INTEGRITY MANAGEMENT FOR THE 21ST CENTURY WITH 20TH CENTURY EQUIPMENT†

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Many of our assets in the process industries were built over 20 years ago and are still operating today – well beyond their anticipated design lives. By understanding the underlying causes of deterioration and thereby loss of integrity we can build a robust integrity management system and develop a practical action plan to operate these ageing assets in a safe, productive and cost effective manner.

Using a case study, the paper shows how some existing approaches can fail to provide the required degree of assurance. It also highlights how weak systems can combine with organisational and human factors to undermine years of apparently satisfactory performance.

The paper goes on to describe the key elements of an integrity management system, applicable to process facilities which are being operated beyond their design life. This approach is also potentially applicable to plants that have not yet reached their design life. It shows how consideration of asset life underpins process safety, maintenance and renewal policies to give a robust long term asset strategy.

INTRODUCTION

The process industries face challenging times. Increasing stakeholders' expectations and relentless economic pressures are compounded by the difficulties of managing an aged asset base. Many of our assets were built and commissioned through the 60s, 70s, 80s and are still operating today.

Many operating companies have introduced initiatives to maintain integrity or improve reliability such as Risk Based Inspection (RBI) and Reliability Centred Maintenance (RCM). However, they may still suffer from significant "unexpected" failures and losses of containment. Such incidents include leakage from storage tanks and failures of "non-critical" pipework which causes disruption to production, despite an apparently good maintenance and inspection history.

It is not just mechanical systems and equipment that needs to be addressed. Deterioration of instrument/electrical equipment and structural elements of plant can lead to an unacceptable risk to plant and to personnel. Even if the condition of the equipment is preserved, obsolescence can affect the useful life of certain types of asset, notably control equipment and machines.

Operating companies are increasingly "sweating the assets" – operating existing assets beyond their original design life, rather than building new plant, and tying up valuable capital. Indeed, many existing plants are now so far beyond their original anticipated life, that design margins have been used-up. For example, at the design stage, the selection of materials of construction for pressure equipment is based on the process fluid, the intended operating conditions and the expected rate of corrosion. A corrosion allowance is determined on the basis of the rate of corrosion over the desired operating lifetime. After many years in operation the corrosion allowance may be used up. The integrity of the equipment may potentially be further compromised by plant modifications, and a history of operating excursions outside of the operating envelope. Other life-limiting deterioration can be caused by operating cycles and stresses exceeding the fatigue design life, and the cumulative effect of operating for longer periods than assumed in the determination of the creep design life.

In the UK further challenges arise from economic factors – there has been little significant investment in new plant and reduced investment in refurbishment and maintenance of existing plant has been the norm since the late 80's. Pressures have been placed on maintenance budgets, resources, etc. to cut operating costs.

Yet, the industry is facing increased expectations from the public, employees and other stakeholders in such areas as environmental protection, continuous safety improvement, and enhancing the company's reputation as a "socially responsible" enterprise, whilst at the same time remaining profitable in a competitive global market. This is particularly acute in the wake of a serious incident and there have been a number of serious incidents around the world in recent years which have drawn attention to the importance of continued management of major hazards.

Companies' abilities to deal with these challenges may be restricted by an ageing workforce, an undoubted reduction in the recruitment and training of young people through the 90's, and a trend for reducing in-house core competence in favour of out-sourcing.

Operators are increasingly realising that achieving safety, reliability and plant integrity targets requires a holistic approach to integrity management. They are beginning to realise that safety, integrity and reliability are all linked and are all manifestations of a risk management system that is operating effectively.

There are many benefits that flow from effective integrity management, including:

1. Increased equipment availability/reliability
2. Increased output
3. Improved safety and environmental performance
4. Optimised maintenance costs
5. Statutory and regulatory compliance

INTEGRITY MANAGEMENT – A CASE STUDY

If integrity management is so important and worthwhile an objective, how can it be achieved? Who is responsible for it?

Integrity management is not just about assessing the condition of plant equipment. The elements of an effective integrity management system are best illustrated by a looking a specific case study. Effective learning from incidents provides a powerful means to improve integrity management of ageing plant, as long as the true root causes and contributory factors are determined.

On a chemical manufacturing site, an above ground piping system was used to transfer a hydrocarbon liquid product from a storage tank to a unit in another part of the site. The piping was NPS 4 stainless steel and approximately 1km long. Although the product was toxic to the environment, the duty was not arduous – ambient temperature and pump transfer pressure less than 10barg. After the pipework had been in service for many years, part of it needed to be rerouted to accommodate the demolition of a building, and this presented an opportunity to make the new section as an all-welded construction, removing a number of flanged joints that had had a history of leakage.

Some time after the modification had been commissioned a significant leak of the hydrocarbon product was detected coming from a filter at one end of the piping system. As the filter was in an out-of-the-way location, the leak was not detected immediately – by which time an estimated quantity of 150 te of the liquid had been released. It was concluded that approximately 1 te entered the nearby canal, 20 te evaporated, and 3 te were recovered, with the rest remaining in the ground with minimal prospect of recovery.

The direct cause of the incident was the failure of the filter due to over-pressure. The piping system was used on an intermittent duty, and during a shut-in condition, the liquid had been warmed by sunshine and ambient air, generating a pressure that eventually caused the filter lid retaining clamp to fail.

As with many incidents, the underlying causes of the failure arose from the cumulative effect of several factors across the life cycle of the pipework:

1. The original design specification did not appear to have considered thermal relief.
2. The flanged joints "sprung" in reaction to over-pressure and so acted as impromptu thermal relief devices.
3. The flange leaks were not adequately investigated, giving rise to the view that these were "troublesome flanges" and therefore their removal was seen as only having a beneficial effect from a maintenance point of view.
4. With no significant deterioration mechanisms to threaten the integrity of the piping (except possibly deterioration of pipe supports), the integrity of the pipework could be regarded as a "maintenance issue" to do with the flanged joints, rather than a focus for "inspection".
5. After the modification, with no flanges to relieve any over-pressure, the filter was the next "weak link" in the system.
6. The modification to reroute the pipework did not appear to consider the pressure relief requirements for the whole pressure system, apparently focussing only on the implications of the modification on the affected part of the pipework.
7. Leak detection systems and operating procedures were inadequate, to mitigate the consequences of a leak.

In practice, perhaps the most effective point of prevention for this incident might have been in the control of the modification, through improvements in the management of change procedure and increased competence of the technical review team who were responsible for the modification.

So, we can learn a lot from real incidents. But simply studying incident databases does not move us forward. We need to distil the key messages and turn them into useful guidance and action.

THE ASSET LIFE CYCLE

The asset life cycle has a number of stages from scope definition (the business case) through to demolition and disposal. Each stage is interlinked. Safe, reliable and cost effective operation into the future is dependent on all stages of the life cycle. In particular, modification to the plant, re-rating of equipment, and assessments of current condition to effect life extension beyond the original intended design life, all need to be addressed by going back to the first stages of the asset life cycle, scope definition and revisiting the original design basis.

To illustrate these issues, it's worth considering an example – pipework. Four years ago there was a major focus on pipework in the UK. Pipework accounts for the most serious and largest number of loss of containment incidents. Pipework does not generally receive the attention that main plant items receive and is often neglected. Maintenance and inspection policies often do not adequately reflect the importance of ensuring integrity against the consequences of loss of containment.

Furthermore, the life cycle for pipework is more fragmented than for any other functional area. Numerous groups, personnel, teams, suppliers, contractors etc. have a part to play at each stage. A robust management system is required to ensure coordination between each of these stages and that all aspects relating to integrity of the plant have been addressed.

Not only are many of these stages often outsourced, or implemented by a different organisation, but within each stage there are often further specialisations of resource, leaving to further fragmentation.

A study carried out by ABB Global Consulting for the UK's Health and Safety Executive (Ref 1) found that most incidents arose from the cumulative effect of a range of errors and vulnerabilities introduced throughout the life cycle of the asset through design, construction, operation and maintenance.

Setting up an effective integrity management system requires a structured approach relating to the identification and implementation of improvement initiatives, sharing of experiences within the process industry and learning from past incidents (not just your own company), taking a fresh perspective on significant issues and going through a process of highlighting the vulnerabilities relative to the plant. It is vital that priorities are defined and investment made available to address those priorities.

The issues of fragmentation of the pipework life cycle discussed above, and illustrated in the case study, are structural ones to do with the way the industry handles the subject of pipework. Such issues can only be effectively addressed by concerted management effort. It's not surprising therefore that many pipework integrity programmes fail to deliver sustained benefits.

Many "integrity improvement projects" regard pipework integrity as purely an in-service inspection exercise – integrity is the responsibility of the Inspection Department (or contractor) and if only they could identify the "magic" inspection technique all would be well. In these cases the typical outcome is a mass of inspection data that fails to provide the degree of assurance or a practicable improvement plan. In some other cases, the operating company sets up an ambitious project which attempts to tackle issues on all fronts, and ends up diluting its efforts and running out of steam.

Clearly it is not practical for every company with high hazard pipework to achieve a "100%" target against each benchmark factor in design, construction, maintenance etc. What is important, however, is to identify the key factors – those that are likely to make the largest impact. For example:

a) For existing plants, re-validating or re-engineering the assets to modern standards may not be practical. But, what is the real impact of the original design and construction standards on on-going integrity? And how do such standards affect the engineering of modifications and maintenance activities?
b) To what extent do operational practices affect the integrity of pipework?
c) What is the real affect of "maintenance cost reduction" projects on pipework integrity?

The principles underlined in the above example of pipework apply to all the asset types, and point to the need for a consistent approach.

THE ELEMENTS OF AN INTEGRITY MANAGEMENT STRATEGY

To answer the questions posed in the previous section, and to develop a pragmatic integrity programme, it is necessary to take a holistic look at the relevant factors, and to identify those where the site can set clear and realistic targets. Needless to say, this is likely to be different for each company, taking into account such factors as the health, safety and environmental impact of losses of containment; production consequences of credible failure scenarios; design and construction pedigree of the assets; plant upgrade plans etc.

Human factors become increasingly important in such a scenario – ranging from management understanding and support, and communications across the life cycle stages and organisations involved, through to the establishment of effective information systems, and sufficient understanding of the design and construction features and deterioration mechanisms by all the relevant groups (plant teams and external specialist resources).

What does the integrity management system actually consist of and what does it look like? Figure 1 shows how an integrity management system can be developed. The approach hinges on a coherent Asset Strategy that defines the requirements to be placed on the assets to support the long term business strategy. The Asset Strategy is implemented by a range of policies covering process safety, maintenance and inspection, renewal, and competence.

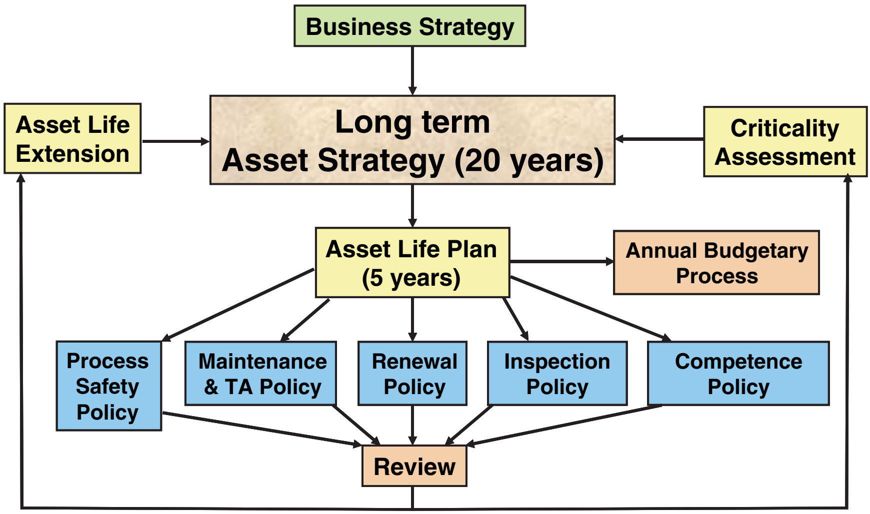

Figure 1. Asset management strategy

The main aspects of these policy areas include the following:

1. Process Safety policy should cover identification of the major hazards, and measures to eliminate, reduce and mitigate those hazards. This would include a documented design basis for the process, identification of residual risks and definition of risk reduction measures.
2. Maintenance policy should set out how safety, health, environmental risks, and the risks to production are to be monitored and controlled by engineering maintenance activities. This includes defining the optimum balance between on-stream and off-line maintenance; and how preventative maintenance is complemented by turnarounds and overhauls to ensure continued fitness for purpose and integrity for operation. It should also cover the policy for critical spares.
3. The Inspection policy should address the WHAT (what is to be inspected, types of equipment, specific areas of the equipment), HOW (how it is to be inspected, on-line versus offline, invasive versus non-invasive techniques), and WHEN (when should it be inspected, what is the period between inspections relative to known deterioration mechanisms). Gathering of data during inspections and storage of that data in a history file is key to addressing the issues of ageing and the ability for continued service into the future.
4. The Renewal policy would address the question of when does the equipment come to the end of its life? The key to this question is not about how old the equipment is, but about knowing what condition that equipment is in at the present time and how that condition changes over its operating life. In many cases, the decision to extend the life

of equipment is as much economic and practical decision as it is a technical one. How well are the life-limiting deterioration mechanisms known? What is the impact of equipment obsolescence? Which factors trigger the decision to carry out significant repairs and replacements? This is a particularly pertinent issue for most large scale process plant as much effort has been undertaken in recent years to reduce the duration of, and extend the period between, major planned shutdowns. By using such techniques as Risk Based Inspection (RBI) and Reliability Centred Maintenance (RCM), operators have focussed maintenance and inspection activities on minimising the need for maintenance and inspection work, so maximising production cycles.

5. The Competence Policy declares how the core competence of the organisation is to be maintained: what are the knowledge, skills and experience required of the key personnel, and how that is to be developed to ensure effective organisational competence. It should also cover the competence and availability requirements of external resource, and how their role in maintaining integrity is communicated and assured. The policy should also describe how learning from incidents and feedback from audits is used to strengthen integrity management processes.

Each policy area needs to be robust, supported by Procedures, Practices and Standards. It is further supported by competent resources, effective communication between groups, auditing and management reporting.

ASSET LIFE PLAN

We need to take a wider view – not just focus on known “critical assets” or problem areas. The diagram shows the key issues and aspects that need to be addressed to resolve those issues (Fig. 2).

Items of equipment can operate for many years, well beyond their original design life providing condition is determined and history is known and a plan is defined to ensure the item is maintained in an operable state, focussing on its vulnerabilities.

This requires a thorough understanding of the design basis, the design features and vulnerabilities, deterioration modes and operating and maintenance histories. In many cases, such information may not be readily available, placing more emphasis on the experience and expertise of the review team.

As part of an Asset Life Study, a re-validation of the design and of operation beyond the nominal design life is required. Using a multi-discipline team including external specialists to give an independent view and experience and good practice from other companies/industries, it is necessary to determine the current condition, deterioration modes, opportunities for improvement in asset care practices, costs and expenditure profiles for the projected life extension.

When it comes to revisiting the original design assumptions, it is necessary to ask: what was the original basis for the defined life of the equipment? As part of the asset life strategy for the plant, analysis should be carried out to identify items of equipment where life will be limited, and hence where the equipment will need replacing, within the

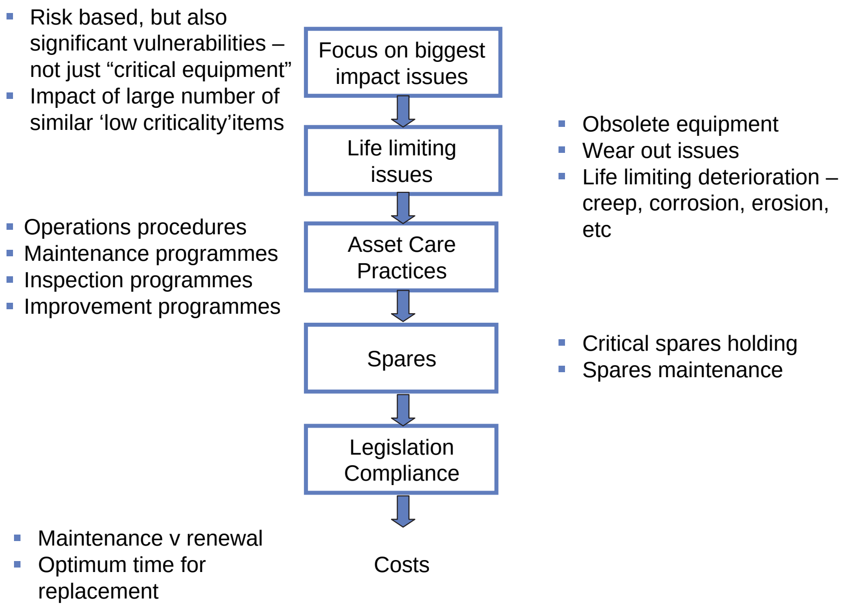

Figure 2. Asset life key issues

operating life or required extended operating life. This analysis should be based on safety grounds relative to the point where it is no longer economical or practical (e.g. spares availability) to keep the piece of equipment in operation.

The outcomes from such a study provide a technical justification for continued operation, but also can be used to generate cost information to help define maintenance budgets and rejuvenation investment plans.

ORGANISATIONAL COMPETENCE

To develop and deliver effective integrity management across the life cycle requires competence, communications and commitment. If any of these three areas are deficient in any way, integrity management will be compromised.

It is not sufficient just to collect data on plant condition, though that is itself a major task. It is also important to use the data effectively for decision-making. For example, measured wall thicknesses should be analysed:

1. to identify trends in deterioration and patterns of failure
2. to challenge the accuracy and validity of the data, depending on how critical the consequences of failure may be

3. to make the appropriate decisions about frequency and extent of future inspections and nature and timing of repair or refurbishment work

The various groups involved therefore need the necessary competence to carry out their tasks and to understand the need for communication across the organisational divides. Do your organisational and contract structures enable such communication?

In addition, this defines the data management requirements. Controlling of information through all stages of the life cycle and maintaining a history file is vital if we are to make robust decisions relating to the continued safe operation of plant and to the extension of operation of that plant in to the future. The information needs to be relevant, clear and concise and be readily accessible.

CONCLUSIONS

To summarise: if we are to safely operate, without incident, 20th century equipment well into the 21st century, robust systems relating to integrity management need to be in place. These include management and information systems that support data collection and management decision-making across the asset life cycle; methods and procedures that define the key integrity activities; competence development and training so that personnel (both in-house and contractor) are clear what their roles are in preserving integrity; and monitoring and auditing to reinforce the requirements and recognise and share good practice.

REFERENCE

1. D Jones and D Stanier, Piping Systems Integrity: Management Review, 2001 HSE RR253 available on www.hse.gov.uk.