How does the Insurance Industry use the Principles of Management of Process Safety?

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The Management of Process Safety provides an ideal framework which is used by the Insurance Industry when pricing their portfolios. Pricing risk means understanding risk and the insurance industry has adopted a number of metrics to define upper limits of loss, for uncontrolled events and lower limits of loss for controlled events. Estimating an upper limit of loss is a process that starts with understanding risk information for a particular policy holder and the associated insurance product. This paper presents how the principles of the Management of Process Safety are used in three classes of insurance with examples. The concepts of risk identification, risk assessment and risk mitigation are illustrated with data as seen in the field. A final quantification of the exposure of the risk is provided with the metrics typically used in insurance.

An Introduction to Insurance Concepts

The function of insurance is effectively to act as a risk transfer mechanism and to provide a form of financial security and peace of mind for the insured. General insurance is mostly provided by means of annual policies and programmes depend on portfolios or pools of similar risks. In order to manage maximum limits of acceptance for particular categories of risk, insurer and insured have at their disposal a range of risk sharing options such as co-insurance, dual insurance, and self-insurance (Thoyts, 2010).

Insurance Metrics

Pricing risk means understanding risk and the insurance industry has adopted a number of metrics to define upper limits of loss for uncontrolled events and, lower limits of loss for controlled events. Measures of loss used at Allianz Group Corporate and Specialty (AGCS) are the Maximum Foreseeable Loss (MFL) and Estimated Maximum Loss (EML). The deciding peril the MFL and EML are derived from is mainly fire but one could also have a Vapour Cloud Explosion (VCE), a catastrophic equipment breakdown or explosion depending on the risk. For equipment breakdown perils, the Probable Maximum Loss (PML) is more commonly used. Natural hazard perils such as earthquake or flood are considered separately with dedicated MFL and EML assessments.

The MFL is defined as the largest loss when the most unfavourable circumstances are combined. The EML is defined as the largest loss to occur under normal conditions where limiting factors, such as safety devices, physical protection systems and human factors, are taken into account. Both are measures of significant events with the MFL always exceeding or equalling the EML. The normal loss expectancy or event (NLE) is the amount of loss to incur during normal conditions with all risk mitigation systems and processes working correctly. It can be used to establish deductible limits. The integrity of limiting factors for both the MFL and EML are shared by underwriters and loss control engineers. The primary responsibility for identifying and routinely assessing physical MFL/EML limiting factors on a particular risk normally rests with the loss control engineers if a survey is carried out.

The foundation for every MFL/EML/NLE is based on obtaining accurate insurable values. The total MFL/EML is comprised of two elements. Property Damage (PD) is an estimate of the damage to insured property based on the loss scenario and it is based on replacement values. Business interruption (BI) insurance covers the consequential loss from an insured peril that interrupts or diminishes production. Following a waiting period or time exclusion stated in the insurance policy, BI insurance covers lost income and continuing or non-avoidable expenses during the time required to restore production.

The scenarios associated with the MFL and EML consider the extent of a loss (i.e. severity of the risk) and not the likelihood of that event occurring. The MFL/EML philosophy is hence based on identifying the most likely initiating event to produce a large loss which may be affected by qualifying limiting factors. In some cases, the MFL event could include the entire site. If the complexity of operations on site is such, then the largest most likely scenarios should be taken and the rationale documented in order to define the most likely MFL/EML.

In the absence of an engineering visit and insurance report, the MFL may be considered to be the total insurable value on any one site, plus exposed interdependent BI also known as Loss of Income Values. The responsibility for assessing and validating BI interdependencies and make-up capabilities begins with the underwriters. Loss control engineers may also provide an assessment and validation of interdependencies and make-up at site level if the information is readily available with persuasive evidence for make-up strategies where they have been credited.

Using the Principles of the Management of Process Safety and Risk Rating

The Management of Process Safety programme is divided into 14 elements which include: process safety information, process hazard analysis, operating procedures, training, contractors, mechanical integrity, hot work, management of change, incident investigation, compliance audits, trade secrets, employee participation, pre-start-up safety review and emergency planning and response. All of these elements are interlinked.

The insurance industry ties these principles into scenario based assessments and starts the assessment of the risk with the identification of hazards and the associated safety systems or protective barriers which are in place. Scenario based assessments provide a good foundation to address the adequacy of safeguards or safety devices in place and ask the following basic questions: 1.What the safeguards are? 2. What do they do? 3. How do they help to prevent or mitigate the situation? There is a useful acronym 'MARSHED' used in hazard and operability (HAZOP) studies to help rate the safeguards and meaning: *maintainable, available, reliable, safe, human factors, education* and *defeat.*

Insurance audits are based on credible scenarios and initiating events. Mitigating elements in an assessment would include positive human elements and the physical barriers that reduce the risks. The direct link to scenarios and barriers makes it easier to make concrete recommendations for improvement.

Insurance risk rating models quantify the severity of a risk and tend to do so by using the principles of the Management of Process Safety to achieve this. Either in a holistic way, where data collated in the field is processed in a distributed weighted system or in a discrete weighted model where flagged exposures are given penalty points. This process is also very reminiscent of the Dow's Fire and Explosion Index (F&EI) Hazard Classification. This index has been widely used in Dow and outside Dow. It is the leading hazard index recognized by the chemical industry. In fact, it is also used in insurance to support underwriting decisions for chemical risks. The purpose of the F&EI system is to:

1. Quantify the expected damage of potential fire, explosion and reactivity incidents in realistic terms.
2. Identify equipment that would be likely to contribute to the creation or escalation of an incident.
3. Communicate the F&EI risk potential to management.

Even though insurance companies work on MFL events which are typically based on significant loss events in worst case conditions, there is also an equally important drive to determine separate loss expectancies (LEs) for smaller realistic losses. The potential for risk improvement or risk reduction is then extracted from these LEs which provide an estimate of reduction of loss when the deficiency is resolved with completion of the recommendation.

Principles of Management of Process Safety and Insurance Metrics in Context: A Selection of Major Classes of Insurance

The pricing of a portfolio of properties for a company starts with defining its business operations. It is equally important to identify all of the perils (natural and/or man-made) the portfolio is exposed to in the territories the company operates in. Estimating an upper limit of loss is hence a process that starts with collecting and understanding information about a particular policy holder or risk and the scope of the associated insurance product. This paper would like to present examples in three classes of commercial insurance namely, industrial property, engineering and pecuniary loss.

The starting point for all commercial property insurance is the standard fire policy for the simple reason that when the cover originated, fire was the only peril covered. In its modern version, cover is offered for losses arising out of fire, lightning and explosion. Other type of policies can offer cover for a wider set of perils, and fire resulting from other commonly insured perils (earthquake or riot) would be excluded (Thoyts, 2010).

In *industrial property*, cover is usually divided into three categories, although variations may exist according to the nature of the business. Buildings are generally covered for the full rebuilding cost. The variety of buildings insured is wide, and cover may be limited in the case of particularly vulnerable structures, for example an exclusion cover for open sided structures. Plant, machinery and other contents are permanent physical assets and they are almost always insured on a reinstatement cost basis (the cost of replacing the item with a new item of similar quantity and specification). The stock cover consumables used in the business and includes raw materials, finished goods, stock held for sale. Such property is insured on a replacement cost basis, so the policy does not cover expected profit margins on the sale of such items (Thoyts, 2010).

In *engineering insurance*, the policy is designed to cover against sudden and unforeseen damage and breakdown to items of machinery and plant. This may be extended to include operator error, damage to surrounding property or collision and, if required the business interruption arising in consequence. Most engineering insurers also provide the periodic surveys of pressure and lifting plant required by law. The '*target risk'* will be any item of machinery that is vital for the smooth running of the business. It could be an autoclave, turbine, crane, motor, packaging machine or similar. The extent and likelihood of damage will depend on the particular technology and the equipment risk factors. Equipment risk factors are generally used to quantify the quality of the risk. Frequency-based *equipment factors* include: operating environment and conditions, age/history, maintenance, and operators are factors that impact on the frequency aspect of the equipment risk equation. Consequence-based *equipment factors* include: safety devices and contingency planning, but also operators are factors that impact the consequence aspect of the risk to equipment.

There is a large spectrum of technologies and associated loss scenarios and a loss control visit or desktop analysis is the best way to identify the target risks and appropriate loss scenarios. In the worst case scenario, i.e. an MFL event, the loss value would equal the total insurable value of the piece of equipment as damage may be beyond repair. Replacement values are driven by ageing, unique, bespoke, criticality or long lead time machines or spares. The PML would generally be 70 % to 80 % of the MFL depending on the severity of the event, the possibility of repairs or the need for replacement of the equipment. This paper presents examples in the power generation and fragmentizing industry.

In *pecuniary loss*, insurance cover purely financial losses. The largest and perhaps most critical form of pecuniary insurance is BI insurance, also known as consequential loss or loss profits insurance. This form of cover compensates the business for the loss of expected future profits following damage to the insured premises and also due to other defined events, such as, for example, the interruption of the internal or external supply chain. The basic intent of the cover is to provide the necessary compensation to allow a business to survive while physical damage is repaired. The cover is often extended to cover damage occurring other than at the insured premises which causes interruption to the business. This would include damage causing denial of access to the premises, damage to the premises of public utilities and suppliers or customer's premises. The latter refers more specifically to contingent business interruption (CBI) and examples are provided in this paper for the plastic compounding industry and the phosphate fertilizer industry.

Examples

Example 1 – Engineering - Combined Heat and Power with an Organic Rankine Cycle (ORC)

Insurance policies for power generation and renewable energy typically include Material Damage, Mechanical and Electrical Breakdown with BI. The target risks are dependent on the technology and equipment installed. To correctly identify the target risks, it is important to understand the technology and list major equipment found in an installation. As a starting point, the process examines the total insurable values (TIVs) for major equipment. Then most probable loss scenarios are identified, along with the availability of adequate safety devices, space separation, fire breaks and non-continuity of combustibles to be able to assess if the total insurable value can be reduced to represent the PML. The extent of the damage will depend on hazards inherent to the operation of the equipment as well as external exposures.

In power generation plants, for example, high hazards include fire on the lube oil systems supporting the operation of the turbine. A thorough evaluation is conducted to assess the potential for spray fires or large releases of oil, the normal operating pressure for the lube oil, curbing and or drainage around the turbine. Explosion hazards are associated with the operation of the boiler. Other fire hazards are associated with oil-filled transformers. Serious equipment breakdown can involve the turbine (i.e. uncontrolled over-speed events) and the generator with severe electrical faults.

In the example of a combined heat and power plant with an ORC, a biomass-fired boiler can use wood and bark and the heat from the gases of combustion is used to heat a closed loop of thermal oil. The thermal oil loop is integrated with an ORC plant where pressurised silicone oil is vaporised and slightly superheated (i.e. 250°C at 10 bar) in an evaporator. The pressurized silicone oil is then expanded in an axial turbine which is directly connected to an asynchronous generator. The condensation of the oil takes place at a temperature which allows the heat recovered to be utilised as district heat (i.e. hot water feed temperature about 80°C to 90°C) (Breeze, 2014).

The target risks are the boiler, the turbine, the generator and the step-up transformer. The design and construction of boilers represent one of the largest capital expenditures in the industrial sector. The operational reliability and availability of these boilers is often critical to the profitability of the facility. The safe operation is dependent on a number of factors including fuel explosions, contaminated feed water, low-water conditions, improper blowdown techniques, poor water treatment, improper warm up, pulling a vacuum on the boiler, impact damage on tubes, flame impingement, severe over firing.

The value of producing and understanding a production flow diagram (PFD) is illustrated below in the assessment of the risk and of the flow of BI through the plant.

There are two largest engineering target risks:

a) The biomass-fired boiler using mass burning (i.e. wood and bark) are burnt directly in a special combustion chamber and conventional grate.

b) The sealed ORC based plant.

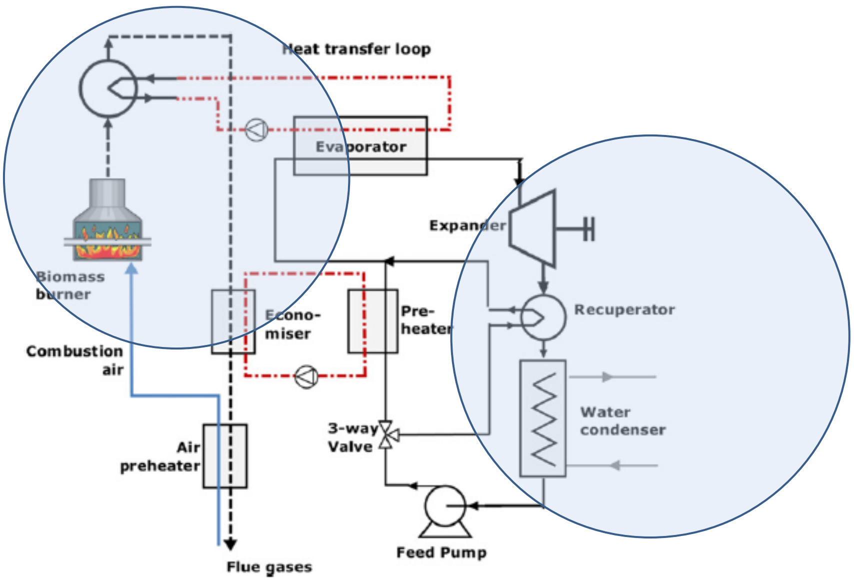

Figure 1: Working principle of a biomass Combined Heat and Power Plant with an Organic Rankine Cycle (ORC). **Source**: Quoilin, Sylvain & Van den Broek, Martijn & Declaye, Sé & Dewallef, Pierre & Lemort, Vincent. (2013). Techno-economic survey of Organic Rankine Cycle (ORC) systems. RENEWABLE & SUSTAINABLE ENERGY REVIEWS. 22. 168-186. 10.1016/j.rser.2013.01.028.

A boiler furnace explosion would cause severe damage to the biomass-fired power plant, the thermal oil system and the ORC power plant. An uncontrolled fire could be anticipated because of the thermal oil system, in addition to the lack of sprinkler protection, inadequate containment, lack of emergency drainage and inadequate space separation.

MD MFL = MD PML = 100% TIV

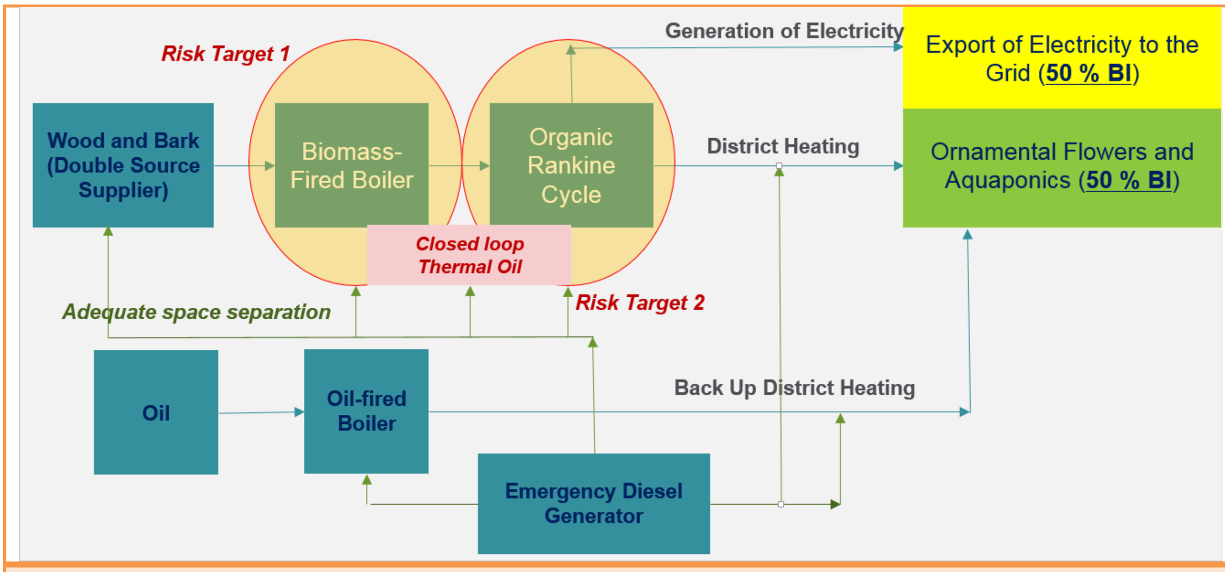

Figure 2: BI Calculation at a Combined Heat and Power Plant with an Organic Rankine Cycle.

Example 2 Fragmentising Plants

Fragmentising is a technology which is successfully used in the recycling industry for the recovery of metals and plastics. Waste material can include end-of life vehicles, waste electrical and electronic equipment (WEEE), including computers, televisions, and packaging. Valuable ferrous and non-ferrous secondary raw materials can be retrieved and can be melted into new production materials. Fragmentising plants use hammer mills and this is a long established process. A hammer mill is a mill whose purpose is to shred or crush aggregate material into smaller pieces by the repeated blows of hammers. These machines have applications in many industries including ethanol plants (BMRA, 2013).

In order to control and reduce emissions and to suppress potentially flammable atmospheres, a controlled injection of foam is added in the mill in what is known as a damp process. Because of the repetitive action of the hammers during their operation, inherent maintenance issues associated with mills include the replacement of the hammers through normal wear and tear, and the modification and upgrades to other parts of the mill. So with routine replacement of parts and servicing programmes, installations will have components significantly younger than the operational age. The monitoring of the electrical load on the mill gives a good indication of the mechanical stresses and strain the mill is experiencing and a pre-shredder (ripping and tearing metal) is normally installed to alleviate the strain put on the mill that can be caused by large and chunky metal waste (BMRA, 2013).

Hammer mills will typically be unique and designed for the raw materials which they are processing. Typical fire hazards associated with metal recycling occupancies are mostly linked to external fire exposures because of yard storage. Best practices would therefore see good physical separation implemented on site along with a good fire emergency response plan, good pre-planning with the Fire Emergency Services and the provision of yard hydrants. Good physical separation is not always observed as locations can get very busy and congested with scrap metal and other recyclable waste.

Examples of proven technology include Danieli Henschel (pre-shredder), Cheng Ho Hsing (hammer mill) and Quad (electric motor). With reference to equipment breakdown, large hammer mills used in automobile shredders may be driven by diesel or electric motors ranging from 2000 to over 5000 horsepower (1.5 - 3.7MW) fed by a dedicated transformer and locations will hold a spare. Additionally, the drive shaft is a critical spare and it has a life expectancy too. It is a spare which is uniquely designed for each recycling plant. Because of the repetitive and smashing action of the hammers, and because of the vibrations which are continuously absorbed by the shaft, the shaft can see its yield strength altered in time, in the same way a piece of metal can be rendered brittle by cooling and heating it repetitively, and a sudden and unforeseen failure of the shaft has occurred. The spare is made from special steel and has long lead times (up to 12 months).

MFL BI = 100% BI = 12 months.

The most dramatic and unexpected cause of brittle failure in ferrous alloys is their tendency to lose almost all of their strength when the temperature drops below their ductile to brittle transition temperature. Between 1942 and 1952 approximately 250 large welded steel ships were lost due to catastrophic brittle failure. Another 1200 welded ships suffered relatively minor damage (cracks less than 10 feet long) while over 1900 riveted ships have broken in two and were lost at sea. Most of the failures occurred during the winter months and they occurred both when the ships were in heavy seas and when they were anchored at dock.

Example 3 – Supply Chain, Business Interruption (BI) and Contingent Business Interruption (CBI)

Introduction

Supply chain management is based on principles supporting the effective flow of materials and information to meet the requirements of customers. The concept of supply chain is not new and it is in fact a military term used in the 1900s to describe the process of getting food, weapons and ammunitions to the front line of battles by creating supply points between military bases and battlefields. The efficient management of a supply chain requires suppliers that are reliable and this means that they produce a quality product that meets the manufacturing needs and the product is delivered on time. The effective management of the supply chain is important because supply chain disruption can occur at many levels – from a localized warehouse disruption (because of a fire or flooding for example), a disruption to a critical manufacturing location, to regional/global network failures caused perhaps by a major natural disaster. Recent examples of supply chain disruptions published in the media (e.g. Coty, Inc. and Reckitt Benckiser in the *Financial Times*, November 2018), have had severe implications in financial results, in investment, in values of the stock market and market share.

In light of the international nature of businesses with often a presence at global level, insurance companies currently invest a lot of effort and resources in understanding market structures and available capacity for critical suppliers and the type of operational integrations which are inherent to a company's business model. International supply chains are logistically and technologically complicated, and an international presence also requires an involvement in politics, trade tariff laws, quality control and international relationships.

One of the ways in which companies can formally approach the management of risk in their supply chain is through the adoption of the ISO 31000 standard. Although it is not a certification process, it can help provide guidance for internal and external audits and can also help organizations mitigate disruptions to their supply chain. Coca-Cola uses the standard in its approach to managing risk in its supply chain operations. It broadly categorizes risk management into 'deployment' and 'sustain' stages. In addition to the ISO 31000, a further related standard exists, ISO Business Continuity Plan (BCP) 22301, detailing best practice in business continuity management to which companies can gain accreditation. The standard identifies threats and the critical business functions they could impact and the process involves formalizing a company's response to extreme weather, fire, flood, natural disaster, theft, IT, outage, staff illness or terrorist attack (Morrison, 2009).

Business continuity management standards encourage the setting up of a permanent structure to manage continuity and risk to supply chain. Excellent benefits can be obtained if companies have the courage and structure to use them to best effect. Not all the actions on the map are or can be completed. It is a matter of getting used to continual improvement (Manners-Bell, 2018).

Supply Chain - Aluminium Trihydrate

This case study concentrates on the supply chain of key raw materials in plastic compounding with a focus on halogen free and low smoke formulations used in the cabling or automotive industry. Given the high risks of fire due to vehicular heat generation, almost every plastic part of automobiles for example, needs to have a good flame retardant. Compounding in the plastic industry starts with a base resin or polymer. The base polymer can either be a thermoplastic elastomer (TPE) or ethylene vinyl acetate (EVA) copolymer resin. The incorporation of additives and fillers allows for specific properties to be achieved in conductivity, flame and wear resistance. For specialty compounded products used in the cabling market, raw materials would include petroleum oils, polymers or resins, fillers and the key additive aluminium trihydrate (ATH).

ATH ($Al_2O_3.3H_2O$) is a white translucent powder that is also called aluminum hydroxide. Its major application as a flame retardant and smoke suppressant in materials is due to its ability to release water of crystallization as water vapour when heated above 220 °C. The annual production of ATH is around 100 million tons which is nearly all produced through the Bayer process. The process dissolves bauxite (the aluminium ore) in sodium hydroxide (NaOH) at elevated temperatures. ATH is then separated from the solids that remain after the heating process. Guinea has some of the largest bauxite (i.e. the aluminium ore) reserves in the world. Australia, China, and Brazil are some of the most dominant countries in mining production (Future Market Insights, 2016).

Loss Estimate

From an insurance perspective, the mitigating factors in terms of BI and the capacity that would be provided in terms of CBI cover would depend on the Client's ability to secure lead times and alternative suppliers taking into account price, grade and quality of additive. Research in the ATH market provides invaluable insights in terms of market distribution and structure, major primary suppliers, their production and make-up capacity. Findings show that the global ATH market is highly competitive with tier-1 suppliers as well as fragmented sectors consisting of small scale market participants which also hold a considerable share of the global market (Future Market Insights, 2016).

The structure of first tier suppliers will vary but it is not uncommon for manufacturing to rely on one main location with secondary lower capacity plants. First tier suppliers will sell bulk quantities directly to end users at an agreed price under important primary contracts. By production capacity, tier-1 ATH manufacturers constitute over 70% of the global production. Some of the market participants involved in the production and sales of ATH include Alfa Aesar, Sumitomo Chemical Co. Ltd, Albemarle Corporation, Nabaltec AG, Huber Engineered Materials, Showa Denko K. K., Ecolab, Inc., MaL Zrt, Alcoa Inc. and Aluminum Corp of China Ltd. Expansion in the market and optimization of operations are the key strategies followed by these manufacturers for sustained business development and growth (Future Market Insights, 2016).

Based on the above BI and CBI can reach 12 months or longer if plastic compounding operations rely on a single source supplier which is not an uncommon occurrence in industry as the deviations in quality and prohibitive pricing can hinder contracts with secondary suppliers.

Figure 1: Bauxite (**Source**:http://www.world-aluminium.org/images/bauxite); International Aluminium Institute, 2 Duke Street St James's, St. James's, London SW1Y 6BN.

Figure 2 Port, Fria bauxite and alumina complex, Guinea (United Company RUSAL[1]) (**Source**:http://www.world-aluminium.org/images/bauxite). **Note 1**: United Company RUSAL is the world's second largest aluminium company by primary production output. It was the largest until overtaken by China Hongqiao Group in 2015. UC RUSAL accounts for almost 9% of the world's primary aluminium output and 9% of the world's alumina production.

Supply Chain Sulphuric Acid and Phosphoric Acid

Industries with vertical integration in their operations require a careful assessment of their interdependencies to support an appropriate BI and CBI cover. The production of phosphate fertilizers is such an example where sulphuric acid, based on operations using elemental sulphur, is used with phosphate rock. The largest single sulphuric acid consumer by far is the fertilizer industry.

Figure 3: Eshidiya Phosphate Ore Operating Mine (Jordan) **(Source:** Google Earth, Imagery Date 10/4/2016).

Jordan for example has enormous resources of phosphate ores with high quality phosphorus pentoxide (P_2O_5) content which encouraged the country to develop four operating mines at different locations in the middle of Jordan. Phosphate bearing horizons in Jordan occur at varying depth, cover about 60% of the total area of the country and comprise about 1 billion ton of resources. Al-Hassa mine (3.4 million tons), Al-Abiad Mine (2.5 million tons) and Eshidiya Mine (3.25 million tons) have provided Jordan with the capacity to produce 9.25 million tons of phosphate on an annual basis (Abu-Hamattah, 2005).

In the context of insurance and the BI exposure, key elements to identify include market conditions to determine the relationship of markets for phosphate rock, phosphate fertilizers and elemental sulphur, and market conditions for elemental sulphur and sulphuric acid (H_2SO_4). For vertically integrated sulphuric and phosphoric acid (H_3PO_4) plants, there are additional interdependencies in the form of recovery of waste heat for electrical power and steam production. Variations in the phosphate rock composition, the presence of detrimental impurities and their impact on the technology used will also determine the value of contingent mining locations.

The phosphoric acid plant, based on a wet process, requires phosphate rock and sulphuric acid for the digestion process. Nearly all elemental sulphur is converted to sulphuric acid. Elemental sulphur is burned with air in a furnace to produce sulphur dioxide. The hot gases are then passed over solid catalyst, usually based on vanadium pentoxide to further oxidize the sulphur dioxide (SO_2) to sulphur trioxide (SO_3). Sulphur trioxide reacts with water in an absorber to produce sulphuric acid. The main reason for most phosphoric acid producers to buy elemental sulphur and make their own sulfuric acid rather than purchase sulphuric acid is due to the highly exothermic sulphuric acid process. As excess steam is generated, this can be used in the phosphoric acid evaporators (Douglas, 2005).

MFL BI

It is well known and understood that when sulphuric acid is exposed to steel the resulting chemical reaction produces hydrogen gas. Most plant operators are aware of hydrogen grooving in storage tanks and have experienced minor hydrogen bangers. The larger BI loss would be the stoppage of production in the event of a catastrophic failure of the sulphuric acid plant. Incidents in sulphuric acid plants can involve large hydrogen explosions. The incidents are typically initiated by steaming equipment or acid cooler leaks that result in severe ask acid excursions. The weak acid corrosion then generates enough hydrogen to accumulate explosive concentrations in various locations of the gas side process equipment. The equipment location where hydrogen gas accumulation most commonly occurs appears to be at the top of the interpass acid tower, but accumulations in drying towers, converted beds, heat exchangers and ductwork have also been reported (Douglas, 2005).

Conclusions

The insurance industry is exposed to an invaluable breadth of data and information and makes significant contributions to industry through lessons learned, publications on claims and the use of internationally recognised engineering standards to make meaningful risk improvement and loss prevention recommendations at Policyholder locations.

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