'s *Process Safety Management of Highly Hazardous Chemicals* that covers pressure vessels & storage tanks, piping systems, relief and venting systems, emergency shutdown systems, controls and pumps.

Since equipment failures can lead to costly loss of production as well as dangerous situations, the DD Team will ascertain whether flow streams can readily be rerouted to alternate equipment. Thus having an adequate redundancy and capacity of installed spare equipment such as pumps will be evaluated, as well as a readily accessible inventory of non-installed spare parts needed for routine maintenance such as filters or fan-belts. The extent and capacity of these should be based on anticipated time-to-failure, time-to-repair, and economic impacts of having a non-operating plant. Major equipment vendors normally provide advice that should be considered concerning spare parts for their equipment. It is not very uncommon for companies to limit their purchases of certain equipment or services to a single vendor (a sole-source supplier) without having discussions with, or obtaining bids from, others. While there may be good reasons for this such as protection of intellectual property, there are also downsides such as not becoming sufficiently aware of recent technical developments. The reasons for and implications of using a sole-source supplier of any component must be carefully evaluated. This may also involve an assessment of the technical and financial strength of the sole-source supplier and whether it has any exclusive rights such as patent protection or trade-secret knowhow for their products that would make it difficult to disengage from this favored supplier if necessary.

In today's world plant operation and safety are almost completely dependent on the availability of electricity. Examples of the problems that have arisen when reliability enhancements and adequate maintenance to backup electricity generators were not in place arose during Hurricane Sandy, and more extremely, at the Fukashima Daiichi Nuclear Power Plant in Japan. These have certainly gotten the attention of those who perform Due Diligence projects, and much has been learned from them! We therefore devote a noticeable amount of attention to determining whether the Plant has:

- adequate uninterrupted power supplies, particularly for critical safety-shut-down instrumentation. This is typically a battery bank, or more dependably, a fuel-cell system.
- a backup generator to meet other-than-safety electricity demands such as those for office and selected plant equipment. The capacity of the backup generator may be established by analyzing the electricity needs of each piece of equipment to function dependably and safely. It is usually not necessary for a backup generator (and its fuel supply) to meet the plant's full production capacity; this is an interesting evaluation that considers technology, economics and contractual matters. It is specifically noted that the probability of successfully starting and then successfully operating Diesel-generators

when needed has not been high. If they must be relied on, a properly performed due diligence effort should determine whether:

- ✓ they are started and checked at least once per month
- ✓ they have an adequate fuel supply on-site
- ✓ they, and their fuel storage tanks, are at an elevation substantially above anticipated storm surge and flooding levels, and their enclosures adequately protect them from flying debris during severe storms
- ✓ their fuel system includes an automatic filtration system to assure the absence of water or sludge arising from the fuel being stored for too long periods of time
- ✓ their starting batteries are functional since they are susceptible to internal electrode failures, and failures of automatic recharging systems. They, as a practical matter, have dependable useful lives of only three or four years.

Safety of the plant operation, as well as that of its transporters of raw materials and products must be evaluated. The toll an accident takes on people in the plant or delivering material as well as people off-site such as those near the plant or a delivery route can be horrific and dwarf considerations of financial liability. **Our major concern by far is that the plant is not, will not, and hopefully cannot be, operated at conditions that exceed the limits for which its equipment, piping and safety systems were designed.** We therefore always compare the requirements and limitations shown on the as-designed and installed Equipment Data Sheets with information from operating and production logs that show how the plant was actually operated. These, unfortunately, are occasionally found to differ in unsafe ways, leading us to promptly have tense discussions with plant management.

Several times a year, throughout the industrialized world, there is a serious accident in a mine, a chemical production or processing plant or a utility company's facility that leads to multiple deaths. Information about the causes of many of these, and recommendations for avoiding them, is available from groups such the *U.S. Chemical Safety Board*, the *National Fire Protection Association (NFPA)*, the *AIChE's Center for Chemical Process Safety (CCPS,)* and many other professional societies.

In addition to process, equipment and instrumentation/ control matters, the plant layout will often be reviewed by a DD Team to ascertain compliance with codes that contain minimum allowable spacing between items of plant equipment and between the plant equipment and property lines, and relevant aspects of fire-water and fire extinguisher systems.

Serious accidents, however, also occur in the world's transportation network. Many, but not all, companies therefore limit their transportation providers to a small group, each member having been carefully vetted. The danger of not adequately examining their safety records and practices was illustrated in 2013 by the death of 47 people and the destruction of much of the city of Lac Mégantic in Canada caused by the derailment of a runaway freight train that was carrying light crude oil. Following an extensive investigation, the *Transportation Safety Board of Canada* concluded that this was caused by:

- Using defective equipment (the locomotive)
- Poor maintenance
- Driver error
- Flawed operating procedures
- Lack of safety redundancy
- Weak regulatory oversight

These conclusions illustrate the benefits that probably would have arisen from a proper due diligence effort, whether performed in-house or by others directed toward continuous performance evaluation and improvement. Some of the deficiencies would have been identified and rectified, and there is a high likelihood that this horrendous catastrophe would have been avoided. The effort would have been invaluable!

Importantly, an independent due diligence study would also have considered the risks of shipping crude oil by rail. Since the Lac Mégantic incident, there have been several other serious *accidents involving the shipment of crude oil and other hydrocarbons. Various new regulations* concerning the properties of materials that may be carried by railroad tank cars, and the design of the tank cars have now been put in place, but implementation of many of them is not required for several years. Although it normally would not be part of a due diligence assignment, depending on the specific situation we now ask whether shipment by barge or pipeline has been considered, what risks would be associated with using them and, for recovered byproducts, whether their value justifies the operational and shipping risks that may be incurred.

Based on the unfortunate occurrence of too many accidents in the chemical and energy production sectors, a DD Team will always assess a plant's and company's safety culture and practices. We accomplish this by:

- interviewing plant staff and determining the extent and type of in-house training that is required and who provides it. In-house training may be supplemented by having staff participate in seminars and conferences such as those offered by the AIChE's CCPS and by other professional institutes. Simple low-cost steps that may increase safety, such as subscribing to and encouraging staff to read safety-oriented publications, may be useful
- verifying that standard *Safety Data Sheets* for each chemical handled in the plant are readily available to, and understood by, the operating and maintenance staff
- examining emergency response instruction documents such as those related to evacuations and notification of fire departments, police, hospitals and environmental protection agencies
- determining whether there are periodic fire and evacuation drills that enhance employees' behavioral reliability under stressful conditions

The effectiveness of a company's actual safety-related performance may be inferred by studying the company's insurance claims, and by reports submitted to the *Occupational Safety and Health Administration (OSHA.)* These organizations have, moreover, developed base-line statistics that can be used as self-assessment benchmarks.

A DD Team is unlikely to ignore any combination of risks and consequences that fall into the medium or high probability ranges and that would have disastrous impacts such as loss-of-life or even noticeable impacts on financial performance.

Permits are required for any facility that discharges quantities of air, water and solid pollutants that exceed governmentally established thresholds (de minimis values.) Not having required permits or having permits with unduly restrictive conditions can be a huge problem; these have in fact been deal-killers! Within the United States, for example, it may be necessary to secure a *Title V Operating Permit* (colloquially, an *"Air Permit"*) that contains conditions that forbid certain activities, limit others such as maximum rates and times of emissions, and requires others such as periodic testing and event-reporting.

In order to obtain an Operating Permit in the United States it is necessary to demonstrate, among other things, that ground-level concentrations of criteria pollutants will not exceed those included in *National Ambient Air Quality Standards.* Demonstrations are developed by using EPA-Approved air dispersion models that consider the most recent five years of hourly measurements of meteorological conditions (air temperature, wind speed and direction) ground surface characteristics, stack dimensions, and, for each operating scenario to be approved, the exhaust gas' flow rate, temperature and composition. Additionally similar amounts of background air quality data are required. It may take years to collect the required data and go through the necessary procedures, which may cost several hundred-thousand dollars. Typically, the air quality modeler develops a *Modeling Protocol* that identifies the particular EPA-approved model that will be used, sources of data, and an explanation of how the results will be interpreted. This is submitted for review and approval, with possible revisions, by the State's *Department of Environmental Conservation* (or similarly named Agency) prior to modeling actually being performed. When results become available, a *Report* is prepared and submitted to the State's Agency for its review and approval. Given the review and approval process for the specific dispersion model, the data used, and the resulting Report, a careful due diligence examination of the Modeling Protocol and the Report will normally suffice; calculations will normally not need to be duplicated.

Additional requirements such as having a *Water Allocation Permit,* a *Water Discharge Permit,* a *Process Safety Management Plan,* a *Spill Prevention, Control and Countermeasures Plan,* and Hazard *& Operability (HAZOP) studies & Results* and a *NOx RACT Control Plan* may apply to the facility; there are numerous other possible federally mandated requirements such as those, for example, limiting carbon monoxide emissions from reciprocating internal combustion engines. Other Permits from local fire or health departments may be required for the storage of certain chemicals.

A viewpoint we occasionally encounter is that *"Our facility is not subject to certain requirements because of the industry we are in, or we are a quasi-governmental entity, or our plant is grandfathered out of the requirement."* This may be true from a narrow legal compliance viewpoint, but we must, and do, point out that the requirements were often promulgated for valid technical concerns. If they have to do with avoiding situations that may lead to serious injuries inside or outside of the plant, that position should be reconsidered.

While details may differ somewhat, all industrialized countries have similar requirements. The possession of all required permits and an evaluation of the conditions they impose absolutely must be verified and evaluated by the DD Team. It is, moreover, critical that there be a determination of whether or not the plant can and realistically will be operated within the terms of each permit.

Closing Observation

Serving the client to the greatest possible extent requires that the DD Team possesses, or has access to, all of the expertise and information it believes to be relevant, and is sufficiently independent to be able to present its conclusions completely and fairly. While not a guarantee of "no surprises," undergoing a due diligence assessment limited to technology-related considerations is likely to help avoid unpleasant events arising from factors that should have been, but were not, adequately considered.

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