SAFETY ASSESSMENT FEDERATION

Guidelines

Pressure Systems

Guidelines for Competent Person In-service examination of pressure systems pipework

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1. INTRODUCTION

The purpose of these Guidelines is to provide guidance to competent persons on in-service examination of typical industrial or commercial pipework systems containing steam, air or other relevant fluids. These Guidelines are intended to provide a consistent approach to inclusion of pipework within a written scheme of examination (WSE) and to establishing appropriate examination regimes. Large-scale, complex pipework systems such as those at petroleum refineries and major chemical plants require a comprehensive pipework integrity management programme and are outside the scope of this document. Pipework requiring examination under these Guidelines will be part of a pressure system subject to the Pressure Systems Safety Regulations (PSSR) but the examination philosophy can be applied to other pipework systems where the owner/user requires examination to be carried out. The PSSR take account of the risks due to the release of stored energy and the scalding effect of steam. However, owners and users of pipework systems may need to consider system contents that could create other hazards if release should occur.

The experience of SAFed member companies is that owners and users of pressure systems may take different approaches to application of the PSSR to pipework examination. The Guide to the PSSR, included in the Approved Code of Practice, suggests that most pipework systems do not need to be included within a WSE, however any exclusion must be justified and agreed by the user. This justification may be challenged at any time by the relevant enforcing authorities. The examination requirements specified within a WSE by competent persons also vary. The terminology used to describe a system of pipes conveying a fluid from one location to another varies but in this document 'pipework' is used as a general term to cover any system of pipes, piping or pipeline together with associated components such as hoses, flanges, valves, supports and anchorages. Where pipework crosses the boundaries of premises this is defined as a pipeline within PSSR. This brings in specific responsibilities under PSSR for pipelines > 2 bar and may be subject to further legislation such as the Pipeline Safety Regulations, as amended.

The original design and construction of the pipework should have been carried out to appropriate standards. Any in-service examination programme will be based on the premise that the initial integrity of the system was satisfactory and that any modifications have been carried out to the same standards. Where there are obvious deficiencies in the pipework system it will be necessary to carry out a special assessment of the pipework integrity before a suitable examination scheme can be put in place.

2. SCOPE

This document provides a risk-based approach to determining whether a pipework system containing a relevant fluid requires examination within a WSE and provides guidance on pipework examination, repairs and modifications. It covers the full range of pipework sizes commonly included as part of pressure systems.

A relevant fluid is defined within PSSR as:

A. steam;

B. any fluid or mixture of fluids which is at pressure greater than 0.5 bar above atmospheric pressure, and which fluid or mixture is –

1. a gas, or

2. or a liquid which would have a vapour pressure greater than 0.5 bar above atmospheric pressure when in equilibrium with its vapour at either the actual temperature of the liquid or 17.5 degrees Celsius; or

C. a gas dissolved under pressure in a solvent contained in a porous substance at ambient temperature and which could be released from the solvent without the application of heat;(1)

(1) Part (c) of the definition of a relevant fluid covers the storage of acetylene in cylinders so is not relevant to PSSR although acetylene gas in pipework will come under the regulations when at a pressure >0.5 bar.

Small-bore pipework ≤ DN25(2) at pressures up to 40 bar does not present a significant risk of release of stored energy. Pipe wall thickness for small bore pipe is generally comparatively greater than for larger bores so there is a greater factor of safety and because of the low volume per unit length the stored energy is low. In addition the lower fluid flow rates through small-bore pipework reduce the consequences of a failure. Even for pipework carrying hazardous gases being supplied in accordance with the Pressure Equipment Regulations, there are no requirements for conformity assessment by a Notified Body for sizes up to DN25 and for sizes between DN25 and DN100 up to PS(3) x DN = 1000

(2) DN is the nominal size of pipework components (mm)

(3) PS is the design pressure (maximum allowable pressure) (bar)

In the particular case of steam pipework the risk of water hammer is present when the fall of the pipework and the drainage provisions permit pockets of water to accumulate. Whilst water hammer is a result of operational problems, rather than release of stored energy, the consequences can be very serious and it is important to check drainage provisions as part of routine examinations. In particular the suitability of condensate drainage provisions during shut-down and start-up conditions needs to be considered. Regular maintenance and checking of steam traps is necessary to ensure that the pipework condensate removal functions correctly. The competent person may need to confirm that steam trapping arrangements appear functional at the time of the examination.

Compressors, pumps and other mechanical equipment where pressure containment is not a fundamental criterion of the design need not be included within examination requirements but should be subject to appropriate maintenance. Where non-metallic pipework systems are included within examination requirements it may be necessary to involve technical specialists where more than visual examination is deemed appropriate.

3. REQUIREMENTS OF PRESSURE SYSTEMS SAFETY REGULATIONS

The following extracts from HSC Publication L122, 'Safety of Pressure Systems', The Pressure Systems Safety Regulations 2000 - Approved Code of Practice - are particularly relevant:

- Para. 102. The effect of regulation 8 is to enable the exclusion of most 'pipework' from the written scheme where appropriate. It should be noted, however, that all pipework, irrespective of diameter or pressure, will be subject to the initial integrity, installation, operation and maintenance provisions.

- Para. 110 (c). Pipework, which is widely defined to include pipes, associated valves, pumps, compressors, hoses, bellows and other pressure-containing components, will only need to be included in the (written) scheme if:

- Its mechanical integrity is liable to be significantly reduced by corrosion, erosion, fatigue or any other factors; and

  Failure resulting in the sudden release of stored energy would give rise to danger

It is, therefore, only necessary to include pipework within a WSE when it is subject to a significant degradation mechanism and where failure would result in a sudden release of stored energy that would give rise to danger

The extent of the pipework under consideration needs to be specified. Pipework is generally considered to start at the isolation valve connected to a pressure vessel. Where there is no isolation valve between the pipework and the pressure vessel it may be necessary to advise that a suitable valve be fitted or to consider the pipework up to the first valve as part of the pressure vessel. When the fluid falls to such a pressure or temperature that the contents are no longer a relevant fluid then such parts of the system do not come under the regulations. Even when pipework and pressure vessels have been excluded from examination requirements within a WSE (e.g. because there is no relevant fluid in that part of the system) any protective devices should still be included where their failure or malfunction could create danger elsewhere in the system.

For large systems it may be convenient to break the pipework down into discreet sections so that the WSE does not become too complex. In this case the termination points of each section need to be clearly defined and care is necessary to ensure that all appropriate parts are covered in the WSE. It may be useful for the owner/user to provide piping isometric drawings for these sub-systems to target and record inspection findings.

Pipework is generally defined as transporting fluids within a system rather than storing, as in the case of pressure vessels. Some large diameter pipework sections and manifolds, however, can possess considerable stored energy compared with small pressure vessels. These may warrant examination regimes that are more onerous than such pressure vessels to take account of the risks of release of stored energy.

The pipework to which a transportable pressure receptacle (4) is, or is intended to be, attached is defined as a pressure system within PSSR. Such pipework is often small bore and low pressure and presents little risk from the release of stored energy. However, where the pressure is >0.5bar, a WSE would normally be required, even though it may be acceptable to exclude the need for examination by a competent person.

[4]This can also mean an old pressure receptacle or transportable pressure equipment as defined in the Carriage Regulations

4. HAZARD ASSESSMENT

The susceptibility of the pipework to degradation and the consequences of failure needs to be taken into account in determining whether pipework should be included in a WSE. The flow chart in Figure 1 can assist. For other hazards due to toxic or flammable contents reference should be made to section 7.

The diameter and pressure of pipework systems needs to be taken into account to determine the hazard due to release of stored energy.

The following criteria shown Table 1 can be used to assist in deciding what parts of a pipework system need to be considered:

Table 1 — Hazard assessment criteria

	Relevant fluids other than steam	**Steam, or hot water > 110°C**
Diameter	>DN 150	>DN 50
OR		
PS x DN	>10^3 bar mm	>10^3 bar mm

Pipework falling below the above criteria is generally not considered to pose a risk from the sudden release of stored energy or scalding in the case of steam. However pipework systems need to be considered on a case by case basis taking account of the likely proximity of personnel so may need to be included in a WSE in certain circumstances.

Systems above these thresholds should be considered and susceptibility to deterioration and system location taken into account to determine examination requirements. These limits are based on experience of the consequences of failures where there was a possibility of release of stored energy and take into account the low hazard categories for pipework within Pressure Equipment Regulations.

Where small bore connections are made into larger pipework sections it may be necessary to consider the possibility of fatigue failure at the connection where a failure or leak could lead to a serious incident.

Most pipework failures are due to external corrosion, particularly under lagging. Deterioration mechanisms that may need to be taken into account where appropriate include:

External corrosion — Where continuous operation at high or low temperature will cause any moisture to evaporate or freeze, external corrosion should not occur. However, when operating or standing out of use at temperatures where moisture can be present or condensation can occur on pipework (for carbon steel -4°C to +120°C), the possibility of external corrosion needs to be assessed. Particularly susceptible areas are at temperature transition points such as at the termination of insulation or soil/air interfaces. Suitable protective coatings are effective at preventing corrosion but localised corrosion can occur where coatings are damaged, for example by movement at supports, or where restricted access prevents effective application.

Internal corrosion — Depends on materials of construction and nature of contents. Threaded connections can be susceptible to corrosion where the threads do not provide an effective seal against the contents.

Erosion — Particularly at sharp bends, at and just downstream of injection points and at changes of section

Stress corrosion cracking — In particular caustic cracking of steam pipework due to carryover and chloride stress corrosion cracking of austenitic stainless steel pipework.

Fatigue due to cyclic stresses — Small branches are particularly susceptible where loads are applied to the branch or where they are anchored and cannot allow for expansion or movement of the main pipe.

Thermal fatigue — Where rapid temperature changes can occur.

Corrosion fatigue — Where cyclic stresses are present in a corrosive environment.

Mechanical damage — Including wear at threaded connections.

Vibration fatigue — From pumps or compressors, particularly at small bore connections

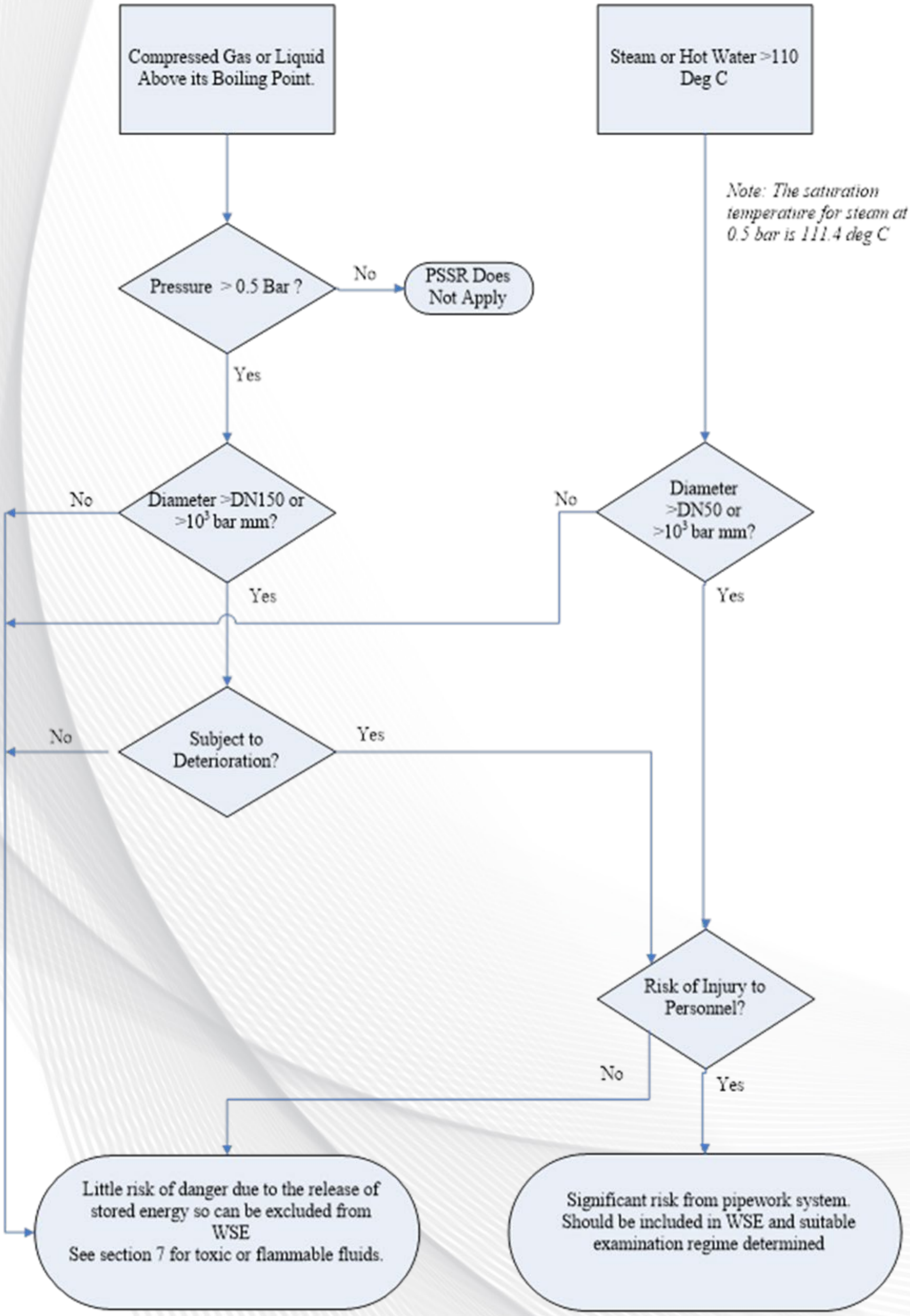
Creep — In high temperature pipework.

Flange leakage and flange bolt failure.

Failure of supports and anchorages can lead to unacceptable stresses.

Bellows and expansion joints — Are often vulnerable components.

Figure 1 — Assessment of pipework >DN25 for inclusion in WSE



5. PIPEWORK EXAMINATIONS

Having decided that a pipework system is subject to degradation and that the consequences of failure are not acceptable, the scope and frequency of examinations need to be determined. An assessment is necessary by the owner/user and the competent person to determine the requirements for external examination and, where appropriate, thorough examination. Where pipework is part of a system that is subject to PSSR, the results of this assessment should be documented in a WSE.

5.1. External Examination

Except in particular circumstances such as buried pipework, the examination will generally include walking the length of the pipework to assess its external condition. It may be necessary to provide additional access at certain locations where problems are suspected or further investigation is required.

The object of this examination is to determine if any deterioration is evident and to check for:

- Corrosion
- Leakage
- Damage to insulation or protective coatings
- Mechanical damage including misuse
- Condition of supports and anchorages
- Sagging or excessive movement of the pipework
- Vibration
- Condition of flanges, valves and connections

The examination will generally be carried out under normal operating conditions but can be carried out with the pipework depressurised or under other conditions, for example hydraulic test, at the discretion of the competent person.

5.2. Thorough Examination

The scope and frequency of thorough examinations will depend on the possible failure mechanisms and the rate of deterioration that could affect the pressure integrity of the pipework. Pipework systems can extend for many metres and be situated in awkward locations such as roof spaces and pipe racks. Unless particular problems are found, thorough examinations will be carried out on selected parts of the system, deemed to be representative of the rest of the system, at locations likely to be most severely affected, or where the risks of failure are unacceptable.

External corrosion can be assessed visually and by thickness testing except where pipework is lagged or concealed, for example in covered trenches or under clamps and supports. Sample areas of lagging removal or exposure of parts of the pipework will generally be necessary under these circumstances. Where the lagging is in good condition and there is no evidence of water ingress then the number of thickness testing points can be kept to a minimum with sample locations at low points, bends, supports and Tee's providing confirmation that deterioration is not occurring. If corrosion under insulation is occurring then sufficient lagging removal will be necessary so that the full extent of the corrosion and the minimum remaining thickness can be determined and evaluated.

Where internal corrosion/erosion can occur the thorough examination will involve an assessment of the internal condition of the pipework. This will normally be accomplished by non-invasive means such as ultrasonic thickness testing and can be carried out with the pipework either in or out of service. For steam mains that are not shut down periodically, and where ultrasonic thickness testing in service would create practical difficulties, it will be necessary to determine whether tests on other parts of the steam pipework will be representative of the steam main. Where pipework could corrode internally at different rates around the circumference, for example due to stratified flow or corrosive substances remaining in the lower parts when drained, it may be appropriate to carry out thickness scans around the circumference rather than spot readings. Only in exceptional circumstances will removal of sections of pipework need to be considered.

Other techniques that can be used for determining the condition of corroded pipework include:

- Long range ultrasonic testing
- Use of intelligent 'pigs' in the pipework
- Flash radiography
- Profile radiography
- Remote cameras
- Thermography
- Pressure testing

Individual circumstances will dictate when these techniques can be a viable part of the thorough examination but modern non-destructive testing techniques can be much more cost effective than extensive lagging removal or taking out sections of the pipe for examination.

Where fatigue or other cracking can occur it may be necessary to include crack detection techniques as part of the thorough examination. These can include:

- Ultrasonic testing
- Magnetic particle testing
- Dye penetrant examination
- Eddy current testing

- Metallurgical examination and replication
- Radiography

Again individual circumstances, materials of construction, location, type and extent of possible defects will dictate which techniques are most appropriate.

Care needs to be taken when assessing older pipework systems to avoid extensive repair requirements that may not be necessary. The welding of many existing pipework systems may have flaws that would not pass modern non-destructive testing procedures and acceptance criteria in current standards. However, with the low stresses involved and large factors of safety such welds may be suitable for many more years of safe operation. Providing that the pipework system does not have a history of leaks and weld failures, and where a minor leak would not create a significant hazard, it may be more practical to base a judgement of integrity on a history of safe use and limit any non-destructive testing to vulnerable parts of the system.

5.3. Buried Pipework

Whilst the danger due to the release of stored energy may be reduced by burying pipework, failure can still result in sudden displacement of earth, paving, etc. and contamination of surroundings due to leaking pipework needs to be considered. Because of the inaccessibility of the pipework for external or thorough examination it is normally necessary to excavate sections periodically whenever examinations are required unless other suitable techniques can be utilised. Particular care is required not to damage the pipework or protective coatings when excavation is required and where coatings have to be removed for testing they must be reinstated in a suitable manner.

The examination periods in the following section can be used as a guide for buried pipework but the nature of the external environment will be dependant on the quality and durability of the protective coatings and additional external examinations may be required to confirm that protective coatings are performing in a satisfactory manner.

5.4. Examination Periods

For common situations the following examination periods, shown in Table 2, are suggested based on SAFed's extensive experience with pressure systems. They will depend on the level of normal maintenance and individual site conditions so it is necessary to confirm that they are suitable in each case:

Table 2 — Examination periods — Common situations

Duty	External	Thorough
Non-corrosive	36/38 months	Not applicable [a]
Corrosive environment	24/26 months	24/26 months [b]
Corrosive or erosive contents	24/26 months	24/26 months [b]
Steam	24/26 months	24/26 months [c]
Fatigue	As above but subject to remnant life assessment	As above but subject to remnant life assessment
Creep	As above but subject to remnant life assessment	As above but subject to remnant life assessment
Notes. (a) The external examination can be supplemented by additional tests or examinations to confirm integrity where the consequences of failure are high. (b) This period may be extended up to 72 months depending on the rate of corrosion and the condition of the pipework. (c) This period may be extended to 48/50 months when the pipework is in good condition and is not in a corrosive environment		

5.5. Examination of Protective Devices

Protective devices mounted on pipework are not considered as part of the pipework and would be identified separately in a WSE. They may need examination at more frequent intervals than the pipework on which they are situated. Where appropriate they should be examined/tested at the frequencies specified in SAFed Guidance, 'Guidelines on Periodicity of Examinations' (PSG1).

Where liquid can be trapped between closed valves in pipework, liquid relief valves or an expansion vessel should be fitted to prevent over-pressurisation of pipework due to expansion of the liquid should the temperature rise. Liquid relief valves need to be removed and tested periodically to ensure that they will still function, normally 5 or 10 years depending on duty.

5.6. Other Components

Flexible hoses and bellows units may comprise part of the pipework system and should be included in the written scheme where appropriate. Because of their susceptibility to physical damage flexible hoses should be visually examined by the operator each time before use. In addition they should be visually examined for alignment, kinks and torsional loadings at each examination and referred back to the manufacturer for re-certification and testing at the specified frequency.

Bellows units need to be installed so that they take account of movement of the pipework. Suitable anchors should be installed to prevent extension of the bellows and they should not be used to take up misalignment of the pipework. Examinations should confirm that the installation is satisfactory and that the convolutions of the bellows are not twisted.

6. REPAIRS AND MODIFICATIONS

Repairs and modifications need to be carried out to suitable standards, normally at least equivalent to the original pipework. Significant modifications to pipework may be subject to the Pressure Equipment (Safety) Regulations (PE(S)R) although a Notified Body will only need to be involved in larger diameter high pressure systems. The appropriate classification charts in PER need to be consulted to determine the conformity assessment requirements for the pressure and DN of the pipework.

Whichever regulations apply, the repairs or modifications should be carried out to suitably documented procedures. Records of the following should be available to confirm that the work has been carried out correctly:

Design drawings

Method statement

Material certificates for pipe, flanges, bolting and other pressure components

Weld procedure approvals

Welder certification

Examination records

Pressure test report

Non-destructive testing records

Records of any heat treatment carried out

Prior to any repair or modification being carried out the condition of the pipe should be determined to ensure that any repair technique used does not affect the integrity of the pipework.

It is important to consider the flexibility of pipework systems when carrying out repairs or modifications. If additional restraints are imposed on the system by modifications this can have a major effect on its flexibility.

Leak sealing repairs are sometimes carried out by the use of leak repair clamps. The type of clamp concerned is effectively a split pipe with seals at the ends that can be placed around a leaking pipe or flange and bolted together, containing the leak within the clamp. Sealant may then be injected between the clamp and the pipe preventing the leak. This can be achieved with the pipework under pressure so is used as an alternative to shutting down the system for repair. The repair will stop the leak but does not provide additional axial strength should the pipe be too thin to resist these forces.

Another form of on-line sealing of flange leaks is carried out by injection of sealant between flange faces. Serious incidents have occurred where the flange bolts were weakened and subsequently failed. The condition of bolts needs to be determined before flange leak sealing is carried out in case bolt degradation is the cause of the leak and this is particularly important where the sealing operation needs to be repeated.

Both these methods should be treated as temporary repairs. Where a temporary repair has been carried out there should be an indication of the life expectancy of the repair, details of which should be recorded and the pipework re-instated or replaced accordingly.

7. APPLICATION TO OTHER PIPEWORK SYSTEMS

The hazard assessment in Section 4 is based on the risks due to the release of stored energy and additional requirements may be necessary when there are other hazards present not covered by PSSR.

Owners and users of pipework systems may need to consider system contents that could create other hazards if release should occur. Where the pipework contents are flammable or toxic the consequences of a failure or leak should be taken into account.

For liquids which are not relevant fluids, and therefore not covered by PSSR, there may still be risks due to the release of stored energy at very high pressures where their compressibility could become a significant factor.

The pipework examination philosophy detailed in Section 5 can be used as part of the assessment to determine the examination requirements and these should be documented. It may be useful to produce a WSE similar to that specified in PSSR.

For petroleum refineries, pipework examinations are detailed in API 570. This provides a structured approach to classification of fluids, deterioration mechanisms and examination intervals. However the scope is limited to refinery products so would not apply to most general industrial pressure systems and relevant fluids.

8. REFERENCES

SI 2000 No. 128. The Pressure Systems Safety Regulations 2000

SI 2016 No, 1105 The Pressure Equipment (Safety) Regulations 2016

SI 1996 No. 825 The Pipelines Safety Regulations

HSC Approved Code of Practice. Safety of Pressure Systems. No. L122.

SAFed Guidance PSG1. Pressure Systems. Guidelines on Periodicity of Examinations

Institute of Petroleum. Model Code of Practice Part 13. Pressure Piping Systems Examination

API 570. Piping Inspection Code. American Petroleum Institute