**EEMUA 231 Edition 2 / SAFed IMG1**

# Addendum 1

Following the publication of Edition 2 of EEMUA 231 / SAFed IMG1 by EEMUA in February 2019, there have been some queries raised regarding the relationship between the Integrity Assessor and the Competent Person who fulfils duties in the Pressure Systems Safety Regulations (PSSR). This addendum has been produced to provide clarity and help explain how the process can vary to meet the differing organisational arrangements that may occur.

In considering the roles defined in the Terms and Definitions sections, 1.2.1 and 1.2.2, it should be remembered that the working relationship between the Integrity Assessor and the PSSR Competent Person may be very close as the PSSR Competent Person may form part of the team that fulfils the role of Integrity Assessor. This is explained under Roles and Responsibilities in section 5.4.

However, it should be noted that: **The examination report provided by the PSSR Competent Person is a formal report under the regulations and cannot be ignored**. **It should be considered by the Integrity Assessor in assessing the integrity and use of the equipment examined, but its conclusions cannot be over-ridden.**

This latter point is also relevant to Integrity Assessment, Section 8.3, in situations where stored energy and steam are the only hazards. Here, the PSSR report will itself provide the final adjudication of the examination and test findings providing its own formal documented statement upon the suitability of the equipment to return to service or not.

# The mechanical integrity of plant containing hazardous substances

## A guide to periodic examination and testing

EEMUA Publication 231
SAFed Publication IMG1
Edition 2

EEMUA

HSE

SAFed

## Foreword

This document has been developed and written by the Safety Assessment Federation (SAFed) and the Engineering Equipment & Materials Users' Association (EEMUA) in consultation with the Health and Safety Executive's Hazardous Installations Directorate, together with other interested stakeholders who use such plant, including operators, inspection bodies (including 'competent persons') and providers of specialist services to the process.

The Health and Safety Executive (HSE) considers maintenance of the integrity of plant containing hazardous substances to be a fundamental element of good process safety management. To this end, we believe this document provides a sound basis from which to develop arrangements for the management and delivery of periodic examinations aimed at achieving this.

The guidance contained within this document should not be regarded as an authoritative interpretation of the law, but if you follow the advice set out in it, you will normally be doing enough to comply with health and safety law in respect of those specific issues on which the guidance gives advice.

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| ISSUE STATUS AND REVISIONS | | |
|---|---|---|
| **Issue** | **Date** | **Pages** |
| 01 | September 2012 | New document |
| 02 | February 2019 | Fully revised |
| | | |
| | | |
| | | |

Proposed revisions should be notified to either the SAFed technical manager or the EEMUA technical director

SAFed Publication – IMG 1 – Issue 2
EEMUA Publication 231 – Edition 2
ISBN 978 0 85931 221 9
Imprint reference 2-2019
First published 2-2019

# Contents

# 1 INTRODUCTION

A range of plant and equipment is used in chemical plants, factories and depots for the storage, transfer and processing of hazardous substances. The mechanical integrity of vessels, pipework and other items of equipment containing these substances is the primary barrier against a loss of containment, and the potential realisation of inherent hazards those materials possess.

This document aims to provide guidance on managing the mechanical integrity of such equipment. This is a matter for the whole lifecycle, from original specification and design, through its operation to decommissioning. However, this guidance focuses on the issue of ensuring integrity through periodic examination and testing.

This guidance is published in the UK and therefore refers to the regulatory framework of that country. However, much of the description of good practice it contains will be relevant further afield.

This guide refers to various regulations, standards and guidance. It is the reader's responsibility to check for the latest edition of all documents referenced.

## 1.1 SCOPE

This guidance covers all onshore equipment that provides the primary containment boundary to hazardous substances, which will include pressure vessels, relief streams, atmospheric storage tanks, reactors and pipework. It will cover machines such as pumps, agitators, valves and compressors in so far as they are required to maintain primary containment. It does not cover the maintenance of such machines necessary to ensure their continued operation.

The hazardous substances considered include those with the potential to cause harm (either to people and/or the environment) because of their toxicity, flammability or other form of chemical reactivity (including explosivity). This includes the dangerous substances listed in the Control of Major Accident Hazards (COMAH) Regulations. COMAH is the implementation of the Seveso III Directive in the UK.

The guidance is aimed at sites which handle, process and store such dangerous substances. This includes establishments where the COMAH Regulations apply. It may also be relevant to sites outside the scope of COMAH where there are hazardous substances present.

All those involved in some part in the management of mechanical integrity of plant and equipment should find the guidance relevant. This will include site operators, inspection bodies (including Competent Persons, as defined by relevant regulations) and those offering specialist services to the process.

## 1.2 TERMS AND DEFINITIONS

### 1.2.1 Integrity Assessor

The Integrity Assessor is the person, team or corporate body that takes overarching responsibility for all the elements of an examination (including those parts carried out by another person or body) together with the interpretation of the results, and the formulation of conclusions and recommendations that may follow. As a person, team or corporate body, the Integrity Assessor may be either directly employed by, or contracted to the site operator. In all cases the Integrity Assessor should be competent (having the necessary knowledge and experience to carry out the role) and independent (see Section 1.2.5).

The Integrity Assessor should be determined prior to the commencement of the examinations.

The term Integrity Assessor is created and used within this guidance to recognise that there are responsibilities within managing the mechanical integrity of plant containing hazardous substances that go beyond those of the Competent Person under the Pressure Systems Safety Regulations (PSSR), both for the reasons explained in Section 3 and because some plant sits beyond PSSR.

The Integrity Assessor is therefore seen as the umbrella term to cover all responsibilities, although it is recognised that where PSSR applies some of these responsibilities will be taken on by the PSSR Competent Person to meet their duties under those regulations. In fact, in some situations the PSSR Competent Person may fulfil all the responsibilities of the Integrity Assessor. Under such arrangements, the person or body of persons who fulfils the role of Competent Person under PSSR, may be the same person or body of persons fulfilling the role of Integrity Assessor. Equally the Competent Person may be a separate person or body of persons reporting to the Integrity Assessor. Whichever arrangements are used, Site Operators retain their duties under Health and Safety legislation for the safe operation of the plant, which will extend to ensuring the role and responsibilities of the Integrity Assessor are satisfactorily fulfilled.

EEMUA[1] and CDOIF[2] provide guidance on the use of third party services.

### 1.2.2 Competent Person

The term has a specific role within PSSR, and is given the following definition;

*'competent person' means a competent individual person (other than an employee) or a competent body of persons corporate or unincorporate; and accordingly, any reference in these Regulations to a competent person performing a function includes a reference to his performing it through his employees; The competent person is appointed by the user.*

The Approved Code of Practice (ACoP) to the regulations gives comment on the role as follows;

*The term 'competent person' is used in connection with two distinct functions:*
*a) drawing up or certifying schemes of examination (regulation 8); and*
*b) carrying out examinations under the scheme (regulation 9).*

And;

*In general terms, the competent person should have:*

*a) staff with practical and theoretical knowledge and actual experience of the relevant systems;*
*b) access to specialist services;*
*c) effective support and professional expertise within their organisation; and*
*d) proper standards of professional probity.*

However, the term 'competent person', has also been used in other publications in a context much wider than PSSR.

Whilst the Integrity Assessor has, in this guidance, a wider remit than the Competent Person we have retained the use of Competent Person when reference is made to the PSSR.

### 1.2.3 Inspection / Examination

Within this guidance these are considered interchangeable terms to describe various activities aimed at assessing the integrity of plant and equipment.

Inspection and examination are considered as focussed activities that lead to a report on the condition of a piece of equipment and its suitability, or not, for further service. They may consist of a single part of an activity, e.g. a visual examination, or be the sum of several parts, e.g. a visual examination and a range of non-destructive examination techniques (ultrasonic thickness measurements, crack detection, etc.).

The reader should be aware that other documents may use these terms in other contexts, or as interchangeable terms.

### 1.2.4 Test

An element of an examination and a discrete activity aimed at providing information for an examination report. However, in itself, it would not usually provide information into all aspects of the current condition or assessment of ongoing equipment integrity. Examples include a hydraulic test, a holiday test (standard practice for checking for discontinuities in a coating) or a thickness test.

### 1.2.5 Independence

Independence is the management structure that ensures that the individuals and teams making key decisions relating to integrity management are impartial and isolated from other factors that might result in a conflict of interest. For example, a desire to maximise production may create pressure to operate equipment beyond the time for which its integrity may be assured. Alternatively, if the person responsible for maintenance is carrying out the statutory inspection then their impartiality may be questioned because they would be inspecting their own work.

### 1.2.6 Written Scheme of Examination (WSE)

A plan used to define the scope and frequency of examinations to be carried out. (NB There are specific requirements for a WSE within the Pressure Systems Safety Regulations, where they apply.) It should be noted that different terms may be used for this 'plan' where PSSR does not apply. For example, EEMUA 159 (Above ground flat bottomed storage tanks, guide to inspection, maintenance and repair) refers to an equivalent document called the Specific Inspection Plan.

### 1.2.7 Operator or User of the plant and equipment

Operator is a term used in the COMAH regulations and means the person (i.e. individual, corporate body or partnership) who is in control of the operation of an establishment, and the term is used in the guidance to cover that person who is in control of operations on the site whether it is a COMAH establishment or not. User is a term used in PSSR, and relates to a pressure system, and has a similar meaning to Operator, i.e. employer or self-employed person who has control of the operation of a pressure system or vessel. COMAH and PSSR provide formal definitions of each term. There is greater flexibility within the term user, to recognise that the person in control of a pressure system, may not be in control of the site as a whole. This term is also used within this guidance, as the User has important responsibilities within PSSR.

Overall, within this guidance, where PSSR applies, the Operator or User are likely to be the same person or body, however the term Operator is more often used to cover the wider responsibilities outside of PSSR. The term User is also used in places to remind the reader of the specific responsibilities of PSSR where appropriate.

Further information is given in Section 5.4.2 on the role and responsibilities of the person in control of the site or equipment.

# 2 OVERVIEW OF INTEGRITY MANAGEMENT THROUGHOUT THE PLANT LIFECYCLE

Successful management of plant integrity requires a clear strategy; not just for periodic examination, but for the whole plant lifecycle. This is especially important on sites storing and processing hazardous substances, where the consequences of integrity failure can be major.

Whilst this guidance is focused towards examination, it is very useful to put this into context, as this is only one element of an integrity management strategy. If the plant specification, design or construction was less than ideal, ongoing integrity management may require a unique approach and be a challenge. Also, key to maintaining integrity, is the assessment of the results of examinations and the appropriate action taken, especially where the inspection report states that the equipment has defects.

Diagram 1 shows an 'Overview of integrity management throughout the plant lifecycle'. This flowchart provides an overview of the different elements of the strategy, and how they link together and inform one another. All elements of the flowchart are discussed briefly in this chapter, but some are beyond the main scope of this guidance document. Those elements are shown shaded in yellow.

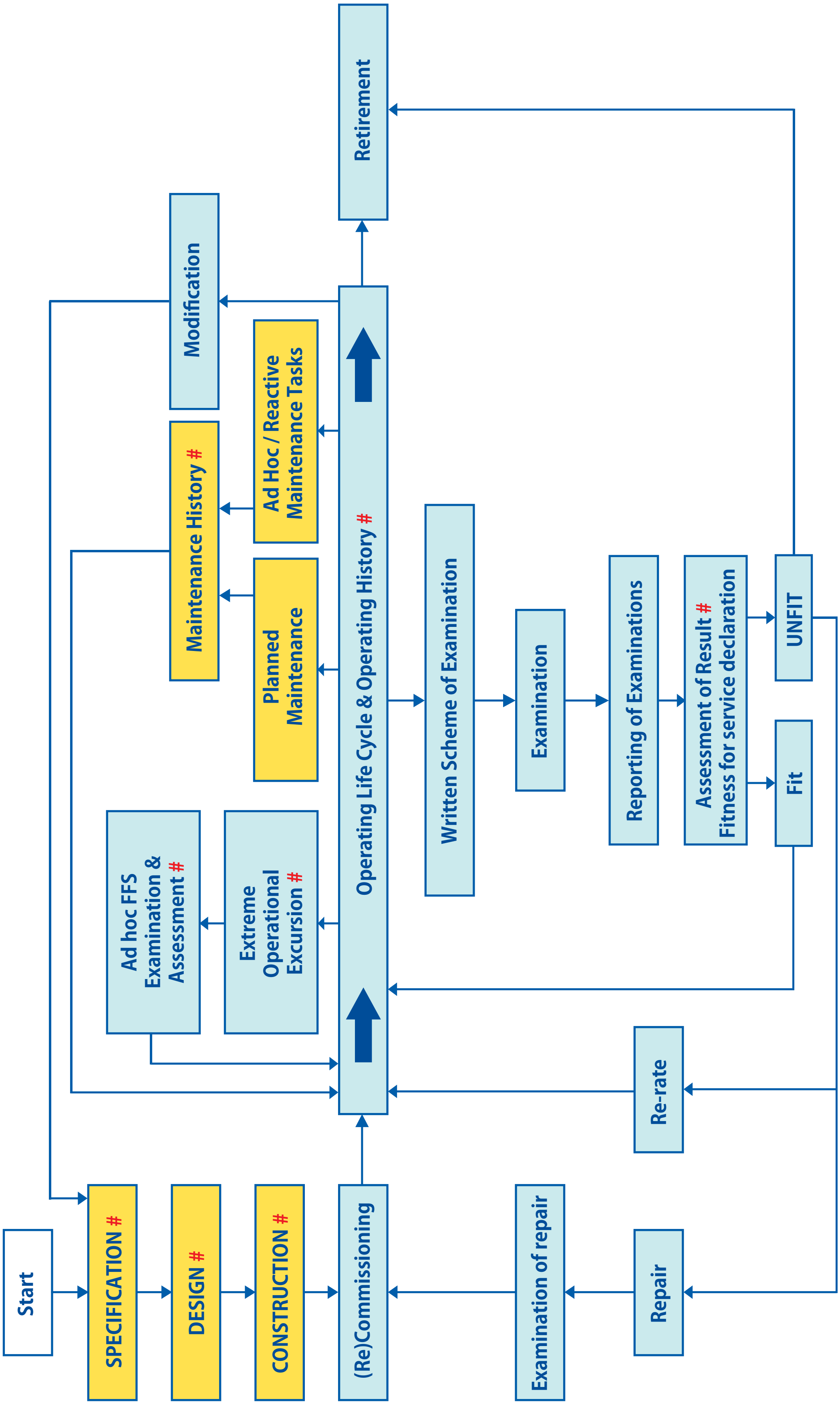
## 2.1 SPECIFICATION

Getting the original plant specification correct is key, so that plant is designed to be suitable for the intended duty. Some of the issues that need to be addressed include:

- How big does the vessel / storage tank need to be?
- What will it contain in normal use?
- What will it contain during other operating circumstances, such as during start-up, shut-down and cleaning?
- What are the hazards of this substance?
- How might the contents affect the vessel / tank / pipe-work?
- What temperature and pressure range will it operate at?
- If control of the process is lost, what extreme temperatures and pressures might it be exposed to?
- What Pressure Relief arrangements and associated devices are required (relief stream)?
- What operating cycles will it be exposed to?
- How long a life is required?
- What degradation mechanisms might arise given the process conditions?
- What degradation mechanisms might arise given the environmental conditions near the vessel?

Plant can frequently be put to new duties partway through its life, e.g. when a process is reconfigured. The matters above need to be considered again at this time.

DIAGRAM 1: OVERVIEW OF INTEGRITY MANAGEMENT THROUGHOUT THE PLANT LIFECYCLE




Items marked # will inform the Written Scheme of Examination.
The yellow-filled boxes are not specifically covered within this guidance.

## 2.2 DESIGN

This is where the specification is translated into a physical detailed design that is fit for the intended duty. Up to this point the design has been more of a concept, but now it will take shape. The designer should consider matters such as:

- Selection of appropriate design code(s) and appropriate guidance from recognised bodies.
- What materials will be used for construction, and how do they impact inspection?
- What design loads (e.g. temperatures and pressures) to feed into design codes?
- Additional thickness for corrosion allowance?
- What fatigue life has been calculated based on loads and cycles?
- What creep life has been calculated based on time at temperature?
- If subject to Pressure Equipment (Safety) Regulations (PESR) and / or Supply of Machinery (Safety) Regulations (SMSR), how will conformity with the relevant legal requirements be ensured?
- What documentation should be supplied to the end user, for example to help evaluate future changes in duty?
- How will the end user (and the manufacturer) examine and maintain the equipment?

## 2.3 CONSTRUCTION

The physical construction needs to meet the detailed design intent, and there needs to be means to ensure this. The construction may be in a fabrication shop or built out on site, and these present different issues to be overcome.

Control measures to ensure sound construction may include:

- Suitable welding procedures and welder qualifications;
- Casting procedures with appropriate examination and testing of the components;
- Traceability of materials to demonstrate compliance with design specification / code;
- Non-destructive testing to meet requirements of customer and design code;
- Assessment of defects found at examination, leading to re-work where necessary;
- Hydro-testing;
- Nameplate fixed to equipment bearing required information;
- Conformity procedures, including Notified Body as required, to meet requirements such as Pressure Equipment (Safety) Regulations (PESR) or Supply of Machinery (Safety) Regulations (SMSR) etc.

## 2.4 COMMISSIONING / RE-COMMISSIONING

It is essential to ensure that all equipment is working correctly before starting the process. It is during start-up that a plant can see some of the most extreme transient operating conditions, before settling into steady state conditions. It is also likely that this is the operation that staff are least familiar with. Similarly, during cleaning and shutdown, equipment can be subjected to unexpected short-term but significant conditions.

A commissioning / start-up plan should be produced in advance to document all steps that should be taken to ensure a safe and orderly commissioning. This would include checks to instruments and control loops, as well as mechanical equipment. This could be the initial commissioning after construction, or recommissioning following a plant outage. For re- commissioning it will be necessary to reverse some of the steps taken during the earlier shut-down process, for example checking that all spades and isolations have been removed.

## 2.5 OPERATING LIFE CYCLE & OPERATING HISTORY

This forms the bulk of the 'life' of the asset, frequently lasting for decades. After the initial commissioning the brand new asset will enter service and be subject to operating loads. Over years of service the asset will be examined and maintained, and will age and deteriorate in condition.

It is important to keep records of the operating history and problems encountered during the life, for example running hours, duty cycles, operational excursions, changes in duty or process (See Section 11). This information may inform the Written Scheme of Examination (WSE) and will also be important in any transfer of ownership of the asset.

## 2.6 OPERATIONAL EXCURSION AND AD-HOC FITNESS FOR SERVICE (FFS) EXAMINATION / ASSESSMENT

Ideally, actual operating conditions will never exceed those originally envisaged at the specification stage. However, this is frequently not the case, and often there are operational excursions where the actual operating conditions can exceed those for which the equipment was designed, e.g. temperatures and pressures beyond the design scope, and this can cause permanent damage.

Where an operational excursion has occurred, the owner / operator should consult with the Integrity Assessor and jointly agree if a formal fitness for service assessment is required. This inspection is outside the normal schedule of examinations as specified in the WSE, and is designed to detect and assess if the asset has been damaged as a result of the excursion. Where damage has taken place, does the asset remain fit for further service, and does the WSE need updating to look at this damage more closely in future? Has the excursion 'used up' years of fatigue life and creep life?

## 2.7 PLANNED / REACTIVE MAINTENANCE TASKS / MAINTENANCE HISTORY

Routine 'Planned Preventative Maintenance' tasks are primarily designed to ensure the ongoing safe use and availability of the asset. These will include 'servicing' and operator routine check sheets that form the lowest level of inspection.

Reactive Maintenance Tasks are not performed routinely – these may be breakdown or other remedial works that have been found necessary to correct a problem.

Both planned and reactive maintenance tasks should build up a written maintenance history over months and years. These entries will typically be far more frequent than any examinations carried out under a WSE, though not normally as thorough. It is important that these maintenance histories are considered when reviewing a WSE, as they can reveal ongoing problems / failure modes with that asset. As a result, the written scheme may be informed to look specifically for certain known problems.

## 2.8 WRITTEN SCHEME OF EXAMINATION (SECTION 6)

A WSE is a cornerstone of an examination regime, whether or not PSSR applies. It specifies the minimum examination and testing that will be carried out, how often, and any techniques that may be required.

Before this can be developed, it is necessary to consider how the asset(s) can degrade over time, and which techniques that can detect this.

Diagram 1 shows many boxes labelled with a **#**. This is to show that these boxes provide an input to the WSE. When developing the WSE many issues should be considered, including past operating, excursion, maintenance and examination history. Integrity issues encountered on similar plants and processes should also be considered.

It shows the WSE acting as a trigger for examination during the operating life. Note however that for new plant, the WSE should generally be developed and approved prior to the plant being commissioned. For plant where PSSR applies, this is a specific requirement.

## 2.9 EXAMINATION (SECTION 7)

The execution of those examinations specified in the WSE.

Depending on the nature of the plant and the extent of examination, it is likely that various preparation works will be required in advance, particularly for any internal access that may be specified.

Careful prior planning between all interested parties is required to complete the examinations specified in a timely manner, minimising any plant downtime.

## 2.10 REPORTING OF EXAMINATIONS (SECTION 8)

Reporting of the examinations is necessary to inform the operator, allow assessment of suitability for continued service, and to build up a history for future reference.

## 2.11 ASSESSMENT OF EXAMINATION RESULTS AND FITNESS FOR SERVICE DECLARATION (SECTION 8)

Examination reports should be assessed to determine whether the plant is fit to return to service, and if so, for how long. These reports may have been produced by specialist contractors, and unless the plant is 'as new', it is likely that defects of varying severity may be reported. These defects should be assessed to determine whether they are of no consequence, or require remediation. There are various methods available to assess defects, including simple screening tools, corrosion allowance, reference to original design codes and other fitness for service codes. Where an asset is not 'fit for service', the options are to repair, re-rate or retire.

## 2.12 REPAIR, RE-RATE OR RETIRE

Usually a repair is the preferred route to return the plant to the original duty. Repairs need careful specification and planning to ensure that the original duty can be maintained. On completion further examination will usually be required to verify that the repair is satisfactory. Repair can include the renewal of a specific piece of equipment.

Repairs are not always possible or cost effective, and an alternative is to re-rate the plant and continue to use it for a less arduous application, for example at a less demanding pressure or temperature.

When a repair is not technically possible or cost effective, and re-rating is not possible, retirement of the asset may be the only option, and to replace with new, the old asset being decommissioned.

When an asset is mothballed, retired or decommissioned but not demolished or removed, hazards from residual contents and loss of structural integrity will still need to be managed by some form of continuing examination.

## 2.13 MODIFICATION

There may be times during the life of the plant when it needs to be modified. The driver for this may be a desired process change, or in response to revised best practice or regulation for that industry. Whatever the driver, it is important that the modification is subject to 'management of change' procedures, including appropriate risk assessments.

So that the Modification is carried out correctly, the Specification, Design and Construction steps discussed earlier should be reconsidered, to ensure that the integrity of the plant is maintained. In addition, where the plant is subject to legislative essential health and safety requirements (e.g. Pressure Equipment (Safety) Regulations or Supply of Machinery (Safety) Regulations) the modification should also conform to this current legislation. These matters will also inform the WSE, which may need revising.

Examples of modifications include:
- Installing an additional nozzle (or enlarging an existing nozzle);
- Installing an agitator to an existing vessel;
- Altering the tank / vessel to make it larger / smaller;
- Change of process conditions;
- Retro-fitting steam coils to heat the contents;
- Installing or removing insulation to / from the exterior of a tank / vessel.

# 3 LEGISLATIVE CONSIDERATION

UK legislation covers the maintenance of plant and arrangements for the use, handling, storage and transport of substances through the Health and Safety at Work etc Act 1974 (HSWA) and other regulations. These include but are not limited to the following:

- Management of Health and Safety at Work Regulations (MHSWR)
- Provision and Use of Work Equipment Regulations 1998 (PUWER)
- Pressure Systems Safety Regulations 2000 (PSSR)
- Control of Major Accident Hazards Regulations 2015 (COMAH)
- Dangerous Substances and Explosive Atmospheres Regulations 2002 [as amended April and June 2015] (DSEAR)
- Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)
- The Pollution Prevention and Control Regulations, 2000 [as amended to 2016]

Further information on legislation, is given in Appendix 1.

## 3.1 COMPARISON OF DUTIES RELATING TO INSPECTION OF PLANT CONTAINING HAZARDOUS SUBSTANCES

The PSSR and its associated Approved Code of Practice (ACoP) provide detailed guidance on what is required of an examination regime. These principles are well established and followed. They are often used as a benchmark for maintaining integrity. However, their scope is limited in that they only apply where the substance contained in a pressure system is a relevant fluid (as defined by the regulations) and they do not consider the hazardous nature of the contents (except for steam), only a release of stored energy.

This means that a PSSR regime may not ensure the integrity of all plant containing hazardous substances.

Therefore, compliance with PSSR is unlikely to be sufficient to satisfy more general regulations such as PUWER, the wider duties of COMAH (where it applies) or HSWA. A similar situation exists with LOLER. This is because PSSR and LOLER focus on specific risks and may not consider the effects on containment or process operating conditions.

For example, a relatively small leak of a hazardous substance that may not cause serious injury to persons from release of stored energy (therefore not of concern under PSSR) may still be sufficient to cause harm and compromise any of the general duties of HSWA, MHSWR or COMAH. Such harm would also be relevant when considering the suitability of an inspection regime under PUWER. Therefore, the inspection regime required under PUWER or COMAH, is likely to be wider or more rigorous than one set up purely for PSSR.

**Case Study 1 – Pipework and PSSR**

The Operator of a COMAH site has low pressure hydrogen pipework that has been excluded from the requirement for routine examination by a Competent Person under a PSSR WSE.

The Operator, in conjunction with the Competent Person, decided to have the pipework examined to meet his obligations under PUWER, particularly because of the fire risk should leakage occur.

The pipework had very little documentation available and required further assessment by the Competent Person to confirm its suitability for use. Once this had been carried out an inspection plan was derived which included examinations for condition, leakage, earth conductivity, support adequacy, etc. The results of this examination and testing were used by the Operator to help demonstrate his safety case under Regulation 5.1 of COMAH.

## 3.2 REASONABLE PRACTICABILITY

Many of an employer's duties under HSWA are qualified by the term 'so far as is reasonably practicable'. The concept of reasonable practicability creates a principle of balance between the cost and effort of risk reduction against the benefit to be gained.

(Note: This balance can only be considered where the risk is not intolerable. Where the risk is intolerable all possible risk prevention, control and mitigation efforts should be applied to reduce the risk into a tolerable level.)

The operator of a COMAH site has a duty to take all measures necessary to prevent accidents and limit their consequences to persons and the environment. Guidance to the regulations states 'prevention should be considered in a hierarchy based on the principles of reducing risk to as low as is reasonably practicable (ALARP)' and 'where hazards are high, high standards will be required to ensure risks are acceptably low'.

Application of the principles of reasonable practicability will mean that an integrity management regime needs to consider the likelihood of degradation and all potential consequences. Therefore no one regime will fit all; a high hazard situation will require a more rigorous examination regime than a low hazard one.

**The following examples illustrate this point:**

- What is considered to be a reasonably practicable examination regime for a simple air receiver in a remote part of a site would be much less than that expected for a reactor vessel, containing hazardous substances, sited in a populated area and which is subject to complex process conditions, giving rise to multiple degradation mechanisms.
- Where the likelihood of a degradation mechanism affecting a vessel is very remote, but the consequences of a release from that vessel are high, it may still be considered reasonably practicable for the examination regime to take it into account and employ inspection techniques to detect it, should it occur.

This guidance is aimed at equipment providing the primary containment boundary for hazardous substances, where consequences of release are likely to be significant, and it is considered reasonably practicable to go beyond the requirements of a PSSR examination regime. The focus of this document is where hazards are high, the examination has to be sufficiently robust to manage the likelihood of loss of containment.

What is considered reasonably practicable in most situations is documented in recognized good practice produced by regulatory bodies, standards bodies and trade associations etc. Further guidance is available in Reference 3.

## 3.3 OTHER ACTIVITIES AND REGULATIONS

The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER), include requirements for thorough examination by a Competent Person. While thorough examination of lifting equipment is not covered in this guidance, it is worth noting that some principles contained here may be applicable to such a regime. For example, where failure of lifting equipment could lead to a major accident on a COMAH site, perhaps because lifting operations take place close to equipment containing a hazardous substance, then it is reasonable to expect that the examination regime will be to a higher standard than that for equipment used in less hazardous circumstances (for example there may be an increased frequency of examination, or greater safety margins).

While maintenance and examination schedules to ensure the operability of mechanical items (such as pumps, agitators, valves etc) may be a requirement of PUWER or PSSR, it is not the focus of this guidance. However, many of the principles contained here may be relevant to these schedules. For example, competent personnel are still required, as is a structured process for defining the work scope or any subsequent repair, and only authorised postponements should be allowed.

It is also important to consider that where the failure of a machine could affect the integrity of the primary containment boundary (e.g. agitator failure), then this should be considered in the integrity management regime.

# 4 EXAMINATION POLICY

An examination regime is something which would be expected to cover the life of the plant or equipment, and be made up of several examinations / tests of the asset. Therefore, careful thought and planning is required, particularly where the consequences of release are significant.

The main tool used in planning and specifying examination / testing requirements is the WSE, which is covered in more detail in Section 6. However, there are several basic issues that need to be considered to identify the approach to planning and implementing an examination regime and any testing techniques to be used.

## 4.1 OBJECTIVES OF EXAMINATION

The ultimate aim of an examination regime is to ensure that the plant is safe. However, the specific objectives of any examination or test may vary, therefore it is important to be clear about what an examination regime is intended to achieve.

It may be expected to monitor damage from known degradation mechanisms or it may be required to guard against or identify an unexpected degradation mechanism. A combination of both may be the aim. Alternatively, a one off examination may be required to provide information for a fitness for service assessment or to allow specification of a repair.

Whatever the objective, clear identification will help in determining the best approach to take.

## 4.2 TYPES OF EXAMINATION

There is a range of examination options available. Usually the more onerous offer greater benefit in terms of scope and detailed information gained. However, the simplest of checks can still provide benefit, and gain value from the ease and frequency with which they can be performed.

Selection of the most appropriate, and effective, approach is likely to differ between equipment types and service duties. Therefore, there is no 'one size fits all' answer to the problem. The solution will be a combination of methods.

To illustrate this point commonly used options are described below:

a) **Thorough internal examination:** A detailed examination from both the interior and exterior of the equipment. It is usually considered onerous because of the need to take the equipment out of service, clean and make safe and therefore the frequency of inspection can be an issue. Most commonly used on vessels, and may not be an option for smaller equipment such as pipework.

b) **Intermediate external examination:** A detailed examination but undertaken from the exterior only and therefore can sometimes be carried out when the equipment is still in service, or at least without the requirements for internal cleaning and confined space entry. It is usually accepted that this provides less information than an internal examination, but it is considered less onerous and for that reason it can be carried out at greater frequency. It is often used to supplement the less frequent thorough internal and external examination, hence the term 'Intermediate'.

c) **Operator routines:** These usually only consist of brief checks on equipment condition at a very basic level. They can provide value as they are not considered onerous and therefore can be carried out on a regular basis, at a high frequency in comparison to more detailed examinations. They are particularly useful for equipment in remote locations, where damage may otherwise go undetected for some time.

This list is not exhaustive, but provided only to illustrate that one cycle of an inspection regime may be made up of a combination of one thorough examination, one or more intermediate examinations and many operator routines. Other specific types of examination are described below.

## 4.3 STRATEGIES FOR DETERMINING EXAMINATION INTERVALS

There are a number of alternative approaches to determining the interval between examinations.

One option is to use a prescriptive approach. This is based on guidance, produced for particular types of equipment, which gives recommendations for examination intervals. SAFed guidelines PSG011[4] and EEMUA 159[5] Appendix B provide examples of such an approach.

An alternative is to calculate the next examination interval as a proportion of remaining life, based on measured or predicted degradation rates. This is considered an evidence based approach. It is important that there is a factor of safety in this method, and the concept of half remaining life is commonly used. Examples of an evidence based approach can be seen in EEMUA 159[5] Section 5, and API 510[6]. EEMUA 159[5] Section 17 takes the concepts of Risk Based Inspection (RBI) and Reliability Centred Maintenance (RCM) as the building blocks for Probabilistic Preventive Maintenance (PPM).

Predicted degradation rates will usually be most accurate when based on historical evidence from the equipment and process in question. However, where this is not available, evidence from similar situations or degradation rates taken from published guidance may be used. The reliability of predictions should always be considered when basing assumptions upon them, and attempts should be made to build up historical evidence and increase the reliability over time.

It is also possible to use a combination of approaches, which is also evident in some of the examples above. Equally risk based inspection is often used as a means of determining the frequency and scope of examinations.

## 4.4 EQUIPMENT AGE

The requirements for examination can change through the equipment life.

In the early stages it will be necessary to ensure that a whole range of issues potentially arising from the design, manufacture and first exposure to service conditions are addressed. It will also be required to test assumptions on active degradation mechanisms or verify predicted rates. This will lead to relatively shorter intervals between examinations, compared to later stages of its life.

As the equipment gains service history, experience of degradation will increase.

If degradation assumptions can be verified, including predictability of rates, and service conditions remain within limits, it may be justifiable to extend service periods.

With further age, damage may begin to accumulate. Safety margins, such as corrosion allowance or remaining fatigue life, may reduce significantly. Degradation rates may increase, and overall confidence in the mechanical integrity will decrease. It would now be appropriate to reduce service periods between examinations.

This is discussed in more detail in HSE Research Report RR509[7] Section 3.4.1. Consequently, in addition to those mentioned in Section 4.2, the following types of inspection should be considered:

a) **Initial examination (pre commissioning):** Normally carried out before plant or equipment is taken into service for the first time. This is used to assist in establishment of the initial integrity of the asset.

b) **First examination (post commissioning):** This examination which provides an early opportunity to identify any issues with the design, manufacture or installation, once the vessel has entered service. The benefit of this examination is greatest if the period between commissioning and the first in-service examination, is restricted below that normally used for thorough examinations.

c) **Additional examination:** An examination made in response to a change of some form. This may be a modification to the plant or equipment, or a change in service conditions. Such a change in service may be either planned or as the result of an excursion beyond normal operating or design limits. The nature of the additional examination will be dependent on the change that brought about the need for it.

## 4.5 ADMINISTRATIVE ARRANGEMENTS

Arrangements must be made to cater for issues such as the scheduling of examinations and record keeping. It would be useful to construct and maintain an examination management plan or perhaps use one of the many available software scheduling tools.

It will also be necessary to make decisions on who will carry out the examination. This may be a combination of more than one person or organisation, especially where specialist techniques are used, or a range of types of examination / testing is required.

## 4.6 NON DESTRUCTIVE TESTING TECHNIQUES

The exact nature of the examination techniques to be used is a matter for consideration in formulating the WSE. However, it is important that at an early stage, the role of Non-Destructive Testing (NDT) is considered.

NDT has many uses and there is a wide variety of guidance available. Developing technology is extending the potential benefits. However, it is important to ensure the reliability of any technique used and to note the probability of detection. Therefore, any new technique should be validated before adoption into part of the examination regime. Equally, personnel carrying out the inspection should be competent and certified to apply the specific technique.

The HSE have been promoting improvements in the reliability of all methods of Non-Destructive Testing

(NDT) through the Programme for the Assessment of NDT in Industry (PANI) projects and associated best practice documents[8, 9, 10, 11].

NDT procedures should not be generic but be targeted at the defect and geometry of inspection. Job specific training may also be required. An EEMUA Industry Information Sheet[12] is available which references probability of detection with respect to the NDT technique used.

Where Non-Destructive Testing is used the requirement of competence outlined in 5.3 should be maintained.

# 5 ORGANISATIONAL ARRANGEMENTS FOR INTEGRITY MANAGEMENT

Implementation of an effective integrity management regime will require consideration of a number of factors that cross a range of subject areas. This produces a need to ensure that appropriate competence is gained across these subject areas, and that information is shared and co-operation between the different parties involved is achieved. Part of the way in which these aims are met will be through appropriate and clear setting of roles and responsibilities. So, careful thought needs to be given to the organisational arrangements for such a regime.

## 5.1 LEADERSHIP

Within any organization, leadership by senior management is fundamental to managing health and safety effectively. This is particularly so in industries dealing with dangerous substances where senior management commitment to maintaining the integrity of plant and its safe operation should be apparent. It is therefore expected that senior management are aware of the performance of the various systems that deliver continuing asset integrity in order that they have confidence that the site remains in a fit state to operate. In addition, it is important that those in ultimate authority demonstrate a commitment to asset integrity by providing independence and resource to those who are charged with making key decisions regarding fitness for service and supporting the decisions they make.

Elements that demonstrate organisational commitment can include:

- Up to date company policies in place for integrity of plant, its operation and maintenance.
- Up to date systems and procedures in place that deliver policies, e.g.:-
  - comprehensive maintenance;
  - condition assessments;
  - monitoring and feedback from operations;
  - thorough hazard studies;
  - competent risk assessment;
  - high standards of examination and testing.
- Process safety performance indicators in place relating to major hazards which are routinely reported and assessed by senior location management and at corporate board level.
- Investment in staff competence, development and succession management for plant integrity matters.

## 5.2 TYPES OF INSPECTION BODIES

Organisational arrangements can differ, particularly in relation to who carries out the inspection/ examination function. BS EN ISO/IEC 17020[13] classifies these arrangements as 3 different types: -

- Type A for an inspection body providing 'third party' services. There is published guidance on engaging 3rd party bodies. Examples are CDOIF guidance on the use of external contractors in the management of ageing plant[2], EEMUA publication 232[1] on engagement of 3rd party bodies,

- Type B for an inspection body providing services to its parent organisation (i.e. an in-house arrangement), or
- Type C for an in-house inspection body that also provides services to external parties.

Whatever arrangements are in place for actually carrying out the inspection, it is likely that a team will be required to implement an effective integrity management regime. This is because a range of different disciplines and competencies will be required to bring in the required information and control the whole process from planning and execution through to decision making and review. More information is given below.

## 5.3 COMPETENCE

Those responsible for managing and undertaking maintenance, testing and inspection should be competent for this. Someone with an appropriate engineering qualification and relevant experience would be expected to manage the maintenance, inspection and testing systems and arrangements.

In addition to the formal arrangements for ensuring competence, it should be remembered that an effective integrity management regime will require consideration of all aspects of the potential degradation, inspection and assessment of the equipment involved. Therefore, the team involved will require competency to provide input in the following areas:

- Design of the equipment;
- Process conditions and potential consequences of a loss of containment;
- Operating conditions (including upsets and process creep);
- Maintenance;
- Materials technology (including, where relevant, degradation mechanisms, corrosion or metallurgy expertise and integrity assessment);
- Inspection techniques.

Achievement of this will almost certainly require input from organisations or departments outside the inspection body. That is, at the very least, input of process specific knowledge from the site operational team.

A site operator using third parties in asset integrity management should have checks in place to confirm the competency of those parties involved. These should include competence checks as part of the selection and monitoring processes for contractors. This is likely to be achieved by a range of means including review of previous experience, provision of references, demonstration of technical competence and external accreditation or membership of trade associations.

Inspection bodies should be able to demonstrate competence. One way to achieve this is through UKAS accreditation to BS EN ISO/IEC 17020[13].

Where a site operator uses in-house resource, it is equally important that there are means to ensure the competence and impartiality of those involved.

The Approved Code of Practice to PSSR[14] sets out the attributes required for a Competent Person against three different categories of equipment increasing in size and complexity. However, it should be noted that in some cases (e.g. a major hazard site) the high consequence of equipment failure may warrant higher levels of expertise for those involved in integrity assessment. See also EEMUA Publication 193[15] for recommendations on the competence assurance of in-service inspection personnel including contractors. The CDOIF guidance: The Use of External Contractors in the Management of Ageing Plant[2] is also relevant.

NDT personnel should be able to demonstrate training and competence. One way to achieve this is through UKAS accreditation to BS EN ISO/IEC 17020 or BS EN ISO/IEC 17025[16] for the scope of NDT. Alternatively, the principles of qualification and certification of NDT personnel are given in BS EN ISO 9712[17]. Such certification can be achieved under either a central certification scheme (e.g. PCN) or an employer based scheme (e.g. ASNT). See also Reference 1.

## 5.4 ROLES AND RESPONSIBILITIES

Careful clarification of roles and responsibilities is required to ensure that the different parties involved in an integrity management regime will interact effectively, each role is filled by competent personnel and regulatory requirements are met. Arrangements also need to ensure independence and impartiality of the inspection body from the site operating and production pressures.

Roles and responsibilities should be communicated so that those involved understand what is required of them. Definition of exact roles and responsibilities is not given here, as this is a matter for agreement by the relevant parties in any given situation, but the following sections provide an overview of some issues to consider.

### 5.4.1 Integrity assessment

It is important that following examination, an assessment of the integrity of the plant or equipment is undertaken. This is required to determine its fitness for continued service or otherwise, and may involve specification of conditions for continued service or repair. The responsibility for this task should be clearly allocated.

Under PSSR the task is the responsibility of the Competent Person. However, if PSSR does not apply, or where the examination regime extends beyond the requirements of PSSR, the role has to be created and specifically allocated (this role is the Integrity Assessor). This could be to either an in house role or external body. In either case, it is important to ensure it is carried out by competent personnel, and all parties involved should be clear as to with whom this responsibility lies.

It is also important to ensure that whoever is allocated the responsibility for integrity assessment is able to undertake this task impartially, without undue influence from other parts of the organisation with other, potentially conflicting, responsibilities or priorities.

Furthermore, those in ultimate authority for the site's or company's operations, should be able to demonstrate a commitment to asset integrity by providing the necessary independence to those they charge with making key decisions regarding fitness for service. Support for such decisions will also be necessary.

### 5.4.2 Site Operators

An examination or inspection regime would normally form part of the demonstration that the operator of a COMAH plant has taken all measures necessary to prevent major accidents and limit their consequences. Specifically, in terms of in-service inspection, the Operator is required to ensure the plant is maintained in a safe condition (i.e. minimise the hazard from pressure, toxic substances, flammables etc) and part of this would include the examination, inspection and testing etc to confirm that this was the case. That is also a general requirement under HSWA and PUWER as well COMAH.

Whilst a site operator or employer may seek to rely on third party expertise to help ensure equipment integrity, they should be aware that the responsibilities allocated by health and safety legislation cannot be delegated.

Comprehensive management systems may be required, probably with implementation by a multidisciplinary team throughout the life cycle. As such the technical basis for such a regime and the arrangements to implement it should be robust. Major accident hazards could be fire, explosion, toxic releases or an uncontrolled release of stored pressure energy. The level of complexity involved to manage the integrity of process equipment means that a multidisciplinary team would normally be needed with access to site specific information and process knowledge to inform technical decisions. In such cases, a team made up entirely of third party experts could not be expected to suffice, because of the need for detailed site specific input.

**Case Study 2 – Cooling systems – Stress Corrosion Cracking (SCC)**

Austenitic stainless steel can suffer from SCC where chloride concentrations occur. It is often associated with pitting or crevices at welds and the problem can occur due to chloride content in towns water, chlorides from the atmosphere or other sources such as insulation or seawater cooling.

A site has a stainless steel reactor vessel with water cooling via a stainless steel limpet coil containing towns water. The coil is not used for heating the vessel.

Initially the cooling water was not thought to reach a temperature sufficient for the onset of SCC. However, consultation between the operating team and metallurgists determined that this may be the case and so there was a clear likelihood of SCC.

If the cooling circuit failed there was a high likelihood of an exothermic reaction in the reactor. Also water leakage into the reactor could itself trigger an exothermic reaction.

Because of the consequences of failure of the limpet coil or water contamination of the product, additional crack detection of the coil and welds was specified using eddy current techniques.

Under PSSR the site operator is likely to fulfil the role of user. The user will be a firm or organisation in control of the operation of the system and therefore in the best position to ensure inspections of the integrity of the plant are completed by their due date and if they cannot, that the equipment is not operated beyond this date.

A number of factors will determine who has responsibility as the user.

These factors may include:

(a) who decides when the plant will be turned on or off;
(b) who decides who has access to the plant;
(c) who is responsible for the controls of the plant; and
(d) who maintains and runs the plant on a day-to-day basis.

Where the operator is to rely on the work of a third party in the role of Competent Person or Integrity Assessor then the operator should ensure that any WSE adopted takes account of all relevant degradation mechanisms to prevent both catastrophic failure and also reduce the likelihood of any loss of containment, involving hazardous substances. If this is not the case, for example where the WSE is focussed on PSSR compliance, then the operator should decide what further measures are required e.g. to prevent/mitigate the hazards from a loss of containment not involving release of stored energy. More information on the scope of agreement between different parties is included in Section 6 of this document.

### 5.4.3 Third party inspection bodies

Where a third party is acting to provide the operator with a competent source of advice, they have duties under HSWA Sections 3 and 36 to ensure the health and safety of those other than their employees. They should act appropriately in their role. This includes ensuring they are competent to carry out the role.

A third party contracted to carry out a function, would be expected to clearly state, at the earliest possible opportunity, if they are not competent to carry out any part of that function.

Where a third party takes on the role of Competent Person under PSSR, then they become responsible for those duties under the regulations, which cannot be delegated. If required to take on the extended role under this guidance the same party has to take into account the wider issues related to the containment of hazardous substances and the risks they present (e.g. toxicity, fire, explosion, danger to the environment). It is also important to recognise that third parties may have limited operational and historical knowledge of the equipment and additional effort will be required from the equipment operator/user to balance this shortfall.

# 6 WRITTEN SCHEME OF EXAMINATION

## 6.1 PURPOSE OF WRITTEN SCHEME OF EXAMINATION

The WSE is one of the most important documents associated with asset integrity. It is used to define what examinations and testing shall be carried out, when, by whom and how the results should be reported. It also specifies what preparatory work needs to be undertaken to allow the examination to proceed.

It is, therefore, important that it is worded carefully and is prepared by one or more individuals with an extensive and detailed knowledge of the equipment and the processes contained within the plant.

The WSE is an instruction to an inspector about what to look for during an examination. This will always be the minimum acceptable and although the inspector can always request more, the inspector should not do less than is specified, unless it is in accordance with approved amendments to the WSE.

## 6.2 CONTENT OF WRITTEN SCHEME OF EXAMINATION

### 6.2.1 Introduction

It was the Pressure Systems and Transportable Gas Container Regulations 1989 that introduced the idea of the WSE into a formal framework and this was extended by the PSSR. Its use has now spread to other areas where such a document can be of value including plants handling high hazardous materials whether covered by COMAH or not. It is, therefore, logical to start with the WSE as defined in those original Regulations and then build on that where necessary.

PSSR Regulation 8 states that a WSE should contain, as a minimum, details on the nature and frequency of examinations, measures necessary to prepare the system for examination, and include any examinations necessary before equipment is used for the first time. The ACOP then lists further information that should be included. Appendix 2 in this guidance takes these requirements as a basis and extends them to form a more comprehensive list from which the relevant items can be picked when drafting a WSE.

In the past it has been a common practice to have a small number of generic Written Schemes of Examination each covering several similar items of equipment. Use of generic WSEs is not good practice, and would only be acceptable for low risk situations where all equipment involved could be shown to be of similar design and condition, and exposed to identical threats. It is currently good practice to have a single WSE for each item of equipment that contains a hazardous substance. However consideration should be given to system issues such as protective devices and the consequence that failure may have on other equipment and its contents (see 6.2.6).

The WSE should identify what is within its scope by defining its termination points.

### 6.2.2 Nature of examination

It is important that during an examination the inspector knows what to look for. Therefore, the first stage in specifying the nature of the examination should be to identify the anticipated modes of deterioration. This requires a detailed consideration of the substances and processes contained within the equipment and their effects on the materials of construction. Then the examination necessary to detect and quantify the damage caused by this deterioration can be specified. In many instances a particular examination technique will be the most suitable to detect specific deterioration. However, to reduce the possibility of a WSE becoming out of date the option of using additional techniques, at the inspector's discretion, should be included. Any different techniques selected should be equally good or better at detecting the likely defects.

It should be remembered that, although some modes of deterioration have been identified prior to the examination, the inspector should always be prepared for other types of damage. For example, where a pre-assessment has failed to identify deterioration mechanisms for a particular piece of equipment this should not be used as an argument against carrying out periodic examinations.

The nature of the examination could include visual, internal or external and whether or not techniques such as NDT are required. The examination of an item of process equipment will always have, as a minimum, a visual examination of the external appearance of the containment looking for any signs of corrosion or other failure mechanism. This can often be supplemented by an internal examination if a degradation mechanism affecting the inner surface has been identified. Surface inspection also includes magnetic particle inspection (MPI) on ferromagnetic materials and dye penetrant (DP) methods, these are more sensitive and searching than visual alone.

Where the evaluation of the equipment determines that a periodic internal examination is necessary careful consideration should be given to how this can be best carried out. Certain equipment can be difficult and costly to prepare for internal access. There may also be confined spaces issues to consider and whether there is a risk to an inspector entering the equipment.

If alternative non-invasive techniques (e.g. Remote Visual Inspection (RVI), NDT etc.) are to be considered the alternative examination techniques need to be evaluated to determine whether they have equivalent capability of detecting the degradation mechanisms as would visual examination. NDT techniques such as ultrasonics (US) and radiography provide information of volumetric defects such as internal cracking that visual alone cannot and techniques are now well established and normally required as part of WSE examination.

NDT is frequently used for measuring the remaining wall thickness where corrosion or erosion might have removed some of the original material, or for examining for other signs of damage. In most cases the type of NDT can, and should, be specified in the WSE. However, as previously stated, it is important not to make the WSE so specific that it reduces the freedom of the inspector to use a different technique if they consider it relevant. Therefore, the option to use additional techniques or to replace one with another if it can be shown to be more suitable should be included.

During examinations a check-list provided as part of the WSE can be of great benefit. It can provide a reminder to the inspector when they are undertaking the examination and can form a basis for part of the resulting report. A checklist can help to direct the examination towards the areas of the examination considered important by those defining the integrity strategy.

It may sometimes be necessary to define the extent of an examination within the WSE in terms of percentage of welds to be examined or amount of lagging to be removed etc.

### 6.2.3 Frequency

Examinations are carried on a routine basis with the frequency defined in the WSE. Where possible the anticipated rate of deterioration should be taken into account when determining the inspection interval.

The frequency of examinations should ensure that any deterioration in material or equipment condition or malfunction is identified in sufficient time to prevent loss of containment.

It is considered good practice to select a short interval, when the equipment is first commissioned; this can then be adjusted with experience. The principle of 'half-life' is often used to monitor age-related damage mechanisms. The rate of deterioration is calculated from measured changes in material condition over time (e.g. loss of thickness due to corrosion, extent of cracking due to fatigue) and extrapolated to find when that condition will reach the minimum acceptable for safety. The next examination is then set at half that remaining life.

The WSE should be reviewed to ensure that it remains appropriate. If the time between examinations needs to be altered, for example if it is found that damage is occurring more or less rapidly than was expected, then the frequency will be changed and the WSE updated. A predefined frequency does not preclude holding examinations of equipment at other times should the need arise and the WSE should reflect this.

There are many publications available that provide advice on examination and testing frequencies and those relevant to specific cases should be used wherever possible.

### 6.2.4 Measures necessary to prepare the equipment for examination

This section of the WSE is vital but there is a tendency to see it as less important than the nature or frequency of the examination. It will often be impractical to carry out the examination if the equipment is not prepared correctly. For example, if it is necessary to do an internal examination the equipment should be off-line and have been cleaned sufficiently to allow for safe access. It is, therefore, important that the WSE defines clearly all the steps that should be taken to prepare the equipment. However, it should be remembered that it is the operator's/user's responsibility to prepare the equipment for examination and they should know best what is required, provided certain basic information about the inspection is available.

The WSE should concentrate on those details that might not be obvious to the operator and in particular, those that can vary between examinations. For example, if it is necessary to remove insulation to allow for the detection of corrosion under insulation the amount and location of the insulation should be made clear otherwise there is a possibility that one area will be examined at every examination rather than ensuring that a different area is considered each time. When inspection techniques such as MPI, DP, US testing are to be applied, quite specific surface preparations may be necessary (such as shot blasting, grinding/polishing, removal of weld caps). It is expected that these are contained in the detailed specifications for the inspection.

It is preferable that the WSE includes an indication whether the equipment can be examined while it is in service. This is particularly valuable for the operators so that they can ensure that correct preparation is completed. The WSE is primarily a statement to tell the inspector what they should cover during the examination but it is also for the owner/operator so that it is clear what needs to be done to make the equipment available.

### 6.2.5 Examination before equipment is used for the first time

It can be important to undertake an examination before equipment is put into service for the first time. This examination can ensure that the equipment has been designed and manufactured in accordance with all the relevant drawings and specifications. It can be used to allow material thickness measurements to be taken before any deterioration has taken place. Material tolerances mean that actual thicknesses can be quite a bit different from those shown on drawings and specifications and this can lead to concerns about material loss during examination and tests later in life. It also allows the WSE for the scheduled inspections to be tested under more realistic conditions and to permit the trial of those techniques being considered.

### 6.2.6 Other considerations

It should be remembered that a WSE is the minimum that should be undertaken. It should always be within the inspector's prerogative to do more and to ask for additional time, or access to other areas if there is concern that a specific deterioration mechanism has not been examined sufficiently. All Written Schemes of Examination should include a statement that the examination detailed in the document is a minimum and the inspector might require additional tests.

The WSE should be prepared and approved before the equipment it refers to has been commissioned. This is to minimise the possibility that the Scheme includes an aspect that cannot be achieved in practice. It will usually be much easier to eliminate such a discrepancy before the plant goes into service.

An important part of any containment system is the relief stream. It is considered sensible that all Written Schemes of Examination identify the relief stream that protects the equipment or system being covered to assist the assessor during examination. Similarly, if the WSE is for the relief stream it should include details of the equipment being protected, including any associated devices. An associated device is any device which is required to ensure the proper operation of a relief stream, for example:

- Valves – locked open/shut (e.g. using 'carseals');
- Restrictive Orifice Plates;
- Non Return Valves;
- Control valves;
- Valve limiters;
- Steam or electric tracing;
- Cladding;
- Interlocks;
- Instrumented systems;
- Drainage;
- Flame Arrestor.

Relief stream Written Schemes of Examination should include the likelihood of the pipework becoming blocked and the risk of the protective device failing to operate. The relief stream interval should be separately assessed and should be set at an interval appropriate to the potential consequences of failure if the relief fails to operate. PSSR (ACOP) states that protective devices should be examined at least at the same time and frequency as the plant to which they are fitted. Some protective devices may need to be examined at more frequent intervals.

As stated above it is essential to consider the modes of deterioration and this will help to clarify what damage might be present and, therefore, how to detect it. Additionally, it is necessary to consider the consequence of failure of an item, for example, how its failure might affect other plant in the area and this will clarify the significance of each type of deterioration.

The WSE should include indication if the equipment is covered by any specific regulations. This is mainly to ensure that equipment that is covered by the PSSR is known as there are certain responsibilities that apply to the examination of equipment under these regulations.

The WSE or the inspection procedures in place at a particular site should make clear what action should be taken if an examination or test cannot be completed as defined in the WSE. Normally it is mandatory to complete all the requirements of the WSE and every effort should be made by the operator/user and the inspection body to complete them. However there may be instances where unforeseen events make this impossible. In such cases the Integrity Assessor should be consulted and subsequent action will depend on a number of factors including the risks determined by consequences and likelihood of failure. It may be necessary to reconvene the team that prepared the WSE to consider the implications. Alternatively, it might be necessary to take equipment out of service or to instigate a postponement (see Section 9).

In the case of PSSR the inspection shall be completed on or before the due date or be postponed before that date. There is no exception and the owner/user is breaking the law if they continue to operate. Non PSSR equipment should be managed in the same fashion.

## 6.3 PREPARATION

The WSE should be prepared by personnel with sufficient knowledge and experience of the process equipment in general and the specific item being considered, in particular. In many instances one person will not have the necessary knowledge and experience to prepare a WSE and it will be more appropriate to have a team approach.

The qualifications of the individual or the team members are probably less important than their experience and expertise. However, it is unlikely that someone who is not a Chartered Engineer will have the necessary background or standing within the engineering community to be able to act as the approver of WSE for a plant handling hazardous materials.

This team will need to include people with knowledge and experience of a number of aspects of the items of equipment including:

- Inspection techniques;
- Deterioration mechanisms;
- Process and operations;
- Design and technology;
- Metallurgy;
- Maintenance.

In some instances, it will be considered appropriate to use the Risk Based Inspection process where a team works through a predefined process to develop a WSE that is targeted to cover those areas where the risk is highest. This process is described in more detail in Appendix 3.

In most companies there will be a standard format for a WSE and preparation will be a simple matter of following that format and including all the necessary relevant information which will have to be built up from information held elsewhere within the company or the individuals' knowledge.

## 6.4 APPROVAL

It is important that the WSE is approved, as this provides an opportunity for the contents to be checked to ensure that all the relevant information has been provided and that the whole is consistent and understandable. This approval should be by an individual who is not directly involved with running or maintaining the plant concerned as this would provide an opportunity for the WSE to be made less onerous. This would normally be the Integrity Assessor. This degree of independence of inspection from production is to limit the possibility that production and financial pressures would be allowed to overrule the need to maintain plant integrity.

For equipment that comes under PSSR the WSE approval should be by the Competent Person.

It is preferable that all Written Schemes of Examination are also accepted by someone directly involved with the operation of the plant: the 'user'. This acceptance should not be considered to be an approval as this would damage the independence of the inspection organisation but it will show that the plant personnel are aware of the inspection and what they need to do and when, to ensure that it can proceed.

## 6.5 REVIEW OF THE WSE

As with any other working document the WSE should be reviewed to ensure that it is still relevant and fulfils its prime purpose of defining the examination required. A suitable opportunity for this review is immediately after a scheduled examination when the WSE will have been used, possibly for the first time for a number of years. The review is also an opportunity to review the WSE of similar plant, for example a second or third unit. Reviewing the WSE at this time allows the inspector who has just completed the examination to make comments and to take account of his experience. In particular, care needs to be taken to ensure that any deterioration noted has been as a result of one of the modes of deterioration already included in the WSE. If the deterioration is as a result of an unexpected damage mechanism then it will need to be added to the WSE along with the examination necessary to look for it.

The review of a WSE should be undertaken by the same team as originally prepared the WSE or, if they are not available, by a team comprising individuals with similar levels of expertise and experience.

A WSE should not be amended just before an examination or test except to increase the scope, unless technically justified, risk assessed and approved by the Integrity Assessor (Competent Person where PSSR applies). This change could be a result of additional information on deterioration or failure mechanisms becoming available.

## 6.6 DIFFERENT REGIMES

Compliance with PSSR requires that a WSE is in place for any equipment coming within those regulations. Inspection is also an expectation of COMAH and PUWER and in line with this guidance it is considered good practice to have a WSE to cover any equipment containing hazardous substances. However, there is no need for these to be a single document. In some plants the tasks required for complying with PSSR might be contracted to an outside body whereas other examination needs could be met from in-house.

## 6.7 PROPORTIONALITY

All equipment that is to be inspected should have a WSE as described in this section to define what is to be inspected, when and by whom and to define any preparatory work that is required before the inspection can be completed. The type of inspection and its frequency will vary depending on the equipment and the hazards that it presents to personnel, the environment and even the business that relies on it. High hazard equipment needs more detailed and frequent inspection than a comparatively low risk set up.

It is difficult to judge the necessary rigor of a WSE to be used in a particular instance without undertaking a comparison of other equipment in the same or similar situations. This comparison can be undertaken in a number of ways but in every case, it needs to take into account two specific features: the likelihood that the equipment could fail and the consequences of that failure. The product of likelihood and consequence represents risk.

Each item of equipment needs to be assessed under the two criteria of likelihood and consequence with the highest risk equipment being given a much more detailed and frequent inspection and thus a more rigorous WSE than the low risk.

In some instances, there might be more than one mode of deterioration identified for a particular item and in this case there might be more than one outcome for the likelihood.

The consequence of failure may vary at different locations for the same deterioration mechanism, for example leakage in a vessel jacket or to atmosphere as a result of internal corrosion.

It is particularly important that the consideration of the relative risks and hazards are recorded and that their conclusions can be seen to result in logical categorisation of the equipment and its WSEs.

**Case Study 3 – Scope of Written Scheme of Examination**

During a risk based approach to the examination of pipework carrying COMAH substances it was identified that the piping at high level could be at increased likelihood of failure if the supporting gantries were not in satisfactory condition. The assessment considered that the gantries could suffer from corrosion due to the inclement weather, particularly at the ground level.

The examination regime was amended to include inspection of the supporting steel work and at the first examination following the change significant damage was found to a number of structures.

The condition of the gantry steel work was found to be extensively damaged in a number of locations. Fortunately suitable repairs were completed to return the supports to a safe condition.

The personnel completing the examination in the past had been focussing on the pipework itself, completing examinations from access platforms and mobile elevated working platforms. As they were working at height the support structure was never examined.

It is essential to ensure that the scope covers all areas that may have an effect on the integrity of the system as a whole.



# 7 DELIVERY OF PERIODIC EXAMINATIONS

## 7.1 INDIVIDUALS INVOLVED

It should be understood that the periodic examination itself will involve a number of parties, each having an important role to play in the success of the integrity assessment, they will include:

- The owner / operators of the equipment – this is likely to include representation from planning departments, production and procurement staff;
- The inspecting bodies themselves – for example, this may be the third party Competent Person as defined within PSSR, user inspectorates, and third party organisations;
- NDT contractors employed to carry out supplementary activities in support of the periodic examination;
- Contractors employed to prepare plant for examination – for example scaffolding, insulation or refractory contractors, tank or vessel cleaners etc.

All of those identified above will need to establish and maintain effective methods of communication in order to carry out a suitable examination programme. Notably the owner/ operator of the equipment has to ensure it is made available for the inspection. Continued operation beyond a required examination date should not be tolerated simply because the equipment was not made available for examination.

## 7.2 EXAMINATIONS CARRIED OUT DURING PLANT SHUTDOWNS

It is common within the process industries for plants to be periodically shutdown for overhaul and maintenance, making large numbers of equipment available for examination at the same time. This can introduce its own issues to the examination process.

It is important for the effective planning of a shutdown that sufficient time is allocated to the examination of plant, this should include allowance for:

- Plant preparation – including scaffolding, de-lagging, de-gassing, cleaning, isolation from all sources of energy and chemicals and necessary arrangements for confined space entry.
- Initial overview examination – allowing time to carry out a plant walk round to establish general condition, or identify any obvious defects / deterioration.
- Detailed examination in accordance with any existing WSE – this to include any supplementary NDT activities.
- Whenever possible, time should be allocated in the shutdown programme to respond to potential repairs that may be required as a result of the examination.

Those involved in the shutdown should be able to respond to the demands placed upon them by the requirement for examination. This may well include time pressures placed upon them to get the plant back into operation.

Any variations from the inspection plan should be fully justified and not affect the safety of the plant. The justification needs to be based on continued plant safety and not operational demands. This requires the independence of decision making discussed in Section 5.4. Justifications should be fully documented and approved by the Competent Person/Integrity Assessor.

Also, the team should be able to respond effectively to any time advantages that may be gained from unexpected progress in the shutdown program. This may include having NDT contractors / inspectors on 'stand-by' to carry out work as and when required.

## 7.3 COMMUNICATION OF INITIAL FINDINGS FROM AN EXAMINATION

The production of a detailed report from an examination (see Section 8) can often take some time. However, there may be a need to communicate initial findings promptly, so that issues can be rectified in a timely manner.

For example:

- When the Integrity Assessor can declare at an early stage that inspection of specific equipment has not revealed any defects or deterioration then an interim statement to this effect could be issued.
- Repairs of defects may need to be undertaken before a return to service.
- Equipment may need to be taken off line following a working examination, or consideration may need to be given to what to do in the case of an incomplete examination (see Section 8.8).

Some companies have a specific proforma, or slip, used to provide feedback of such key outcomes.

# 8 REPORTING OF EXAMINATIONS AND INTEGRITY ASSESSMENT

The final examination report is a very important document which should provide clear communication of the outcome of the inspection activities. Principally this includes identifying whether the equipment is suitable for continued service, but will also include identification of any remedial measures necessary.

In order for such decisions to be made an assessment of the integrity of the equipment, based on the inspection findings should be made. This Integrity Assessment is discussed further in Section 8.3 below.

The examination report also provides a historical record of the equipment condition. This not only justifies decisions made, but also creates a source of data for future analysis and trending of degradation.

It is important to remember that this final examination report may be required to bring together separate reports of individual inspections, for example NDT reports, that have taken place during the examination activities. It is much more than a record of condition as it is a tool in the decision making process.

## 8.1 EXAMINATION REPORTS

Following an examination, the person responsible for undertaking the examination should issue an overarching report which could be termed the final report of examination. The purpose of the report is to clearly record the examination stating: what has been done, what hasn't been done and give the results in the form of a condition report of that equipment. The report should meet any special requirements laid down in the WSE as well as being accurate and timely. The report can be in several different formats and is usually dictated by the type of examination, such as in-service, out-of-service, intermediate, external etc.

Typically the report will contain:-

- The name and address of the site, owner and operator (if different from the owner);
- The location of the equipment;
- Identification of the equipment with Piping and Instrumentation Diagram (P&ID), serial number and plant number;
- Full WSE Reference including version;
- Parts that were examined / not examined;
- What was exposed / what was not exposed;
- Type of examination;
- Links to NDT reports;
- Condition of the equipment;
- Results of the examination (explained further in Section 8.4).

The results of the examination shall be stated on the report along with other relevant details and information on the condition of the equipment. The results of examination and tests on protective devices can be included if relevant to the condition of the equipment it protects.

## 8.2 REPORTING ON COMPLEX EXAMINATIONS

A complex examination may be considered as one made up of a number of focussed examinations or tests.

Where PSSR equipment is installed on a high hazard site then the examination reporting requirements may be more demanding. If examinations are carried out within a documented risk based system there may be further demands for more comprehensive reports. This should not be reporting by exception, but a detailed report stating exactly what examinations and tests were carried out and the results. A typical report for a reactor vessel on a COMAH site may include the following:

- Clear details of the extent of the examination. What lagging was removed, the access to internal and external parts of the vessel, areas inaccessible.
- If the steam jacket has been hydraulically tested, details of the pressure applied, the time period and the result of the test should be recorded.
- Where appropriate proving the relief stream condition. There may be an acoustic ranging or a smoke test report which should be referenced.
- A supplementary test such as a holiday test on the glass lining giving details of the condition of the lining. The test report will also be referenced.
- Crack detection of high stress areas of the vessel, giving reference to the test report findings.
- Ultrasonic thickness testing giving details of the number and location of readings and the results together with the minimum required thickness where necessary.
- Where safety valves and other protective devices are overhauled by a sub-contractor, test certificate details should be on the report, including confirmation that they are fit for the intended use.
- Pressure gauges' / sensors' calibration certificate details should be recorded.
- Where specific tests are carried out for potential failure mechanisms it would be appropriate to report whether or not evidence of such a degradation mechanism was found.

Non-PSSR items such as atmospheric storage tanks require reporting in a similar way on high hazard sites. The report form will not be a standard PSSR type but should refer to a WSE and should be reported in a similar manner.

The Pressure Systems Safety Regulations (PSSR) guidance to Regulation 9 gives suggested items to be included in a typical report. The guidance also provides some details of the timing of the report, requiring it to be issued within 28 days of the completion of the final examination. In the case of imminent danger (PSSR Regulation 10), the Competent Person shall forthwith produce a serious defect report to notify the duty holder immediately to allow action to be taken to prevent the danger. When a serious defect report has been issued the Competent Person shall send a written report to the appropriate enforcing authority within 14 days. A similar approach to reporting timescales should be applied to equipment outside of PSSR.

The Integrity Assessor / Competent Person can be called upon to witness any remedial actions taking place and report them. That could be a repair report which should reflect the method statement and reference it and the procedures and materials specification. Any NDT methods used to confirm the continued suitability should be reported, such as a hydraulic test upon completion of the repairs.

## 8.3 INTEGRITY ASSESSMENT

It is essential that all examination and test findings, included within the final report, should be assessed by the integrity management team or individual(s) nominated by the team (the Integrity Assessor). The Integrity Assessor may be staff employed by the operator of the equipment or may be a third party organisation. However, in all cases they should have the necessary competencies to carry out this review / assessment. The Integrity Assessor should be determined prior to the commencement of examinations.

The assessment is to provide for a final adjudication of the examination and test findings and to ensure that a final, formal documented statement is made upon the suitability of the high hazard equipment to return to service or not.

## 8.4 ASSESSMENT OF DETERIORATION

As part of the assessment, any deterioration identified during the examinations and tests should be considered. This may be within previously defined limits (e.g. corrosion allowance), and it would be considered acceptable to allow continued use. In other cases, further work is required. This process is often referred to as a Fitness For Service assessment or Engineering Criticality assessment and is a re-evaluation of the structural integrity of an item of equipment for further service. Fitness For Service Assessment can cover a wide range of activity from a screening engineering assessment through to detailed design review and possibly finite element analysis. This decision making process is illustrated in Diagram 2 below.

As a minimum for assessment of deterioration, rates of deterioration should be determined to substantiate that the equipment will remain safe to operate until the next inspection. Trending of deterioration following several inspections should be carried out e.g. corrosion rates, crack growth rates as this data can then be utilised to assist in the prediction of end of life when repairs / replacement of equipment will be necessary. Comprehensive guidance is given in the Health & Safety Executive publication Plant Ageing RR509[7].

The assessment will include the following points which will form part of the documented results of examination (Section 8.1):

- A clear and unambiguous statement as to the equipment's ongoing Fitness For Service;
- All deterioration is recorded;
- Prediction that current deterioration will remain within acceptable limits by the next examination;
- When future examinations should be carried out. This will normally be a calendar date but may also include additional parameters such as running hours, operational cycles, changes in process etc;
- Any limitations to the equipment's use.

When the equipment is not considered suitable for further service then details of required repairs should be included.

## 8.5 INTERACTION WITH THE WRITTEN SCHEME OF EXAMINATION

Deterioration identified during the examinations should be included in the review of the WSE to advise where future inspections and tests need to be concentrated. In addition, where other equipment is in service in a similar duty then consideration needs to be given to the updating or amending of the WSE for that equipment to reflect the deterioration identified elsewhere. Where no deterioration is noted, this too can be included in the review of the WSE. It is considered good practice to review the WSE (or at least those parts of it appertaining to the actual examination) after each examination has been completed, to ensure it remains suitable. The WSE should also reflect the age and condition of the equipment.

## 8.6 REPAIRS

When repairs are considered necessary for the continued use of equipment then these should be carried out to recognized standards and by the specified date. SAFed PSG15[18] gives detailed guidance on repairs and modifications. The following documented information should be considered as a minimum and records kept:

- Specification of the repair;
- Documented approval for the proposed design / method;
- QA requirements and evidence.

The information relating to the repair should be included and / or referenced within the final documented report and the Integrity Assessor should confirm that the repairs are considered satisfactory and were implemented by a competent organization. It will be necessary to consider the implications of the PSSR and PESR when repairs are undertaken.

While there is a general expectation that repairs are carried out to recognised standards and codes where possible, it is recognised that the need for temporary repairs may arise. It is important that there is a formal management system for temporary repairs, including specification, approval, and the use of a register to facilitate monitoring, ongoing inspection and eventual replacement.

## 8.7 OTHER REMEDIAL ACTION

Remedial action arising from an inspection may not be limited to just repairs, or a requirement to retire or re-rate equipment. There may be administrative, assessment or maintenance requirements, for example:

- Conduct a review of an RBI study or a WSE to factor in intelligence gained during an inspection;
- Implement new maintenance or inspection regimes;
- Carry out non-urgent work, such as repainting.

Clearly this type of work need not necessarily be conducted before the equipment goes back into service, but nevertheless the continued service of this equipment (with approval of the Integrity Assessor) is dependent on the remedial action being taken. Therefore, it is important that there are methods or management systems in place to track the completion of such work.

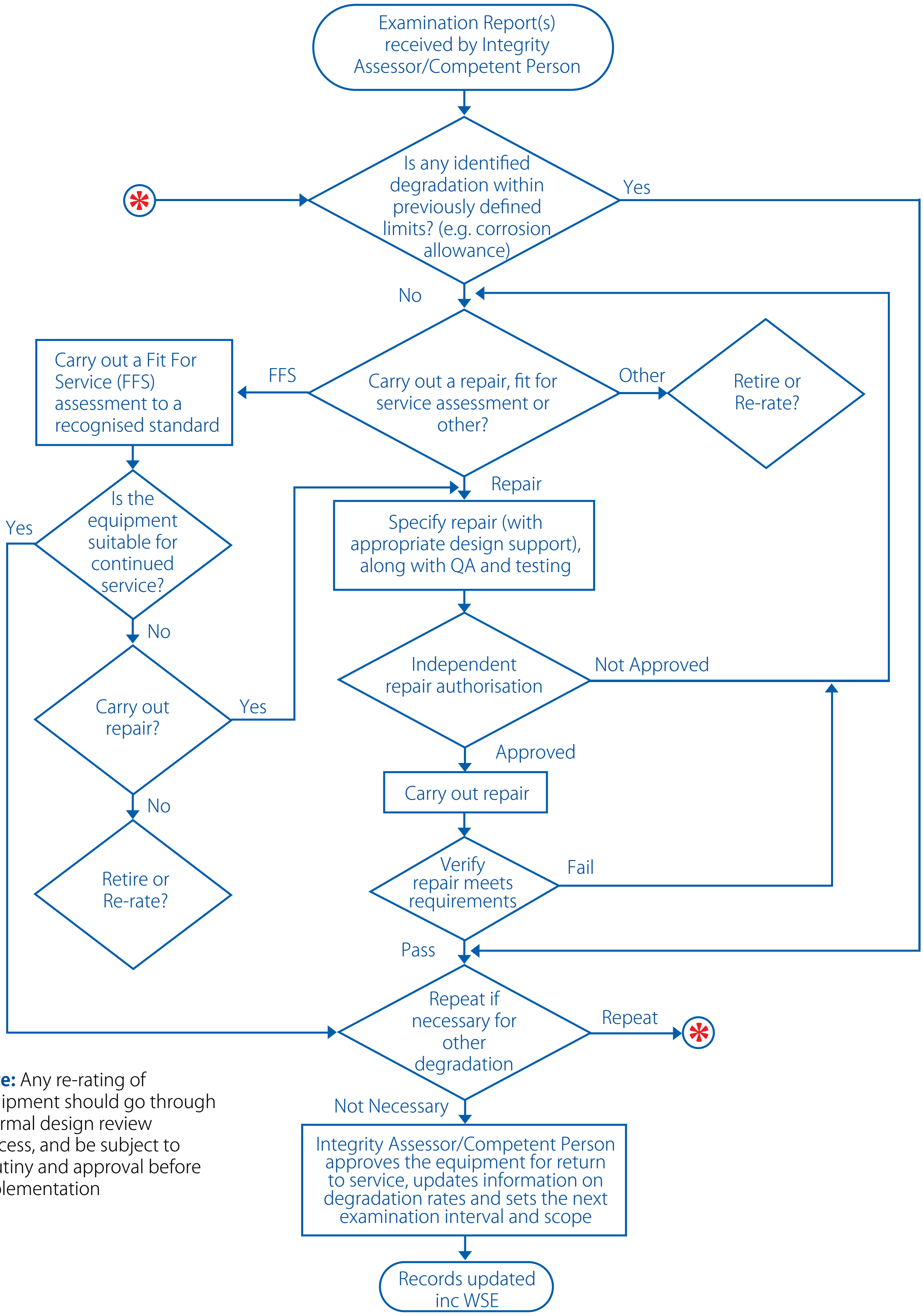
## 8.8 INCOMPLETE EXAMINATION

If the examination cannot be completed exactly as required in the WSE, the Integrity Assessor should be informed as soon as possible to advise what further actions are necessary.

The reporting of equipment, or parts of equipment, that have not been examined to the WSE is important and it should clearly raise concern. A non-compliance report may be a means to achieve this, bringing immediate attention to the matter and a consideration of how to handle the non-compliance.

There may be exceptional instances when it is required to return equipment into service in the above circumstances. This may be considered acceptable by the Integrity Assessor, provided the equipment is assessed as fit for continued service and documentation includes any outstanding inspection activities, mitigating measures for non-completion and specified timescales for future completion of inspection activities. Alternatively, if not considered acceptable by the Integrity Assessor, it may lead to the equipment being taken out of service, or a postponement of examination being put in place (see Chapter 9). Note: This will not be compliant for equipment falling under the PSSR where inspection activities included within a PSSR WSE shall be completed prior to the issue of the examination report.

### Diagram 2: Examination report interaction with the plant/process




**Note:** Any re-rating of equipment should go through a formal design review process, and be subject to scrutiny and approval before implementation

# 9 POSTPONEMENT OF EXAMINATION

Situations may arise, generally for operational reasons, where the operator requires to postpone an examination on equipment containing hazardous substances beyond the scheduled date. However, agreement will be required for this in advance from the Competent Person/Integrity Assessor who set the scheduled date. Therefore, the examination should not be just allowed to become overdue and a formal process to postpone the examination due date should be undertaken.

Postponements for equipment coming under PSSR have to comply with the legal requirements of those regulations including notifying the enforcing authority. Notwithstanding this, all equipment containing hazardous substances (including non PSSR equipment) should be subject to a process, including competent assessment and approval as above, to provide justification and independent oversight of the postponement proposed.

Diagram 3 depicts the postponement process as next described.

## 9.1 FACTORS TO CONSIDER

Where equipment falls within the scope of the PSSR, then the process of postponement will be twofold:

a) Following the procedure laid out in Regulation 9(7) to satisfy the PSSR element.
b) A further review to ensure that risks arising from the hazardous nature of the contents are adequately assessed.

For equipment outside the scope of PSSR a similar approach is recommended.

When an operator is considering postponing an examination then the following conditions should be considered:

- **What duration of postponement is required?**
  For the purposes of PSSR only a single postponement may be given in any one inspection period, this can be considered good practice for all high hazard equipment. The duration of the postponement should be kept to the minimum, and ensure that it does not give rise to danger. The requirement for a postponement should be documented and sufficient evidence given to establish continued safe operation of the plant for the duration of the postponement. This may include risk based assessment.

- **Does the postponement significantly increase the risk of loss of contents?**
  The current condition of the equipment should be assessed when considering a postponement. This may be done by reviewing known degradation mechanisms, for example creep life or corrosion rates. Additionally, visual examination can provide assurance of equipment condition. Factors to consider include:
  a) Supports for tanks, vessels and pipework;
  b) Condition of tanks, vessels and pipework;
  c) Coatings in good order;

d) Joints remain suitable;
e) Bolting (in particular where covered by flange guards etc.);
f) Couplings, hoses etc;
g) Mechanical Seals;
h) Fire protection (where applicable);
i) Secondary containment (where applicable);
j) Emergency control devices (valves etc.) function.

In some circumstances it may be beneficial to schedule a more detailed additional examination to justify the postponement.

- **Will the postponement lead to a reduction in safe operation?**
The operator should be able to demonstrate that all safety functions will remain in working order for the extended period. This may include:
a) Pressure Protection (Including vacuum breakers etc.);
b) Interlock devices;
c) Level trips and alarms;
d) Guarding;
e) Lighting;
f) Operator Access.

The results of assessments and testing, together with a statement as to the suitability of the equipment, for the extended period should be kept as part of the postponement justification.

## 9.2 TIMING

Assessment and approval of a postponement should be carried out reasonably close to the due date, typically no more than three months in advance to ensure it is relevant and takes account of any recent changes in plant condition.

## 9.3 AGREEMENT TO THE POSTPONEMENT

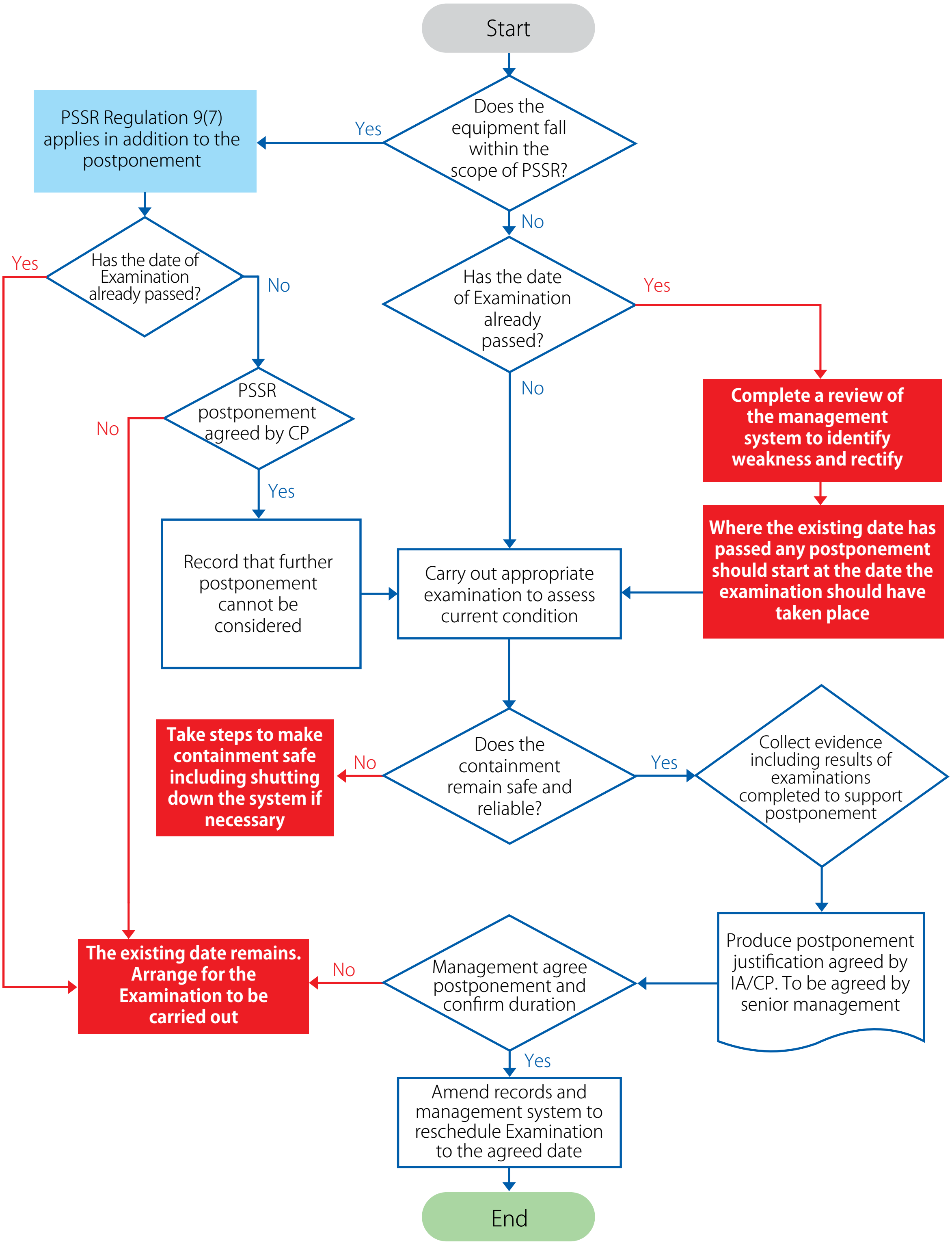
In addition to the agreement required by the Integrity Assessor and/or Competent Person, as defined in PSSR, the postponement, whether it is PSSR or not, should be agreed by a senior member of the management team responsible for the overall safety of the plant/equipment before implementation. This should, for example, cover any impact on the Safety Management System, and where appropriate, the Safety Report under COMAH Regulations.

## 9.4 POSTPONEMENT WHEN THE EXAMINATION DATE HAS PASSED

The Pressure System Safety Regulations place a clear duty on users/owners to ensure that equipment is not operated beyond the date in the current examination report and do not consider a postponement of examination if the examination date has passed.

Where the equipment is not within the scope of the PSSR then retrospective validation of the 'unauthorised' postponement could be accepted, where the review process above has been satisfactorily applied. Additionally, a review of the management system that allowed the date to be missed should be completed to identify any weakness in the system and measures taken to address any issues found.

## Diagram 3: Postponement process



# 10 RECORD KEEPING

As part of an integrity management system it is necessary for the operator to keep accurate, timely records, this ensures that decisions about the specific integrity of an individual piece of equipment can be easily traced and justified.

This record keeping would normally be in the form of a technical file(s) applicable to individual items of equipment, and would be expected to contain the following information:

a) Documentation confirming the safe operating limit of the equipment, i.e. original declaration of conformity or certification.
b) Manufacturing information such as databook including material information, welding information, testing information etc.
c) Details of the normal maintenance routine including reports of such.
d) Any reports of inspection/examination testing.
e) Information pertaining to any repairs/modifications that have been carried out. See point b) above.
f) The WSE, including records of amendments.
g) Any information pertaining to any postponements etc.
h) Details of the operating conditions and the operating history of the item, i.e. how long has it been on certain duty, what duty was it on previously etc.
i) Any associated risk assessments, periodic reviews, ageing plant reviews etc.
j) Any other reports which contain information relevant to the assessment of safety.

While the above list will not be completely exhaustive it gives a good guide as to the type of information that may be required. It should also be noted that the extent of information usually available for differing types of equipment will vary, for pressure vessels it would be usual for all the above to be present, however historically the level of information that has been kept on pipework and storage tanks has, in certain circumstances been less.

The above records should be accessible by the relevant personnel involved in the integrity management and it would be preferable that they are kept together and secure.

# 11 CHANGE, REVIEW AND AUDIT

## 11.1 INTRODUCTION

Once an integrity management regime is in place it will only remain effective and efficient as long as it is current. Hence the integrity management process should be adapted to changing conditions.

As part of the process more data is gathered that is pertinent to the integrity management of the equipment in question. While in many cases this will only be background information, such as process conditions, however more appropriate data will arise that will need formal assessment as part of the integrity management process.

## 11.2 CHANGE

During the life of a plant it will see many changes, some of which will affect the integrity management strategy for that individual item, a list of some possible changes is noted below:

- A serious process or operational upset;
- Failure of an item of equipment;
- Operational regime;
- Internal or external operating environment;
- Where time dependent operating conditions exist such as fatigue or creep;
- Industry practice;
- Plant management or ownership;
- Level of operator training and knowledge;
- Technology.

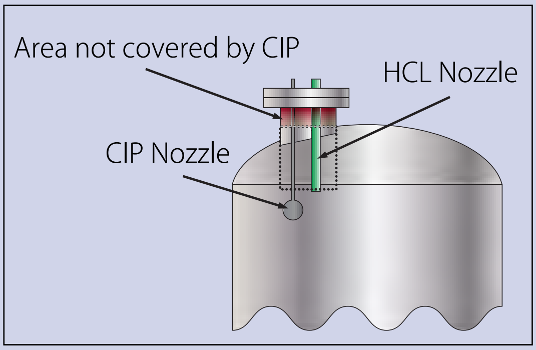
Once one of these events is noted by any member of the integrity management team then this should trigger a review of the integrity management of the individual item.

This review should be formally documented to show that the change has been catered for in the ongoing integrity management systems. The review should not just focus on one particular item but should be wide ranging in the possible effects of a change to the system.

**Case Study 4 – Change in process**

A process change required hydrochloric acid (HCL) to be utilised in the production stream. A 316L stainless steel process vessel was incorporated into the process which could be affected by stress corrosion cracking in the presence of HCL. An assessment had been made that stated the risks had been considered and that during the production process the HCL would be diluted to such an extent that stress corrosion would not be an issue. Additionally the cleaning in place system would remove any residual HCL at the end of each batch.

The vessel entered service. Unfortunately the assessment had not considered that the HCL was being supplied via the same nozzle assembly as the CIP (cleaning-in-place) system, which left an area inside the nozzle that was not effectively cleaned of HCL residues.




This resulted in severe chloride attack of the welds including the seam weld of the nozzle pipe resulting in loss of content through the failed nozzle flange.

## 11.3 REVIEW

This should be a higher level activity which should be undertaken by management to ensure that the whole process is operating effectively and is encompassing all aspects of integrity management. It should normally be time based and ensure that all the information that the original integrity management decisions were based on are still accurate and valid.

This review may be linked to wider business needs:

- Outage planning;
- Plans for new equipment;
- Audit reports;
- Failure investigations;
- Performance reviews;
- Business risk assessments.

A formal record should be kept that each assessment on which structural integrity is based is reviewed by the integrity management team, this will ensure that any changes that the equipment has seen have been effectively captured by the process.

It would be expected that some form of performance indicators are in place to facilitate the performance review. Guidance on the setting of such performance indicators is given in the HSE publication HSG254[19].

## 11.4 AUDIT

It would normally be expected that the whole process of integrity management would be subject to some level of periodic independent auditing. These audits should establish that the process exists and is properly designed, is being operated at all stages and is effective at meeting its objectives. These audits should be formally recorded in the form of audit reports with non-conformances identified where relevant.

It is important to note that the auditors carrying out such audits should be technically able to challenge the judgements that are being made, this may require specialist knowledge on the part of the auditors.

# APPENDIX 1 – OVERVIEW OF RELEVANT LEGISLATION (AND THEIR INTERACTION)

## A1.1 Health and Safety at Work etc. Act 1974 – HSWA

This is the principal piece of legislation in relation to health and safety law in the UK. It places a duty on employers to ensure the health and safety of employees and others who may be affected by their activities.

The main duties under the Act are imposed on a 'so far as is reasonably practicable' basis. The employer's duties extend, among other things, to maintenance of plant and systems of work. HSWA is considered as goal setting and does not prescribe how the duties can be achieved or demonstrated. However, it is also enabling legislation and a number of Regulations have been made under it. These Regulations, while often also goal setting, do provide a more prescriptive approach and more detail on satisfying the general duties of the Act.

## A1.2 Management of Health and Safety at Work Regulations 1999 – MHSWR

MHSWR require employers and self-employed people to assess the risks to workers and any others who may be affected by their work or business, to implement preventive and protective measures. Employers need to make sure that appropriate arrangements are in place to cover health and safety.

## A1.3 Provision and Use of Work Equipment Regulations 1998 – PUWER

PUWER applies in relation to work equipment and this covers almost any equipment used at work. It requires work equipment to be maintained and any which can deteriorate and be liable to result in danger, to be inspected.

Any inspection completed for PUWER should take into account the risk present. The resultant maintenance and inspection regime should be proportionate to this risk. This is particularly relevant on high hazard sites where loss of containment of dangerous substances can cause significant harm.

## A1.4 Pressure Systems Safety Regulations 2000 – PSSR

PSSR covers the operation of pressure systems as defined within the Regulations, which mean that it is concerned with danger from steam or stored energy.

The scope of PSSR is also limited to defined 'relevant fluids' and a minimum pressure and pressure volume product. Therefore it can be contrasted with PUWER, which has a larger scope, covering pressure systems containing non relevant fluids and non-pressure systems, such as storage tanks.

PSSR stipulates a prescriptive format detailing the type of pressure system, the working fluid and what examinations are required and what has to be included in the WSE.

## A1.5 Control of Major Accident Hazards Regulations 2015 – COMAH

COMAH Regulations implement the Seveso 3 Directive (European legislation that arose as the result of significant major accidents involving chemical plant) and applies to a range of high-hazard sites which hold qualifying quantities of certain types of dangerous substances.

Regulation 5(i) of COMAH has a general requirement for the Operator to take all measures necessary to prevent major accidents and limit their consequences to persons and the environment.

COMAH sites by their very nature contain substances which pose danger to persons and the environment should containment be lost. Ensuring the mechanical integrity of equipment providing the primary containment to hazardous substances is one of the key expectations of COMAH.

Even where pressure systems are concerned, all risks from loss of containment may not be covered under a PSSR WSE, because its scope is limited in that PSSR only applies where the substance contained is a relevant fluid (as defined by the regulations) and it does not consider the hazardous nature of the contents (except for steam), only a release of stored energy.

Therefore, even where a PSSR WSE is in place, other procedures such as an extended examination / inspection plan may be required to meet the requirements of COMAH.

## A1.6 Lifting Operations and Lifting Equipment Regulations 1998 – LOLER

LOLER requires the Thorough Examination of lifting equipment either in accordance with frequencies specified in LOLER or by applying a scheme of examination. The vast majority of lifting equipment in use in the UK is examined in accordance with the 'standard' frequencies within LOLER. These frequencies have been assessed on the potential danger to persons from failure of the equipment and not the consequences of the loss of containment of a hazardous substance due to equipment failure.

COMAH would require the operator to take account of potential hazards of each lifting operation and address this and reduce the risks to as low as is reasonably practical (ALARP) e.g. by increased inspection frequency, or lowering the rejection limits for ropes chains or lifting tackle.

## A1.7 Comparison of duties relating to inspection of plant containing hazardous substances

There are limitations in the scope and hazards considered the more specific individual regulations such as PSSR and LOLER. Therefore, compliance with such regulations may not be sufficient to satisfy more general regulations such as PUWER, the wider duties of COMAH (where it applies) or HSWA. This is because PSSR and LOLER focus on specific risks and may not consider the effects on containment or process operating conditions.

For example, a relatively small leak of a hazardous substance that may not cause serious injury to persons from release of stored energy (therefore not of concern under PSSR) may still be sufficient to cause harm and compromise any of the general duties of HSWA, MHSWR or Regulation 5(i) of COMAH. Such harm would also be relevant when considering the need for an inspection regime under PUWER.

# APPENDIX 2 – OVERVIEW OF ISSUES TO CONSIDER IN A WRITTEN SCHEME OF EXAMINATION

When considering the issues to be included the following topics will help:

### Nature of examination
Internal or external or both. Visual.

Other types of examination eg:

- NDT
  - Ultrasonic;
  - Radiography;
  - Crack detection.

### Preparation
Access – normal platforms or scaffold or MEWP or other. Removal of lagging.

Removal of agitators or other equipment.

### Anticipated degradation mechanisms
Internal and external and their location.

Detail helps inspector identify problem areas.

Should include the results of the assessment for high hazard equipment.

Also include those mechanisms identified at the assessment as being unlikely and then examination can confirm that these have not been detected.

### Examination methods
These are often best aligned with the degradation mechanism.

### Identification
Obvious information such as the plant ID number.

Useful also to include information on location in case inspector is not familiar with the particular part of the plant.

### Relief stream
Identification of the relief streams protecting the equipment including their location. If the WSE is for a relief stream then the items being protected should be identified.

### Photos
To include photos:
- Some general views of that area of the plant;
- Some taken from closer so give an idea of the size and complexity of the equipment;
- Others if there are any particular points that need to be considered.

### References
Identify any useful documents, e.g. RBI report, drawings, P&IDs.

### Design data
As a minimum, design pressure and temperature data (should be on the nameplate but that may not always be visible).

### Operating data
Maximum and minimum operating temperatures and pressures.

Contents.

### Material of construction
Essential information for the inspector as it will influence what NDT they might request.

### Pressure test
Might need to undertake in-service pressure test so would need to define pressure, duration and fluid to be used.

Pressure tests should be undertaken in accordance with existing guides, for example the HSE document GS4[20].

### Dates
Date of manufacture.

Date of commissioning in this location and duty.

### Frequency
Period between examinations.

# APPENDIX 3 – OVERVIEW OF RISK BASED INSPECTION

## A3.1 Introduction

Risk Based Inspection, or RBI as it is widely known, is a process to ensure, as much as is possible, that the risks of failure of process equipment are minimised. The term RBI is often used to refer to the formal process whereby a group of individuals with a detailed knowledge of the item of equipment being considered reviews the processes and design of the equipment, assesses the likely modes of failure and agrees how these can be mitigated by routine inspection. The final outcome of the review is a directed WSE.

In an RBI the review of the design of the equipment and the processes involved leads to the identification of the hazards of failures and a list of a number of possible failure mechanisms. These are then used to assess the consequences associated with the failures (e.g. to health and safety of staff and public, environmental impacts, prosecution and company reputation) and any ways that these risks can be mitigated. If these mitigation processes include the examination of the equipment then a WSE will be drawn up to define that inspection.

There are numerous guides and standards available to assist with the delivery of RBI, including EEMUA 206 - Risk based inspection Guide to effective use of the RBI process[21]. There are also a number of commercially available software packages that can be used to help complete RBIs in a structured and formal manner but their use is not essential provided a series of minimum requirements are followed:

- Presence of individuals with specialist knowledge of the design of the equipment and the processes involved;
- Attendance of individuals with a knowledge of inspection techniques;
- Individuals with a detailed knowledge of the plant.

## A3.2 Attendance

To allow an RBI to be completed successfully there is a minimum number of personnel who should attend:

- Design engineer with specialist knowledge of the type of equipment being considered;
- Inspector with experience of the type of equipment;
- Process specialist who can comment on the full range of process conditions;
- Operations to be able to discuss the full range of ways the equipment is used, and
- Materials specialist with experience of the materials of construction and the process fluids being handled;
- Expertise in the potential consequences of failures and leaks of hazardous chemicals, fire and explosion, on-site and off-site impacts to people and the environment, breaches of regulations, etc.

The RBI should be chaired by a senior person who should be independent of the operation of the equipment. This independence is important because the final WSE could have implications on the way that the plant is run and the outcome should not be limited by purely operational constraints.

In addition there should be an individual who can prepare a detailed record of the discussions. This can be through the use of commercially available software or simply as a set of notes from the meeting. The use of software does help to drive consistency in outcome.

## A3.3 Content

When considering risk the two components of likelihood and consequence should be considered separately and then be combined to give a risk rating. This allows equipment operating under widely different regimes to be compared. If the risk is shown to be serious then mitigation, other than inspection, may be required. This mitigation can include changes to the process or the way that the equipment is operated.

When identifying the deterioration mechanisms, it is important to consider both those that can be predicted, for example corrosion and those that are more difficult to predict such as cracking resulting from an increase in pH following a process excursion.

The outcome from the RBI should be a directed WSE that ensures that any inspection is pointed towards those parts of the equipment that have been identified as most likely to suffer degradation and whose failure could lead to a significant risk. An important part of this WSE will be the frequency of inspection. In the past the periodicity tended to be fixed by a number of rules, for example boilers should be examined every year. With an RBI it is possible to define the examination frequency on the basis of known modes of deterioration.

The initial interval will be set from consideration of the identified deterioration mechanisms and the rate at which they will influence the mechanical integrity of the pressure envelope. As operating experience is built up and the conclusions of the RBI are confirmed the interval can be adjusted, either increased or decreased, depending on the measured rate of deterioration. It is comparatively simple to select and adjust intervals to monitor age-related deterioration but the interval should also take into account the possible presence of deterioration mechanisms that are not age-related. It might be necessary to schedule additional inspections beyond those essential to monitor age-related deterioration in order to consider the effects of other damage processes.

## A3.4 Verification

The final part of the RBI process is verification where the results of the examination are compared with the conclusions of the RBI and the WSE and the interval are adjusted to take account of any learning. This is, perhaps, the most important part of the whole RBI process and is often neglected. Without this review there is no way of knowing whether the assumptions and conclusions of the study were correct and it could happen that the WSE is directed towards a less risky or non-existent hazard.

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