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Ageing Plant and Maintenance

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Executive Summary

Given the unsettled global economy and the pressure on companies to be extremely competitive to win business, as well as to provide satisfactory returns to demanding shareholders, it is accepted that industry will maximise their limited resources, which extends to their plant and equipment. Equipment will typically be used for longer periods, often past its design life, and at a capacity closer to maximum output.

As an industry, insurance has to respond to the demands of its customers. However, in order to be profitable, and to ensure the ability to meet all future claims needs, insurers must carefully assess equipment risks and apply reasonable terms and conditions.

Maintenance programmes should preferably be predictive, or condition based, rather than reactive. Insurers should not be seen as the total risk management plan. The support of an OEM Long Term Service Agreement (if available) will typically provide a better risk. However, the OEM has to ensure that customers are not simply seen as a cash cow, but as a true partner.

Customers should be encouraged to employ reasonable maintenance programs which satisfy their equipment demands. It is in everyone's interests to avoid claims, particularly large claims that could put customers out of business if they are out of the race for their competition.

It is also in all stakeholder's interest that insureds take a pride in their workplace, that equipment is maintained in a manner that considers the safety of operators and others in the vicinity.

In line with the IMIA vision, the ultimate aim of this paper is to promote understanding and best practice in engineering insurance and raise awareness of technical features related to Ageing Plant and Maintenance.

In addition, it is to provide contractors, brokers and underwriters with a basic guidance on necessary information to be contained in the underwriting submissions, for example, to align all parties' interests to ensure commonly acceptable solutions and pro-active risk management practice.

1. Introduction

With global competition forcing the need for businesses to be as cost effective as possible, investments in equipment and people will always be a challenging decision, sometimes made by those with limited knowledge of equipment.

These decisions will often be deferred or postponed indefinitely to protect scarce resources, prolonging and possibly increasing the risk to ageing plant & equipment.

Equipment in operation will often be kept running longer and harder than it was designed to do, with shorter and shorter periods to inspect and maintain, and with reduced resources.

This provides concerns for insurers, as the likelihood of breakdowns increases with age and/or use, and rapid advances in technology, particularly in electronic equipment, can result in early obsolescence.

In the western world we see increasing numbers of industries retaining old equipment for longer periods, squeezing as much life out of them as possible. A survey by Morgan Stanley found that most industrial equipment in North America is, on average, over 10 years old. Not since 1938 have North American factories worked with such outdated equipment.

In the rest of the world, investments are being made to boost economic activity and increase standards of living through higher GDP with new manufacturing facilities being erected quicker than ever, often with cheaper equipment which can bring its own quality and reliability risks.

This paper looks at how businesses manage the operation of older equipment, their options, and also what insurers need to consider in providing coverage for these risks.

2. Definition of ageing plant with variations by occupancy and equipment

Firstly, we have to consider what is meant by “ageing “. It is difficult to truly define, but can most simply be described as plant and equipment that has reached the latter stages of its design life. It can also be used to describe equipment for which there is evidence or likelihood of significant deterioration and damage taking place since new.

Ageing is the process of change in the properties of a material, a machine or equipment over a period of time, and will usually be associated with an increased risk of damage or failure which has been shown to be a major factor in equipment incidents.

Like human beings, equipment will experience infancy, normal operation, and wear-out stages. As equipment ages, it tends to fail more frequently, requiring more extensive maintenance and repair, eventually reaching its end of life.

Ageing can emanate from, or be influenced by various factors, for example, insulation deterioration in electrical components, fatigue failure due to cyclic stresses in rotating equipment, corrosion or erosion. Different machines will age in different ways and at different rates. For example, machines with moving parts tend to age more rapidly as they have limited tolerance to deviations from the design conditions. However, equipment, such as process vessels, tanks and

pipes, tend to age more slowly as they often have much greater tolerance to operating variations and under benign conditions they can remain in service for many years.

Typically, the following patterns and indications of ageing are observed for different types of equipment;

- **Rotating Machinery** – improper installation, poor alignment, vibration, normal wear, cyclic stresses (fatigue), lack of proper care (such as inadequate lubrication), contamination, deterioration due to environmental conditions, etc.
- **Piping systems** – susceptible to damage from corrosion (internal and external), erosion, fatigue, creep, ratcheting, leakage from gaskets, loose fittings, loss of insulation or protective coatings, mechanical damage, internal scaling or fouling.
- **Protective devices** – prone to a variety of ageing mechanisms such as fouling, condensation and calibration inaccuracy
- **Storage tanks** – suffer from corrosion, leading to wall thinning (particularly in unprotected, coastal or damp locations) and fatigue cracks at liquid level
- **Pressure vessels and boiler** –susceptible to corrosion, fatigue and wall thinning, particularly at crevices, external supports and saddles, cyclic stress (resulting in thermal expansion/contraction).

The typical factors involved in machinery or equipment failure are usually; force, time, temperature and a reactive environment. Each of these can be interpreted as stress and a combination of these factors will usually accelerate the rate of equipment failure. Table 2.1 below highlights the most common ageing failures and their causes.

Table 2.1: Classification of equipment failures

Cause	Resultant failure mode	
	Normal issues	Additional Ageing related features
1. Defective material/ design/construction/ installation/ manufacture/inherent faults	<ul style="list-style-type: none"> • Early life failure • Under/ overcapacity /overload • Incorrect physical conditions 	<ul style="list-style-type: none"> • Surface & material changes (corrosion) • Fatigue • Fracture • Wear out • Deformation & distortion • Creep
2. Improper operation/ Human error/ inadequate safety systems	<ul style="list-style-type: none"> • Accidental action • Incorrect/inadequate procedure • Failure to follow procedure • Inadequate training • Errors of omission • Incompetence 	
3. Maintenance deficiencies	<ul style="list-style-type: none"> • Neglect • Improper • Misalignment • Postponed • Inadequate lubrication 	
4. Harsh external environment	<ul style="list-style-type: none"> • Acts of nature • Contamination/dust/dirt • Abnormally high/low temperature • Humidity/moisture • Fire/smoke 	

Long term reductions in failures will always be accomplished by correct design specifications for actual purpose and environment.

3. Process industries and territories facing particular challenges

Machinery and equipment is designed to operate safely and reliably according to anticipated operating conditions such as temperature, pressure, corrosion rate, fatigue cycles etc.. This is the design life and takes into account the expected equipment degradation over time. In reality verifying remaining design life for older equipment is a challenge that needs to be studied thoroughly. In addition, some sites have no structural integrity program in their maintenance budgets, and may be facing challenges to stay in compliance with stricter environmental regulations.

Many process plants, including power stations, worldwide are now operating beyond their original design life, many years past their expected decommissioning.

Many Power plants built between the 1960s-1980s had a design life of 40 years. Process plants typically have a design life of 20-30 years and electrical power distribution equipment has about 20 years. Electrical control systems and instrumentation (sensors, displays etc.) may have a considerably shorter life at 10 to 15 years, due to technological obsolescence.

Understanding an asset's designed life, recognizing ageing mechanisms and introducing a structured management approach can mitigate the potential for failure, helping to reduce the incidents of major loss events.

a. Nuclear and Thermal Power Generation

Many nuclear and thermal power plants are ageing assets facing an uncertain future in the current energy sector. Conventional power plants are now commonly operated with frequent startups and shut downs to integrate with renewable energy production.

This cyclic operation creates extreme stress in plants originally designed for continuous operation. Upgrading these aged plants requires large investment that may be delayed by uncertainties driven by market forces, political decisions and legal regulations. They may also face ever changing obligations to comply with safety and environmental regulations in order to keep or extend their operational license.

The design life of nuclear plants is between 40-60 years, depending on the reactor vessel design. Life might be extended if the reactor vessel condition is approved, following a remnant life assessment and a thorough assessment of the asset integrity. The majority of US's nuclear plants have successfully received 20 years extensions to their original 40 year old operating licenses.

Note:- conventional equipment and machinery in a nuclear power station such as a steam turbines and generators will need earlier replacement due to shorter design life.

b. Power Transmission and Distribution

After an investment wave in the 1970s and 1980s, there has been less investment in electric utility networks over the following decades. As a result, some older networks are now approaching over load and becoming obsolete.

They are often in need of enhancements to improve grid availability and to integrate with new technologies such as renewable energy, distributed generation etc. Consequently, Transmission & Distribution companies are now having to make crucial decisions on upgrades.

c. Oil and Gas, petrochemical and chemical industries

The oil and gas, petrochemical and chemical industries face particular ageing issues due to hazardous process substances, aggressive environmental conditions, extreme operating temperatures and pressure (leading to fatigue) etc. Pipework corrosion and difficulty accessing critical equipment for maintenance and inspection further adds to the problem.

Ensuring regular effective maintenance in the upstream oil and gas industry can be particularly challenging due to the cyclical nature of oil prices and high maintenance costs. The downstream operations face similar ageing challenges, with many older plants running at maximum capacity due to high demand and the availability of low cost feedstock. Market conditions are often pushing many companies to increase output by extending major maintenance outages, refurbishment or replacement cycles.

Market conditions can also result in temporary decommissioning of plants increasing the risks from the ageing components when the plant is recommissioned. This may be further impacted by the departure of ageing staff in many parts of the world including the EU, USA and Japan, resulting in a reduced knowledge/experience base necessary for effective operation, and maintenance of existing aged designs. This is becoming a major issue during startup, shutdown and breakdowns.

d. Primary Metal Manufacturing

Steel and aluminum smelting operations (including metal forging) also frequently face major challenges regarding ageing equipment and infrastructure. These facilities operate in hostile environments using process equipment that may be obsolete and no longer supported by the Original Equipment Manufacturer (OEM).

e. Mining Industry

The mining industry faces accelerated ageing due to aggressive environmental conditions and brutal wear to machinery and equipment. In these extreme working conditions, the design life of some equipment may be reduced by half. The Industry is frequently faced with large commodity price fluctuations, with periods of low prices that can have very negative implications for ageing plant, as maintenance budgets are cut.

f. Change of Operating Conditions/ Processes

Plants in many industries will face additional ageing and maintenance challenges due to ad-hoc or in-house changes to their operating conditions or processes to improve production rates or product quality. The mechanisms of deterioration and the impact of operational changes have to be well understood if significant impact on equipment life and reliability is to be avoided.

For example:- As a rule of thumb, a rise of only 10 °C in the operating temperature may double corrosion rates.

Another example,- A change of product grade in a polymer manufacturing plant resulted in a higher acidity levels with extensive corrosion to titanium equipment.

g. Locations facing particular challenges

The potential degradation of plant and equipment due to age-related mechanisms is a worldwide issue. USA, Europe and Scandinavia face particular challenges with huge numbers of post-World War II plants which are now over 50 years old. In these countries, the perception of environmental and safety risks are generally more high-profile and so safety, maintenance and lifetime extension issues get more scrutiny from relevant authorities and the public. However, capital and investment are often more accessible.

Less developed territories such as African countries and in Latin America face particular challenges financing new equipment and so they often source second hand equipment and machinery. This brings with it issues of accelerated wear and corrosion relating to how the equipment was operated and maintained in its previous life. This makes the determination of equipment remaining design life a real challenge.

An important issue regarding second hand equipment is the availability of spare parts. In many cases replacement parts may no longer be available from the original equipment manufacturer. In some cases the OEM may even no longer exist.

The level of staff training and expertise in these regions is also something to consider. When combined with second hand equipment this can lead to an increased risk of losses.

4. Managing the ageing process

a. General Considerations

Two sites of similar age may display different ageing symptoms depending on the management and maintenance of the assets. Different options exist to manage old equipment once it has reached, or is approaching end of useful life. At this point it may be exhibiting signs of accelerated ageing (e.g. corrosion, erosion, creep etc.), or increased breakdown frequency. These options include repairs, retrofits, life extension plans etc. and will be discussed in following sections.

Whatever option is taken to deal with the aged asset, all actions must be supported by a comprehensive maintenance, monitoring, trending and inspection scheme that addresses the age, history and condition of the equipment.

Even with good practices for day-to-day plant integrity management, there must be a specific approach and key decisions taken with regard to ageing and life extension. Management of facilities with ageing plant requires a pro-active leadership approach from senior management. Where a cost driven re-active management and maintenance approach is practiced, very little planning is done, leading to asset failures, high repair costs and unplanned business down time.

Key aspects of effective ageing plant management will include the following systems:

- **Asset Register and Integrity Risk Assessment:** A comprehensive list of in-service assets, inspection, testing and maintenance database.
- **Inspection and Maintenance program:** An inspection and maintenance program based on the asset integrity risk assessment, risk based inspection, preventative or condition-based maintenance regimes etc.
- **Information Management:** A complete and accurate record and maintenance of documentation throughout all stages of the facility lifecycle is crucial in ageing plant management as it supports life extension assessments and decisions

Organizations operating ageing facilities need to review equipment management and life extension programs dealing with material degradation and obsolescence they must be aware of the organizational challenges associated with the issue. Ageing is not limited to the condition of the equipment, but includes everything associated with the site such as people, processes and systems.

Older facilities are likely to have undergone several upgrades, changes in ownership and management structure over a period of years. This may complicate matters if for example a new maintenance contractor is not provided with information about the history of the assets.

The OECD Ageing of Hazardous Installations report (2017) stated that failure of equipment due to the ageing phenomena is usually associated with failure in the safety management system of the facility, the report highlights the following lessons learned in terms of management of ageing facilities:

- Contractors and third party personnel need to be adequately trained and have access to specifications of the plant as well as the historical information
- There should be a system to maintain documentation on the maintenance history of the facility and the equipment (e.g. repairs, replacements, additions and defects etc.)
- Inspections need to focus on critical pieces of equipment that are prone to the ageing phenomena
- Risk assessments have to be carried out before modifying or changing the way any equipment is being used
- Lessons learned need to be captured for knowledge transfer.

b. Operation of ageing equipment

Operating conditions is a key consideration when assessing the risk posed by aged equipment. Another is to consider the abilities of the people operating it. Good operators, especially those with technical backgrounds (i.e. electricians, fitters, and mechanics) develop an ‘ear’ for how equipment is running, particularly if they have been working with the plant for a number of years. They can tell when equipment doesn’t sound right or if there are abnormal vibrations. This can help detect and prevent larger problems.

A shortage of skilled operators and maintenance personnel presents a major challenge to plant owners (and as a result insurers) as these essential competencies are critical for equipment reliability and production continuity. Frequently equipment breakdowns and ensuing business interruption losses can be attributed to human error due to the lack of skill and this is often heightened during busy and stressful peak demand periods. These may place the plant’s growth and future at risk.

Skills shortages affect both old and new equipment but the impact on aged equipment may go undetected in the drive to up-skill and retrain staff to face the challenges of new technology. The most frequent human issues related to aged equipment can be summarised under the following headings.

- **Lack of basic maintenance skills and understanding:**

Older equipment designs typically have less automation, making them more reliant on higher levels of operator and maintenance involvement.

This is in stark contrast to modern technology where human involvement is increasingly replaced by reliance on sensors and sophisticated control systems to continuously monitor and fine tune the process.

There is also a move to design new equipment with replaceable modules or assemblies, so that the need to use traditional “fitting” techniques is becoming rare. This loss of traditional skills impacts the ability of technicians to effectively maintain older equipment.

- **Lack of appropriate training program:**

Many facilities, especially in third world markets, often lack systematic and routine training programs for their personnel.

In order to achieve familiarity with and acquire the technical knowledge about their operating environment, machine operators and their supervisors should attend routine training sessions, if possible from Original Equipment Manufacturers. These training programs must be an integral part of the plant's overall risk management strategy.

- **Retirement or loss of specialized and experienced workers:**

Very often senior machine operators retire and are not replaced by equally competent and experienced staff members. Skills can be learned, but as technology changes, the availability of books and technical literature relevant to older equipment becomes more difficult to find.

Many original manufacturer's parts and operating manuals do not survive, being lost or damaged by use over the years. As a result, much of the practical knowledge and skills resides with the operators and technicians who have worked with/on the equipment for long periods, some from its original installation. These staff develop an understanding for maintenance and operating techniques based on a wide variety of incidents and events in the machines life history.

Often, these members of staff are not properly valued for their knowledge and their adherence to "tried and tested" methods and techniques. Frequently no attempt is made to capture what they know or record what they do and why, so that when they retire, there is a real risk that their skills, experience and memories leave with them. Succession planning and mentoring of younger staff is often a serious omission when operating older equipment and one that an effective training program should deal with. Unfortunately even training of younger people has its drawbacks as generation 'x' is less likely to stay in jobs unlike older generations.

- **Recruitment practices:**

Modern recruitment practices often fail to take into account experience gained by time spent learning in a working environment.

Emphasis is placed on numbers of locations worked at, roles held and technological capabilities/skills. It takes time to learn and develop the skills necessary to maintain and operate older equipment and to understand and manage the maintenance and operations of this equipment effectively.

The risk assessment process for insurance underwriters should consider the following;

- Determine the capabilities/skills of those operating the equipment,
- Ensure that those critical items of aged equipment have suitable maintenance and operational procedures in place,
- That the client has suitable training and succession plans in place to ensure that appropriate skills are maintained, and
- That the site has assessed the risk of using this aged equipment and has suitable plans and resources to maintain it, upgrade it or replace it in an acceptable time frame.

5. Options to manage ageing plants – Retrofits/Upgrades/Life Extensions

Equipment may reach a point where it no longer meet the requirements of its owners. Some examples are as follows:

- Insufficient output – the demand for product may be greater than the current machine can offer
- Reliability – the machine may start to suffer excessive downtime due to worn or fatigued components
- Reparability – some spares (or manufacturer support) may no longer be available, making any unexpected breakdown far more serious
- Compatibility – other plant items may have already been changed and the machine may not interface with the new equipment optimally (or at all).
- Legislation – the machine may no longer meet current requirements with regard to pollution / noise / safety etc. In some circumstances this may lead to use of the machine being forbidden by law unless updated to current standards.
- Efficiency – the output may be sufficient but the cost of running the machine on the current basis may become uneconomical.

The options to manage aged plant will depend on the ageing mechanism, the extent of damage, future operational needs and financial constraints etc. These options include:

- Undertaking a Fitness-For-Service/ remnant life assessment.
- Repairs and replacement of worn parts.
- Alternative running regime e.g. de-rate equipment for lower operational duties and longer life.
- Modification or retrofit/ upgrade, including the replacement of obsolete parts.

If old equipment still performs as expected and does not show significant damage or breakdown symptoms, some sites may decide to delay action and continue monitoring more frequently to ensure that the rate of deterioration does not increase significantly.

a. Life extension assessments

For process plants in particular, if historical operational and defect data exists, a cost-effective action would be to undertake an initial fitness-for-service (FFS) assessment to determine the next steps.

A Fitness-For-Service (FFS) assessment is a quantitative evaluation of the structural integrity of components and their suitability for continued service in their current condition. It is carried out by several engineering disciplines and is seen as best practice and a standard used for process equipment within oil & gas, power generation and chemical process industries.

A Remnant Life Assessment may also be performed as part of the FFS assessment to determine expected remaining life, to set future inspection intervals and plan for future capital expenditures. Remnant life assessments are vital when considering life extension for equipment operating beyond its design life e.g. steams turbines, generators, transformers, and thermal power plant boilers.

Outcomes of the FFS assessment can help to determine the options available for the aged plant – e.g.

- The equipment is fit for continued service with regular monitoring, repairs are required,
- Equipment needs to be down-rated in order for it to return to service, or the equipment should be retired/ scrapped.

b. Repairs vs. Replacement

When faced with the breakdown and repair of critical equipment, new replacement usually requires a large capital investment and long lead times for delivery, installation, commissioning, training of operators etc. To avoid this, sites may choose to carry out a repair to quickly return the plant to original duty. Good quality repairs need to be carefully specified, planned and controlled to ensure that the repair method is suitable, so that the equipment's original duty and safety protective devices will not to be compromised.

Appropriate design codes and standards need to be adhered to when specifying a repair, and on completion, further examination is required to validate that the. This costs money and time, with the result that some owners/operators may look for lower cost alternatives such as in-house temporary repairs or the replacement using second hand equipment, both of which solutions increase the risk of future failure.

For second hand equipment, insufficient operation and maintenance history can lead it being installed and or operated in a way which accelerates ageing, causing significant deterioration and damage. With obsolete equipment, there are often issues with spare parts availability and an absence of technical support in the supply chain (Note: Obsolescence is discussed further in Section (6)). This could influence the decision to replace it with a suitable modern alternative, or modify, retrofit or upgrade the asset to use readily available spares.

There are some industries where the risk of failure cannot be tolerated and components are not easily repairable or replaceable. These include high hazard industries such as nuclear or petrochemical sites. If a repair is not possible, an alternative could be to de-rate the plant so that it continues to run at lower operational duties and a less arduous environment e.g. reduce operational pressures, temperatures or loads.

c. Retrofitting or Upgrading

Instead of repairing or replacing, equipment owners may look to upgrade equipment. Reasons for upgrading include:

- Cost saving – cheaper than replacement, especially with decommissioning costs.
- Bespoke equipment – if the equipment is a 'one-off', a full replacement may be particularly costly.
- Compatibility – the equipment may need to interface with other older equipment and modifying those to work with a new machine may be uneconomical and/or impractical.
- Familiarity – the owners may not wish to retrain staff and may wish to make use of existing spares holdings, or the equipment may have "traditional" value, important for the owner, etc.
- Longer term plans – the operation may be scheduled to close in the not too distant future and a 'quick fix' may make more sense than a longer-term solution.

When upgrading or retrofitting equipment to extend its useful life, it will generally be by using one of the following options.

i. Manufacturer-approved / installed packages

These will usually upgrade the machine to nearer the equivalent specification of a newer model and may incorporate efficiency or reliability modifications developed from years of operating experience and user feedback. These are commonly found in Gas Turbine power plants.

Such packages are usually looked favourably upon by insurers as the characteristics of the machine once modified are already understood and are likely to include a manufacturer's warranty and support. In some instances owners must ensure that the entire approved package is installed to receive the full warranty.

Example

A gas turbine was fitted with some parts from a newer edition and the gearbox was changed, which allowed the turbine to run at higher rpm and produce more power. However, the accompanying cooling enhancements were not installed, leading to unreliable operation.

ii. Third-party or user-derived / installed upgrades

These can be more of an unknown quantity as they may not be sanctioned by the manufacturer and may impact warranty conditions. This does not mean that such upgrades are necessarily more problematic – there are many highly competent specialist engineering firms who have a good reputation for upgrading machines and will provide their own warranty. In the case of obsolete or unique machines, this may be the only option available to upgrade or replace.

Evaluation of modifications by insurers is likely to require more specialist knowledge e.g. input from experienced Risk Engineers.

Example 1

A blast furnace can be upgraded from traditional cooling to stove cooling. This replaces the cooling system with a more efficient modern alternative, giving not only a more reliable system, but because it is more compact, the internal volume of the furnace is maximised, allowing increased throughput.

This can be carried out at the same time as a scheduled refractory replacement, minimising additional downtime. However, care must be taken to ensure that the upgrade is fully understood and that the existing auxiliary cooling systems are compatible.

Example 2

An original boiler control system was upgraded with new controls. Unfortunately the "new" control logic introduced unexpected weaknesses that were only discovered following a breakdown.

The two boilers which had always been independent had been unknowingly linked via the new controls. Unseen functionality around the fan controls had not been activated and when a problem developed with the fan fitted to one of the boilers, it shut down both boilers.

Lack of knowledge around the new setup increased remediation time and financial loss.

iii. In-house modifications and upgrades

These are modifications and changes that equipment frequently experience as part of on-going maintenance and operations. Parts may be replaced with different items to increase speed, pressure, output efficiency, or simply because they are cheaper. Although most of these modifications will have been undertaken for the best of reasons, it is common to find that they are unrecorded and/or have not been technically assessed for suitability and technical quality.

Some of these unreviewed / unauthorised changes may introduce potential breakdown and failure modes that were never present in the original design. Older equipment is particularly prone to this form of upgrading and may have significant unanticipated risks.

Example

Flixborough 1974 (UK); a temporary connection pipe was fitted between two reactor vessels replacing a reactor vessel that was removed for maintenance. The pipe had not been formally designed or tested. It failed in use resulting in a massive explosion and significant loss of life.

Subsequent to this incident, Management of Change standards were introduced to ensure that unplanned changes and modifications were controlled. Unfortunately these procedures are not always employed.

d. Alternative running regime

There is another option for extending life which may be employed in lieu of – or in combination with – upgrades or modifications.

This is frequently found where new legislation restricts the running hours of the machine for environmental reasons. A good topical example is an old coal fired power plant. One option is to clean up the emissions by fitting Flue Gas Desulphurisation equipment. This is expensive and may not be financially justifiable. The alternative is to simply run the plant less and stretch out the remaining hours of operation. However this inherently means moving from the original ‘base-load’ regime, to a ‘two-shift’, on-demand or peaking basis of operation usually used by more modern gas turbine power plants.

Where this is outside the original operating design envelope it will subject the plant to different thermal stresses and loads due to the increase in thermal cycling. This typically leads to a higher failure potential and an increase in maintenance. To manage this risk alterations may be required to the monitoring and maintenance regime to ensure ongoing reliability.

e. Re-evaluation

The other option of ‘extending’ life is to simply to re-evaluate the lifespan of the equipment, most likely using more modern analysis techniques and with the benefit of operational experience. From this, the operator may conclude that the original equipment design life can be extended. This situation is particularly common for equipment that is being operated well below its design limits.

However, where this is being proposed, it is most important that the performance, maintenance and operating conditions are considered for the entire life of the machine. In practice some of this information may be missing or inaccurate. Caution should be used when this approach is employed.

Example

A large Hydro power plant had oil-filled main power cables which were assessed as remaining fit for service despite being over 20 years old, on the basis of being run at 50% load and being in good condition. The scheduled replacement with modern alternatives was therefore postponed for several more years.

All was well until the cables were disturbed for some routine maintenance work, they fractured and caught fire, shutting down the entire plant for over 4 months. Water levels were at their lowest for many years meaning electricity prices were at a multi-year high. The resultant insured loss came in at over \$230 million, with over \$75 million being borne by the insured themselves – a true ‘false economy’.

f. Conclusion

There are many valid ways of extending the life of machinery. However most come with a compromise or trade-off of one kind or another. The manufacturer-approved upgrades to a later specification can be considered almost unequivocally as an improvement and may qualify for a more favourable view on insurance terms.

'Home-brewed' upgrades or other workarounds to prolong operational life will need more careful consideration and in most cases are more likely to merit an increase in premium rather than the opposite. These are less likely to be flagged up by the insured, so the onus is on the underwriter to ask the relevant questions and, together with their Risk Engineers, ensure that they understand exactly what they are covering.

6. Obsolescence

One of the many challenges experienced in the manufacturing industries is "obsolescence". "Obsolescence", as defined in the English Oxford dictionary, is "The process of becoming obsolete or outdated and no longer used" and the term "obsolete" as being "No longer produced or used; out of date."

Equipment becomes obsolete for different reasons, to name a few:

- OEM discontinues producing a certain model and its components because it is replaced by a new, more cost-effective / cost-efficient state-of-the-art model. Note:- If the OEM is still in business, then some assistance for old models may still be available.
- The OEM goes out of business, so technical support and original spares are no longer available.
- Newly introduced environmental regulations and policies can lead to equipment obsolescence.

If obsolete equipment breaks down and requires replacement parts or assemblies, these may not be readily available and this may cause delays and difficulties in repairing and reinstating the equipment. This can increase Business Interruption costs substantially.

The most common alternatives in this situation are:-

Alternative parts may be available from third party manufacturers. However, these may not be exact replacements and may be of a different specification to the original parts. Fitting these parts may introduce problems of incompatibility, reliability and, in some cases, safety.

Searching the second hand market may reveal "as new", reconditioned or used parts. The origin and quality of these spares is almost always unknown, but often, they can be recovered, remanufactured or repaired by specialist engineering contractors. Many locations that have old equipment (particularly old electronic control systems) take this route.

It should be noted that this technique may not work for all equipment, or for some large parts and subassemblies. The quality and reliability of the recovered spares can vary and this should be taken into account when underwriting the risk.

Bespoke manufacture of parts using original drawing or from old parts. This can be an expensive and time-consuming option, but for some equipment, where the value of the entire machine far outweighs the value of the required part, it may be the only option. It has a number of problems.

- Lack of original drawings.
- Lack of detailed specifications covering things like material qualities, tolerances, etc.
- Lack of availability of original materials or manufacturing processes.
- Time required to produce manufacturing drawings and find an engineering company capable of manufacture.

There can be very high risks in using non-original parts, largely due to the lack of original design information. The potential for repeat failures or cascading damage may be significantly increased.

Replace the machine with new or second hand. This decision may follow from any of the above actions, or may be the preferred option from the start. Replacement with new has cost and lead time implications that may be significant. Replacement with second hand introduces a range of unknowns that are covered later in this paper.

When presented with a breakdown risk affecting an obsolete critical machine, Insurers underwriters are confronted with two options. The first and easiest option is to decline the risk and keep it out of their portfolio. The second option is to insure the obsolete machine or machines, but a difficulty often encountered is in respect of the insured value on which indemnity should be based.

Insurers might also be challenged with the risk of moral hazard when faced with the insurance of obsolete machines or equipment. For instance, when the Insured is not in a position to dispose of its old machine for a reasonable economic return or sell it to the scrap yard for a sufficient return, a total loss claim might deliberately arise and indemnity be requested from insurers.

Best practice states that all equipment should be insured based on their New Replacement Values (NRV). However, in the case of obsolete machines and equipment the NRV concept is not applicable. Therefore, underwriters need to agree with the insured on the basis of indemnity, i.e. a monetary value which the underwriter(s) is prepared to pay as indemnity in case of a total loss. This is often covered as the 'Actual Cash Value' of the item immediately prior to a loss.

Maintenance is crucial for equipment nearing the end of its lifecycle. It is also frequently more costly than the maintenance of newer equipment because it is carried out more often due to the higher breakdown frequency and the level of expertise required among skilled labour becomes rare.

Experts appointed by insurers to survey the plant locations should clearly identify the presence of obsolete machines, their components, and how they are operated, maintained and managed. Surveyors should inquire how much obsolete machinery and equipment makes up the plant, the spare parts policy and stock, also whether the Insured has a proactive obsolescence management strategy in force.

A proactive obsolescence management strategy is crucial, especially for critical machinery and its spares. A proactive obsolescence management strategy should encompass, for instance:

- An early warning of discontinuance (i.e. "end of life"), such as receiving from the original equipment manufacturers PCN's (product change notifications) or EOL's (end-of-life) notifications,
- Maintenance actions such as knowing where to find alternate replacements from different manufacturers or knowing where to find the closest equivalent substitutes,
- Whether machines and components are designed in full compliance with applicable codes and standards,

- Whether regular reviews of the strategy are ongoing to ensure that the processes remain in full force, and
- Presence and type of maintenance method adopted especially with machines and equipment with their lifecycle nearing the end.

7. Predictive Vs. Preventative Maintenance – Condition Monitoring & Maintenance Strategy

Maintenance is defined according to the European standard (EN 13306: 2001) as “the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to a state in which it can perform the required function”.

In this section we will look at the various maintenance techniques commonly used and consider their benefits and weaknesses in relation to ageing plant and equipment.

In relation to ageing plant, good maintenance will enable the equipment to achieve and maybe exceed its original design life.

a. Equipment reliability

It has been shown over many studies that equipment reliability typically deteriorates with age following the “Bath-tub” curve plot of breakdown frequency against age.

This understanding can be applied to individual equipment or to families or types of equipment. See Chart 7.1 below.

Chart-7.1: The Bath-Tub Curve

New equipment often has an increased risk of failure due to installation, commissioning and general running in problems, including manufacturing and design issues. This is often referred to as “Infant Mortality”.

As the equipment ages, these problems are rectified and the equipment breakdown frequency drops, stabilising (hopefully) at a low level

As the equipment approaches its “End of life”, the frequency of failure will usually start to rise and at this point, most equipment is ready for replacement.

The length of the time between “Infant Mortality” and “End of life”, will be influenced by a number of factors:

- The original service design life and the quality of maintenance provided over the machine’s life.
- What capacity and other operating conditions it is exposed to.
- Changes to maintenance practices, upgrades or repairs - these may recover some lost life but damage or wear sustained in early life is very likely to hasten the end of life.

b. Types of maintenance

There are a variety of maintenance techniques commonly used. They go by many names, but generally fall into the following categories;

- Reactive Maintenance, sometimes referred to as breakdown or corrective maintenance.
- Proactive Maintenance, refers to a more systematic maintenance program.
- Preventive Maintenance, sometimes referred to a scheduled maintenance.
- Predictive Maintenance, sometimes referred to as condition based maintenance.

It is common to find a mixture of these maintenance techniques used as parts of an overall maintenance plan. The appropriate proportions of each vary according to a number of influencing factors and will also be impacted by age and technology.

i. Reactive Maintenance

Reactive maintenance is based on a run-to-failure strategy. Ageing plant is subject to a number of additional features than may result in increasing use of reactive maintenance.

The equipment will often be less efficient than new designs or may operate more slowly. To compete with modern equipment it will have to run harder for longer. This can impact the ability to take equipment off line for maintenance and replacement.

As a result maintenance will often be carried out “on-the-run” under extreme time pressures. Replacement parts may be difficult to obtain and the use of second hand parts or re-manufactured parts becomes more common.

- Technical skills may become difficult to find and training is more difficult to deliver.
- Technical support from the manufacturer may become difficult as the equipment becomes obsolete and specialist contractors go out of business.

ii. Preventative maintenance.

Preventive Maintenance is a planned proactive technique that involves maintaining machines at specified intervals based on time or process cycles.

Achieving full equipment service life is usually based on complying with the manufacturer’s maintenance program, which will be based on a preventive maintenance approach and may include predictive maintenance and machine monitoring. In some cases, this will include a Long Term Service Agreement.

From an insurance perspective, preventive maintenance typically has the following features.

Positive:

- Preventive maintenance is planned and usually well documented.

- Preventive maintenance can provide a good standard of inspection and maintenance based on general operating conditions.
- Unplanned breakdowns are reduced as there is a planned inspection and wear items are replaced prior to failure.
- The service life of the machine is extended due to the maintenance.

Negative:

- Preventive Maintenance requires more on-going effort.
- Parts are replaced at times determined from average failure performance, irrespective of the actual needs of the particular equipment.
- It subjects the equipment to invasive actions with the risk of damage or delays.
- It exposes staff to potentially hazardous maintenance activities.

Note:- If preventive maintenance programs are not followed with skill and competence, then the benefits will be reduced or may be entirely lost.

For new equipment, manufacturer's preventive programs are usually mandatory as part of the manufacturer's warranty and will be required by insurers. However, they may not be appropriate for all installations and may become obsolete with older equipment. In these circumstances it is usual for the owner or operator to modify or change the maintenance tasks or the maintenance schedule based on operational experience or industry good practice.

See Chart 7.2 below.

Chart-7.2: Impact of Preventive Maintenance

iii. Predictive Maintenance.

Predictive Maintenance is a proactive technique, frequently used as part of a planned maintenance program such as preventive maintenance.

This maintenance uses a variety of measurement and monitoring techniques to assess the current health of the machine.

The most common of monitoring and measurement techniques are:

- Vibration monitoring (Rotating machinery such as pumps, turbines etc.)

- Thermographic inspection (boilers, steam system components, electrical equipment etc.)
- Oil analysis (cooling, hydraulic power systems etc.)
- Visual inspection.
- Shock pulse (rotating machinery)
- Ultrasonic leak detectors (hydraulic and pneumatic systems)
- Electrical insulation testing (motor and generator windings etc.)
- Performance testing (heat exchangers, pumps, compressors etc.)
- Wear and dimensional measurements (Sliding and rotating elements)
- Signature analysis, time and frequency domain (rectifiers, power supplies etc.)
- Non-destructive testing (hull structure, shipboard machinery etc.)
- Borescope inspections.

Predictive techniques rely on measurement of operating parameters with data analysis using appropriate techniques. Based on historical data, operational experience and calculation, changes are “trended/projected” to predict the likely future for the machine in terms of failure mode and estimated time before failure.

From an Insurance perspective, predictive maintenance typically has the following features:

Positive:

- Reduced unnecessary invasive maintenance.
- Reduced machinery breakdown losses by prior identification of deteriorating trends.
- Developing defects can be identified in sufficient time to attempt a planned repair or replacement at minimum cost in lost production.
- When predictive maintenance uses in-built sensors, the data can be linked to process control systems and remote monitoring.
- Predictive monitoring can extend the reliable service life of equipment.

Negative:

- Some breakdown events may still happen.
- The systems and techniques take time to perfect; initially there may be false warnings or no warnings of impending breakdown.
- Not all of the techniques may be adaptable for every machine.

Predictive maintenance and condition monitoring is frequently designed into new equipment. However, retrofitting condition monitoring sensors and systems is not always possible on old equipment that was not designed for it. Any reduction in the monitoring may reduce the effectiveness and accuracy of the overall monitoring system and hence may impact the accuracy of the analysis and trended results. Poorly fitted sensors can themselves cause reliability problems.

From an insurance point of view, when considering aged equipment, an assessment of the quality of the condition monitoring procedures and the data analysis can provide an added level of comfort when considering the effective risk improvement due to the predictive techniques being used.

If applicable and correctly used predictive techniques can significantly reduce the potential for unexpected breakdown events and claims. On this basis, they should be encouraged.

c. Second hand equipment

It is common for the original owner to replace machines when they become unreliable, or when they can no longer produce the products the market requires.

Much of this replaced equipment enters the second hand market from where it will re-enter the production environment. Through this process, much of the operational, maintenance and upgrade history will be lost and it is difficult to identify what quality of maintenance second hand equipment has received.

Some second hand equipment traders may carry out some cleaning and basic servicing, but in most cases this should be considered to be only surface treatment. Likewise, any guarantee offered by the second hand vendor is generally of little value.

It should be assumed that second hand equipment will always be at increased risk of historic reactive maintenance and the increased future potential for breakdown. Because reactive maintenance is poorly documented, there is often no history on which to base an assessment of breakdown risk.

Some aged equipment is retained by the owner in production. In these situations there is a good chance that the operating and maintenance history still exists and that if the machine is still in use, the maintenance quality has been good.

d. Conclusion

The right maintenance selection for each plant and individual machine is essential for a reliability service life. There is always a risk that invasive inspection or maintenance will introduce problems.

Aged equipment should always be considered to be at the highest risk of breakdown, particularly if the equipment is not original to the site or to the owner.

Provided that an insurer can be assured that the right maintenance program has been followed and that all required upgrades and replacements have been carried out, then they can have reasonable confidence in the potential breakdown risk as related to the “Bath-Tub” principle.

8. Influence & control of/by Original Equipment Manufacturers LTSA

a. Original Equipment Manufacturer (OEM)

An Original Equipment Manufacturer (OEM) is a company that designs and manufactures parts and equipment. OEM's, especially of larger equipment, often also provide installation and service and may also have third party recommended servicers and/or installers.

Insurers are well aware that a lack of, or incorrect maintenance or misuse of equipment can lead to severe damages irrespective of its age. This is much more important in case of “old” equipment due the increasing possibility of inherent faults and breakdown due to the ageing process.

Typically the maintenance approach will be in-house or outsourced, or a combination of both where the OEM or third party contractor maintains the critical equipment. i.e. a power plant where the OEM maintains the turbo-generators and the power plants own personnel maintain all other equipment.

In-house maintenance will usually be carried out by the Insured's own employees, preferably a dedicated department with the requisite skills and experience of the equipment in use. Outsourced maintenance will be carried out by third parties, which may be OEM's or other service providers. OEM's are preferred by insurers due to their inherent design knowledge of the equipment, and their experience of knowledge gained from maintaining equipment for many customers and over many locations.

Unfortunately, some equipment owners demonstrate a total disregard for maintenance, looking to their insurance policies to cover the risk of failure. In soft markets the price of a Machinery Breakdown (MB) policy may be cheaper than the cost of a maintenance agreement or the cost of keeping in-house maintenance teams.

The main concern with in-house maintenance is whether sufficient care and ability is demonstrated, including full adherence to OEM manuals. Inadequate maintenance can be as bad as no maintenance.

Differentiating between contractor maintenance and in-house maintenance teams is a critical part of risk assessment for an insurer. Generally, MB coverage is provided based solely upon the disclosure of the insured which the insurer takes as a true statement. In case of a loss, the appointed loss adjuster must prove that in-house maintenance has been done properly and professionally in total compliance with OEM's manuals, or at the very least, has not been negligent. In order to prevent false or untrue disclosure some special conditions and subjectivities such as the example below are included in policies. By this means, the insurer tries to establish the right to reject the loss/damage and cancellation of the insurance policy due to false or untrue disclosure by the insured.

An example of subjectivity written into a policy where in-house maintenance is being undertaken by the insured:

This policy has been issued based upon the insured's statement that required precautions related to keep the machinery and equipment maintained and in-service have been taken, operating, control and maintenance specifications described on OEM's manuals have been absolutely followed; overloading in excess of accepted measurements has been prevented; admitted rules and instructions, especially related to operating and controlling process, have been followed by the insured.

Otherwise, the insurer will have the right to reject the loss related with the subjects given above or withdraw from the policy according to general principles of insurance and local insurance laws.

If the insured has an independent maintenance agreement with an OEM, or any other professional service provider, this is welcomed by the insurer as having a positive effect to minimizing and preventing possible breakdown losses. Generally, maintenance agreements, either long term or annual based, provide regular inspection and service in accordance with manufacturer's specifications and instructions. Where they involve the OEM, they may also include updating of the machine and or the control system to extend the design life. The extent of these agreements can be varied, for instance, it may cover a complete plant or only specific machinery. Repairs following damage may or may not be included.

Supply of critical spares is another issue. It is a far better option to have an agreement that includes the supply of critical parts within contractually agreed time limits. Such agreements should normally provide continuous documentation and periodic reporting which help with detection of failure root causes for complex losses.

b. What is a LTSA, with or without OEM

Long term service agreements (LTSA) are contracts made between the plant owner and service providers. These contracts are typically split into two categories:

- Corrective maintenance: This type of contract instructs the service provider to offer its services when the covered equipment suffers a breakdown, does not include scheduled maintenance or spares supply, unless required to complete the repairs.
- Preventive maintenance: In this type of contract the service provider offers its services with a maintenance schedule, in conjunction with the scheduled operating hours. Spare parts are changed at planned intervals.

All Long Term Service Agreement's (LTSA) are subject to rules stated in the contract and most have penalties in case of failure of these services. Moreover, insurers may have the right to subrogate to the service provider (depending on the policy wording) unless it's stated as an additional insured on the policy. For added security, insurers may write additional subjectivities and special clauses into the policies against the absence of a maintenance agreement or on the expiration of an agreement during the policy period.

Insureds often evaluate which type of LTSA to consider based on past breakdown experience of the plant. In practice they should not rely on only the breakdown record, but make their selection based on the overall wellbeing of the plant throughout its lifespan. Either of the above service agreements may be provided either by the OEM itself or by a third-party service provider. In underwriter's point of view, LTSA provided by OEM is the best option since the equipment in question is best known by OEM. However, as previously noted, for aged equipment the OEM may not be available.

In accordance with the scope of service, there is a substantial difference in price between corrective and preventive types of maintenance agreements which may lead some operators to shift their contracts from preventive to corrective over the years. OEMs may also require a corrective LTSA option as prerequisite to keep or extend the respective warranty period. This is frequently the case for ageing equipment.

Another point of interest is the response times in case of an interruption. Where lost production time is critical, and for insurers providing Business Interruption coverage, the response from an LTSA/service provider will be more rapid to clients where an LTSA with preventive maintenance is in force over an LTSA with corrective maintenance.

c. Positive and negative features of an LTSA if OEM are being or not being used

If the owner does decide to use an OEM with an LTSA they should benefit from the following advantages:

- Predictability of maintenance costs.
- Contractually guaranteed OEM support.
- Shifting of risk allocation for Unscheduled Maintenance.
- Year-to-Year budget visibility.
- Guaranteed availability of contracted services and Reliable Distribution.
- Single point contact for outages, planning, mobilization, QHSE and engineering.

- Guarantee/Warranty by a single source provider.
- Inspection support and possibly a containerised replacement equipment fleet available for scheduled and unscheduled outages at a moment's notice.
- Quality of service.
- System Compatibility.

Negative features of an LTSA if OEM are being used:

- Dependence on one supplier.
- Usually more costly than 3rd party.
- High cost of spares and inability to source third party alternatives.
- Obsolescent Equipment. If machinery is near the end of its projected service life, it may not make sense to pay a premium for the advantages offered by OEM parts. Increased resale value will not likely recoup the additional investment required, and durability ceases to be a primary factor in the buying decision.

Price might be the largest driver for an owner to use a non OEM supplier. Especially if the parts and service provided requires low technical skill but is still of a complexity beyond the capability or capacity of the in-house maintenance team.

Be aware that for parts which require a very high degree of engineering and development, OEM prices can be very high, driven by the absence of competitors. As soon as a 3rd party manufacturer has managed to reengineer the requested spare parts, prices may drop. However, OEM's often nullify any warranties provided if non-OEM parts are used, however minor that part may be (e.g. seals, gaskets, bearings, etc.). Some Equipment Manufacturer's might even offer equipment at reduced or breakeven rates simply to benefit from more lucrative ongoing maintenance agreements over a number of years.

In relation to ageing plants, independent maintenance agreements can potentially have significant benefits for maintaining the machinery and for the supply of critical parts which are otherwise hard to obtain. However, it should be noted that service agreements for aged equipment may be difficult to obtain and very expensive, making them financially unattractive.

It may be wise for Insurers to include a subjectivity written into a policy where a maintenance agreement exists. An example follows:

This policy has been issued based upon the insured's statement that there is an existing maintenance contract for the subject machinery and equipment of insurance in accordance with OEM's control and maintenance technical specification during the policy period.

In the event of absence or expiration of an existing maintenance contract during the licy period or proving the negligence or misuse of OEM's control and maintenance technical specifications, the insurer will have the right to reject the loss related with the subjects given above or to withdraw from the policy according to general principles of insurance and local insurance laws.

9. Impact of Jurisdictional Requirements and Legislation - Codes and Regulations

In most industrialised countries, there are legal requirements imposed on equipment manufacturers and operators to comply with defined safety standards that cover design, construction and operation. These are usually referred to as Statutory or Jurisdictional requirements or regulations.

The equipment or systems covered by these requirements vary from country to country and sometimes within countries. In general, regulations are applied to the following equipment groups, but individual countries may include other classes of equipment.

- Specified Systems
 - Pressure systems (PSSR UK)
 - Lifting equipment (LOLER UK)
 - Electrical equipment and installations
 - Work Equipment (PUWER UK)
- Specified equipment
 - Power presses
- Specified occupations
 - Marine
 - Environment
 - Farming
 - Nuclear Power
 - Aviation
- Others.

Some industries such as the petroleum industry, gas industry and railway operations etc. may have consistent equipment requirements based on agreed best practice, and these can often be regarded as quasi regulations, or are incorporated into local legal regulations.

Most industrial countries will have regulatory or inspection bodies whose role is to set and police legal regulations governing general industrial and process issues. This will typically include the investigation of accidents and where necessary, the prosecution of those held responsible.

In almost all cases, Statutory or Jurisdictional requirements are intended to protect the safety of those involved in operating or maintaining the equipment, or of third parties who might be affected by failure of the equipment or its' component parts. They are not primarily intended to minimise Property Damage losses.

Legal requirements to ensure personnel safety cover design, installation, operation and maintenance of all, or part of the machine. In so far as safety features are mechanical or electrical devices or systems, they will require inspection, test and maintenance to comply with regulations. Routine inspection of these safety devices help to ensure that they work as intended to protect life safety, as well as minimising chances of equipment failure and associated ageing related degradation.

Although there is a fundamental difference between safety and reliability, there are similarities that can have an impact on the way equipment is insured.

Statutory/ jurisdictional inspection requirements require a maintenance structure similar to that needed for reliability based preventive maintenance - namely a list of equipment, details of the inspections and tests required, records of completion and actions required. To comply with regulations, the inspections have to be carried out by trained and competent staff with the necessary resources.

Whilst this is not reliability centred preventive or predictive maintenance, it does introduce a routine inspection and maintenance activity from an independent and impartial view. This can play a part in improving overall quality and standards of reliability maintenance.

For example:

i. Pressure systems

Pressure systems such as boilers, and compressed air systems are required to comply with the provision and test of safety devices to prevent over pressurisation. Boilers also require testing of water level controls, burner malfunction and control, fuel gas isolation and leakage.

Inspections cover structural deterioration of the boiler shell or received shell and testing of safety and control devices. All of these requirements can be considered as maintenance activities that will impact on the operational reliability as well as safety of the pressure system.

ii. High hazard sites

In the UK and some other countries, sites that handle and store large quantities of hazardous material/ dangerous substances (e.g. flammable substances, strong acids, explosive material) are required by legislation to demonstrate that all measures have been taken to prevent and mitigate a major accident.

This requires documented evidence that systems are well managed, tested, and maintained to a good standard. This requirement is particularly relevant for high hazard sites (e.g. the chemical industry), which tend to have processes and equipment that are susceptible to ageing related failures and losses.

Specialist inspectors periodically visit these sites to enforce legally binding standards and require improvement actions where necessary. In so doing, they are demanding improvements including safety related inspection and test requirements be put in place to address known safety issues that have sometimes resulted in untold death and injury. This has had a positive impact on insurance of property damage and loss on these sites.

iii. Other machines and devices

The potential for large highly public failures is present for pressure systems and high hazard sites, as well as other machines, processes and devices. So for example, a poor quality or non-compliant electrical system or fitting on an item of equipment may be dangerous to the operators and the maintenance staff, but may also cause increased risk of failure, damage and loss to the equipment. Again, inadequately sized or specified connection bolts may fail, leading to significant equipment damage with total losses significantly greater than the value of the failed component.

iv. Modification to Plant and Equipment

There are legal requirements for companies to ensure that repairs and modification to machinery are carried out by competent people to appropriate design standards, so that equipment is safe

to operate and the asset integrity is maintained. This is generally known as “Management of Change”. As part of this process, documentation (e.g. reports, certificates) of a suitable repair/modification should be kept for review by an inspector, who can request a test of the protective devices on the modified equipment.

Modification of equipment and/ or operating processes may introduce new hazards. The changes introduced to the system, may put the equipment at risk of operating beyond its original design specifications. The Flixborough 1974 explosion is a classic example of catastrophic failure that was caused by the introduction of temporary equipment modification that was not assessed for design or suitability. The Flixborough Report states *‘the disaster was caused by the introduction into a well designed and constructed plant of a modification, which destroyed its integrity’*

v. CE Marking

“All machinery supplied in the European market after 1 January 1995 should have been CE marked. This includes machines manufactured for the makers own use (i.e. ‘in-house specials’). Equipment first used in the EU prior to this date does not need to be CE marked, but equipment which was made before this date but not imported into the EU until later will need to be CE marked since the act of crossing the EU border is considered to be the first supply into the Community. An additional complication comes into play so far as an end user of machinery is concerned, since if the machine is provided for the use of their employees, they will have obligations under the Work Equipment directives (implemented in the UK as the Provision and Use of Work Equipment Regulations 1998 (PUWER)). These state that equipment supplied for employees’ use must comply with any applicable Essential Requirements of the CE marking directives.”

(<http://www.conformance.co.uk/adirectives/doku.php?id=secondhand>)

CE marking is required under European product safety directives (Machinery Directive 2006/42/EC) and applies to all equipment manufactured in, or imported into an EU country from any other global country, as well as second hand and new equipment imported across the EU borders. It does not extend to countries outside the EU, only in so far as it applies to equipment destined for the EU or manufactured in the EU.

It is a widely held view that CE making can be taken as an indication of quality and reliability. However, CE marking is not necessarily an indication of reliability. For example, poor design, such as an undersized bearing or under-rated gearbox may result in a breakdown loss, but may not result in a safety issue.

The CE certification and marking process is a once off requirement and may not subsequently be inspected or checked unless the equipment is sold across an EU boarder. It is an indication that the design and specification were originally to an accepted safety standard, but it does not make allowance for in-use deterioration or damage post certification. Sadly it is also relatively easy to falsify!

From an insurance perspective, with new equipment from a well-respected manufacturer, a CE mark is a positive indicator. However, in terms of second-hand or aged equipment, CE certification does not provide any indication of the item’s condition, integrity, remnant life or suitability for continued safe or reliable operation. In contrast, a current statutory inspection report/certificate (where applicable) may provide more valuable information about the equipment’s potential issues related to ageing e.g. signs of deterioration, major repairs that have been carried out in the past.

vi. Fines

Most statutory or jurisdictional regulations carry penalties for non-compliance. The nature of the penalty will vary from country to country. In most cases, the body held responsible for non-

compliance will be a company rather than an identified person and so financial penalties are the norm.

The scale of the penalties varies depending on the nature of the transgression, with a breakdown that includes injury generally carrying a high penalty. In addition to any legal penalty, (and probably of more impact) will be compensation claims and awards following injury or damage to property. As legal penalties are not coverable events they must be paid by the guilty party. The insurance company however, will in most cases be left to pick up the property damage costs.

Sadly, investigations and penalties are only imposed after an incident has occurred, and the fact that there are still breakdowns and losses indicates that simple penalties for non-compliance are not sufficient to prevent them happening. However in most countries insurance coverage for casualty losses and third parties is compulsory and a requirement to trade legally. This can provide the insurers with a level of authority to insist on sound and adequate maintenance practices.

10. Second Hand Equipment – Basis of loss settlement and Valuation

The problem of how to assess, insure and indemnify ageing equipment is faced by underwriters in different types of Engineering policies - project (EAR), annual (MB) and of course with Business interruption coverages (ALOP, MLOP).

From the point of view of underwriting considerations it is better to assess these coverages as follows.

a. Project policies

Generally most EAR risks offered to insurers will have new equipment being installed. But in some regions many projects will utilize second hand equipment.

Insurers are typically reluctant to provide full coverage for used plant and equipment in projects due to the unknown operational history. They also argue that testing & commissioning coverage should not be provided as the equipment has already been in operation, hence has already been tested. Brokers and/or owners will argue that it is being set up in a new configuration or location so it needs to be re-tested.

Insurers will be more open to providing testing & commissioning coverage if the OEM is involved in the installation of the equipment and if they provide a reasonable warranty, along with higher deductibles.

There is also a possible situation that the equipment can suffer degradation where construction is interrupted or delayed with one or multiple cessations. This is very common situation in post-war regions: ex-Yugoslavia, Iraq, and other regions suffering long-term economic crisis.

When underwriting such projects the following criteria should be analyzed and evaluated:

- How old is the equipment to be installed?
- Who has assessed the condition of the equipment prior to installation - was the inspection carried out before transit or on delivery?
- Who will be responsible for the defects if any?
- Are there to be any modifications to the equipment from original use, or different types of feedstock or fuels used?

- What is now the equipment project lifespan?
- In the case of second hand equipment, was it adequately maintained before the dismantling? Are there any operational records?
- Does the company who is responsible for the installation have the experience with the same equipment? Is there any kind of OEM support and/or warranty?
- How is the SI determined and is it enough to replace the equipment in case of loss?
- Is it still possible to buy the same equipment or spare parts in case of loss?

If ALOP is to be provided then the following questions are also very important:

- The average time to get the new equipment or replacement parts.
- The period of the reinstatement in the case of loss.
- The part of Turnover that would be reduced if the production does not commence as planned.

The question of defects coverage is very important with the ageing equipment.

It is a common understanding that Insurers shall provide coverage for any sudden and unforeseen loss or damage to the insured property except those caused by faulty design, defective material or castings, and workmanship, other than faults due to erection.

In case of ageing equipment, it is very difficult to define clearly the cause of loss and so it is very difficult to prove that the loss was sudden/unforeseen when considering the equipment remnant lifespan. In these cases, underwriters must be very careful when granting any defects coverage (LEG2/96, LEG3/96) especially cover for the maintenance period.

The crucial time for the ageing equipment is during the testing and commissioning (T&C,) period. During the early phase of construction, and well before the start of T&C, the contractor responsible for the project T&C should produce a written document/plan setting out how the process of T&C is to be controlled. This document must be specific to the project, taking into account the particular equipment type, design, services, utilities, risks and hazards that apply to the given project.

Experienced and responsible contractors should have a generic T&C control document available as part of normal quality control documentation, which can be adapted for a specific project. The T&C control document should form an integral part of the overall site safety and construction quality control procedures.

Risk surveys and ongoing risk monitoring are very effective for the different stages of the project until completion, and should be in place for all projects of sizeable sums insured. The surveyors can assist with the:

- Design phase - the surveyor can make recommendations to reduce the risk of damage during erecting and testing equipment. He can assess possible PML scenarios.
- Construction phase - the surveyor can be present on the construction site to assess on-site quality controls, determining adherence & risk to the critical path, in order to verify that the process corresponds to the design and good practice. He can make recommendations to improve the level of risk management on the site
- Testing & commissioning phase – to ensure that implementation practices continue to have a satisfactory level of quality and safety control.

b. Annual policies

For annual policies (MB, MLOP) the underwriter considerations for ageing equipment will include the following:

- Type of equipment – make, model, age, value.
- Operating hours, capacity being used at.
- Loss history.
- Operator skills.
- Maintenance program (as covered previously in this paper), including support of the OEM.
- Location.
- Survey reports, if available.

The survey report is key and will help to provide finer details on the following topics which will be of particular interest to insurers:

- Physical conditions of the machines and equipment.
- Loss related problems associated with older machines - the insurer should ascertain that the specific machine type and all required spare parts are still being manufactured.
- Unconventional features. The risk inherent to operating such equipment warrants prudent evaluations.
- Plant configuration – all technical machines and equipment in a given facility must be overhauled according to specified maintenance schedule. Whenever possible inspection of critical components should be performed without total disassembly.

This can determine whether the insurer will provide a Scheduled (itemized) or Blanket Coverage.

Typically insurers will provide a blanket coverage. This way they have the premium income from all equipment for a plant, or insured, and this acts as a mini portfolio of kind.

Requests for coverage of itemized plant or machines can be considered 'anti selection' or a moral hazard by insurers as the equipment might be deemed higher risk by insureds and insurers miss out on the overall plant premium income from other lower risk machines.

A scheduled coverage would be more commonly seen with contractors Plant & Equipment annual policies. For example, a contractor might have 10 machines of the same manufacturer and model. Under a scheduled policy, each of the ten must be listed, including the year and serial number. Under a blanket schedule, the contractor could report having only 5 of them. The chances of the contractor having a loss of more than 5 items at one time is extremely low. This 'loophole' means that insufficient premium has been collected for the exposure underwritten.

c. Basis of loss settlement

Machinery insurance (both project and annual MB policies) is understood as an accident insurance and cannot be construed as a "life insurance" for machines. Machines have defined service lives governed by design, operating conditions, wear and tear, as well as obsolescence resulting from ongoing technological development.

Therefore machine owners must establish annual depreciation schemes and allocate proper reserves for replacing machines at the end of their service lives. Taking into consideration that machine lifespan is rather small, these depreciation reserves are usually very high. It should be noted that owners generally receive tax deductions for this depreciation and insurance should not therefore be seen as equipment end of life replacement policy.

According to the standard wordings of CAR/EAR and MB, the insurer is liable to pay the whole sum insured in case of the total loss of the item and to pay reinstatement costs in case of the partial damage.

Machinery insurance cover is designed to ensure the necessary capital will be available at any time during the machine service life, for new procurement in the event of total loss or for the repair in the event of partial loss.

d. Valuation Methods

There are 2 main valuation methods in use:

- Actual cash value basis (ACV)
- Replacement or repair basis (New replacement value, NRV)

Agreement should be reached with the insured for establishing depreciation amounts, since the service lives of the different machines may vary widely according to the different parameters. This would also provide contract certainty.

The following formula may be used as a general practice:

$ACV = NRV * (1 - A/SL)$, where

ACV – actual cash value

NRV - new replacement value

A – machine age on the accident date

SL – service life of the machinery.

The primary difference between ACV basis and NRV basis can be summarised as follows:

- In case of so called constructive total loss indemnity under the ACV basis would be restricted to the actual cash value of the insured item on the date of loss occurrence. Thus, repair would be considered no longer economically justifiable. The insured would be in a position to buy a new machine with allocated reserves (depreciation) and the insurance indemnity.
- The NRV basis stipulates that insurers pay full repair costs of the new machinery.

There is no difference for partial loss in which the repair costs remain below the actual value

e. Premium calculation

In case of the ageing equipment, the correct application of the insured values and the sum insured becomes very crucial.

In standard conditions of course the insured value (IV) and sum insured (SI) should be equal as both insured value and sum insured represents the NRV.

But in case of ageing equipment taking into consideration the depreciation and wear and tear, the sum insured should be less than the insured value and should be equal to ACV. Clear

understanding of both these parameters (IV/SI) is the key of the correct assessment and pricing of risk.

When underwriters are determining the policy wording to be applied, and calculating the premium, they have to take into account that in case of partial loss, the most likely indemnity will be repair to return the insured to the position they were in just before the loss. To achieve this, they have to pay for the new parts in lieu of damaged parts. That is why it seems quite logical that premium should be calculated basing on the NRV of the machinery. If actual value is used as the basis of applying the premium rate then, over time, that could end up detrimental to the profitability of the insurer.

Tables 10.1 and 10.2 following demonstrate the impact of rating on an Actual Market Value (consistent with ACV) basis v NRV using a consistent rate of 1.5% (wouldn't that be nice!)_and claims inflation at 10% for easy reference.

	NRV	Claim	Premium	Claim/Premium Ratio
2018	1,000,000	12,000	15,000	0.80
2019	1,100,000	13,200	16,500	0.80
2020	1,210,000	14,520	18,150	0.80
2021	1,331,000	15,970	19,960	0.80
2022	1,464,100	17,570	21,960	0.80
2023	1,610,510	19,330	24,160	0.80

10.1 New Replacement Value as Sum Insured (reproduced from Swiss Re Contractors Plant & Equipment Publication).

	NRV	Claim	Premium	Claim/Premium Ratio
2018	1,000,000	12,000	15,000	0.80
2019	850,000	13,200	12,750	1.04
2020	700,000	14,520	10,500	1.38
2021	550,000	15,970	8,250	1.94
2022	400,000	17,570	6,000	2.93
2023	250,000	19,330	3,750	5.15

10.2 Actual Market Value as Sum Insured (reproduced from Swiss Re Contractors Plant & Equipment Insurance in International Markets publication).

It can be noted that using a rating based on Actual Market Value that the premium income declines significantly over time with claims costs rising with inflation. As most claims will be for repairs, and new parts are normally used as part of the repair, the cost of claims outstrips the premium income if the rate is applied to a depreciating ACV sum insured over a number of years. Therefore prudent insurers will always use NRV sums insured to calculate their premiums.

f. Claims issues

Firstly, it is worth restating that an insurance policy covers the insured's financial interest in the subject matter of the policy, not the actual item itself. It is a fundamental principle of insurance that an insured must have a financial interest in the item that has been lost or damaged, to be able to make a claim. It is also a principle of insurance to return the insured to the position they were in immediately prior to the loss.

If something was of no value to an insured before it was lost or damaged, then the insured can suffer no loss as a result of any loss or damage. Equally, if an insured had only limited interest,

for example shared ownership of something, then they can only suffer a loss to the extent of their share of the financial loss/value of any item. This may then can be ascertained by considering any contractual arrangement that is in place.

Keeping this fundamental point in mind at all times, we can then give more specific consideration to how it can be applied to the different situations.

For significant repairs, the question of economic viability has to be considered. It is perfectly reasonable to look at the second hand replacement cost of items when dealing with a claim on an indemnity basis and such replacements can be significantly cheaper than repairs. Any proposed second hand replacement should be comparable in terms of age, condition and output, although there can be some degree of flexibility in this respect. It is far better to find a slightly better second hand replacement than the damaged item, and still make significant savings against the alternative of repair costs. The value of any salvage should not be forgotten when assessing the claim.

For total losses, again, the second hand alternative is realistic, and especially so if the insured bought the original item second hand in the first place. If a second hand option cannot be found then the measure will be current equivalent replacement less deductions for depreciation, unless specific coverage has been granted for NRV in the event of a total loss. Delivery and installation costs should also, of course, be included (in the overall cost calculation before deductions are made for depreciation), which may be significant in the case of heavy items of machinery.

Where an item is hired or on loaned, the insurable interest is limited to the extent of the insured's financial responsibility under any contract. In the absence of any contract, 2nd hand replacement (or indemnity for repairs) would be appropriate. If a contract should commit the insured to replacement cost, that may not be fully covered by an indemnity based policy – the cover requires deductions for wear and tear to be made, either specifically in some wordings or by reference to the word "value", which refers to the actual value of the loss or damage. The insured could therefore find themselves with cover that falls short of their responsibility under some contracts (leased photocopiers are a common example) as the liability for any loss beyond the "value" is a contractual liability.

Appendix I – Ageing Equipment Photo Gallery

1. Spare breaker of old 33kV switchgear. Note storage conditions and evident deterioration.

2. Old machine in poor condition indicating poor maintenance and potential source of Kiln damage.

3. *Crusher rotor worn and in need of repair to be confirmed as a usable spare.*

4. *In-house manufacture. Insurable?*

5. *Obtaining spares for this car is difficult. Many have to be made to order by a specialist company.*

6. *Aged unit formerly supplied by (former) Soviet Union.*

7. *If you cannot get spares, people will improvise...*

8. *Alcohol Still. Example of historic equipment retained in use because of tradition or due to production quality.*

9. *Potential damage due to fatigue failure in an old boiler.*

Appendix II – References and Bibliography

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