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SAFETY AND ASSET FAILURE: THE CASE FOR ENHANCING RELIABILITY

Any professional who has ever had the privilege of leading a team of employees would know that his or her responsibilities transcend budgetary concerns and that keeping employees safe is job number one.

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INTRODUCTION

Any professional who has ever had the privilege of leading a team of employees would know that his or her responsibilities transcend budgetary concerns and that keeping employees safe is job number one. This is true regardless of whether the leader is a line supervisor with two direct reports or a senior manager responsible for hundreds of employees, and it becomes especially important when any of the employees perform their jobs under hazardous conditions.

Take for example, the men and women who work in the petroleum industry. Conscientious petroleum facility supervisors remind themselves of their responsibility to the employees they supervise every day. Typically, the supervisor begins the day by unpacking his or her responsibility into a handful of manageable concepts. Principal among them is an acknowledgment that the workplace is filled with hazards and conflicts and that working conditions are always in a state of flux. In the context of this dangerous work and the ever-changing conditions, the supervisor reiterates a commitment to the golden rule of safety: the employees' health and safety always come first.

The supervisors' commitment to his or her employees is neither a product of their company's ubiquitous safety slogans nor a result of financial incentives to work safely. Instead, the commitment begins as a heartfelt concern for their employees' welfare. When the supervisor is directly engaged and feels an abiding duty to keep his or her employees safe, the workforce appreciates the effort and will work more carefully and thoughtfully in return. Less sincere engagement or statements of concern are often met with skepticism or outright cynicism and are much less effective at motivating safe work habits. Clearly one of the most important components of a successful safety program is the engagement of the entire leadership team.

A MESSAGE OF SAFETY

The many companies that own and operate petroleum facilities obsess over the safe operation of their assets. This should come as no surprise: it's a dangerous business fraught with lethal hazards, and incidents and accidents are costly to the company's reputation and bottom line. Recently, many oil and gas companies have sought to achieve what has been referred to as "world-class" safety performance. Though world-class safety is defined differently by the many safety experts who toss the term around, the concept usually comprises clear communication and periodic reinforcement of a company's safety expectations to all employees. Once safety goals have been established, the company measures actual safety performance and strives to continuously improve.

Predictably, such a company's safety goal is "zero". Zero incidents, zero accidents, zero injuries. This makes sense because the message should be clear that even one incident, accident, or employee injury is unacceptable. To further motivate employees to work safely, compensation is often tied to safety performance. Goal setting and measurement, along with engagement, transparency, and various levels of commitment, create a culture of safety where safe behavior is rewarded, and unsafe behavior is not tolerated.

In reality though, world-class safety is not a state that can be achieved; rather, it is more akin to a long journey down a poorly lit road. By maintaining a firm grip on the wheel, staying between the lines on the roadway and looking out ahead for potential hazards, companies are arguably functioning at a "world-class" level.

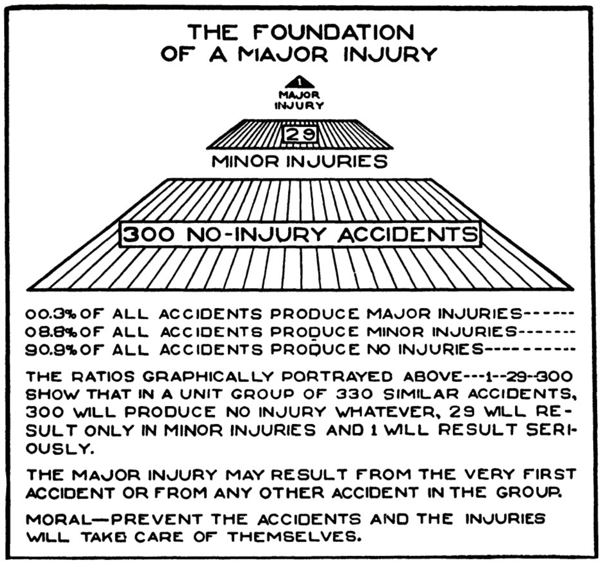
It's a complex journey and the "poorly lighted road" analogy is actually quite apt. It is much easier for companies to focus on the rearview mirror than it is for them to see what lies on the road ahead. Companies struggle to find leading indicators to guide them to better safety performance, and instead, rely on lagging metrics such as incident rate – IR, a numerical representation of a company's incidents calculated as a function of the number of employee hours worked – to tie their contemporaneous operations to metrics that they can only evaluate after the fact.

PYRAMID SCHEMES

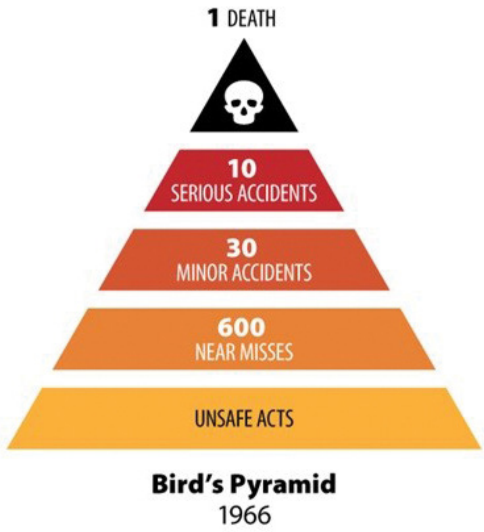
To operate more safely, companies sought a leading indicator that would aid them in identifying unsafe practices. They wanted to know where the next incident would occur so that they could prevent it from happening. In 1931, an insurance company employee named Herbert Heinrich conducted an analysis of 75,000 liability loss incidents in an attempt to find a statistical linkage between employee behavior and the probability of future incidents. Heinrich observed that the ratio of non-lethal incidents to fatal accidents was relatively constant across companies and through time – a relationship referred to as Heinrich's Law.

By conducting an analysis using Heinrich's Law, companies could calculate the probability of future serious incidents and fatalities based on the historical occurrence of minor incidents and close calls. If it was found that the probability of a serious incident was unacceptably high, the company would take action - unsafe employee behaviors would be identified and immediately corrected. Heinrich's Law resulted in the first so-called "Accident Pyramid", and it was the closest thing the industry had to a leading indicator of safety performance.

The precision of the Accident Pyramid that arose from



The “accident pyramid”, as depicted by H. Heinrich in the second edition of his book *Industrial Accident Prevention: A Scientific Approach*.



The “accident triangle” as updated by Frank E. Bird based on accident report analysis

Heinrich’s analysis of liability loss incidents has been improved over the years. In the 1960s, another insurance professional named Frank Bird recalculated Heinrich’s ratios and revised the pyramid based on numerous additional data. Bird’s version of the pyramid has been used over the last several decades to demonstrate the relationship between unsafe acts and serious injury or death and forms the basis of a so-called “behavioral approach” to safety.

Behavioral safety theory suggests that the number of unsafe actions taken by employees is directly proportional to the probability of fatal accidents that might occur in the workplace. It follows that if one could reduce or eliminate the number of unsafe actions that their employees commit, then the probability of serious accidents, injuries, and fatalities would be greatly reduced as a consequence.

Over the years though, the validity of Heinrich’s Law and the Accident Pyramid has been called into question. At its core, Heinrich’s Accident Pyramid is merely an empirical statement of probability based on historical data, not an immutable law with inescapable causes and effects.

Partly as a result of Heinrich’s conclusions, petroleum companies (and others) adopted safety programs focused on eliminating their employees’ unsafe activities. Companies painstakingly broke down daily activities into discrete operating procedures and standards of performance. Employees were trained to always follow their procedures, even during abnormal or emergency conditions. Conventional wisdom suggested that, if employees consistently adhered to standards and procedures, fewer incidents would occur, and a lower IR would result. In summary, according to this logic companies could be reassured that their workplace was “safe” if they could ensure that their workers were “behaving safely.”

THE TEXAS CITY REFINERY EXPLOSION

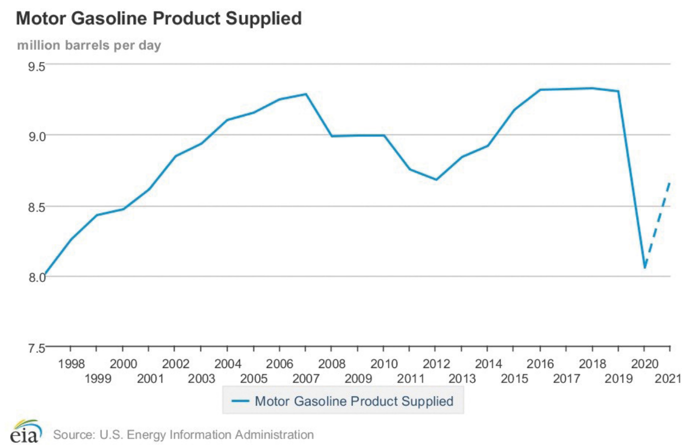
Ensuring consistently safe behavior is important, but achieving the safest possible workplace takes more than just that. As an example, in 2005, a massive explosion occurred when a process unit was started at a refinery in Texas City, Texas. The infamous explosion and resulting fire caused 15 fatalities and 180 injuries, and arguably pushed the petroleum industry away from heavy reliance on Heinrich's methods. The investigation of the incident concluded, among other things, that the refinery operator's safety program relied too heavily on behavioral safety. They also failed to adequately control the hazards to which the refinery employees were exposed. Along with taking measures to eliminate unsafe employee behavior, employers must also take measures to eliminate those situations where their employees' safety is jeopardized.

Controlling or eliminating workplace hazards can take years to achieve, and usually involves eye-popping costs. Focusing on employee behavior is, by comparison, faster, simpler, and less expensive. For years though, it was believed that complicated, dangerous operations could be made acceptably safe through procedures, training, and process discipline alone.

The Texas City Refinery explosion didn't render the Accident Pyramid immediately irrelevant or useless though. The statistical relationship between minor incidents, serious injuries, and fatalities continues to be valid, and like so many other such theoretical correlations, useful conclusions can be drawn from the data. The challenge is, however, to make good decisions and take decisive actions that meaningfully improve workplace safety over the long run. A safe workplace is, after all, equally desired by both employees and the board of directors.

According to the Centers for Disease Control (CDC), the fatality rate for oil and gas extraction workers is seven times higher than in other industries. While this CDC statistic does not include data from other parts of the oil and gas industry, the potential for injuries and fatalities is similarly elevated whenever petroleum workers handle toxic and volatile raw materials, products, by-products, and waste.

Petroleum products such as gasoline have fueled America's growth over the past few decades, and petroleum infrastructure has been busy growing to meet high rates of sustained demand. In 2019, an average of 9.31 million barrels (391 million gallons) of gasoline were consumed by Americans each day, and nearly every drop of this vital commodity was loaded into trucks, trains, or vessels by petroleum storage terminal employees.



High demand and rapid growth create a competitive market environment. To meet the financial performance expectations of their owners and investors, petroleum companies work feverishly to win a larger share of a limited market. To be competitive and reduce annual operating costs, companies often make tough decisions to eliminate staffing or defer equipment procurement. This is not unique in America - every company must grow, but then it must also manage the bottom line in order to survive the long haul.

ARE SAFETY AND RELIABILITY RELATED?

Petroleum facilities do what they can to live within their annual budgets. Preventative equipment maintenance and proactive replacement of older components represent a substantial cost for terminal facilities. To save money, some equipment can be safely operated beyond its normal life expectancy, however, this often results in equipment failure during operation. If the failure doesn't cause any collateral damage, the facility can be shut down for a relatively short time while the equipment is repaired or replaced. The benefit of deferring maintenance is that the equipment may "survive" much longer than expected, yielding a tangible reduction to annual expense.

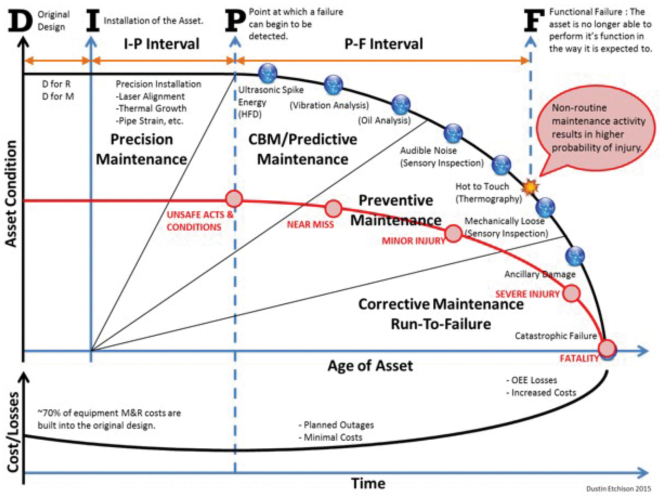
Intentionally allowing equipment to fail in service is a legitimate maintenance strategy known as "run to failure". The most popular example of running equipment to failure is a light bulb: the light bulb is typically replaced only after it fails. Replacement light bulbs are kept in stock because light bulb failures are commonplace events.

Running to failure works fine for light bulbs, but with more complex equipment there is a downside to this strategy that is often overlooked. At an oil terminal, for example, almost every system on the property is crucially important for maintaining employee safety, meeting customer's expectations, or ensuring regulatory compliance. Vapor combustors, loading arms, overfill protection, load preset controllers, meters, pumps, and all means of terminal automation are all critical to the routine function of the facility. However, even though they are critical these components can be intentionally run to failure provided that an acceptable margin of safety is engineered into the failure scenario. In most cases, if the component can fail in service without causing a catastrophic event (such as an injury, a fire, a spill, or some other form of uncontrolled damage) it may appear that there is an economic advantage in operating equipment in this manner. However, if the terminal is repeatedly shut down for unscheduled maintenance activities, is it a reliable terminal? If the terminal is not reliable, does that make it less safe?

Engineers and academics often debate things like the reliability and safety of components and systems. Consequently, whether there is a direct correlation between reliability and safety remains uncertain: theoretically, something that is reliable can be unsafe, and something that is safe can be unreliable.

In 1978, engineers at United Airlines observed and published a correlation between maintenance and reliability, known as Reliability Centered Maintenance (RCM) that is today considered foundational. RCM is often represented graphically through the Asset Failure Curve. The Asset Failure Curve tracks the effects of decreasing maintenance effort upon the condition of an asset over time. Ultimately, without appropriate human intervention to maintain or repair an asset, the asset may fail unpredictably while it is in service. While the initial application of RCM was airline passenger aircraft, its tenets have been applied to many other industries with critical components of one sort or another. Invariably, the point of RCM is that an asset's reliability is a function of design monitoring and maintenance. If an operator does not want an asset to fail in service, then the asset should be designed with an expected operational lifespan, and then equipped with components that are robust-enough to meet that expectation (provided that they are adequately monitored and maintained).

The RCM Asset Failure Curve has been updated and revised numerous times over the decades by engineering and safety professionals. Recently, the Heinrich/Bird Accident Pyramid has been superposed upon the Asset Failure Curve to show a theoretical correlation between safety, maintenance, reliability, and cost. The resulting graphic, below, is both powerful and compelling, assuming one supports its many premises.



The integrated Asset Failure Curve/Accident Pyramid highlights the potential cost, measured in injuries and fatalities, of running equipment to failure. When preventative measures are not taken to reduce the probability of failure in service, undesirable events such as explosions, fires and spills can occur. An example of just such a catastrophic failure is the Texas City Refinery explosion discussed in the paragraphs above.

Clearly, the authors who combined the Asset Failure Curve with the Accident Pyramid believe that reliability and workplace safety are linked. Their graphic suggests that an asset that might fail unpredictably is, according to definition, not very reliable, and degraded reliability results in a less safe workplace. But why is this the case? Some would argue that the probability of catastrophic failure can be reduced to acceptable levels through Process Safety Management and other similar protocols. Hazards arising from sudden failures can be effectively mitigated if all the associated operating procedures are strictly followed, and all engineering safeguards function as intended.

THE COMMERCIAL VALUE OF RELIABILITY

At a typical petroleum storage facility, because safety has been painstakingly engineered into the equipment, and because workers have been trained to follow procedures at all times, catastrophic equipment failures are – thankfully -- extremely rare events. On the other hand, service outages caused by unexpected failures, and the work needed to replace or repair the failed equipment, are quite common.

Most oil storage terminals do not own their inventory – the crude oil, diesel fuel, gasoline, kerosene and other products maintained in storage are owned by other companies. The owners of the terminal's inventory are the terminal's customers, and in most cases, terminals are expected to be in service 24 hours a day, seven days a week so that customers can load their product. Terminal customers, whose accounts often represent many millions of dollars of terminal business each year, become upset when they can't load their inventory due to an unexpected equipment failure. Customers insist that the terminal operates reliably, with no downtime other than that which has been scheduled well in advance. Whether this posture is reasonable or not is beside the point.

When an irate customer calls headquarters to complain about an unscheduled terminal outage, the short-term economic benefit of running equipment to failure begins to lose its luster. In fact, terminals that repeatedly experience unplanned outages often drive their customers to do business with their competitor's terminals that operate more reliably. Terminal inventory owners track terminal performance and are often willing to pay higher fees in exchange for better reliability. This is particularly the case when terminal outages cause transportation and demurrage fees to mount, and retail stations must curtail motor fuel sales.

OUTAGES AND EMERGENCIES

Unfortunately, allowing equipment to fail in service turns out to be a common practice at most petroleum terminals. Sometimes it's just accepted without much thought. Sometimes risk and reward have been carefully considered in the context of safety, regulatory compliance, and customer service. No matter what the decision is based on companies often fail to appreciate the hidden dangers associated with engaging in this practice.

To keep their customers happy, terminals work very hard to shorten the duration of unscheduled outages. It would not be inaccurate to state that outages caused by unexpected equipment failures are treated as emergencies. In order to return the terminal to full operation, employees must respond to outage emergencies immediately, sometimes alone, and often in the worst weather. Under these stressful conditions, employees are much more likely to be hurried, take shortcuts, and disregard the procedures that have been written to protect them from harm. In short, during outage emergencies, employees are much more likely to commit unsafe acts.

It's one thing to train employees to follow safety procedures at all times; it's quite another thing to consistently expose these employees to working conditions that make it difficult to do what they have been told to do. While this contradiction may not be obvious to the employer, it is a harsh reality for the employee who must repeatedly respond to one outage emergency after another.

Heinrich's Law showed us that the number of unsafe acts committed by employees is proportional to the probability that a serious injury will occur. A petroleum terminal that is committed to reliable operation will be a safer place for employees to work, as it will be more obviously devoted to meeting the commercial needs of its customers.

IS RELIABILITY AN IMPOSSIBLE DREAM?

The conscientious facility supervisor that was mentioned at the beginning of this article knows that unexpected equipment failure is the enemy. He or she daydreams of a terminal where employees can do their jobs under the best possible conditions, and terminal customers get the service they have paid for. It's not unreasonable for the supervisor to have this dream. It's a dream of reliable operation, and it's not the impossible dream!

Terminal supervisors dream of oil terminal facilities that are designed, constructed, and operated in such a way that equipment rarely fails unexpectedly. Reliable terminal operation starts with robust, intrinsically reliable equipment, and a maintenance program that reduces the incidence of unexpected equipment failure. Terminal operating companies must be committed to this vision at a high level for it to be successful, because it may cost more in the short run. However, in the long run, the benefits of a safe and healthy workforce and a growing market share represent positive economic factors that will offset the short-term expenses.

To complement this vision for a safer, more reliable terminal facility, equipment manufacturers must ensure that the products they offer meet expectations for intrinsic reliability. Such equipment must be designed, tested, and configured for the end-user's specific applications. The best of these manufacturers will test equipment under a wide range of conditions, fully investigate defects and premature failures, and periodically improve their products based on testing, performance data and feedback from end-users.

Dixon is a North American manufacturer that clearly understands and supports the vision of safe and reliable petroleum facility operation. Terminal equipment like Dixon's loading arms, rack overfill/grounding monitors, swivel joints, API couplers (load heads), and cam and groove fittings are designed and manufactured to be intrinsically reliable and to meet or exceed end users' expectations. Dixon is proud to collaborate closely with the customers using its products to ensure that solutions are manufactured and configured to provide years of trouble-free, reliable service.

To ensure the most reliable products possible, in 2012 Dixon built a 12,000 sq. ft. Innovation Center near its headquarters in Chestertown, Maryland. The Dixon Innovation Center, now nearly double in size, is an integral resource for product development from concept to field, which includes prototype machining, assembly, and in-house product testing. It was specifically intended to support Dixon's industrial market segments including energy/oil & gas, construction, fire protection, food and beverage/pharmaceutical, and mining.

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Austin McClain is a liquid energy Terminal Specialist at Dixon. He has over two-decades of experience in petroleum pipeline and terminal operation, including construction, maintenance, environmental health & safety, and emergency response. He works closely with engineers and end-user customers to select loading systems that improve terminal safety, efficiency and reliability.

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