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PIPELINE INTEGRITY REVIEWS

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Abstract

Most pipeline systems in the world are many years old, with some approaching the end of their design lives. Increasingly, the design, operation and condition of these systems have to be reviewed for a variety of reasons:

i. CODE/REGULATORY/COMPANY REQUIREMENTS,
ii. SAFETY – e.g. following a failure, or because of population encroachments,
iii. POOR DOCUMENTATION – ensure or prove continuing integrity,
iv. UPRATING - a need to increase pressure/throughput,
v. CHANGE OF OWNERSHIP,
vi. CHANGE OF USE,
vii. LIFE EXTENSION, beyond original design life.

This paper introduces the reader to Integrity Reviews and gives outlines on how to conduct them, their contents, and analytical methods. These reviews are being successfully used by Andrew Palmer and Associates/Penspen for clients in Europe, Asia, and Africa.

1. INTRODUCTION

Transmission pipelines have an excellent safety record, but – like all engineering structures – they can and do fail. These failures can be caused by mal-operation, outside force, corrosion, pilferage, etc.. Consequently, a pipeline operator must maintain and survey his/her pipeline both thoroughly and regularly to ensure it is not deteriorating or being damaged. Pipelines will need differing maintenance requirements as they age, and consequently a review of the design and operation of pipelines is now a recognised feature of good and safe pipeline management (1).

Additionally, there will be occasions when an operator needs to conduct an ad hoc review of the design and condition of his/her pipeline; for example if the line is to be sold, or needs to be uprated, or if surrounding population density has increased beyond accepted limits.

This paper introduces the reader to these ‘Integrity Reviews’ and gives outlines on how to conduct them, their contents, and analytical methods. It starts with a brief review of the safety of pipelines as they age, to show the reader that ageing

pipelines can, and are being, operated safely, in some cases beyond their design lives.

2. SAFETY OF AGEING PIPELINES

There is evidence that good maintenance and management of ageing pipelines allows them to operate safely for many years.

i. Figure 1 shows safety data from the American Gas Association, covering the 500,000 km gas pipeline system in the USA. The ageing system (much of the system is over 40 years old) is showing an improved safety record with time.

ii. Similarly, data from CONCAWE on onshore liquid lines in Western Europe indicates older pipelines have as good a 'spill' record as younger lines, Figure 2.

Figure 1. Fatalities Caused by Failures in USA Gas Pipelines (AGA Data (2))

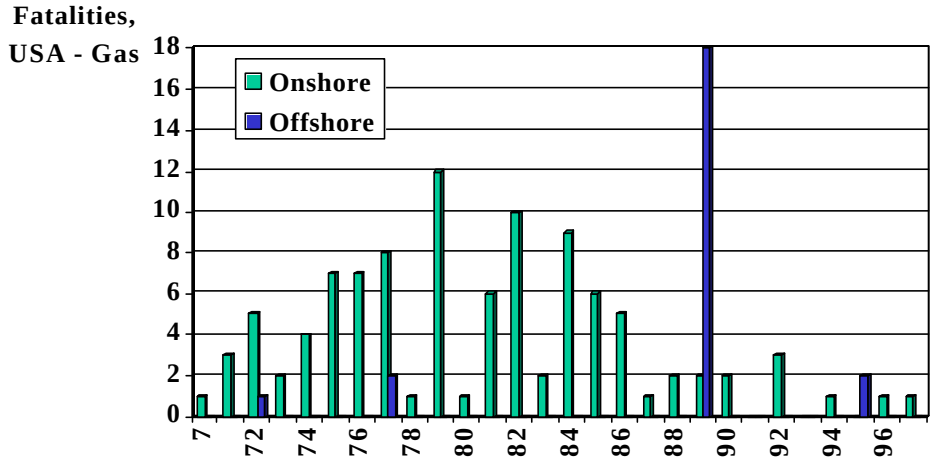
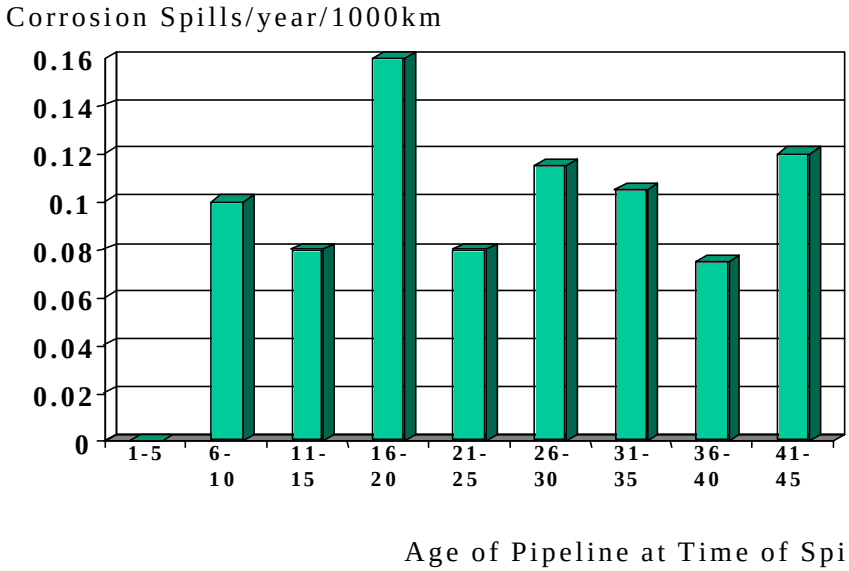
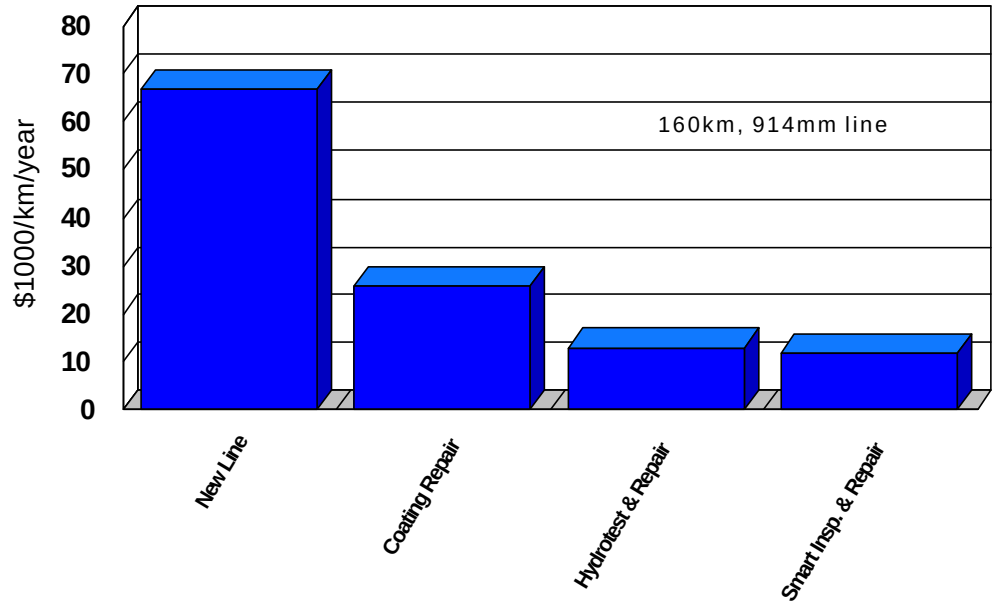


Figure 2. Spills from Western European Liquid Pipelines (CONCAWE Data, (3))



Clearly, good inspection and maintenance are essential for the safety of ageing pipelines (3); many of the pipelines covered by Figures 1 and 2 are now being inspected using smart pigs, and their operators are reviewing their operation using integrity and risk management. Additionally, by proactively reviewing the integrity of your pipeline, you can save much money and ensure integrity (4). For example, Figure 3 (5) shows how an operator maintained pipeline integrity by reviewing various options; this figure shows that you can spend less money (in this case on a smart pig inspection) on an ageing pipeline, and have the same result as replacement or rehabilitation. If the operator had waited too long, he/she would have likely had to replace or recoat the line.

Figure 3. Comparison between replacing an ageing pipeline, and remedial/inspection measures (5).



Reviews of pipeline condition can show how older pipelines can not only be used beyond their design life, but actually be used above their original design limits. For example, Transco (formerly British Gas) conducted an integrity and risk review of several of their main pipelines (6) and showed that these pipelines (over 20 years old) could have their pressure safely increased above design limits to meet increased demand, thus avoiding new constructions.

In summary, ageing pipelines benefit from reviews of the condition and operation, and can be shown to be both safe, and able to operate safely by these reviews. The next sections covers the various needs for these reviews, and how these reviews can be conducted.

3. THE NEED FOR PIPELINE INTEGRITY REVIEWS, AND THEIR BENEFITS

3.1 The Need for Reviews

These are six main reasons why an operator may need to review the integrity[4] of his/her pipeline:

i. CONTINUING SAFETY, SECURITY AND COMPLIANCE - An operator must ensure that their pipeline does not fail or deteriorate to ensure:

-Safety to surrounding people and the environment,
-Legal, Regulatory and Standards compliance,
-Security of supply to customers.

Pipeline and product condition, and surrounding environment, change with time, as do regulatory regimes and standards. Therefore, a regular integrity review of an ageing pipeline is appropriate.

ii. COST EFFECTIVENESS - Every year pipeline operators are faced with a major problem; their major asset has aged a further year. Engineers know that as structures age, they are more likely to fail, and hence they often need more and varied maintenance and inspection with increasing years. Unfortunately, the tendency in engineering companies is to look to reduce maintenance costs, rather than increase them, every year.

Additionally, should a pipeline deteriorate and start failing, both its value and operating costs will badly affected. Consequently, the inspection and maintenance of an ageing pipeline should be carefully and regularly reviewed.

iii. POOR DOCUMENTATION – Older pipelines can have poor documentation. However, these pipelines often have an excellent safety and security of supply record. A review can highlight areas where documentation is missing, and areas that must be covered either by new documentation, or where remedial measures are needed.

iv. CHANGE/EXTENSION OF USE - To decrease operating costs, operators are now looking to transmit other products, increase pipeline capacities, and extend pipeline design lives. Again, the pipeline engineer will need to carefully review all aspects of the pipeline's design and operation to ensure it is safe for different, more onerous, or extended service.

v. REVALIDATION – There are occasions when a pipeline needs to be revalidated, e.g. after a failure, or at the end of design life.

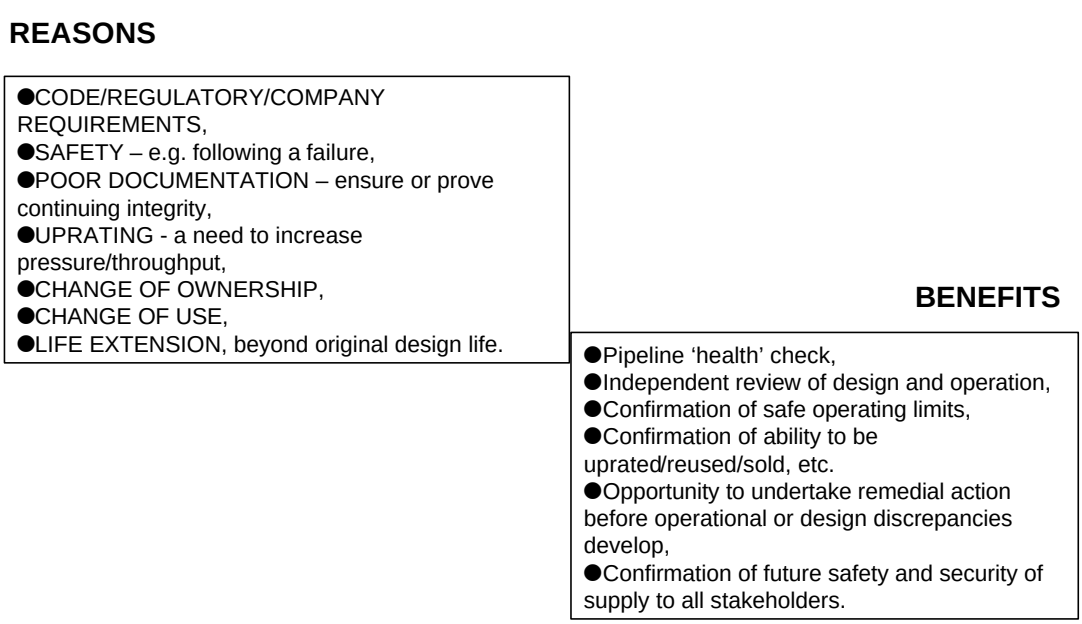
[4] 'Integrity', in this context, usually means a low probability of pipeline failure (or failure to deliver). The USA Office of Pipeline Safety (7) defines 'safety' as 'the protection of the public, environment and property', and 'risk' as 'any threat to achieving these goals'.

vi. CHANGE OF OWNERSHIP/THIRD PARTY ACCESS – Many pipelines are now either being transferred to new owners (e.g. by mergers), or are under scrutiny by third parties wanting to use them to transmit their product. An integrity review is appropriate both for due diligence reasons and also for demonstrating security of (third party) supplies.

3.2 Benefits of a Pipeline Integrity Review

The benefits from an Integrity Review follow on from the needs (Section 3.1). Figure 4 gives a summary of these benefits.

Figure 4. Reasons for, and Benefits from, an Integrity Review



4. CONDUCTING A PIPELINE INTEGRITY REVIEW

The previous section has covered the variety of reasons why an operator would need to conduct an Integrity Review, Figure 4. We will now discuss how to conduct an integrity review. Obviously, a review can be tailored to the operator's needs, and their key objectives; Figure 5 gives an outline of the differing integrity reviews that can be conducted, and the varying amounts of information that will be required. In this paper we will outline a comprehensive review that would cover most objectives.

Before we satisfy the needs, and reap the benefits in Figure 4, we first need to ensure that the pipeline operator has systems and documentation in place (a 'pipeline management system' (1,8)) to allow these reviews.

4.1 Pipeline Management Systems

As a starting point of any pipeline integrity review, it is important that a pipeline operator has a documented management system (1,8) that shows the policies and

procedures in place to deal with all the operation of his/her pipeline system. A complete management system must contain the following:

1. Description of pipeline system, legal & statutory duties,
2. Organisation & control,
3. Key personnel,
4. Stakeholders,
5. Documentation[5] and communication systems,
6. Management of change,
7. Risk analysis, evaluation & control through whole life,
8. Integrity management,
9. Emergency planning,
10. Emergency procedures,
11. Performance measures,
12. Management system review,
13. Management review,
14. Audit of all elements and processes.

The management system is usually a document that will be self-contained, or direct the reader to other company documents that give all the necessary information.

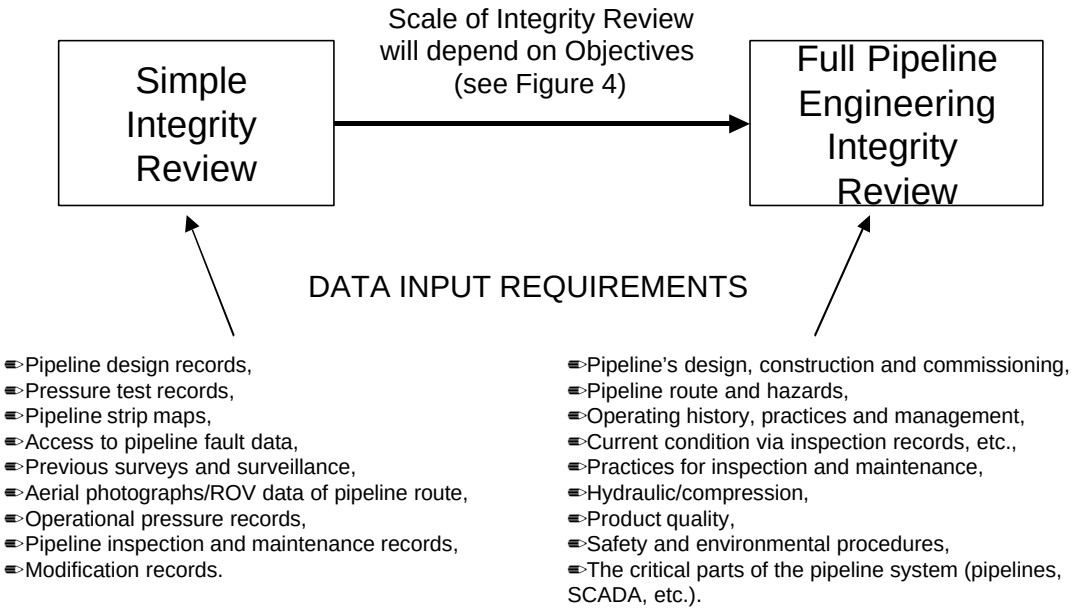
If a company does not have a formal pipeline management system, or its constituent parts, then any integrity review will be slow and difficult to conduct, and many assumptions about the past, present and future state of the pipeline will have to be made.

We will now cover pipeline integrity reviews. As stated above, we can conduct very quick, simple reviews, Figure 5, depending on the objective of the review. The simplest review is called a *simple pipeline risk audit* (5). This review is primarily aimed at ensuring that the risk to surrounding population and the environment are acceptably low, and hence is somewhat limited, albeit highly effective and useful. The difference between an audit and a review is primarily in critique. In an audit we will review specifications and practices, and ensure that what is in place is being implemented. In a review, we will also look at the implementation of these practices and specifications, but we will also critically review the adequacy of these practices, against some agreed benchmark (e.g. ASME B31).

Readers who wish to understand the simple pipeline risk audit are directed to Reference 5.

[5] This documentation system should include original design details, material documents, hydrotest records, failure records, etc..

Figure 5. Types of Integrity Reviews, and Differing Information Requirements



4.2 Pipeline Integrity Reviews

Pipeline operators will often need a thorough review of their pipelines. For example, they may need to review the systems hydraulics if they are wanting to pass more product, or they may need to produce new inspection and maintenance procedures to upgrade and update an ageing system.

We will now cover these Pipeline Integrity Reviews (PIR). It would be better to call them Pipeline Engineering Integrity Reviews, as they cover all aspects of the pipeline engineering, but for brevity we will continue to call them PIRs.

4.3.1 What is a Pipeline Integrity Review?

A PIR is a thorough review of a pipeline system that, as a minimum, will include an analysis of:

1. The pipeline's design, construction and commissioning,
2. Pipeline route and hazards (e.g. proximity of housing, subsidence areas or seabed profile),
3. Operating history, practices and management,
4. Current condition via inspection records, failures, downtime, etc.,
5. Practices for inspection and maintenance of the pipelines,
6. Hydraulic/compression, including delivery forecasts and expansion plans,
7. Product quality; both current and future quality is considered,
8. Safety and environmental procedures and systems,
9. The critical parts of the pipeline system (pipelines, SCADA systems, gas conditioning stations, valve stations, pig launch/receive stations, etc.).

4.3.2 How Do We Conduct A PIR?

The Integrity Review is carried out with a clear objective (e.g. to show that a pipeline can be uprated (with associated costs), or that a pipeline is able to transport third party product reliably and safely), using an agreed programme and execution plan. The review will usually start with extensive data collation at the client's sites, and field visits may be necessary. It will end with a full report on the integrity of the pipeline system, and any corrective actions that are needed.

4.3.2.1 Execution Plan

The PIR must have a clear objective, and an execution plan is tailored to achieve this stated objective. Detailed below (Table 1) is an example of an Execution Plan[6]. It is made general to accommodate a variety of objectives and circumstances.

4.3.3. What Information Will I Need for My PIR?

The information needed for an integrity review depends on its objective, Figure 5. Obviously, if the review is to cover all aspects of the pipeline system, then a large amount of data will be needed.

The quality, reliability and accessibility of information are crucial to the review. If there are few data, or it is of poor quality or unreliable, then the review will need to make major assumptions, and this will affect the conclusions.

4.3.4 The Pipeline Fitness for Purpose and Risk Review

A crucial part of the overall review is the pipeline fitness for purpose (FFP) and risk review. This special part of the overall review focuses on the fitness for purpose of the buried or sub-sea pipeline sections only, and any associated risk.

It is necessary to conduct this special review as:

a. we need to assess, in the overall PIR, the consequences of pipeline failure,
b. the buried or sub sea sections of the pipeline will generally pose the largest risk to population/environment and they will be the parts of the pipeline system that cannot be viewed/visited during site visits.

The ultimate objectives of the FFP and risk review are to:

i. contribute to the overall expert opinion on the integrity of pipeline system,
ii. identify critical sections of the pipeline system (e.g. in terms of security of supply),
iii. assess the remnant life of the pipeline, and its ability to withstand either its existing duty, or change of duty,
iv. provide a review of the risks associated with the pipeline in both its current and future condition.

[6] The execution plan is a detailed and lengthy document, and only a summary is presented below.

Table 1. PIR Execution Plan[7]

ITEM	DESCRIPTION
1. PIR Objective, Scope and Overview of Programme.	i. Descriptions, and ii. Timetable
2. Overview of Activities	i. Office Set Up (if needed), ii. Mobilisation of Review Teams, iii. Kick-Off Meetings/Documentation Review, iv. Data Gathering and Analysis by Discipline (Item 4), v. Integrity and Risk Review (Item 5), vi. Reporting, with Corrective Actions.
3. Activity Schedule	i. Pre-Data Gathering Reviews, ii. Data Analysis & Report Preparation, iii. Review Report Submission, iv. Clarification Meetings on Draft Review Report, v. Final Report and Corrective Actions Report.
4. Scope of Data Gathering Activities by Discipline (many disciplines may be needed during the review)	i. Process, ii. Mechanical, iii. Electrical, iv. Instrumentation/Control, v. Risk and Integrity (Item 5), vi. Pipeline Engineering, vii. Cathodic Protection, viii. Safety and Environment.
5. Pipeline Fitness for Purpose and Risk Review	i. See Section 4.3.4.
6. Additional Information Required from Integrity Review Team	i. CVs of Key Personnel, ii. Organigram, iii. HSE Plan, iv. Security Plan (if necessary), v. Environmental Plan, vi. QA Plan, vii. Communications.

These objectives are achieved by:

a. Identifying the hazards associated with each section/pipeline in the system,
b. Using fitness for purpose methods (9) and qualitative risk assessment to aid in assessing the risk associated with each section/pipeline.

4.3.4.1 Methodology of Risk Review

The basic methodology of the risk-ranking scheme uses the concept of qualitative risk. Qualitative risk is different from quantitative risk in that it is based on a ranking of the probability of failure and consequence of failure developed using simple characteristic equations, expert knowledge and judgement, and previous operational experience and history. Qualitative risk does not require complex

[7] © Penspen Ltd

mathematical solutions, or large amounts of statistical data, but is reliant on the operator knowing their system and its problems.

The risk equation can be presented as:

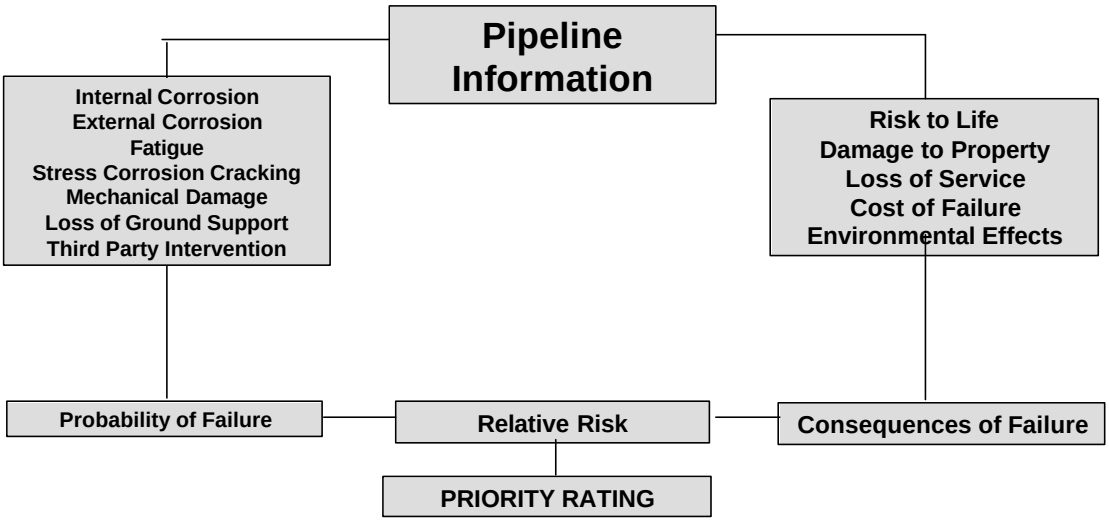
Risk = Probability of Failure x Consequence of Failure

The probability of failure, in the Penspen/APA scheme, is determined by assessing all potential failure modes, and is similar to current practice in the industry (10-13), Figure 6. These modes can include: internal corrosion, external corrosion, fatigue, stress corrosion cracking, mechanical damage, third party intervention, loss of ground support , etc..

The severity of the failure can be combined to give a probability of failure ranking. These consequences comprise: risk to life, damage to property, loss of service, cost of failure, environmental effects, etc..

Combining the sum of these provides the overall risk ranking. This risk number can then be used to rank each pipeline or pipeline segment in terms of safety and security, and then assess the need for inspection, maintenance, or repair. Alternatives can then be assessed and scenarios developed to permit the operator to understand the impact of each inspection, maintenance, test or repair application.

Figure 6. Outline of Risk Assessment (13)



4.3.4.2 Methodology for Fitness for Purpose Review

This specific part of the pipeline integrity review is necessary to ensure the current and future integrity of the pipeline at the current and future operating conditions. All the previous history of failures, defects, repairs, operational conditions, etc., are investigated and recommendations supplied for monitoring, further assessment,

repair or replacement. This part of the review, like the risk review needs data gathered on:

i. The pipeline design, construction and commissioning,
ii. The pipeline route and hazards,
iii. Operating history, practices and management,
iv. Current conditions (via inspection records, failures, downtime, etc.).

It relies heavily on the information about the condition of the pipeline (e.g. from smart pigging), and uses fitness for purpose methods to assess condition and MAOP. The outcome is an overall view of the condition of the pipeline, and guidance on its future condition, including the determination of the safe operating pressure.

4.3.4.3 Outcomes of Fitness for Purpose and Risk Reviews

i) Modifications - The outputs from these reviews can be used to assess the current suitability of the pipeline for testing and inspection. The current pipeline operation can be reviewed and the effect of certain operations can be highlighted, e.g. replacing sections. The effect of these modifications on integrity can then be assessed.

ii) Option Assessment - Various options for inspection, testing, and repair can be assessed to enable the operator to meet current and future demands for the pipeline system. The optimum solution may include an assessment of:

- Smart pigging,
- Hydrotesting,
- Critical point inspection,
- Cathodic protection testing,
- Repair methods,
- Other rehabilitation methods.

The options can be assessed within the qualitative risk assessment to evaluate the impact of each option on the probability and consequence of failure.

4.3.5 The Role of Smart Pigging in the PIR

Smart pigging is an excellent method of gathering data on the condition of the pipe wall. If smart pigging data is available, it usually provides highly reliable data on corrosion, and in some cases third party interference.

However, the integrity review needs far more than a smart pig run data bank. It requires information on management, operation, maintenance, etc.; internal inspection is only one data source, and one aspect of the maintenance process.

A recommendation from the integrity review can be smart pigging of selected lines. This recommendation will depend on the conclusions of the review. For example if

the major problem in a pipeline is third party interference, then smart pigging is of little preventative use; extra surveillance is needed.

If there is very little data available on the condition of the line, and the line has a history of corrosion problems, then a smart pig run may well be appropriate, even during the integrity review. However, this decision should be made by the integrity team, as an early objective.

4.3.6 Who Should Conduct the PIR?

These reviews are often requested by regulators, new owners or new shippers, and therefore must present an independent view on the pipelines' integrity. Additionally, many differing skills are needed during the review, including:

- design, construction and commissioning of above and below ground plant,
- operation, inspection and maintenance of pipeline systems,
- communications and instrumentation,
- defect assessment, repair and rehabilitation,
- risk and safety assessments,
- management consultancy,
- technical audit.

Therefore, the review must be conducted by an organisation with these varied skills.

4.4 The Pipeline Integrity Review Report[8]

The final report will give an overall view of the condition of the pipeline. This will have followed discussions with the client. The report will normally include recommendations to the client on modifications, repairs, etc., to meet future operational requirements.

Table 2 gives an example of the type of pipeline integrity report used by Penspen/APA.

[8] © Penspen Ltd

Table 2. Final PIR Report[9]

	TITLE	CONTENTS
1	Introduction	Objectives, Background, System Description, Data Gathering Sections, and Client's Management System
2	Stations/Platforms/ Wellheads	Individual station/platform/wellhead integrity reports to include observations and comments from all relevant disciplines, major equipment integrity reviews and comments on operations, maintenance, safety, logistics, with station/platform/wellhead summaries and conclusions.
3	Pipelines	Individual pipeline integrity reports covering ROW's/Sea bed routes, ground movement, spanning, valves, ESDVs, etc., with summaries and conclusions.
4	CP System	An overall review of the CP System covering pipelines, associated plant, buried station/topside pipings, power supply system etc., with summaries and conclusions.
5	Buildings, Workshops and Stores	An integrity report to cover technical matters such as power supplies, air conditioning, workshop adequacy and utilisation, stores operation, control and adequacy of storage capacity.
6	Pipeline System Hydraulics	Hydraulic analysis data for current and future elements.
7a	Safety & Environment	A comprehensive review reporting on company safety & environmental policies, strategies and procedures and the implementation and monitoring of these.
7b	Safety & Environmental Issues	Safety & Environmental issues and observations relating to individual station/topside/beach or pipeline facilities.
8	Operations	An overall Operations Department review summarising the individual facilities reports and assessing the organisation, implementation, manning levels, logistics, training, etc..
9	Maintenance	As for Operations above.
10	Logistic Support	An assessment of road/water/air transport adequacy, availability and reliability, in particular for operations and maintenance activities.
11	Risk and Integrity Assessment Summary	This would address all of the areas covered, in Section 4.3.4 above, giving an estimate of remaining life for all systems based on retaining compliance with governing codes.
12	Recommendations	A summary of recommended corrective actions, using cross references to the sections mentioned above.

[9] © Penspen Ltd.

5. CONCLUSIONS

1. Many pipeline systems in the world are ageing, with some approaching the end off their design lives. Increasingly, the design and operation of these systems have to be reviewed for a variety of reasons, including:

- CODE/REGULATORY/COMPANY REQUIREMENTS,
- SAFETY – e.g. following a failure, or because of population encroachments,
- POOR DOCUMENTATION – ensure or prove continuing integrity,
- UPRATING - a need to increase pressure/throughput,
- CHANGE OF OWNERSHIP,
- CHANGE OF USE,
- LIFE EXTENSION, beyond original design life.

2. Integrity Reviews can be conducted on these pipelines in a systematic manner. They provide:

- Pipeline 'health' check,
- Independent review of design and operation,
- Confirmation of safe operating limits,
- Confirmation of ability to be uprated/reused/sold, etc.,
- Opportunity to undertake remedial action before operational or design discrepancies develop,
- Confirmation of future safety and security of supply to all stakeholders.

3. This paper has presented a Pipeline Integrity Review that can be used on either onshore or offshore pipelines. These reviews are being successfully used by Andrew Palmer and Associates/Penspen for clients in Europe, Asia, and Africa.

Acknowledgements

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REFERENCES

1. Hopkins, P., 'Risk and Integrity Management of a Transmission Pipeline System', Conference on 'Ageing Pipelines. Optimising the Management and Operation. 'Low Pressure-High Pressure''. IMechE, Newcastle upon Tyne, October 1999.
2. Vieth, P.H., Roytman, I., Mesloh, R.E., Kiefner, J.F., Analysis of DOT Reportable Incidents for Gas Transmission and Gathering Pipelines - Jan. 1, 1985 through Dec. 31, 1994, Topical Report to Line Pipe Research Supervisory Committee of the Pipeline Research Committee of the American Gas Association, A.G.A. Catalog No. L51745, May 31, 1996.
3. Anon., '25 Years of CONCAWE Pipeline Incident Statistics', Volume 6-Number 2-October 1997.

4. Trefanenko, B et al., 'Risk Assessment: an Integrity Management Tool', Pipeline Risk Assessment, Rehabilitation and Repair Conference, Houston, 1992.
5. Hopkins, P., Fletcher, R., Palmer-Jones, R., 'A Method For The Monitoring And Management Of Pipeline Risk – *A Simple Pipeline Risk Audit (SPRA)',* 3rd Annual Conference on 'Advances in Pipeline Technologies & Rehabilitation '99'. Abu Dhabi, November 1999.
6. Senior, G., Hopkins, P., Francis, A., 'Uprating The Design Pressure Of In-Service Pipelines Using Limit State Design And Quantitative Risk Analysis', 2nd 'Onshore Pipelines Conference', Istanbul, November 1998.
7. Anon, 'Risk Management Program Standard', Office of Pipeline Safety, DoT, USA, September 1996.
8. Hopkins, P., Cosham, A., 'How Do You Manage Your Pipeline?', 7th Int. Conference on Pipeline Risk Management and Reliability, Houston, USA, November 1997.
9. Hopkins, P., Cosham, A,. 'How to Assess Defects in Your Pipelines Using Fitness-for-Purpose Methods', Advances in Pipeline Technology '97 Conference. IBC, Dubai, UAE, September 1997.
10. Mouser, G. F., "Evaluation Criteria for Replacement of Transmission Pipelines", AGA Operating Section, Distribution and Transmission Conference, May 1988.
11. Keifner, J. F., Vieth, P. H., Orban, J. E. and Feder, P. I., "Methods for Prioritising Pipeline Maintenance and Rehabilitation", AGA Report Project PR 3-919, Sept. 1990.
12. Muhlbauer, W. K., "Pipeline Risk Management Manual", Gulf Publishing Company, London, 1992 (ISBN 0-88415-035-6).
13. Kirkwood, M. G, Karam, M,. 'Priority Rating Scheme Guides Maintenance, Rehab. Decisions', Pipe Line & Gas Industry, Vol.78, No.7, July 1995, p.6pp, Gulf Publ Co, Houston, TX, USA.