



Piping systems integrity Management review

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The Health and Safety Executive commissioned this study by ABB Eutech Limited. It deals with the development of a high level strategy for improving pipework integrity on industrial sites in the UK. This project was intended to develop proposals that would help companies reduce the occurrence of pipework failure. The report identifies key areas where improvements, that should help to reduce incidents of pipework failures, could be made.

This study has examined commonly available information on pipework, reviewed typical failures of pipework and has drawn upon practical experience from the chemical industry.

This study has used a 'life cycle' model of integrity to assess findings and present recommendations. For pipework the life cycle starts with scope definition, continues through design, construction, operation, and maintenance, includes modification and repair, and ends with decommissioning and disposal.

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SUMMARY

Pipework integrity is an important safety issue. Despite advances in the UK in the general area of Pressure Systems Management, failure of piping systems in the chemical process industries continues to be a source of concern. It is well established that failure of piping systems is more likely to occur than the failure of vessels.

The Health and Safety Executive commissioned this study by ABB Eutech Limited. It deals with the development of a high level strategy for improving pipework integrity on industrial sites in the UK. This project was intended to develop proposals that would help companies reduce the occurrence of pipework failure.

This study has examined commonly available information on pipework, reviewed typical failures of pipework and has drawn upon practical experience from the chemical industry.

This study has used a 'life cycle' model of integrity to assess findings and present recommendations. For pipework the life cycle starts with scope definition, continues through design, construction, operation, and maintenance, includes modification and repair, and ends with decommissioning and disposal.

Analysis of pipework failures commonly reveals a range of causes that match the stages of the life cycle (e.g. inadequate design or maintenance). However, this study has identified a number of underlying features:

- (a) Fragmentation of the pipework life cycle – no other area in a chemical plant is so fragmented with different groups responsible for each part of the life cycle. Indeed, several groups are often involved in each step. This presents a challenge for communication, and requires sound understanding by each party of the issues at other parts of the life cycle. A clear understanding of responsibility for each activity (such as updating a scheme of examination) is necessary.
- (b) Pipework integrity is dependent on all stages of the life cycle. This requires effective management systems for all the necessary activities. The study has revealed that the areas needing particular attention are competence of personnel and procedures covering:
 - Maintenance (especially flanged joints).
 - Modifications, repairs and life extension
 - In-service inspection
- (c) A considerable amount of information is available for piping systems. This covers all aspects of the life cycle, with few significant gaps. However, most documents are aimed at only one or two specific parts of the life cycle. This can place increased reliance on the expertise and experience of personnel to know what is available. Where knowledgeable personnel are not available (and concerns have been identified that the pool of such people is in decline in the UK), an efficient means of accessing the relevant information is required.

This report discusses these issues and offers recommendations aimed at achieving significant improvements in pipework integrity.

1 AIM

To develop proposals that will help companies to reduce the occurrence of pipework failure.

2 OBJECTIVES

- (a) To identify and summarise the key measures necessary to ensure the initial and continuing integrity of pipework.
- (b) To review available accident information and summarise common causes of pipework failures.
- (c) To review currently available legislation, standards and guidance relevant to pipework integrity and identify gaps or shortcomings.
- (d) To identify, evaluate and recommend action that will reduce the incidence of pipework failures.

3 SCOPE

This review applies to pipework on industrial sites in the UK. It is directed towards incidents of pipework failures involving loss of fluid containment.

Other incidents such as contact burns with unprotected hot pipe, falls by persons from elevated pipes etc are excluded. These are important but are outside the scope of the present review.

The consequences of failure have not been considered in detail in this review; it is often a matter of chance if a leak has major or minor consequences, depending for example on the promptness of isolation or on the proximity of persons at the time.

4 DEFINITIONS

“Pipework” means a pipe or system of pipes together with associated valves, pumps, compressors and other pressure containing components and includes a hose or bellows but does not include a pipeline or any protective devices. (Taken from Ref.1).

“Failure” of pipework means a loss of containment (i.e. escape of the contained fluid).

“Integrity” of pipework means the absence of failure of pipework.

5 ACTIVITIES UNDERTAKEN

The activities undertaken during this piping systems integrity management review include the following:

- (a) Key measures for pipework integrity (see Section 6).

These were developed by discussion with colleagues; contacts in other organisations; review of in-house documentation; HSE documents (especially HSG 65 – Ref.2).

- (b) Accidents, incidents and causes of failure (see Section 7).

These were reviewed by consideration of information from in-house experience, industrial contacts, published literature, HSE and IChemE databases.

- (c) Legislation, standards and guidance (see Section 8).

These were reviewed by accessing published and in-house literature, including training material.

Gaps and shortcomings have been identified.

- (d) Recommendations for action (see Section 10).

Based on the above activities (a) to (c) the need for further guidance has been identified and actions recommended.

6 KEY MEASURES FOR PIPEWORK INTEGRITY

6.1 LIFE CYCLE MODEL

Pipework integrity is required throughout the entire life cycle of the pipework. The life cycle will include the following stages and activities: (see Appendix C)

- Scope Definition
- Design
- Asset Records
- Procurement
- Fabrication, Construction, Installation and Testing
- Handover / Acceptance
- Commissioning
- Operation
- In-service Inspection
- Maintenance, Repairs and Replacement
- Modification, Re-rating and Life extension
- Decommissioning
- Dismantling, Demolition and Disposal

6.2 MANAGEMENT SYSTEMS

Using HSG 65 (Ref.2) as a basis, effective health and safety policies can be devised and implemented to cover all the stages and activities in 6.1 (above), which are detailed in 6.3 (below).

The basic policies (HSG 65, Chapter 2) can be put into effect by following the steps listed therein i.e. organising, planning and implementing, measuring performance, reviewing performance (and auditing all of these).

The application of HSG 65 (mainly in the context of corrosion) is discussed in OTR 1999/064 (see Appendix A Clause (d) of this report), and there is little point in repeating this information. Many of the problems of ensuring life cycle integrity are not peculiar to pipework, but are common to other pressure equipment such as vessels. The most effective approach is likely to involve management systems for pressure systems rather than considering only components such as pipework. This can help avoid leaving parts of a system 'owned ' by nobody.

However, there are aspects peculiar to pipework, which need to be considered. These include the wide spread of a piping system across a plant, leading to difficulties of access and allocation of responsibility, a particular problem where piping crosses boundaries of plant or contractual responsibility. In addition there is the impossibility of thorough internal visual examination (as compared with most vessels), which makes inspection less able to guarantee fitness for further service.

One of the crucial steps is selection of an appropriate organisation to perform an activity. The activity may well be outsourced, so the discussion in Appendix 3 of HSG 65 is particularly relevant.

6.3 REQUIREMENTS FOR EACH STEP

6.3.1 Scope Definition

The purpose and boundaries of the piping system need to be established.

The environment (physical, regulatory etc) in which the piping system exists needs to be established.

The hazards and hazardous events associated with the piping system need to be established for all reasonably foreseeable circumstances, including fault conditions and misuse – typically by an initial risk assessment or hazard and operability studies.

6.3.2 Design

Requirements for design management may be found in BS 7000:Part 4 (Ref.3).

Design will normally include the following steps:

- (a) Establish requirements for design (process conditions, operating conditions including upsets). Carry out detailed risk assessment (this may involve hazard and operability studies).
- (b) Establish the appropriate regulations and standards (e.g. PER, ASME B31.3).
- (c) Specify Engineering Requirements relevant to a fluid or system e.g. detailed Piping System Specification (including Fabrication Specification) plus special needs such as traps on steam systems.
- (d) Select and specify Materials of Construction, taking previous operating experience and in-service history into account.
- (e) Establish component standards.
- (f) Select routing and supporting
- (g) Evaluate:
 - (i) Pipe stresses for code compliance
 - (ii) Loads on connected equipment and structures
- (h) Liase with other parties (Process, Safety, Civil, Machines etc).
- (j) Produce and hand over design documentation package.

6.3.3 Asset Records (Plant Database)

The records need to be kept secure but to be accessible to authorised persons.

The records need to be kept up-to-date throughout the life cycle of the plant and to include the following:

- Original design and construction data

- Operation records and procedures
- Inspection records
- Maintenance records and procedures
- Modifications and repairs
- Training and experience of personnel
- Failures, leaks, excursions beyond design envelope, relief events

6.3.4 Procurement

The required goods and services need to be obtained from appropriate suppliers, to comply with the specifications and be delivered at the required time and cost. Although timeliness of delivery may appear not to be safety-related, late delivery can lead to hurried installation or the use of inappropriate substitutes.

6.3.5 Fabrication, Construction, Installation and Testing

The pipework and components need to be manufactured, fabricated, constructed, inspected and tested in compliance with the specifications. All these activities need to be done in a safe manner.

The means of ensuring compliance with specifications needs to be addressed. Experience indicates that merely relying on a supplier's QA system is unlikely to be sufficient. For critical items it is prudent to invoke independent inspection, even if only on a sampling basis.

Experience shows that specific areas of weakness exist for pipework construction, where it is not uncommon for the installation to be incorrectly assembled (e.g. the installation and set up of spring pots, anti vibration pipe supports, and pipework bellows). This is generally due to lack of technical understanding of the installation requirements of equipment by the construction organisations.

Another area of weakness is the widespread practice within the construction industry to site run small bore pipework (typically, below NPS2). There is evidence that this practice can often lead to poor quality installations, with consequent increased susceptibility to failure, as well as knock on consequences such as causing poor maintenance and operational access.

6.3.6 Handover / Acceptance

The transfer of responsibility between parties (e.g. from Construction to Commissioning) needs to be agreed and to be formalised.

Acceptance of a piping system (e.g. by a client) needs to have acceptance criteria agreed (e.g. compliance with performance or regulatory standards) and to be formalised.

6.3.7 Commissioning

Plans and procedures are needed for safe commissioning.

Clear interfaces between the parties involved in commissioning and operating are required.

It is necessary for commissioning plans to include validation checks on assumptions made at the design stage, for example inspection of pipework to ensure that where vibration was highlighted as a design issue, the design measures utilised to alleviate vibration work correctly.

In addition to this surveys of the pipework during commissioning should ensure that unexpected vibration is not present.

Modifications found necessary during the commissioning phase need to be adequately controlled to ensure integrity is maintained.

6.3.8 Operation

Clear, up to date procedures and instructions need to be available to cover normal operating, emergencies and management of change.

It is important that operating boundaries are established, and documented, including allowable excursions during start-up and shut-down of facilities, and that systems are in place to communicate when pipework has been operated outside of the agreed boundaries, so that appropriate action can be taken.

Past and current experience needs to be captured, recorded and communicated in a robust, sustainable manner.

6.3.9 In-service Inspection

Inspection of piping systems can be difficult due to pipework configuration and geographical layout. As a result care needs to be taken to adequately group pipework into manageable system for inspection.

Inspection resources for pipework should be appropriately focussed using techniques such as RBI (Ref.7) to identify which system to inspect, and what inspection methods to employ. There needs to be a competent inspection organisation implementing a written scheme of examination, in close co-operation with the operations organisation.

Examinations need to be reported and appropriate action agreed, recorded and implemented. The schemes of examination need regular review, including the effect on the schemes of any modifications and any changes in conditions of operation.

6.3.10 Maintenance, Repairs and Replacement

There need to be maintenance procedures for each piping system, which should include joint making practices, gasket & bolting selection.

Companies should have defined maintenance polices for pipework, which define agreed minimum integrity standards, and appropriate resources need to be available to allow the pipework systems to be maintained to meet these agreed standards.

The maintenance system needs to deal with topics such as isolation, permits to work, training and supervision, outage planning, control of spares and materials, control of modifications, control of temporary repairs, rectifying deficiencies, testing after repairs, recording of work done, and transfer of responsibility back to the operations group.

6.3.11 Modification, Re-rating and Life Extension

There needs to be a system to control modifications, including re-rating of equipment and extension of service life. The system needs to address:

- identification of the proposed changes
- risk assessment to identify hazards
- actions to deal with the hazards identified
- effects on operating procedures & maintenance procedures
- effects on schemes of examination
- authorisation and recording of the changes made.

6.3.12 Decommissioning

Plans and procedures are needed for safe decommissioning.

Clear interfaces between the parties involved in decommissioning and operating are required.

6.3.13 Dismantling, Demolition and Disposal

Plans and procedures are needed for safe dismantling, demolition and disposal. These will need to address isolation, decontamination and environmental issues.

7 ACCIDENTS, INCIDENTS AND CAUSES OF FAILURE

7.1 REPORTS AND SURVEYS

There are numerous reports and surveys on these topics and some are listed in Appendix A.

7.2 UKAEA REPORT

A representative paper is the UKAEA report SRD R441 by Blything and Parry, (see Appendix A Clause (a)), which looks at pipework failures in four plant categories (chemical, refinery, nuclear and steam).

Although “failure” is not explicitly defined in the paper, the classification of incidents into failure mode categories “leaks” and “ruptures/severances” implies that “loss of containment” is the type of failure being considered.

7.2.1 From UKAEA Report SRD R441:

“Definitions

Root Cause

This is the principal activity which is considered responsible for initiating the pipework failure.and there may be many contributory factors that are not identified, although it is recognised that human error is a significant factor in all the causes.

Failure cause

This is the principal mechanism responsible for failure, there may also be other less dominant causes which contributed to the failure.

Tentative conclusions

These have been drawn from the analysis of data from the chemical plant and refinery sources. Their validity is dependent on the accuracy in allocating incidents to the various root and failure cause categories and also on the judgements made concerning the influence of other factors.

(a) The two failure cause categories responsible for the largest number of incidents are “mechanical” and “work systems”.

(b) The major root cause of mechanical failure is “design” and no single root cause has been identified for “work systems” failures, although human error is a dominant factor.”

(end of quotation from SRD R441)

7.2.2 Causes of Failures

From the above (7.2.1), it appears that “design” is an activity worthy of attention. The “work system” failures were largely associated with the root causes classified as “maintenance”, “operation” and “design/installation”

7.3 HSE CIRCULAR OC307/10 -- STEAM

To see if steam piping was different from chemical and refinery piping, the HSE circular OC307/10 “Accidents on steam plant and hot water systems 1994” (see Appendix A Clause (e)) was reviewed.

From Table 1 of OC307/10 the two main causes of pipework and hoses incidents are seen to be “unsafe system of work by trained personnel” (50%) and “inadequate system design” (35%). These seem broadly similar to the results for chemical and refinery piping (see 7.2).

7.4 OFFSHORE TECHNOLOGY REPORT 1999/064

From Table 1 of Offshore Technology Report 1999/064 (Appendix A Clause (d)) it can be seen that for mechanical failures in static offshore processing equipment (vessels, heat exchangers, pipework and instrument lines) the failures were largely from leaking gaskets (22%) and corrosion/erosion/pinholes (21%).

7.5 ICHEME ACCIDENT DATABASE

From the IChemE Accident Database Version 4 (see Appendix A, clause (g)) there are numerous incidents involving failures of pipework, but for most entries the limited information in the form of a short abstract is insufficient to determine root causes.

However, incident number 10592 does describe a large oil spill (175m³) in 1998 which resulted from two failed pipework flanged joints. A motorised valve closure subjected the pipe to pump pressure in excess of the pipe design pressure. This appears to be a result of inadequate design.

7.6 HUMAN FACTORS REPORT No.15/1989

From Figure 6 of HSE Report No 15/1989 (see Appendix A clauses (h) and (c)) it can be seen that the origins of failure for all the 921 incidents considered are predominantly ‘design’ (27%) and ‘maintenance’ (38%).

Furthermore, the report states that ‘operator error was the biggest known contribution to incidents’. ‘Operator errors had their origins in maintenance to a large extent’. This is typified by incidents where the operator had opened the wrong valve, or the incomplete emptying of pipework prior to maintenance.

One recommendation of the report is improvements to procedures for checking completion of tasks at the design and construction/installation stages and reviewing operations and maintenance activities.

7.7 CAUSES OF LOSS OF CONTAINMENT IN PIPEWORK

Review of the various incident reports has shown that common causes of loss of containment in pipework include the following (with the most prominent ones stated first)

- leakage at bolted flanged joints
- leakage at corroded pipe (especially under lagging)
- leakage at small bore pipework (e.g. due to fatigue)
- failure of supports
- leakage at bellows (relatively more vulnerable than pipe)

- leakage at instruments (relatively more vulnerable than pipe)
- failure of steam trapping
- modifications
- wrong materials used
- over pressure

8 LEGISLATION, STANDARDS AND GUIDANCE

Currently available legislation, standards and guidance relevant to pipework integrity have been reviewed. The more significant items are listed in Appendix B.

The duty to control risks resulting from pipework failure is normally dealt with by compliance with:

- (a) specific regulations such as PSSR (Ref.1) or
- (b) more general regulations such as Reg 4 of COMAH (Ref.8) or
- (c) other good practice guidance.

8.1 LEGISLATION (SEE B.1.)

- (a) The primary legislation is the Health & Safety at Work etc Act 1974 (HSW Act) which places general duties on all people at work (employers, employees, etc).
- (b) More focused (but still fairly general) requirements are given in the Provision and Use of Work Equipment Regulations (PUWER). Two of the Regulations directly applicable to pipework are
 - (i) Regulation 12 Protection against specified hazards
 - (3) (b) rupture or disintegration of parts of work equipment
 - (ii) Regulation 19 Isolation from sources of energy, particularly for isolation during maintenance work
- (c) For persons involved in pipework, the most directly applicable detailed regulations are the Pressure Systems Safety Regulations (PSSR) which are concerned with the risk created by release of stored energy through system failure. With the exception of the scalding effect of steam, the Regulations do not consider the hazardous properties of the contents released following system failure. These Regulations are wide in scope, including the phases of design and construction, installation, examination in service, operation, maintenance, modification and repair, keeping of records. Although the Regulations cover pressure vessels, pipelines etc. most are also applicable to pipework as defined in Section 4 of this report. The exclusion of pipework from the written scheme of examination permitted by Reg.8 needs careful application, particularly where the contents are hazardous (see paragraph 102 of L122-Ref.1).
- (d) For new pipework, to ensure compliance with the European Pressure Equipment Directive (PED), the Pressure Equipment Regulations (PER) are relevant. These cover the supply and putting into service of equipment that would also form whole or part of a pressure system and fall within the scope of PSSR. As well as considering the hazard from release of stored energy, PER also consider the nature of the fluid released (i.e. “dangerous” or not).

Specific piping items are addressed in Section 6 of Schedule 2 of PER, for design and construction only.

The scope is narrower than PSSR, in that there is less emphasis on requirements for pipework once it has been put into service.

- (e) Additional legislation exists which can affect pipework, but which is not specifically directed towards pipework. For example, Reg.4 of COMAH places a general duty on all operators to take all measures necessary to prevent major accidents and limit their consequences to persons and the environment. This could encourage the use of written schemes of examination for pipework that does not necessarily fall within the scope of PSSR Reg.8.

In addition the Control of Substances Hazardous to Health Regulations (COSHH) may influence pipework design with regard to tolerable leakage rates at valve spindles, procedures for decontamination prior to maintenance, etc.

- (f) Overall, the UK legislation appears to be comprehensive and thorough. The main difficulties arise from a lack of awareness. There is a large volume of legislation and it is difficult for a busy plant engineer to even know which are the relevant regulations, let alone to have a detailed knowledge of all the requirements and duties.

The mere existence of regulations does not ensure compliance. A visitor to the UK using motorways might be surprised to learn that there is a legally binding upper speed limit of 70mph. The existence of the regulations is only part of the requirement - enforcement is also significant. It could be said that just as the best discipline is self-discipline, then the best means of enforcement is self-imposed compliance, but this in turn depends on awareness and acceptance of the requirements of the regulations.

8.2 STANDARDS AND GUIDANCE (SEE B.2.)

8.2.1 HSE Publications (see B.2.1)

There are numerous general and specific documents. The document most directly applicable to pipework is Safety of pressure systems ACOP L122, which provides guidance to the Pressure Systems Safety Regulations. The format of including both the Regulations and the guidance notes in the same document is helpful.

For most of the relevant legislation there exists a corresponding guidance document.

For the important topic of control of modifications, no published guide has been located, though a related training package is available from the Institution of Chemical Engineers (see B.2.9)

As a good example, the guide HS (G) 28 Safety advice for bulk chlorine installations (2nd edition 1999) lists the relevant legislation and HSE guidance in Appendix 3. However this is somewhat dated (e.g. reference to the withdrawn Pressure Systems and Transportable Gas Containers Regulations 1989). In the paragraphs 53 to 79 on pipework the need to avoid pockets, where explosive nitrogen trichloride could collect, is not mentioned. The topic is referred to in paragraph 148 (Vaporisers) but this paragraph would not necessarily be read by a piping designer. Although the guide refers to several GEST publications, it omits reference to GEST 79 /81 Dry Liquid Chlorine Piping, where the topic of dead legs is dealt with in section 5.5 of the 7th edition.

8.2.2 BSI Publications (see B.2.2)

Although there are many British Standards relevant to pipework, the majority are product standards for components (e.g. BS 5351 Specification for steel ball valves).

For piping systems, most relevant British Standards cover only the design and construction stages – e.g. BS806 for piping for land boilers (this specialised standard is referred to as an example because there is no general BS code for pipework which is comparable to ASME B31.3).

Relatively few BSI documents deal with the in-service stages. Those which do include:

- (a) PD 6510, which reviews fitness for purpose assessment of in-service high temperature pressurised systems (a guide for specialists).
- (b) BS 6129, which covers selection and application of metallic bellows expansion joints, including guidance on maintenance, periodic inspection and modifications. Although this particular BS was prepared as a result of a major incident (Flixborough 1974 – Ref.4) there seems to be a low level of awareness of BS 6129 amongst designers and users of pipework (Ref.4).

8.2.3 ANSI Publications (see B.2.3.)

There are hundreds of ANSI standards relevant to pipework – most of which are component product standards such as B16.5 Pipe Flanges and Flanged Fittings. In addition, ANSI recognises other documents (such as ASME B31.3) as national standards.

8.2.4 ASME Publications (see B.2.4)

ASME Code for Pressure Piping B31, includes sections such as B31.1, B31.3 etc. This Code is limited to safe design and construction, but is not intended for operation, examination, inspection, testing, maintenance or repair of piping that has been placed in service. The Code provisions may optionally be applied for those purposes, although other considerations may also be necessary.

An exception which does deal with in-service piping is ‘B31G Manual for Determining the Remaining Strength of Corroded Pipelines’. However, although in common use, it does have limited applicability – it is aimed at assessing external corrosion defects on pipelines. It does not cover adequately areas such as external and local loads.

Each Code section calls up many other standards e.g. piping components standards are listed in Chapter IV of B31.3.

ISO 15649 provides a supplement to B31.3 for piping in petrochemical industries.

8.2.5 API Publications (see B.2.5)

The API Catalogue contains many documents which are codes, specifications and guides, mainly related to oil industry practices in USA.

The most significant for pipework are:

- API 570 Piping Inspection Code
- RP 574 Inspection Practices for Piping System Components
- RP 579 Fitness-for-Service
- RP 580 Risk-Based Inspection

8.2.6 EEMUA Publications (see B.2.6)

The Engineering Equipment and Materials Users Association publishes numerous specifications and guides, mainly for users of equipment.

For pipework the most significant are:

- EEMUA Supplement to ASME B31.3
- Compendium of EEMUA Information Sheets on Topics Related to Pressure-Containing Equipment.

8.2.7 Trade Association Publications (see B.2.7)

Many Trade Associations provide technical information for the storage and handling of their products including recommendations for piping.

e.g. EuroChlor publishes many documents related to equipment standards, safe handling etc of chlorine in liquid and gas form.

8.2.8 Chemical Suppliers (see B.2.8)

Many suppliers of fluids provide technical information for the storage and handling of their products. This often includes recommendations for piping, such as the need for cleanliness for liquid oxygen piping, the need for PWHT for anhydrous ammonia piping etc.

8.2.9 Training (see B.2.9)

Only a limited amount of training has been found for piping, mainly with the Institution of Chemical Engineers.

The 'Safer Piping' package is probably the most generally useful in raising awareness of piping problems.

Vocational training and national qualifications are provided by the Chemical Industries Association.

8.2.10 Text Books (see B.2.10)

Some relevant text books have been located. They tend to be slanted towards design in USA, but can be applied to piping in UK.

8.3 DISCUSSION OF GUIDANCE ETC

- (a) It could be argued that there is already too much published legislation, standards and guidance: a major problem for users is finding which items are relevant to a particular piping system or problem.

In particular, because the PSSR is specific to pressure systems, and includes pipework, these Regulations commonly appear to be interpreted in the industry as the only significant legislation that needs to be complied with. This leads to a variety of approaches to 'duty of care' across the industry and a wide variation in the level of knowledge and application of good piping practice.

- (b) One of the gaps in the published information is the lack of fluid-specific data. For example, no published comprehensive guide for general steam systems was located, even though these systems are widely used.
- (c) Of the published guidance, some has been written in general terms, which tend to hide the intended message. For example, paragraph 59 of L122 (Ref.1) states: “.....the design of a compressed air system or of steam pipework should minimise the number of places, such as low points, where liquid can accumulate and should provide for adequate drainage.”

A novice designer needs more positive guidance. The real need is for provision of adequate automatic steam traps, not just a few manually operated drain valves. The hazards from water hammer are dealt with in the SAFed document FS1 Potential hazards created by water hammer in steam systems (see B.2.7).

- (d) Some guidance documents have become outdated by changes in industry practice.

For example, HSG 65 (Ref.2) seems to have been written for organisations doing most work in-house, with only some outsourcing (although outsourcing is briefly mentioned in Appendix 3). In current practice, the situation is reversed, with the majority of the activities being outsourced (Ref.6).

- (e) Training of designers & engineers in previous years tended to be done by large companies with in-house engineering departments. The training was directed towards the company's own processes and fluids. Nowadays, this has become less common (Ref.6).

Training for fitters/erectors is normally in-house, for topics such as making bolted joints. There does not appear to be a recognised qualification for this topic, whereas persons making welded joints have a recognised scheme for demonstrating continued competence.

- (f) The majority of problems and failures are associated with pipework which has already been through the design stage, making design an area less rewarding than inspection for those seeking a quick improvement in piping system integrity. However, this does not mean that design is not important (see 7.2). Good design will continue to be important both for new plant and for modifications of existing plant. The capture, recording and communication of past and current experience are important for good design. There may well be a need for action to prevent design becoming worse in the future, as well as searching for improvement. This is because the links between operating and design tend to degrade with the increasing use of outsourcing (Ref.6).

Many operators have encountered (and still are encountering) pipework problems leading to loss of containment involving small-bore pipework failures due to fatigue. Good design practices as well as criteria for assessing suitability of existing small bore pipework are contained in “Guidelines for the Avoidance of Vibration Induced Fatigue in Process Pipework”, written in 1999 following awareness that guidance was lacking in this area. This document, developed in conjunction with the HSE, was not known to any of the contacts or companies involved in this project.

- (g) In the UK, the vast majority of pipework is already installed and operating, with relatively little being newly installed. For inspection of existing pipework, there is a comprehensive guidance document already published – API 570 Piping Inspection Code Inspection, Repair, Alteration and Re-rating of In-Service Piping Systems. This code appears to be little used in

the UK, with the exception of the Petroleum Refineries, where the use of API standards is a more common practice.

In addition, API RP580 Risk-Based Inspection provides a basis for concentrating limited resources in the most important areas. However, if used only to reduce costs by extending inspection intervals, the use of RBI will not improve piping system integrity (Ref.5).

9 ANALYSIS OF FINDINGS

9.1 REVIEW OF INCIDENTS

Using a life cycle model of integrity to facilitate a review of pipework incidents reveals that the causes of incidents are spread throughout the life cycle, clustered around design, installation, operations and maintenance. In fact, most incidents have been attributed to a number of causes (see for example the Table of Case Studies and Technical Measures in Ref. 7). This emphasises that pipework integrity is dependent on all stages of the life cycle.

Poor communication between different duty holders is evident in most incidents, though this is often not identified as a specific factor in the incident report summaries.

Abnormal operations feature frequently in incidents, including lack of understanding of consequences of impurities, destructive potential of certain (abnormal) reactions, and other effects of build up of small concentrations of process fluids, which have significant effects over the long term.

Inadequate design of relief systems is exposed in many incidents, though the root cause is usually in other areas.

It is also evident that, to a large extent, the focus of reported incidents is major, or significant, failures. This can lead to a somewhat disjointed or incomplete view of incident causes. Experience across the industry indicates that there is a mass of smaller, often unreported, incidents. Where minor incidents (such as joint leaks) are regarded as 'the norm', the difference between a major incident and a minor one is typically a matter of luck.

From HSE Report No 15/1989 – it is evident that the final barriers to failures are the recovery mechanisms, and although these can be physical, for example bunding of plant equipment, in the main recovery systems are almost entirely human. The report concludes that only 7.6% of the identified contributions to pipework failure were classified as non-recoverable.

The findings from the HSE Report 15/1989 strongly suggest that there is an underlying lack of awareness by duty-holders of the importance of activities such as hazard study (particularly of the design of the plant and the as-built), human factor reviews (particularly of support for operator activities), and checking of completed tasks (particularly maintenance) in reducing pipework failures.

9.2 FRAGMENTATION OF THE PIPEWORK LIFE CYCLE

In comparison with other areas of chemical plant, pipework has the most fragmented life cycle, with different groups responsible for each part of the life cycle. Indeed, several groups are often involved in each step. Relevant factors include

- specialisation within the design team (e.g. layout designers, piping flexibility analysis engineers, pipe support designers, process engineers, civil engineers and engineers from other technical disciplines).
- manufacturing involving component manufacturers and suppliers, various fabricators of assemblies and sub-assemblies, pipework erectors and pressure testing firms.

- maintenance carried out by operations personnel (front-line maintenance), overhauls contractors (major repairs and turnarounds), and component suppliers and repair specialists (for individual components such as valves and bellows expansion joints).

This is in contrast with a typical item of rotating equipment (such as a large turbine) where the supplier is often the designer, manufacturer and even installer of the equipment. The original supplier is likely to provide spares and advice, and may be called in to service, overhaul and repair the equipment.

Similarly with a large vessel, the designer and fabricator are closely associated with one another (and are increasingly part of the same fabrication company). Inspection, fitness for service assessment following discovery of defects, and major repairs tend to involve the original fabricator to some extent.

Whilst it would be impractical to suggest structural changes in the pipework industry to address these issues, for organisations involved in pipework this fragmentation presents a challenge for communication, and requires sound understanding by each party of the issues in other parts of the life cycle.

9.3 MANAGEMENT OF PIPING ACTIVITIES

As pipework integrity is dependent on all stages of the life cycle, effective management systems for all the necessary activities are vitally important. The study has revealed that the areas needing particular attention are competence of personnel and procedures covering the following activities.

9.3.1 Maintenance

Incident reports indicate that flanged joints are involved in a large proportion of failures. In addition, a number of operating companies cite a significant number of leaks from flanged joints during start-up following shutdowns and overhauls. This has financial as well as safety implications as a leaking joint on a single stream continuous process unit often can only be repaired by shutting the plant down.

However, there is considerable experience (recorded and quantified) from operating plants that improvements in systems governing flanged joints have significantly reduced the incidence of such leaks. Measures have included: clarification and rationalisation of gasket and bolting specifications, improved systems for supply, storage and handling of gaskets and bolting, training and validation of personnel in joint making procedures, including more widespread use of control of joint bolt loads, tagging of flanged joints, and identification and recording of personnel involved with each joint.

In this area, guidance documents are becoming available – e.g. ASME PCC-1, however discussions with industry contacts indicated that knowledge of these guidance documents is extremely limited.

Experience in the area of flanged joints suggests other maintenance areas may benefit from similar measures.

9.3.2 Modifications, Repairs and Life Extension

Modifications have been a consistent cause of pipework failures. The need for improved control of modifications is closely tied to the need for improved awareness by personnel

involved in the risk assessment and execution of modifications. Modifications and repairs on operating plant are potentially more problematic than the design of new plants. The availability of competent design resource, the effect of deterioration mechanisms, the consequence of apparently small changes to operating conditions and build-up of small concentrations of process fluids over the long term are examples of additional factors that need to be considered. The inadequate assessment of changes to operating conditions features in many incidents; the adequate assessment of proposed changes can be particularly difficult.

Similar factors apply to life extension assessments.

Management systems should ensure that modifications to pipework should trigger a review of the scheme of examination for the pipework, to ensure that it is amended as necessary. This linkage does not appear to be formally established in many companies, although it is an activity that is specifically mentioned in the Approved Code of Practice for the PSSR (Ref.1, Guide 13, para178(e)).

9.3.3 In-service Inspection

Detecting and rectifying on-going deterioration has proved to be a cause of significant practical problems and costs for many operating plants. Indeed, despite apparently extensive inspection programmes, some companies have still experienced significant failures, which raise serious doubts across the industry. One example is a company which relied on external expertise to manage this activity. However, with the focus on the PSSR definition of ‘relevant fluid’ and ‘danger’ from ‘the unexpected release of pressure energy’, minimal attention was directed to a significant deterioration mechanism of a fluid not deemed to be ‘relevant’, though highly corrosive. Failures occurred after a number of years of operation.

Another example is a chemical company where piping failures occurred despite an extensive in-service inspection programme and considerable in-house expertise. Inspection activities did not focus on certain key locations where deterioration was occurring at an accelerated rate.

Considerable effort is needed to ensure that schemes of examination for pipework are appropriate. Particular problem areas that are specific to pipework need to be addressed such as dead legs, start-up and shut-down pipes that are out of service most of the time, pipework that is in intermittent use, injection points, and stagnant areas of pipework. Common use of generic schemes of examination which skirt over such issues, tend to lead to inadequate pipework inspection, with resultant pipework failures. Understanding of the deterioration mechanisms associated with contaminants within the process stream is also extremely important and an area that is sometimes neglected.

9.4 INFORMATION

A considerable amount of information is available for piping systems – design codes, guidance, and case studies/incidents, as well as UK legislation. This covers all aspects of the life cycle (see Appendix C). The study has identified a number of areas that could be regarded as significant gaps:

- Application of ‘good piping practice’ across the industry – many integrity management systems include pipework to a very limited degree. The focus appears to be equipment that is perceived to be addressed by specific legislative requirements (e.g. PSSR). And yet there are many examples where good practice is being applied and is being further developed.

- Steam systems – many serious incidents have involved steam and condensate systems. The nature of steam and its widespread use accounts for the frequent occurrence of pipework failures on incident databases. However, the subject as a whole does not appear to be adequately covered by information which is commonly available.
- Life extension – in the UK chemical industry the focus is on maintaining existing assets past their originally expected design life, rather than designing and building new assets. Relatively little information exists on assessing mature assets for continued use, although various practices have been developed.
- Decommissioning/dismantling – although relatively few failures have been recorded in these areas, there is potential for personal injury as well as loss of containment.
- Modifications – although well known as a cause of incidents (Ref.4) there is little published information dealing with the topic of plant modification in a comprehensive manner.

Most of the available guidance documents are aimed at a specific part (or small range of parts) of the life cycle. Much of this information is written ‘by experts for experts’ and requires a considerable investment of time to find, read, assimilate and apply the key or relevant parts. This can place increased reliance on the expertise and experience of personnel to know what is available. Where knowledgeable personnel are not available (and concerns have been identified that the pool of such people is in decline in the UK), an efficient means of accessing the relevant information is required.

10 AREAS FOR IMPROVEMENT

10.1 HEALTH AND SAFETY MANAGEMENT SYSTEMS IN INDUSTRIAL PLANTS

To improve health and safety management systems in industrial plants, duty holders should be encouraged to use HSG 65 as a basis to develop their own management systems for managing risks of pressurised systems to cover the whole life cycle of the pipework. An edited version of OTO 1999/064 (Appendix A Clause (d)) could be produced and used as a base reference document. It is important that systems developed cover all aspects relating to the duty of care. For example, the hazardous nature of fluids needs to be considered, as well as compliance with the PSSR, to ensure that all piping systems are satisfactorily designed, properly constructed, and subject to appropriate maintenance and inspection.

Pipework is low down the priority list for many companies. A methodology is needed to increase the profile of pipework throughout the industry and to ensure that duty holders make adequate provisions for pipework throughout the lifecycle.

10.2 AWARENESS OF EXISTING INFORMATION

To improve awareness of existing information a guide to the existing legislation, standards and guidance should be published. This should be:

- based on the internet
- user focused
- tested on users before publication
- kept up to date

The existing HSE Level 3 guidance for COMAH (Ref.7) could be updated and used as a basis for new guidance for more general plant. This may best be done in conjunction with a trade association (such as EEMUA).

The benefits would include a better-informed population of users/operators, who would be less likely to repeat the errors of their predecessors.

10.3 INSPECTION OF IN-SERVICE PIPEWORK

To improve the inspection of in-service pipework, and hence reduce the number of failures, organisations should be encouraged to use relevant existing guidance such as API RP570 “Piping Inspection Code”, which includes inspection, repair, alteration, and rerating for metallic piping systems in refineries and chemical process plant. HSE could review the guide RP570 for completeness and applicability to general pipework.

More details of inspection techniques are given in the TWI report (Ref.5).

10.4 INTEGRITY OF BOLTED FLANGED JOINTS

To improve the integrity of bolted flanged joints, organisations should be encouraged to develop and implement appropriate systems. These systems would include all the life cycle steps from design through to life extension. With clear specifications, training and qualifying installers, this is an area where quick benefits can be obtained.

10.5 INTEGRITY OF MODIFICATIONS

To improve the integrity of modifications, a guide should be published, focussing on pipework. The unpublished HSE Level 3 COMAH Guidance 'Plant modification/Change procedures' could be used as a basis.

10.6 QUALITY OF DESIGN

Design shortcomings feature in many of the pipework failure incident reports. To improve the quality of design, organisations should be encouraged to ensure that past and current operating experience is captured and communicated to those responsible for carrying out the design activity. This is particularly important where the design organisation is separate from the operating organisation.

Future maintenance and inspection of pipework needs to be considered fully at the design phase, and incorporated into design packages. This will require increased awareness by Design Contractors of the whole pipework lifecycle. Duty holders have a responsibility to ensure that the design is competently carried out (PSSR, Reg.4) and that appropriate information is provided to the designer. This is a complex area, as the means to improve design quality and to learn from incidents (for example) are not readily apparent.

10.7 INTEGRITY OF STEAM PIPEWORK

Steam systems are widely used but still have a long history of repeated failures. There is a need for framework guidance on risk management for steam pipework, particularly for the nature and hazards of steam and condensate systems.

To improve the integrity of steam pipework, a guide should be published to cover the whole life cycle of steam systems.

11 RECOMMENDATIONS FOR ACTION BY HSE

11.1 HEALTH AND SAFETY MANAGEMENT SYSTEMS IN INDUSTRIAL PLANTS

The root cause of any given pipework failure, from an engineering point of view, can usually be determined clearly (e.g. corrosion). However, the underlying events that give rise to the incident often span a range of factors that match the stages of the life cycle (e.g. inadequate design and maintenance). This review has revealed that a key underlying feature of pipework incidents is the general lack of a coherent approach to risk management in industrial plants. This is evidenced by fragmentation of the pipework lifecycle and lack of clear understanding of responsibilities.

In addition, pipework is low down the priority list for many companies. A methodology is needed to increase the profile of pipework throughout the industry and to ensure that duty holders make adequate provisions for pipework throughout the lifecycle.

To improve health and safety management systems in industrial plants, duty holders should be encouraged to use HSG 65 as a basis to develop their own management systems for managing risks of pressurised systems to cover the whole life cycle of the pipework. It is important that such systems take into account the hazardous nature of fluids, as well as compliance with the PSSR, to ensure that all piping systems are satisfactorily designed, properly constructed, and subject to appropriate maintenance and inspection.

A guide should be developed which would act as a framework document for use in industry by duty holders for developing their own safety risk management systems for pipework integrity.

An edited version of OTO 1999/064 (Appendix A Clause (d)) could be produced and used as a base reference document to prepare such a guide for the use of HSG 65 for pipework integrity.

In addition, the same base could be used to prepare an audit tool document for use by HSE, including relevant questions and appropriate answers.

11.2 INTEGRITY OF MODIFICATIONS

The review of piping incidents has revealed that modifications have been a consistent cause of pipework failures. All modifications (whether 'large' or 'small') have the potential to cause a major incident.

Particular attention is needed for the control of small modifications. The resources available for large modifications carried out by a big project team are usually substantial, whereas the level of expertise etc available to those persons perpetrating small modifications can be limited.

To improve the integrity of modifications, guidance should be published. There is a need for a general document covering the control of modifications to plant (change control), and also a more detailed document covering those aspects relevant to pipework. The unpublished HSE Level 3 COMAH Guidance 'Plant modification/Change procedures' could be used as a basis for producing these documents.

To have a significant beneficial effect in reducing incidents associated with plant modifications, the guidance would need to be publicised and implementation encouraged.

11.3 INTEGRITY OF BOLTED FLANGED JOINTS

There are many minor (and some major) incidents associated with leaking flanged joints. Reducing the number of leaks can help reduce the number of major incidents.

A number of companies report significant quantifiable safety and financial benefits from joint management programs which move towards a 'zero emission' state, even though this may be ultimately not completely attainable.

To improve the integrity of bolted flanged joints, organisations should be encouraged to develop and implement appropriate systems. These systems would involve a range of measures, depending on the joint's 'criticality' (determined by a risk assessment). They would cover all the life cycle steps from design through to life extension, and include training and qualifying installers.

This appears to be an area where significant benefits can be obtained in the short term: demonstrable safety and financial benefits, an approach that can be readily implemented, and a number of working examples in industry.

HSE could, in conjunction with a trade association such as EEMUA, develop and publish guidance on this topic. This could tie in with HSE's offshore initiative in this area, and reinforce the dialogue between the safety authorities and operators about raising general safety standards.

REFERENCES

1. Safety of pressure systems, Approved Code of Practice L122,
HSE Books 2000 ISBN 0 7176 1767 X.
2. Successful health and safety management, HSG 65,
HSE Books 1997 ISBN 0 7176 1276 7.
3. BS 7000-4, Guide to managing design in construction
BSI ISBN 0 580 25318 X.
4. Kletz T, Flixborough – 20 years after,
2nd Biennial Canadian Conference on Process Safety and Loss Prevention.
5. Best Practice for Plant Integrity Management by Risk Based Inspection
TWI Report No.12289/1/01
6. Business re-engineering and health and safety management:
Best practice model CRR HSE Books 1996 ISBN 0 7176 1302 X
7. Level 3 guidance for the assessment of the technical aspects of COMAH safety reports.
Internal HSE document
8. A guide to the Control of Major Accident Hazards Regulations L111
HSE Books 1999 ISBN 0 7176 1604 5

APPENDIX A: SOURCE DOCUMENTS FOR ACCIDENTS, INCIDENTS AND CAUSES OF FAILURE

- (a) Blything, K.W. and Parry, S.T. Pipework failures – A review of historical incidents. UKAEA Report SRD R441, 1984
- (b) Hurst, N.W. and Ratcliffe, K. Development and Application of a Structured Audit technique for the Assessment of Safety Management Systems (STATAS). I.Chem.E. Symposium Series 134.
- (c) Human Factors in Pipework Failures. HSE, NIGM 17/1990/10
- (d) Corrosion risk assessment and safety management for offshore processing facilities. (Capcis Limited) HSE OTO 1999/064.
- (e) Accidents on steam plant and hot water systems 1994, HSE, OC 307/10. Internal HSE document.
- (f) Dangerous Maintenance – A Study of Maintenance Accidents and how to prevent them, HSE Books ISBN 0 11 8867347 9, 1992.
- (g) The Accident Database, Version 4, The Institution of Chemical Engineers.
- (h) Bellamy, L J, Geyer, T.A.W and Astley, J A, Evaluation of the Human Contribution to Pipework and In-Line Equipment Failure Frequencies. HSE 15/1989 ISBN 0 717603245

APPENDIX B: LEGISLATION, STANDARDS AND GUIDANCE.

B.1 LEGISLATION

www.hsedirect.com

See Appendix 2 of PSSR 2000

- HSW 1994
- MHSWR 1999
- PSSR 2000
- PER 1999
- COMAH 1999
- COSHH 1999
- PUWER 1998
- CDM 1994

B.2 STANDARDS & GUIDANCE

B.2.1 HSE

www.hsedirect.com

Numerous general and specific documents, including;

- L1 Guide to HSW
- L5 ACOP for COSHH
- L21ACOP for MHSWR
- L22ACOP for PUWER
- L111 Guide to COMAH
- L122 ACOP for PSSR
- L54ACOP for CDM

- HSG28 Chlorine
- HSG39 Compressed Air
- HSG48 Reducing Error
- HSG65 Successful health and safety management
- HSG140 Flammable liquids
- INDG261 Pressure systems - safety and you
- INDG178L Written schemes of examination

B.2.2 BSI

www.bsi-global.com

BSI documents are mainly on design and product standards, with comparatively little guidance on maintenance and inspection.

- CP312 Thermoplastics pipework
- BS 806 Ferrous piping for land boilers

- BS 5351 Steel ball valves
- BS 5760 Reliability of systems, equipment & components
- BS 6129-1 Metallic bellows expansion joints
- PD 6470 The management of design for economic production
- PD 6510 Assessing remanent life
- BS 7000-4 Guide to managing design in construction
- BS 7159 GRP piping systems
- BS 7339 Checking of metallic materials of construction

B.2.3 ANSI

www.ansi.org

- Many standards for piping components.
- e.g. ANSI B16.5 Pipes Flanges and Flanged Fittings
- Recognition of other documents (such as ASME B31.3) as national standards.

B.2.4 ASME

www.asme.org

- ASME B31.3 Process Piping
- ASME B31G Manual for Determining the Remaining Strength of Corroded Pipelines
- ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly

B.2.5 API

www.api.org/cat

The API catalogue contains many documents which are codes, specifications & guides, mainly related to oil industry practices in USA.

Piping related items include:

- RP 520 Pressure Relieving Systems in Refineries – Sizing & Selection
- RP 521 Pressure Relieving and Depressurising Systems
- API 570 Piping Inspection Code: Inspection, Repair, Alteration and Re-rating of In-Service Piping Systems.
- RP 574 Inspection Practices for Piping Components
- API 576 Inspection of Pressure Relieving devices
- RP 578 Material Verification Program
- RP 579 Fitness-for-Purpose
- RP 580 Risk Based Inspection
- API 581 Risk Based Inspection Resource Document
- API 598 Valve Inspection & Testing
- API 750 Management of Process Hazards
- API 1129 Assurance of Hazardous Liquid Pipeline System Integrity
- API 2001 Fire Protection in Refineries
- API 2510A Fire Protection for LPG Storage Facilities
- API 2028 Flame Arrestors in Piping Systems

B.2.6 EEMUA

www.eemua.co.uk

Numerous specifications and guides. Piping related items include Publication Numbers:

- 149 Identification of materials
- 153 Supplement to B31.3
- 167 Carbon steel valve castings
- 168 Pressure testing
- 170, 171, 172, 173 Production testing of valves
- 179 Carbon steel in wet H₂S
- 182 Integral block & bleed manifolds
- 184 Isolation of pressure relieving devices
- 185 Hot tapping
- 188 Operating periods of safety valves
- 192 Valves for low temperature
- 193 Assessment of inspection personnel
- 195 Information sheets on pressure equipment
- 196 Valve purchaser's guide to PED
- 199 On-line leak sealing
- 200 Spring supports

B.2.7 Trade Associations

Numerous trade associations provide technical information for the storage and handling of particular fluids and related activities such as inspection.

For example:

- EuroChlor www.eurochlor.org for chlorine
- Chemical Industries Association www.cia.org.uk for a wide range of chemicals.
- British Compressed Gases Association www.bcga.co.uk for gases.
- Safety Assessment Federation SAFed www.safed.co.uk for steam and also for inspection and risk management
- Institute of Petroleum www.petroleum.co.uk for oil industry products

B.2.8 Chemical Suppliers

Many suppliers of fluids provide technical information for the storage and handling of their products. This often includes recommendations for piping, such as the need for cleanliness for liquid oxygen piping, the need for PWHT for anhydrous ammonia piping etc.

B.2.9 Training

Institution of Chemical Engineers www.icheme.org

Safety Training Packages

- 012:Safer Piping
- 020:Learning from Accidents

- 025:Modifications-the Management of Change
- 032:Safety Management Systems

Courses

- Chemical Plant Commissioning
- Design for Safe Handling of Industrial Chemicals
- Hazard Studies in Project Management
- Pressure Relief-A Proven Approach

Institution of Mechanical Engineers www.imeche.org

Courses

- Introduction to Pressure Systems
- Design of Piping Systems

Chemical Industries Association www.cia.org.uk

NVQs on Process Engineering Maintenance and Process Operations and Process Manufacture

B.2.10 Text Books

- Crocker & King, “Piping Handbook”, McGraw-Hill. ISBN 07-013841-9.
- Smith P E and Van Laan P E, “Piping and Pipe Support Systems, McGraw-Hill, ISBN 0-07-058931-3.
- Bickford J H, “An Introduction to the Design and Behaviour of Bolted Joints”, Marcel Decker, ISBN 0-8247-8167-8.
- Thompson G, “An engineer’s guide to pipe joints”, Professional Engineering Publishing, ISBN 1 86058 081 5
- “Pipe Joints – a state of the art review, IMechE, 1984
 - Part 1 – Gaskets ISBN 0 85298 553 3
 - Part 2 – Non-metallic ISBN 0 85298 554 1
 - Part 3 – Metallic pipe joints ISBN 0 85298 611 4
- “ Guidelines for the avoidance of Vibration Induced Fatigue in Process Pipework”, MTD, ISBN 1 870553 373

B2.11 Process Industry Practices www.pip.org

APPENDIX C: PIPEWORK ACTIVITY LIFE CYCLE MODEL

A model has been developed showing the flow of key activities during the life cycle of pipework. This model also describes the main linkages between the activities. The corresponding table describes the key measures necessary for each activity, and highlights relevant guidance and legislation.

The life cycle model and table have been shared with various contacts within the Petroleum Refining and Chemical Industries. They have been tested against several individual company systems for pipework design, maintenance, and inspection, and reflect generally agreed best practice.

As part of the discussions with industry contacts, deficiencies in pipework design, maintenance, and inspection work practices & procedures were discussed, and best practices shared. This has helped to ensure that the recommendations for improvement are focused on the areas that should provide the greatest benefits.

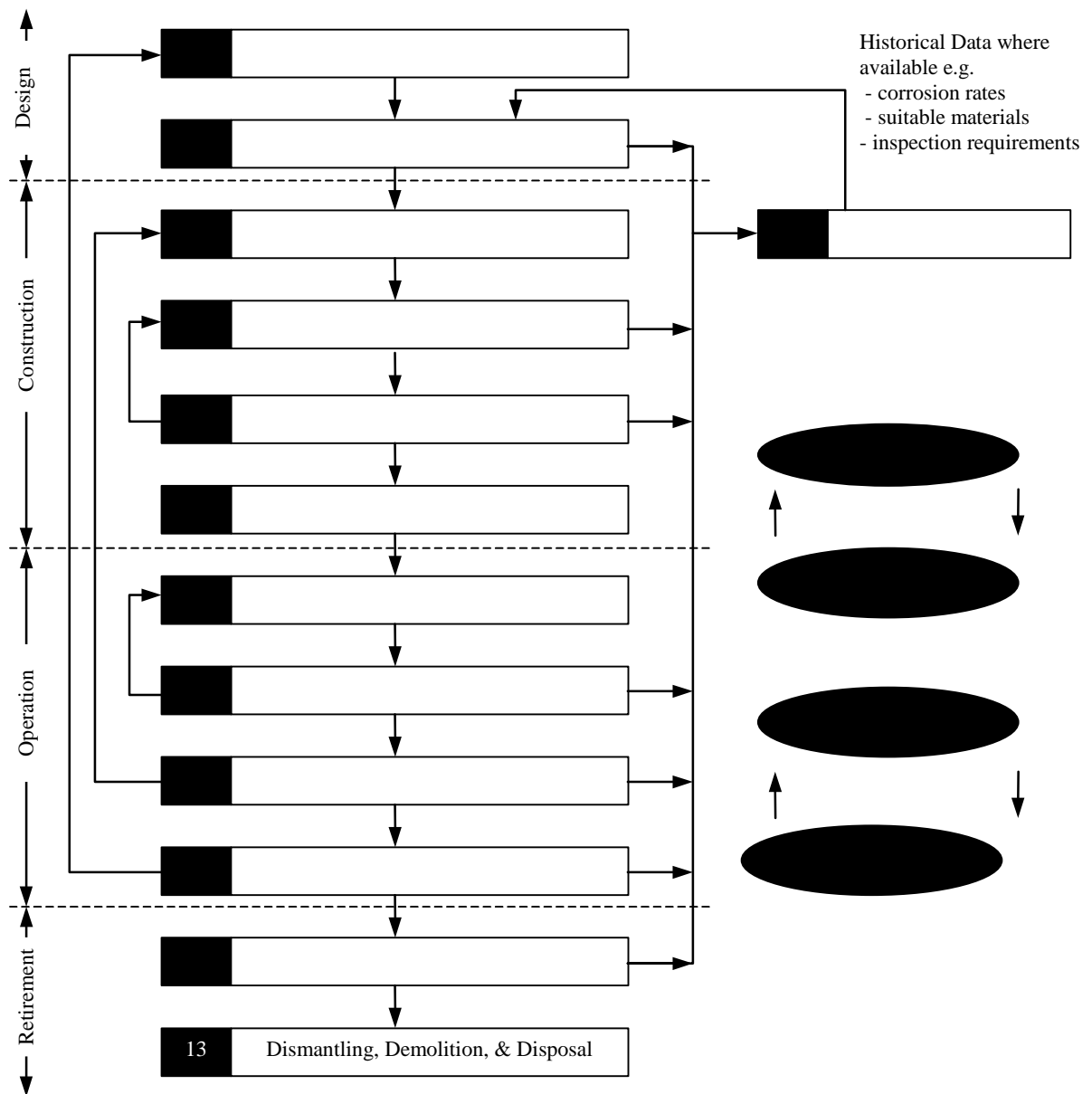


Figure 1
Pipework Activity Life Cycle

Table 1
Pipe activity lifecycle; key measures, guidance and legislation

Pipework Lifecycle Activity	Key Measures	Guidance	Legislation
1. Scope Definition	<ul style="list-style-type: none"> • Purpose • Environment 	<ul style="list-style-type: none"> • ACOP - L1 HSW 	<ul style="list-style-type: none"> • HSW Act
2. Design	<ul style="list-style-type: none"> • Establish appropriate regulation & standards, including risk assessment (e.g. PER, ASME B31.3,) • Establish requirements for design (process conditions, operating conditions including upsets & contaminants) • Process engineering documentation package • Selection of appropriate materials of construction • Detailed mechanical design • Mechanical design documentation package • Design review or Hazop 	<ul style="list-style-type: none"> • ACOP – L122 PSSR • ACOP- L54 CDM • BS7000-4 Guide to Managing Design in Construction • ISO 15649 Petroleum and Natural gas Industries – Piping • ASME B31.3 Process Piping • NACE / In-house experience • Guidelines for the Avoidance of Vibration Induced Fatigue in Process Pipework 	<ul style="list-style-type: none"> • HSW Act • PSSR - Reg. 4 • PER • CDM Regulations
3. Asset Records	<ul style="list-style-type: none"> • Maintenance of documentation • Access & security 	<ul style="list-style-type: none"> • ACOP – L122 PSSR 	<ul style="list-style-type: none"> • PSSR – Reg. 7, 14
4. Procurement	<ul style="list-style-type: none"> • Appropriate suppliers • Compliance with specification • Positive material identification where appropriate • Deviations recorded and documented • Procurement QA system 	<ul style="list-style-type: none"> • BS 7339 Material identification 	
5. Fabrication, Construction, & Testing	<ul style="list-style-type: none"> • Compliance with design & construction specifications • Appropriate fabricators • Quality assurance • Safe systems of work • Construction documentation • Deviations / concessions recorded • Confirmation of integrity as appropriate (pressure testing / NDT etc.) 	<ul style="list-style-type: none"> • ACOP – L122 PSSR • ACOP – L54 CDM • ASME B31.3 Process Piping • Process Industry Practices • GS4 – Safety in pressure testing • ASME PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly 	<ul style="list-style-type: none"> • CDM Regulations • PSSR - Regs. 4,5,6 • PER

Pipework Lifecycle Activity	Key Measures	Guidance	Legislation
6. Handover / Acceptance	<ul style="list-style-type: none"> • Handover / acceptance System • Compliance with specifications 	<ul style="list-style-type: none"> • ACOP – L54 CDM 	<ul style="list-style-type: none"> • CDM Regulations
7. Commissioning	<ul style="list-style-type: none"> • Commissioning plans & procedure • Validation of design assumptions e.g. vibrating pipework / correct operation / setting of spring pots 	<ul style="list-style-type: none"> • ACOP – L122 PSSR 	<ul style="list-style-type: none"> • PUWER • PSSR – Reg. 11
8. Operation	<ul style="list-style-type: none"> • Operating instructions / procedures which have clearly defined operating boundaries including allowable start-up / shut-down excursions • Emergency procedures • Management of change procedure • Adequate management systems to ensure pipework is operated within agreed boundaries e.g. corrosion inhibitor monitoring & control system including cathodic protection where necessary • Reporting of abnormal operation, or excursions beyond operational boundaries including notification to in-service inspection organisation 	<ul style="list-style-type: none"> • ACOP – L122 PSSR 	<ul style="list-style-type: none"> • PSSR – Regs. 7, 10, 11

Pipework Lifecycle Activity	Key Measures	Guidance	Legislation
9. In-Service Inspection	<ul style="list-style-type: none"> • Classification • Review of degradation / deterioration mechanisms • Multi-discipline review team • Identification of safe operating envelope • Written scheme of examination • Competent inspection engineers • Inspection management systems • Suitable Inspection policy for pipework supports / coating / lining / insulation • Suitable identification and attention to areas of the system that have unusual operational characteristics e.g. dead legs, start-up and shut-down lines, injection points, stagnant area • Examination & report • Multi-discipline review of inspection report , appropriate action agreed, recorded, and initiated • Root cause analysis of pipework failures • Regular review of pipework classification and written scheme of examination • Management of change procedures 	<ul style="list-style-type: none"> • API 570 - Piping inspection code: Inspection, repair, alteration, and re-rating of in-service piping systems • API RP 574 Inspection practices for piping system components • API RP 579 – Fitness for Service • API RP 580 – Risk-Based Inspection • API 581 Base Resource Document – Risk Based Inspection • Best practice for plant integrity management by risk based inspection – TWI/HSE research report • BS 6129: part 1: 1981 the selection and application of bellows expansion joint for use in pressure systems • ASME B31G – Manual for determining the remaining strength of corroded pipelines (n.b. limited applicability for pipework) • ACOP – L122 PSSR • IP – Institute of Petroleum documents • EEMUA guidance documents 	<ul style="list-style-type: none"> • PSSR – Reg. 8

Pipework Lifecycle Activity	Key Measures	Guidance	Legislation
10. Maintenance, Repairs, & Replacement	<ul style="list-style-type: none"> • Systems to ensure deficiencies identified by inspection are rectified and documented • Control of bolted joints • Selection of gaskets • Leak testing following maintenance • Confirmation of integrity as appropriate (pressure testing / NDT etc.) • Control of temporary pipework repairs e.g. clamps • Documentation 	<ul style="list-style-type: none"> • ASME PCC-1 – Guidelines for Pressure Boundary Bolted Flange Joint Assembly • Gaskets – company in-house standards / gasket manufacturers • ACOP - L21 MHSWR • ACOP - L22 PUWER • ACOP – L122 PSSR • GS4 – Safety in pressure testing 	<ul style="list-style-type: none"> • PSSR - Reg. 12 • PUWER - Reg. 5 • HSW Act • MHSWR
11. Modification, Re-rating, & Life Extension	<ul style="list-style-type: none"> • Modification programme in place which includes requirement to: • Reference original design specifications • Consider new duty, including any change in fluid or contaminants • Ensure operational changes taking pipework beyond documented design basis are reviewed as modifications • Check integrity of modification • Ensure protective devices still adequate • When extending life of asset beyond the original design life, thorough review carried out of design basis, current condition, current rates of degradation in order to identify fitness for continued service • Review written scheme of examination and ensure continued suitability 	<ul style="list-style-type: none"> • API 570 – Piping inspection code: Inspection, repair, alteration, and re-rating of in-service piping systems • BSI – PD6510 – Assessing remanent life of pressurised systems. • ACOP – L122 PSSR 	<ul style="list-style-type: none"> • PSSR, Reg. 13
12. Decommissioning	<ul style="list-style-type: none"> • Adequate preparation / mothballing for possible re-use • Adequate on-going maintenance of asset. 		<ul style="list-style-type: none"> • HSW Act

Pipework Lifecycle Activity	Key Measures	Guidance	Legislation
13. Dismantling, Demolition, & Disposal	<ul style="list-style-type: none"> • Redundant pipework should be removed where possible 		<ul style="list-style-type: none"> • CDM Regulations



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