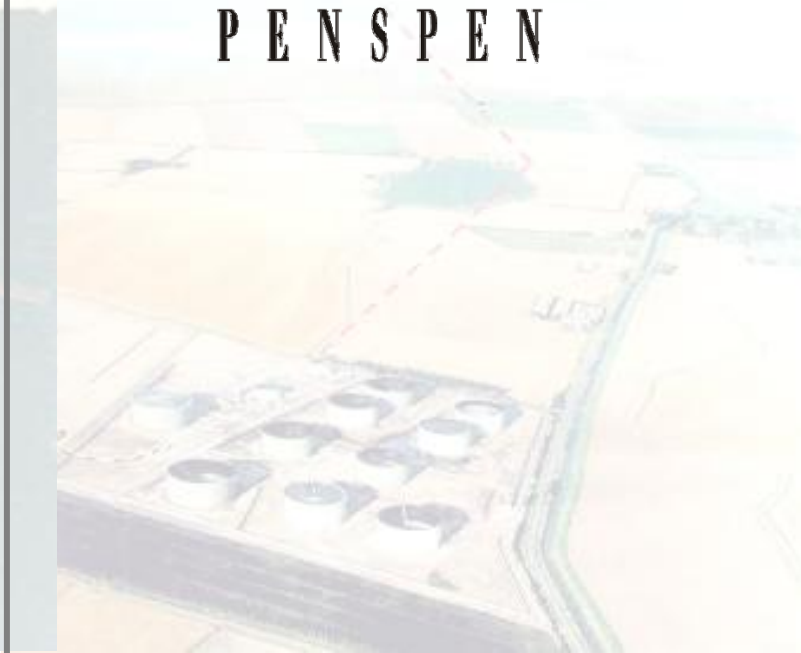


Penspen Integrity

*Know and
manage your
pipeline risk*



P E N S P E N



Profile



PROFILE

Penspen Integrity is a business stream of Penspen Limited (incorporating Andrew Palmer and Associates).

Penspen Integrity is a specialist pipeline engineering consultancy. It provides services such as: Pipeline Integrity Management Systems (PIMS), pipeline risk analysis and management, pipeline defect assessment, corrosion and cathodic protection (CP) advice and field support, pigging data analysis, inspection integrity management and direct assessment advice.

Penspen Integrity is independent of construction and intelligent pigging companies.

Penspen Integrity's mission is to provide the international onshore and offshore pipeline community with a complete and independent integrity service, using a combination of: first-class engineers, sound engineering practice, state-of-the-art techniques and innovative technology.

As part of the Penspen Group, Penspen Integrity's expertise is enhanced through Penspen's portfolio of project management and operations in the UK and worldwide.

Penspen Integrity also offers comprehensive training courses.

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PENSPEN PROFILE Better by Design

The Penspen Group has provided engineering and management services to the oil and gas industry worldwide for over 50 years. Penspen has no ownership ties with operators, contractors or suppliers and therefore can offer a truly independent, best practice service.

Penspen has undertaken over 5000 projects in almost every country in the world and has tackled almost every conceivable challenge from the economic evaluation of pipelines in developing nations and complex integrated design and construct contracts, to limit-state design of pipelines in deep water.

Penspen has an international network of offices and offers unequalled onshore pipeline and facilities design, integrity management and rehabilitation, training, instrumentation and control, pipeline operation and maintenance (through GreyStar and Unipen) and submarine pipelines and structures (through Andrew Palmer and Associates).

Specialist services are provided individually or can be integrated for large complex world-class onshore and offshore projects. Typical projects include transmission pipelines, metering, pressure control, compressor and pump stations, civil and military aviation fuelling systems, instrumentation and SCADA systems, offshore pipelines, risers and manifolds and integrity and operability studies.

In addition to engineering and project management, Penspen provides extensive training services, which cover every aspect of pipeline design, operation, maintenance and emergency response.

We place great emphasis on and take pride in the personal care and quality of the services we provide to our clients, partners, suppliers and subcontractors.

We look forward to being of service to you.

David Stanley
Chief Executive Officer



David Stanley has degrees in Mechanical Engineering from Leeds University and Business Administration from Cranfield. He has worked extensively in Qatar, Kuwait, Greece and Houston, Texas and for short periods in Mexico, Trinidad, Bolivia, Abu Dhabi and Singapore. He became a director of Penspen in 1998 and Chief Executive Officer in 2002.

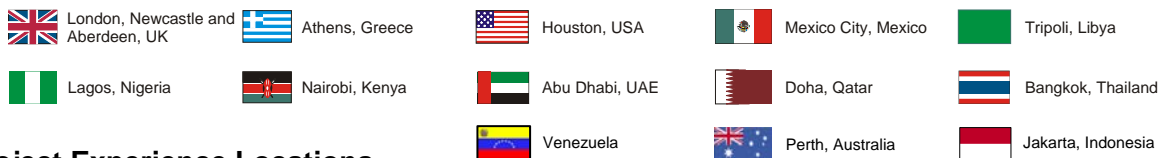
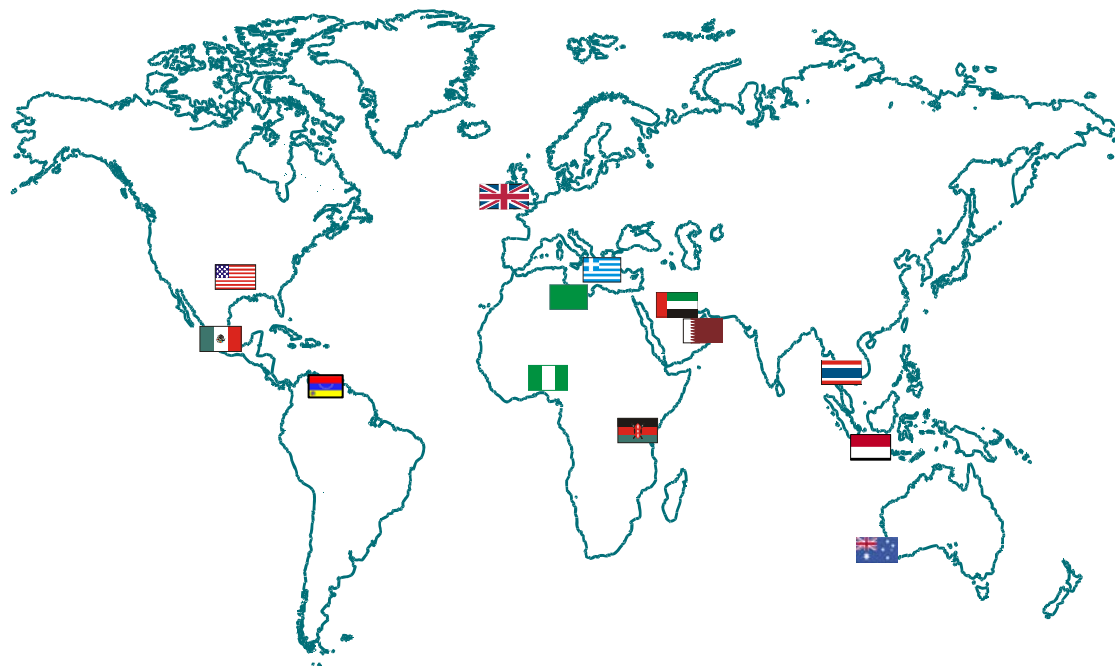
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International Offices



Project Experience Locations

Europe:

Czech Republic
Denmark
France
Germany
Greece
Hungary
Ireland
Italy
Netherlands
Norway
Poland
Portugal
United Kingdom

Africa:

Algeria
Ethiopia
Kenya
Libya
Madagascar
Namibia
Nigeria
South Africa
Sudan
Tanzania
Tunisia
Uganda
Zambia
Zimbabwe

Middle East:

Bahrain
Cyprus
Egypt
Iran
Iraq
Jordan
Kuwait
Lebanon
Oman
Qatar
Saudi Arabia
Syria
Turkey
UAE
Yemen

Central Asia:

Azerbaijan
Bangladesh
India
Pakistan
Kazakhstan
Turkmenistan

South East:

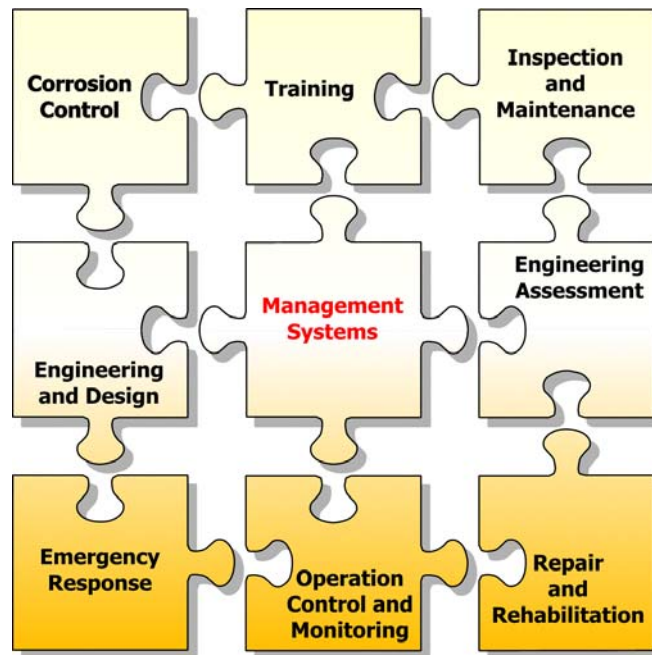
Hong Kong
Indonesia
Malaysia
Myanmar
Philippines
Singapore
Thailand

Americas:

Argentina
Bolivia
Brazil
Colombia
Costa Rica
Ecuador
Mexico
Trinidad
Venezuela

INTRODUCTION TO PIPELINE INTEGRITY

PENSPEN INTEGRITY provides consultancy and services related to the overall integrity, risk assessment and risk management of onshore and offshore pipelines. We are independent of construction and intelligent pigging companies and offer a wide range of pipeline integrity services. Our services are represented by the following Jigsaw:



- Engineering Assessment - Pipeline wall defect assessment, remnant life prediction, corrosion assessment and mitigation, CP and coating condition assessment, fitness for purpose assessment, failure investigation, engineering criticality assessment, up-rating, safety audits, risk analysis and analysis of geo-hazards.
- Inspection and Maintenance including Smart Pigging - Advice on pigs and pigging procedures, risk-based inspection and reliability centered maintenance.
- Direct Assessment to satisfy the ASME B31 Integrity Appendix.
- Pipeline Management Systems – Pipeline Integrity Management Systems (PIMS), corrosion management systems, corrosion control, advice on health safety and environmental issues, legislative reviews and pipeline database systems.
- Baseline Plans to satisfy the new API 1160 standard on integrity management and help an operator of a pipeline system to assess risks and make decisions about risks in operating a hazardous liquid pipeline.
- Repair and Rehabilitation - Internal coatings, linings, sleeves, clamps and re-coating.

- Training - Integrity management, rehabilitation and emergency response. Courses can be public or in-house.
- Operating Control and Monitoring – SCADA and leak detection systems.
- Emergency Response - Planning, incident command systems design and procedures.
- Corrosion Control – Cathodic Protection design and engineering (i.e. impressed current systems or galvanic systems), coating and lining selection and specification, material selection and specification and supply of specialised materials.
- Engineering and Design – Pipeline modifications (e.g. replacement, upgrading, construction management and procurement and pigging facilities). Limit state design (e.g. high stress, high temperature or high pressure operation).

INTEGRITY TECHNOLOGY

PENSPEN INTEGRITY has a focus on technology gained through industry funded research. Our achievements include “The Defect Assessment Manual” and the development of an International Standard Pipeline Data Model.

PENSPEN INTEGRITY PEOPLE AND SUPPORT

We have 50 dedicated staff with a wide variety of backgrounds including operations, fieldwork and assessment. We have offices in London, Newcastle, Aberdeen, Houston and Abu-Dhabi. In addition to this we can obtain support from 400 Penspen staff in 13 international locations with experience of routing, design, construction, commissioning and economics, and from GreyStar our pipeline operating company.

ENGINEERING SERVICES IN SUPPORT OF PIPELINE INTEGRITY

Penspen Integrity and Penspen Limited can provide an engineering solution, when pipelines need to be validated but are not suitable for intelligent pigging, either by their design or following operational repairs. This may involve design, procurement and construction management of modifications to the pipeline to allow the pipeline assessment integrity process to proceed.

Modifications such as the replacement of unpiggable bends or tees will be permanent but there are options for permanent or temporary modifications for pig traps and launch and receive piping, which can be optimised to suit the operator's long-term objectives.

Penspen is experienced in optimising a cost-effective solution for the necessary repairs; sectional or total replacement depending on the results of the integrity study and in accordance with the action plan for remedial work. Penspen will prepare techno-economic studies for remedial works and route, environmental, feasibility and cost-benefit studies for pipeline replacement, if necessary.

Penspen will engineer, design, procure and project manage the remedial works in a campaign designed to suit the particular conditions. Where necessary, Penspen will undertake construction work to provide a single contractual responsibility to the operator.



Leading the way in Pipeline Integrity Management Systems

Background

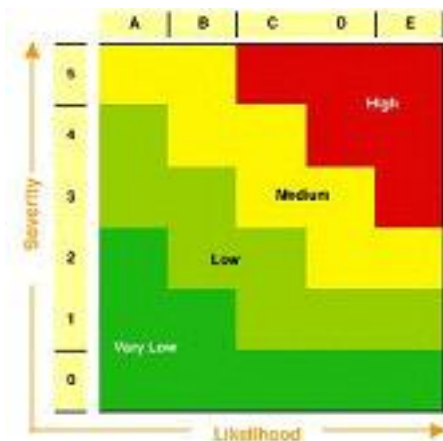
Regulatory authorities in Canada, the USA and the UK are moving away from prescriptive approaches to pipeline design and operation, to 'risk management' as the safest and most cost effective means of maintaining and improving safety levels in pipelines. Risk management is a combination of risk assessment and risk control.

A Pipeline Integrity Management System (PIMS) is expected to be a requirement in all countries of the European Community in the near future. A PIMS uses risk management methods, and management systems, and combines these two approaches to produce a complete risk management system, which includes emergency planning and procedures.

Penspen Integrity has completed PIMS for a number of key operators and now has ongoing support responsibilities.

Risk Analysis

At the core of the PIMS will be a risk analysis. This analysis can be either quantitative or qualitative. A qualitative analysis is usually the preferred first step, and this should show an operator the key risks, and they can be quickly addressed. Quantitative analysis can follow this first step, if necessary, but in both cases (quantitative and qualitative) expert judgement and analysis will be required.



PIMS

A Management System is a management plan, that explains to company staff, customers, regulatory authorities, etc. how the company and its assets are managed. In general the PIMS will:

- Identify all events that could lead to failure
- Examine the likelihood and consequences of potential pipeline incidents
- Examine and compare all risks
- Define who is responsible for each aspect of the asset and its management
- Define what policies and processes are in place to achieve targets and goals
- Define how policies & processes are implemented
- Define how performance is measured
- Define how the system is reviewed and audited.

The document would normally be agreed at a high management level, and be constantly and systematically reviewed and updated. All levels of management would comply with its contents. Many companies operate such a system in a piecemeal or unstructured manner. It is the production of a single, detailed document that encompasses all the above aspects that creates the 'system'.

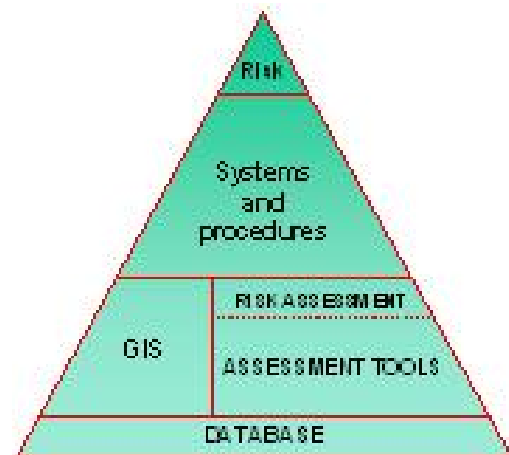
Audit

The whole risk management system (organisation, plan, implementation, processes utilised, and performance measures in place) should be regularly reviewed against specified criteria. Where deficiencies are identified, procedures must be in place and implemented to ensure rectification.

The whole system, and all its elements should be subject to regular audit. This audit should be a 'critical audit' that appraises both the system in place, and each element, to ensure it is performing its stated function effectively.

Data Management

The long term storage and retrieval of pipeline data is an essential part of any PIMS. Penspen Integrity advocates the use of formal data management systems separate from applications using third party software such as Oracle or Microsoft SQL. Penspen Integrity can provide data management solutions with value added partners. To improve our offering in this respect we are part of a Joint Industry Project to develop an International Standard for Pipeline Data Management (ISPDM). This is an open standard, which eventually will become an ISO Standard.



Software Tools

An important part of the development and ongoing support of a PIMS is the use of software tools. Penspen Integrity has a number of established and validated software tools:

- MDRLP – Multiple Defect Remnant Life Prediction
- PI RBI - Risk based inspection
- PI Risk - Quantitative risk assessment
- PI Priority - Qualitative risk assessment

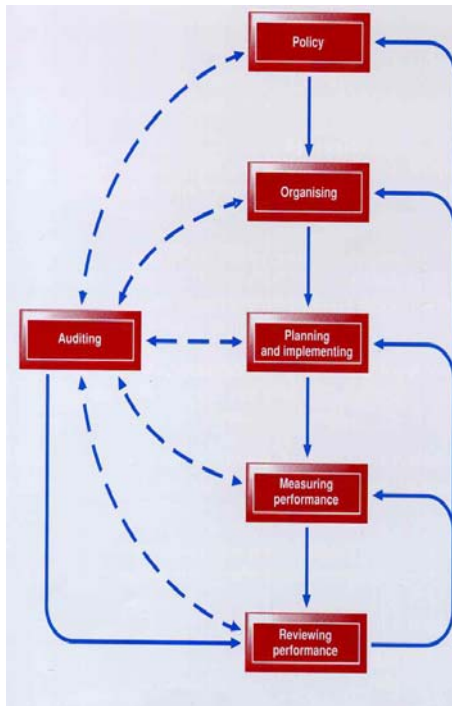


Leading the way in Pipeline Management System Audit

Background

Most operators now have comprehensive Pipeline Management Systems, with integrated organisations and procedures for ensuring the effective design, construction, operation and de-commissioning of pipelines. However all systems are subject to change. Such changes may be due to external influences such as new or revised legislation or from internal factors such as company re-organisation or new staff. Whatever the cause, each change brings a threat to the continued effectiveness of the systems in place.

It is recognised that an effective management system must have procedures for monitoring, reviewing and auditing their performance towards this goal. Line management review is subject to the same changes as the system that it is controlling and thus may not recognise threats to the effectiveness of the system.



Audits are however independent of the system they are addressing and seek objective evidence of the adequacy of the system.

Penspen Integrity has carried out a considerable amount of work in respect of developing systems for the effective management of operating pipelines. This work has included the development of Pipeline Management Systems, risk analyses, Major Accident Prevention Document's, Environmental Impact Assessments, Emergency Procedures and the like.

Given the breadth of its experience and the capabilities of its personnel, Penspen Integrity is ideally suited to carry out independent audits of a pipeline operator's systems to establish whether legal compliance is being achieved and whether systems are effective. Indeed Penspen Integrity

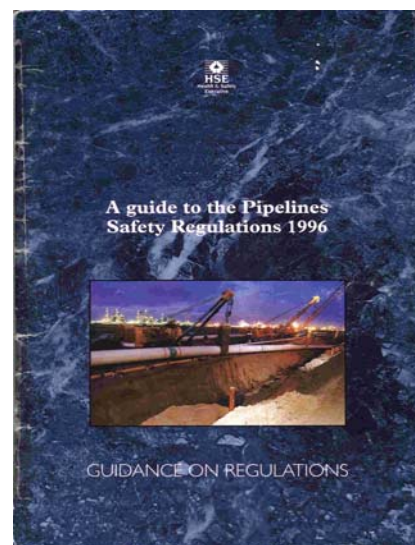
have already carried out both types of audit for a number of operators.

When carrying out comprehensive system audits 14 key elements are examined.

- ◆ Policy and Objectives
- ◆ Management Organisation
- ◆ Risk Analysis
- ◆ Design Control
- ◆ Construction Assurance
- ◆ Commissioning and Handover
- ◆ Planned Inspection and Maintenance
- ◆ Normal Operations
- ◆ Emergency Operations
- ◆ Accident Investigation and Reporting
- ◆ Change Control
- ◆ Document Control
- ◆ Procurement
- ◆ Audit

A Pipeline System Audit performed by Penspen Integrity provides independent and objective assurance that the systems and procedures are being implemented as intended and are effective in ensuring the integrity of the pipelines operated.

As a result of the new or revised Pipeline Safety Regulations in 1996, the Pipeline Owner and Operator has an increasingly difficult task of ensuring compliance with all the legislation. A Legal Compliance Audit performed by Penspen Integrity provides an independent and objective review of a company's legal status.



Audits can look at single or multiple pipeline systems, single or multiple assets and can be phased so that pilot schemes are run before carrying out full system wide exercises. Should non-compliances be found, recommendations and advice can be offered as to how to correct the situation, and formal actions plans with associated time schedules can be agreed and, if required, monitored.



Leading the way in Pipeline Integrity Reviews

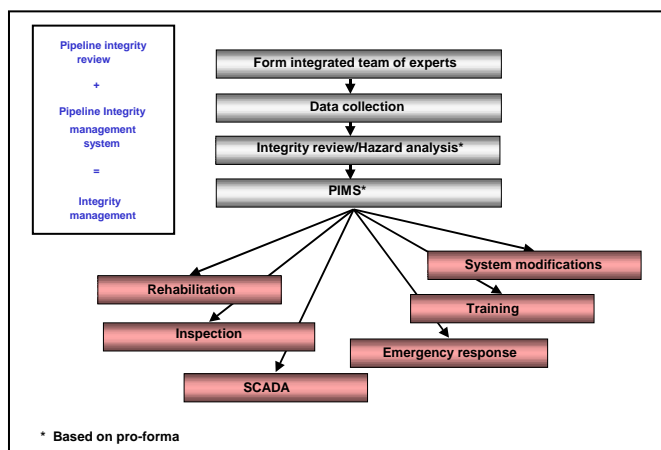
Background

Pipelines are often required to supply more product, e.g. by uprating, or can deteriorate during service. Additionally, operators are sometimes faced with lines that have either poor documentation, are due hydrotesting/smart pigging, or need a thorough audit.

In all these cases, there is a need to conduct a review of the pipeline's integrity. These reviews can require a thorough 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 pipelines
6. Hydraulic/compression, including delivery forecasts and expansion plans
7. Product quality; both current and future quality to be considered.
8. The critical parts of the pipeline system (pipelines, SCADA systems, gas conditioning stations, valve stations, pig launch/receive stations, etc.)

This engineering integrity review may reveal needs for changes to operation, management or maintenance and inspection of the pipeline. Inspections, such as smart pigging, may subsequently be needed.



Integrity Reviews

Integrity reviews fall into three categories:

- i. Integrity review – **audit** (new owner, regulatory need, following failure, etc.)
- ii. Integrity review – **change of duty** (within code)
- iii. Integrity review – **change of duty** (outside code)

These reviews must be conducted by independent bodies who can cover:

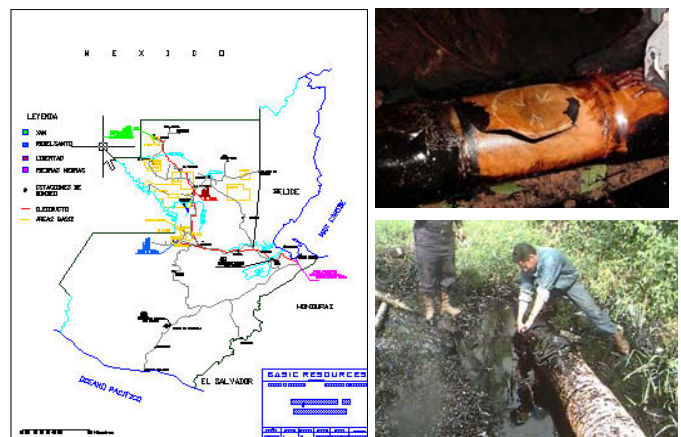
- design, construction and commissioning
- operation, inspection and maintenance
- defect assessment, repair and rehabilitation
- risk and safety assessments
- management consultancy
- technical audit

Managing a Review

Penspen Integrity, with the support of Penspen, can offer a complete pipeline engineering integrity review. Its mixture of world experts on integrity and extensive experience of the design, operation and maintenance of pipelines presents the client with a unique service.

The reviews start with extensive data collation at the client's sites, and field visits may be necessary. An overall view of the condition of the pipeline is first put forward. Following discussions with the client, the pipeline may be modified, repaired, etc., to meet future operational requirements.

Penspen Integrity can offer full support services, ranging from management of an inspection run, to assessing detected defects, to recommending and organising repair and rehabilitation where necessary.



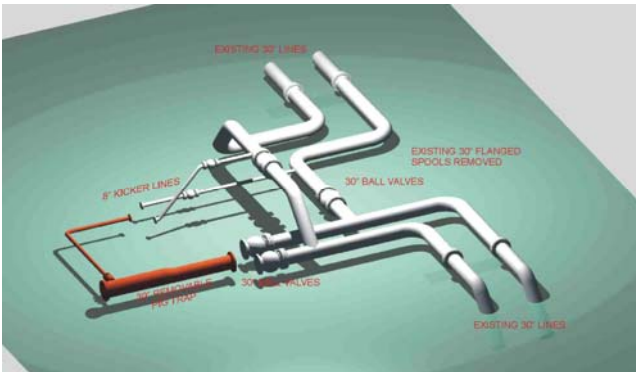


Leading the way in Pigging Strategy

Background

The inspection of pipelines using intelligent pigs is one of the key methods that pipeline operators employ to monitor the integrity of their pipeline assets. We can offer independent and impartial services to the pipeline operator that will help them answer the following questions:

1. Do I need to inspect my line using an intelligent pig?
2. When should I conduct my first pig inspection?
3. Should I conduct a baseline pig inspection on a new pipeline?
4. How often should I inspect my pipeline using an intelligent pig?
5. Which intelligent pig is best for my particular needs?
6. What has the inspection told me about the condition of my pipeline?
7. How do I incorporate the inspection results into my pipeline inspection and maintenance strategy?



Examples of Recent Projects

Examples of the pigging strategy related work that we have undertaken include:

- Setting the schedule for the first intelligent pig inspection of an offshore oil pipeline using probabilistic methods.
- Quantifying the benefits of a baseline intelligent pig inspection compared to the information generated by the pre-commissioning hydrotest.
- Fitness for purpose assessment of a pipeline based upon the results of an intelligent pig inspection.
- Developing simple, easy to apply, defect acceptance limits to assess the results from an intelligent pig inspection.
- Selecting the most suitable pig to use using probabilistic methods to assess the detection and accuracy capabilities.
- Using probabilistic methods to determine the optimum time to repair corrosion defects in an onshore pipeline, and the number of repairs required.
- Developing pipeline inspection strategies, incorporating intelligent pigging.

Related Pigging Services

A comprehensive listing of the services related to pigging strategy and the assessment of the results of intelligent pig inspections that we offer is given below:

Pipeline Inspection Data Analysis

The results of an intelligent pig run can be analysed rapidly, and an assessment of the severity of defects, and any necessary repairs, provided to the pipeline operator. Both deterministic and probabilistic approaches are offered.

Pipeline Inspection Reviews and Strategies

Reviewing inspection needs, setting internal inspection schedules and setting pig defect acceptance criteria.

Integrity Management

Providing pipeline companies with high quality integrity management consultancy.

Pipeline Defect Analysis (Engineering Criticality Assessments)

The significance of all defects and damage found in pipelines and their welds can be assessed, using state-of-the-art methods (simple defect acceptance methods through to advanced, elastic-plastic fracture mechanics) and programs, as appropriate to the particular situation and the available data.

Hydrotest Reviews and Strategies

Reviewing in-service hydrotest needs.

Pipeline Maintenance Reviews and Strategies

Providing operators with optimised maintenance and inspection programmes.

Pipeline Revalidation, Rehabilitation and Upgrading

The integrity of older pipelines can be assessed and the need for revalidation or rehabilitation assessed. Additionally, pipelines can be analysed to determine their suitability for upgrading.





Leading the way in Smart Pigging Consultancy and Management

Background

The most popular smart pigs are inspection tools, which can measure:

- metal loss defects
- pipe geometry and shape
- pipe and weld cracks

An operator will run an intelligent pig if he/she:

- has a defect/damage problem
- is required to inspect by code/regulation
- needs to revalidate or rehabilitate the pipeline

Smart Pigging – THE PROBLEMS

Running a smart pig presents an operator with a number of problems:

- Cost** – Smart pig runs can cost anything from \$1,000 to \$4,000/km of line.
- Variety & Technology** – there are a large number of vendors and there are various technologies (MFL, ultrasonics, etc.).
- The pipeline and the pig** - correct pig traps are needed, and there must be no obstructions (e.g. reduced bore valves or tight bends).
- Cleanliness** – the pipeline will need to be clean to ensure good results from the pig.
- Running the pig** – conditions such as flow rate must be suitable for the pig run.
- Optimising runs** – an operator needs to know which of his/her lines to inspect first, and what level of data recording is needed.
- Defect assessment** – many thousands of defects may be identified, which will require engineering assessment.
- Repair & rehabilitation** – the pipeline may require engineering works after the inspection.

Therefore, a variety of engineering skills are required before, during and after a smart pig run.

Operators – THE MISTAKES

Not assessing the engineering – A smart pig run is an engineering project, and should not be left simply to the pig vendor to solve – they are not pipeline engineering companies.

My needs not the salesman - Operators often choose a smart pig simply from vendors' quotes, without considering their own needs.

Is a smart pig the best option? - Operators often do not appreciate that some pipelines do not require a smart pig; it may be better to apply other maintenance methods such as coating checks.

Accept high smart pig prices – Most smart pig vendors will quote a price based on the operator's scope of work. This may be a limited scope resulting in a high quote to cover uncertainties.

The pig is only an inspection tool – After a smart pig run, an operator may need extensive advice on the defects detected, and engineering works required to remedy those defects.

Benefits of pigging – it is important to assess the engineering benefits of a pig run, along with all other inspection, surveillance and maintenance activities. It must not be treated in isolation.

Solution – INDEPENDENT ADVICE

When you are considering a smart pig run, you need the advice of a specialist independent pipeline engineering consultancy. Penspen Integrity have a track record of saving customers \$100,000s on both cleaning and smart pig runs. We offer:

- Integrity and risk reviews for pipelines to determine the need for pigging
- Smart pigging strategies for entire systems
- Scopes of work for a smart pig run
- Engineering assessment, design and remedial work on pipelines before pigging work
- Management of pigging contracts and pig runs
- Assessment of defect reports following pig runs
- Full fitness for purpose service from any pig
- Repair, remedial, rehabilitation advice and works.

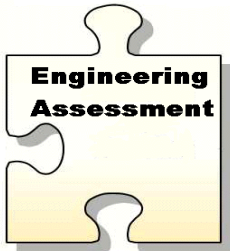
Examples of Recent Projects

Project A, Africa – Review, inspection and remedial work on an onshore gas system (**Ongoing, 2001**)

Role - Provide a complete integrity review of the pipeline system, to include field surveys, and integrity and risk assessments of all pipeline segments. The suitability for both cleaning and smart pigging was assessed. To scope a cleaning and smart pig programme, award the contract and manage all aspects of the pigging operations.

Project B, UK - Review of the inspection and maintenance practices of a UK client for its high-pressure transmission gas lines. (**1999**)

Role - Expert review of inspection and maintenance practices, including smart pigging, currently utilised by client, and changes necessary to allow pipelines to operate at higher stresses.



Leading the way in Risk Based Inspection

Introduction

At Penspen Integrity we believe Risk Based Inspection should be a regularly updated, fully justified, well-documented analysis of pipeline risks, how they are controlled and how inspection contributes to that control.

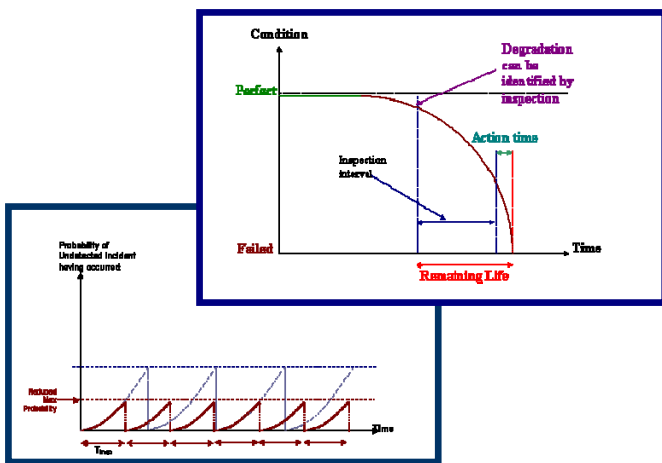
Penspen's Risk Based Inspection system PIRBI has been developed to satisfy this requirement.

How Inspection Controls Risk

Inspection is one of the key ways in which risks can be controlled, but for inspection to be effective it must be carefully targeted.

- For some failure modes, such as corrosion, inspection can monitor deterioration.
- For other failure modes, such as impact damage, inspection can find damaged areas, but cannot prevent the damage from occurring.

Remember that inspection does nothing to control risk by itself: appropriate remedial action must be taken when required. Otherwise you are doing nothing but watching the pipeline fail!



PIRBI Philosophy

The PIRBI philosophy contains the following elements:

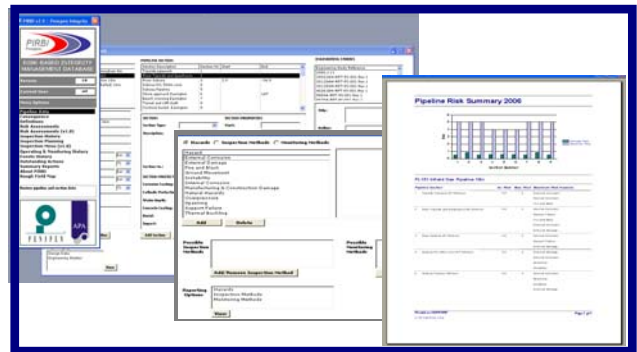
- Understanding of how the pipeline can fail.
- Understanding how design, operational control and inspection contribute to the risk control.
- Consideration of safety and economic failure consequences.
- Assessments based on semi-quantitative information to give a relative risk ranking for each hazard in each pipeline section.
- Where good data is available and benefit would be gained, more detailed quantitative assessment can be included.

- Optimised inspection scheduling.
- Annual update of assessments.
- Traceable records of assessments and decisions (database tools can be utilised).
- Philosophy tailored to individual client needs.



PIRBI Database

The PIRBI assessment process has been implemented in a database system.



PIRBI Benefits

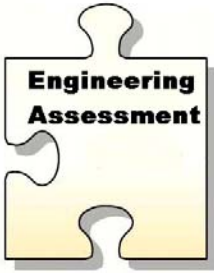
In many countries, regulatory authorities now require pipeline operators to demonstrate that the risks presented by their pipelines have been identified and controlled. PIRBI can provide the solution to this.

PIRBI appropriately represents the relationship between inspection interval and risk, distinguishing between time dependent and randomly occurring hazards.

PIRBI clearly highlights areas where measures such as operational control or re-design are required to effectively control risk.

PIRBI eliminates unnecessary inspections and therefore can provide a justified cost saving.

PIRBI ensures money invested in inspection is efficiently spent.



Leading the way in Pipeline Risk Assessments

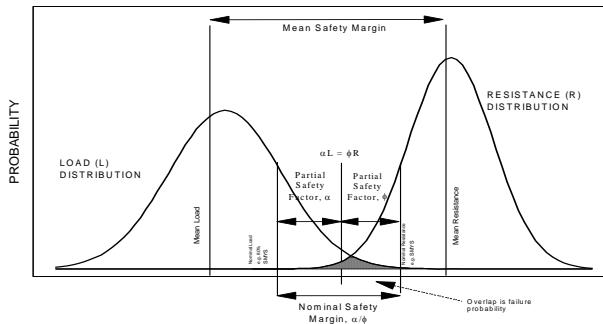
Background

Risk assessment methodologies have been used extensively in other industries for a number of years, but it is only recently that they are being applied to pipelines. With the issuing of management Regulations in the USA and UK, the application of risk assessment methods to pipelines has increased dramatically. A risk assessment can be used for a wide variety of applications, but the basic methodology is the same irrespective of the industry or the application.



Methodologies

Risk is a function of the probability of an adverse event occurring, and the consequences of that event.



It has historically been defined as:

$$P_f(\text{Pipeline}) = \left[1 - (1 - P_{i_flowing})^{N_{flowing}} \right] + \left[1 - (1 - P_{i_stagnant})^{N_{stagnant}} \right]$$

Risk = Probability x Consequence

although, this is not a unique definition. The probability can be determined from historical data, expert opinion, or by the use of sophisticated structural reliability techniques, where the uncertainties associated with any engineering calculation are taken into consideration.

The consequence of failure can include:

- Effects upon humans and society
- Effects upon the environment
- The financial implications of failure.

The choice of the consequence component, determines what the "risk" value measures. The "risk value" has to be assessed against some criteria to determine the acceptability of the proposed measure. These criteria may be defined by society, by a regulator, by the

owner, or by any other stakeholder. The basis for the criteria can be historically acceptable risks, financial limits, environmental sensitivity, public image, or similar.

Benefits

Applying risk-based methodologies which allow risks to be measured and compared can provide considerable benefits, such as:

- saving money (by justifying changes)
- improving safety (by targeting resources)

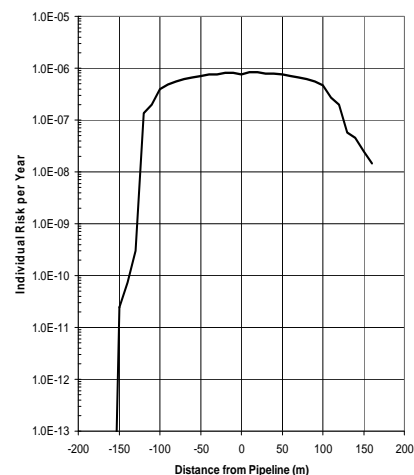
The key benefit is that risk assessment allows decisions to be made and resources to be allocated within a transparent, logical and consistent framework.

Examples of Recent Experience

Penspen Integrity has experience in using risk assessments, and applying risk methodologies. Some of the major applications include:

- Assessments of proposed, and modified pipeline systems to determine the acceptability of the design or modification. This also includes changes in use.
- Assessments to determine the mitigation measures that are necessary for new designs.
- Assessments to determine appropriate safety management systems.
- Assessments of installation procedures.
- Assessments to determine the acceptability of damaged pipelines.
- Assessments to determine the measures necessary for pipeline modifications.
- Assessments to determine the most appropriate inspection and maintenance strategy.
- Assessments to determine the most appropriate repair and rehabilitation strategy.
- Assessments to determine the remnant life, and mitigation, for extending the pipeline life.

Individual Risk Transect





Leading the way in Pipeline Defect Evaluation PDEV

Introduction

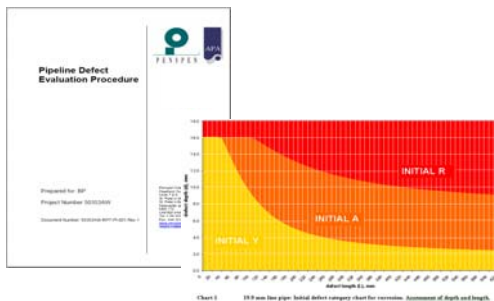
As part of a major industry JIP, Penspen Integrity have developed the Pipeline Defect Assessment Manual (PDAM). PDAM presents the 'best' currently available methods for the assessment of pipeline defects (such as corrosion, dents, gouges, weld defects, etc.), and gives guidance in their use. It is based on an extensive critical review of published 'fitness-for-purpose' methods and test data.

Following from PDAM, Penspen Integrity offer an additional product, the Pipeline Defect Evaluation Procedure (PDEV).

PDEV Objective

The PDEV is a pipeline-specific expert's interpretation of the guidance give in PDAM, providing clear step-by-step procedures, including assessment charts, for the evaluation of defects found in a given pipeline.

Guidance is given on the identification, investigation and assessment of defects in the pipelines. The requirements and timescales for remedial actions are also defined.



PDEV Benefits

PDEV provides the specific benefits of:

- Allowing a rapid assessment of defects and therefore a minimisation of the consequences resulting from in-action and/or lack of availability of appropriately skilled staff.
- Allowing the most suitable method of assessment and mitigation to be discussed and agreed in advance

Defect Categorisation

As a result of the PDEV defect evaluation, defects are classified as Yellow, Amber or Red. The required further actions and timescales depend on this categorisation.

Yellow:	Superficial Damage
Amber:	Significant Damage
Red:	Severe Damage

Scope

PDEV gives guidance on:

- Initial actions to be taken on discovery of defect (not emergency response)
- Pressure reductions required.
- Assessment and categorisation of defects according to the type and location of the defect.
- The requirement for repair, with timescales, following defect categorisation.
- The reporting procedure for the defect assessment.
- The requirement for further inspection or expert referral of defects.

Defects covered by PDEV procedures typically include:

- Internal corrosion.
- External corrosion.
- Dents and ovality.
- Gouges.
- Dent-gouge combinations.
- Girth weld anomalies.



Training

PDEVs are intended for use by competent inspection engineers authorised by the appropriate authority, and trained in the use of the procedures. Penspen also offer training to accompany the PDEV development.

Format

PDEVs can be developed as a paper-based manual or as a database system.



Leading the way in Pipeline Defect Assessment

Background

Pipelines can experience many forms of damage during their life, ranging from damage introduced at the time of manufacturing and construction, to in-service damage due to corrosion or external interference.

To establish the short and long term integrity of damaged pipelines, it is important to assess the effects of the damage on the fitness for purpose of the pipeline under the given loading conditions.

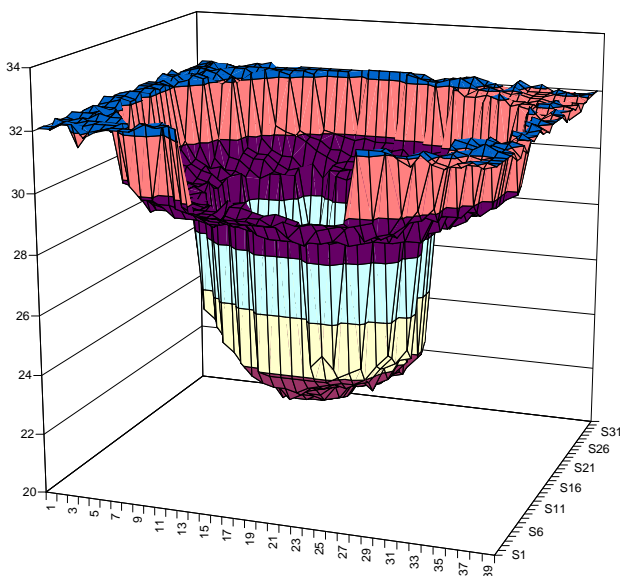
Detecting Defects in Pipelines

The detection of defects is the first stage of a repair and rehabilitation programme. Fitness-for-purpose methods are available for assessing defects in pipelines using fracture mechanics as their technical basis. This means that when defects are detected, their 'significance' can be determined.

Response to Discovering Defects

Before attempting to assess the significance of defects, it is first necessary to ensure that the pipeline is safe. The immediate response plan is:

- 1) **Reduce Pressure** - it may be necessary to reduce pressure to a safe level and plan pressure reductions or isolation for repair or rehabilitation,
- 2) **Critical Information** - Establish critical information for the engineering assessment,
- 3) **Location Assessment** - Assessment of damage location to define access requirements and available repair and rehabilitation methods.



Defect Assessment

The reported defects can be assessed using fitness for purpose methods. The urgency of the analysis and repair depends upon the defect severity, the pipeline's financial & strategic value, any threat to environment & public relations, the regulatory, legal and insurance considerations, and the potential for further failures.

Defect assessment requires a structured and systematic approach. Penspen Integrity has extensive expertise and experience in assessing a wide variety of different types of pipeline and pressure vessels defects, and of applying defect assessment methods to the problems of defining inspection strategies, pipeline design and pipeline uprating.

Penspen Integrity has also been involved in the development of new, advanced defect assessment methods.

Examples of Recent Experience

Examples of the defect assessment related work that we have recently undertaken for our clients include:

- Fitness for purpose assessment of a pipeline based upon the results of an intelligent pig inspection.
- Setting the time for the first intelligent pig inspection of an offshore oil pipeline using probabilistic methods.
- Development of girth weld defect acceptance limits for new offshore pipelines - using fitness for purpose methods.
- Assessing the value of "finger print" or "baseline" smart pig inspection.
- Assessment of pipelines containing corrosion, dents, dents combined with corrosion, etc. (under both static & cyclic loading).
- Assessment of corrosion defects under combined pressure and bending loading.
- Analysis of the effect of corrosion on pipeline buckles (using finite element analysis).
- Using probabilistic methods to determine the optimum time to repair corrosion defects in a pipeline, and the number of repairs required.
- Setting lamination acceptance levels in an offshore pipeline (under static & cyclic loading).
- Technical consultant and expert witness in hearings on the proposed fracture control plan for a new rich gas pipeline.



Leading the way in Pipeline Upgrade and Repair

Background

Many pipelines need emergency repair and most require rehabilitation as they age, or are expected to operate beyond their design life.

To avoid unnecessary repair or rehabilitation, pipeline operators need methods to assess the significance of defects detected in the pipeline. If a repair is necessary, a strategy is needed to select the most appropriate repair or rehabilitation method. These methods and strategies are of great importance to operators, who are expected by the authorities to have ready a response plan, repair procedures and stand-by repair equipment.

Detecting Defects in Pipelines

The detection of defects is the first stage of a repair and rehabilitation programme. Fitness-for-purpose methods are available for assessing defects in pipelines using fracture mechanics as their technical basis. This means that when defects are detected, their 'significance' can be determined.

Response to Discovering Defects

Before attempting to assess the significance of defects, it is first necessary to ensure that the pipeline is safe. The immediate response plan is:

- 1) **Reduce Pressure** - it may be necessary to reduce pressure to a safe level and plan pressure reductions or isolation for repair or rehabilitation,
- 2) **Critical Information** - Establish critical information for the engineering assessment,
- 3) **Location Assessment** - Assessment of damage location to define access requirements and available repair and rehabilitation methods.

Assessing Defects and Damage

The reported defects can be assessed using fitness for purpose methods. The urgency of the analysis and repair depends upon the defect severity, the pipeline's financial & strategic value, any threat to environment, regulatory, legal and insurance considerations, and the potential for further failures.

Selecting Repair/Rehabilitation Method

The last stage of a complete repair and rehabilitation assessment is the method selection and fitness for purpose assessment, to determine which defects to repair and to select an appropriate repair method. If the defects or damage are extensive a rehabilitation or repair programme may be required. Methods include:

- Grinding
- Weld metal deposition
- Full circumferential (welded) sleeves

- Composite reinforcement sleeves
- Mechanical clamps
- Pipe section or pipeline replacement
- Upgrading cathodic protection
- External (re)coatings/internal liners
- Combined inspections/repairs/rehabilitation



Isolation Methods

- Existing pipeline valves
- Piggable plugs set remotely
- Freezing
- Hot tap, stopple and bypass

Examples of Recent Projects

Damage Assessment & Repair Strategy

Penspen Integrity assisted with damage assessment of pipelines associated with a refinery, including a 40-inch crude oil loading line, 12-inch and 16-inch product lines and a 16-inch ballast line. The scope of work included damage assessment and producing a repair strategy.

Internal Corrosion - Onshore Pipelines

Penspen Integrity investigated an internal corrosion problem and identified the corrosion mechanism. A scheme of inspection, repair and inhibition was developed to rehabilitate the pipeline. Epoxy sleeves were recommended as the repair method, after an assessment of hydrocarbon flowlines with internal preferential weld corrosion. Penspen Integrity completed a detailed study of the long term integrity of these repairs in the event that active internal corrosion grew through the pipe wall. This included a finite element analysis to predict the likely performance of the repair.

Spoolpiece Damage

A survey of spools on a field in the UK Central North Sea showed significant and unacceptable spoolpiece displacements with failure of one of the spools. Penspen Integrity determined the current stress state in all critical spoolpieces before and after replacement and collected data to identify the cause of the observed movement. Penspen Integrity also undertook an analyses and review of the remaining life of the spoolpiece CP system.



Leading the way in Operational Support

Background

Penspen Integrity offers a wide variety of consultancy and engineering services to pipeline operators and related clients. These are services, which add value to existing, operating pipelines throughout their lifetime from the outset with commissioning right through to de-commissioning.

Overseeing pipelines of which many carry dangerous or polluting products at high temperature and pressure. It is a complex business which requires a firm grasp, not only of the specialist engineering, but also the cost, safety and environmental aspects.

The breadth of our operational support capability requires detailed explanation. The list below, however, provides an indication of our strengths:

- Development of Pipeline Integrity Management Schemes (PIMS)
- Identification of safe working limits
- Hazard identification
- Risk assessment
- MAPD preparation
- Development of inspection regimes
- Inspection co-ordination
- Offshore survey support
- Defect assessment
- Corrosion assessment
- Anomaly assessment
- Span and instability calculation
- Intelligent pigging support
- Technical integrity review
- Failure investigation
- Legislative guidance
- Environmental management
- Decommissioning appraisal and planning

Many of these activities draw on other areas of expertise within Penspen Integrity, such as rigid and flexible pipeline design, front end engineering studies, environmental engineering, corrosion and materials engineering, fracture mechanics, finite element analysis, risk and reliability, statistical analysis, safety and legislative expertise.

In summary, Penspen Integrity offer a high level of professionalism and expertise that ensures the integrity and cost efficient operation of the pipeline system.

Operational support work can be undertaken in two ways:

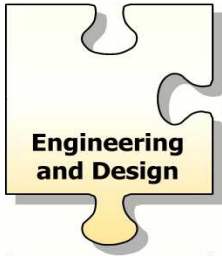
Discrete Tasks

Single tasks awarded for the study of particular phenomenon or operating scenarios. This type of work is normally carried out for operators with smaller pipeline systems, or those who perform much of their work in-house.

Call Off Contracts

A Penspen Integrity engineer will be assigned to support the operator and will often work as an integral part of the operator's own engineering team or pipeline department. This type of "general support" role is the main focus of the work we perform and allows the operator to call on Penspen Integrity for small items of work without necessitating expensive administration.





Leading the way in Pipework Stress and Flexibility Analysis

Background

Hazardous pipework (carrying flammable product, or operating at high temperatures or pressures) may require analysis to a recognised code during design or operation.

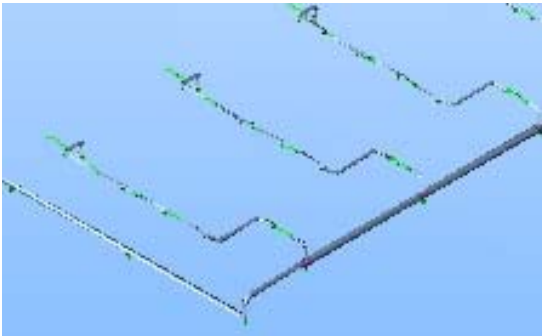
This requirement is to ensure that the pipework stresses, displacements and reactions remain within the limits imposed by the relevant design code, in order to ensure safe plant operation.

Analysis may be carried out at the feasibility or detailed design stages, on any change in construction or operation, as part of periodic design audits, or to provide data for detailed defect assessment.

Analysis Codes

Penspen can carry out pipework stress and flexibility analysis to a range of internationally recognised codes including:

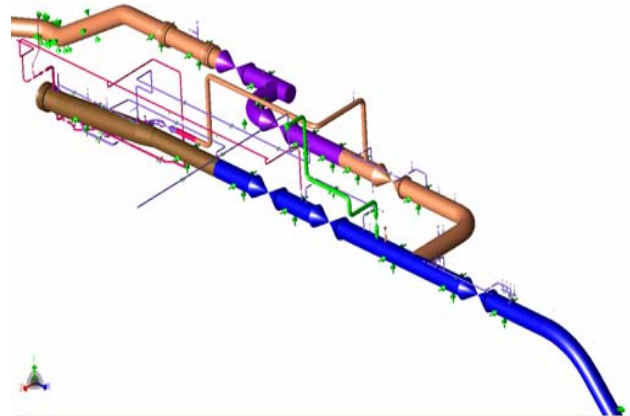
- ASME B31.1 (power piping)
- ASME B31.3 (process piping)
- ASME B31.4 (liquid hydrocarbons piping)
- ASME B31.8 (gas piping)
- IGE/TD/12 (gas industry plant)



Inputs to Analysis Process

Pipework flexibility analysis will take account of:

- Pipe grade (strength), Schedule (thickness) and lengths
- Bend, tee and reducer types
- A range of soil parameters for any buried sections of pipework
- Weights for pipework, coatings, linings and contents
- Weights for all fittings including valves, actuators, meters and flanges
- Spacing and configuration of all supports
- Pressure and temperature conditions including any hydrotest, start-up and workover scenarios
- All sustained, operating and fatigue load case combinations required by code



Software

Penspen use the internationally-recognised industry-standard analysis package Caesar II. This software can interface with a range of standard CAD software to supply design details.

For features such as non-standard tees and supports, detailed stress analysis can be carried out using the general-purpose finite element program Abaqus. This provides Stress Intensification Factors (SIFs) where required for design optimisation. Using user-generated SIFs can eliminate undue conservatism in design.

Outputs from Analysis Process

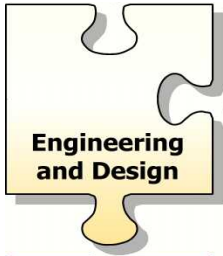
The flexibility analysis will provide a detailed 3D output of:

- Stresses
- Deflections
- Reactions at restraints and equipment

Penspen provides expert guidance on interpreting these results. This can be particularly valuable where a client may require design changes, advice on reasonable displacement levels, or liaison with equipment suppliers in order to ensure optimise and integrate system behaviour.

The analysis deliverables include a report, schedules of pipework, supports, bends, tees and valves. These can be used to automatically generate a complete bill of materials.

The report includes all ancillary checks carried out on the analysis, and extensive recommendations for any modifications or clarifications required to ensure full code compliance and safe plant operation.



Leading the way in Engineering and Design

Background

Onshore and offshore projects are conducted from the conceptual stage, through feasibility studies to basic engineering and front end engineering design (FEED) stages in readiness for detailed engineering, procurement, installation and construction contract award. Engineering projects are undertaken by integrated teams of specialist technical staff with project services support and can be mobilized to any area of the world as required.

Strong project management systems ensure that engineering teams are coordinated and managed to deliver the project objectives in terms of quality, cost and time. The project management function also integrates the planning and project controls activities from the Engineering Projects Group with other project participants including contractors, subcontractors, suppliers, local resources and the client management structure.

Basic and Front End Engineering Design (FEED)

These are key phases in the development of engineering projects. The concepts and philosophies defined in earlier conceptual phases are developed to a degree of definition enabling project budgets to be accurately assessed and implementation schedules to be set. All requirements for subsequent phases of the project are generally defined at this stage and FEED packages may be used as the basis for obtaining competitive tenders from EPC contractors.

Controls & Instrumentation

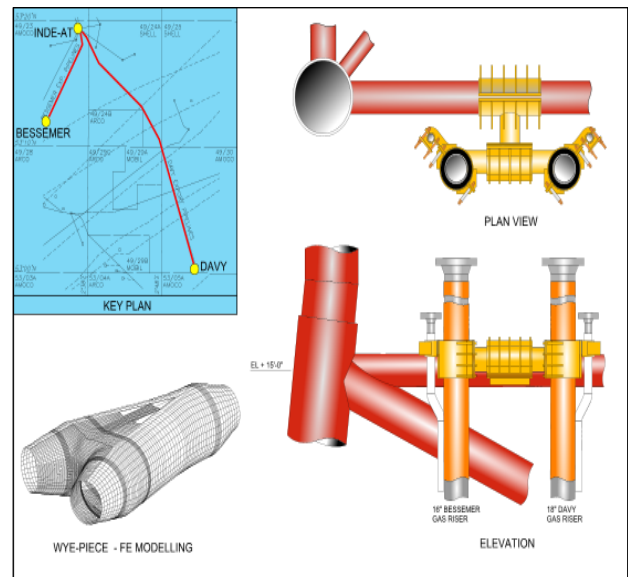
The controls and instrumentation aspects of engineering projects have become increasingly important as technology has advanced in recent years. Penspen has a dedicated controls and instrumentation department which provides state-of-the-art solutions at basic, front end or detailed engineering stages.

Technical Audits

With engineering expertise in depth in all disciplines, Penspen is able to provide a comprehensive technical auditing service to clients. The scopes of such audits have included vetting of third party designs, auditing of contractor procedures and performance, as well as auditing and assessing the performance of client organisations themselves. Technical audits add considerable value to the successful close-out of key milestones in project development, from early design stages through to construction and commissioning.

Project Controls

One of the keystones of any project management system is the availability of effective project controls. Penspen project controls systems are well-established and are continuously developing and improving as best practice techniques and available technologies advance throughout the industry. Project controls systems cover all aspects of planning, cost control, resource assignment, information control, document and



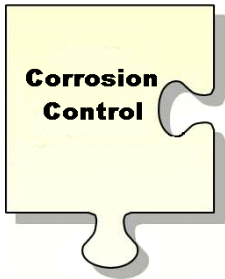
deliverable control and change control.

Detailed Engineering

Generally following on from basic or FEED engineering activities, detailed engineering develops the full definition of project requirements in terms of materials and equipment, and construction and installation. Penspen integrates detailed engineering with procurement, contracts and planning services to ensure that fully defined packages will satisfy all the client requirements for successful projects.

Design Appraisal

Penspen is able to provide independent technical appraisal to industry standards, of submitted designs or part designs or modifications, for pipelines, block valves, pig traps, pressure reduction installations and other above ground installations.



Leading the way in Corrosion Control

Background

In the field of cathodic protection, both technical and economic assessments, site surveys, engineering design, contract management, specialised materials supply, installation supervision, system testing and commissioning can be offered.

In addition, routine maintenance inspections can be undertaken, at designated intervals, to monitor the effectiveness of all types of cathodic protection systems. Specialised over-the-line surveys and computer software systems have been developed specifically for the management of cathodic protection monitoring data.

For steel reinforced concrete structures, Penspen is able to assess concrete quality and reinforcement corrosion and has undertaken fundamental research into the most effective approach to cathodic protection. In addition, expert advice can be offered for the evaluation of all commercially available rehabilitation techniques. Penspen can offer advice on protective coating and lining selection and production of specifications, together with subsequent control and inspection of material application both in the factory and on site.

In addition, comprehensive training courses and seminars on corrosion protection subjects have been organised and undertaken for a variety of companies in the oil, gas and water industries around the World.



Survey Capabilities

A specialised pipeline survey capability has been developed, which is able to accommodate the requirements of pipeline operators who require detailed investigations into external pipeline coating condition, levels of cathodic protection achieved on pipelines and associated problems on the pipeline protection system. The techniques offered are:

Close Interval Potential Survey

A survey to provide a detailed profile of the potential level along the entire route of a pipeline. The profile can include both 'system ON' and 'instantaneous OFF' potentials and is used to assess the performance of the cathodic protection system, the condition of the pipeline coating system and presence of interaction effects.

DC Voltage Gradient Survey

Using a pulsed dc current on the pipeline, the survey investigates voltage gradients associated with external coating defects, using two earth contact probes and a sensitive centre-zero voltmeter. Severity of defects can be assessed and effectiveness of cathodic protection at the defect determined.

Pearson Coating Survey

A survey technique to detect external coating defects, which employs an ac signal injected onto the pipeline and compares the potential gradient between two mobile earth contacts. At coating defects, increases in voltage gradient occur which are recorded.

Signal Attenuation Coating Survey

An ac signal is applied to the pipeline and this signal will gradually decrease as it leaks to earth through the capacitive and resistive effects of the coating. At coating defects the signal loss will be greater and the survey equipment is used to measure this intensity at selected pipeline locations to determine coating condition.

Each survey technique has its particular attributes, in general Pearson and signal attenuation coating surveys directly examine the external coating, whereas close interval potential surveys investigate cathodic protection levels and thereby provide an indirect report of coating condition. The dc voltage gradient survey is a hybrid approach, as the technique can locate coating defects and is then able to evaluate whether cathodic protection is achieved at that coating defect.

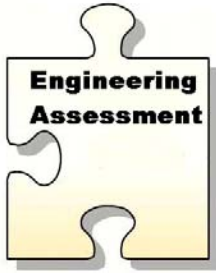
Advice can be given on survey selection to develop and the most efficient investigative approach and to then to formulate the most appropriate pipeline protection rehabilitation programme, with consideration of coating material and application specifications and upgrades to cathodic protection systems.

Examples of Recent Projects

Projects have been successfully completed on offshore platforms and submarine lines, coastal outfalls, jetties and water screening facilities, together with onshore tank farms, process facilities, well casings and pipelines.

Expert witness duties have been undertaken and specialists can be provided for investigation of corrosion failures and material selection for corrosive situations.

Advice can be offered on protective coating and lining selection and production of specifications, together with subsequent control and inspection of material application both in the factory and on site.



Leading the way in Assessment of Geohazards & External Loading on Pipelines

Background

Pipeline construction and management frequently has to cope with hostile or extreme environments subject to a range of geohazards. These typically include:

- Ground shaking in seismically active regions.
- Landsliding ranging from slow creep to rapid debris flows.
- Ground subsidence and settlement by natural or man-made activities.
- Displacements across geologically active faults.
- Freeze-thaw displacements.
- Erosion events leading to exposure, spanning and impact incidents.

In addition, a range of construction activities may directly load or present a hazard to pipelines including formation of embankments, quarry excavations, live loading effects, landfilling operations and major civil engineering structures.

In these circumstances operators may need to investigate whether the pipeline is experiencing an increase in load and then either satisfy regulatory requirements or demonstrate that the pipeline is fit-for-purpose.

Assessment of Pipeline Integrity from External Loading

Penspen Integrity has highly experienced geotechnical specialists that can supply a wide range of pipeline integrity services covering the assessment of pipeline integrity from ground movement and external loads. The principal services cover,



- Conduction of field surveys and investigation works to determine the nature and extent of loading.
- Quantification of representative loading and load distributions.
- Understanding and experience of the key influence of soil restraint on pipeline behaviour.



- Detailed calculations to demonstrate the integrity of the pipeline
- Access to sophisticated finite element analysis and pipeline stress analysis techniques tailored to complex buried pipeline configurations.



- Specification and execution of direct monitoring and evaluation programs for pipeline integrity.
- Implementation of measures to protect pipelines from high loads or methods of controlling these within safe levels.
- Design and execution of siteworks for remediation of highly loaded pipeline structures.

Assessment of Geohazards

Penspen Integrity has the capability to assess and manage the effects of geohazards on pipelines. In addition to aspects of pipeline integrity assessment from external loads, the services cover:

- Investigation and inspection of pipeline routes to determine the presence of hazards.
- Use of screening assessments to rank the level of threat to the pipeline and prioritize the critical sites.



- Probabilistic evaluation of geohazard loads.
- State of the art analysis of critical sites to determine pipeline integrity including non-linear geometrical and material behaviour.
- Evaluation of the probability of failure and failure frequency of pipelines subject to geohazards.
- Sound recommendations on proven methods for mitigating or avoiding geohazards.



Leading the way in Pipeline Integrity Training

Courses

Penspen Integrity is the world leader in pipeline integrity training. We have trained 2000 people and we have provided technical and management training to thousands of staff in Europe, North and South America, the Middle and Far East and we are now the world leader in training in the pipeline industry. We do far more than technical training courses; we can present courses on management and other business skills.

Courses can be custom designed for our client's needs or we run a series of public courses. Our list of courses includes:

- Onshore Pipeline Engineering Training Course
- Offshore Pipeline Engineering Training Course
- Introduction to Corrosion Engineering
- Defect Assessment in Pipelines
- An Introduction to Hazard, Risk & Safety and it's Management in Transmission Pipelines
- An Introduction to Risk & Integrity Management of Pipelines
- Using Fitness for Purpose Methods for Optimising 'Intelligent' ('Smart') Pig Inspections
- An Introduction to Pipeline Repairs
- Upgrading Pipelines
- Management of Change
- Introduction to Pipeline Engineering – new technical staff
- Introduction to Pipeline Engineering for non-technical staff
- Emergency Response and Planning
- Being a Consultant
- Ethics, Morals and Responsibilities in Engineering

For Training Course dates please visit our website:-

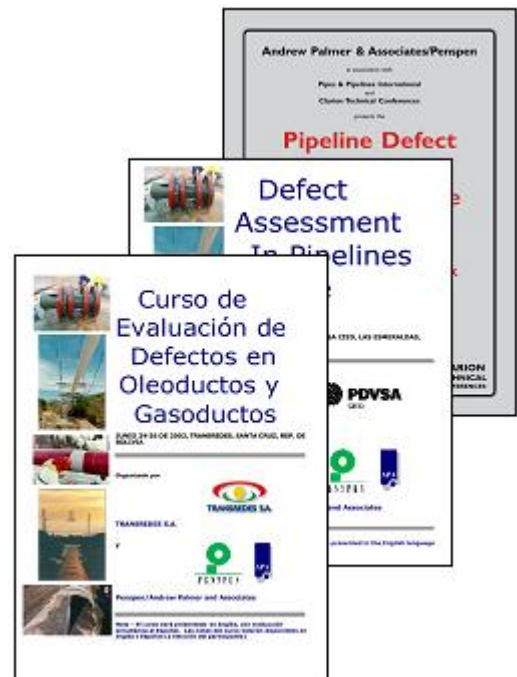
www.penspenintegrity.com

Training

Penspen staff are experienced in training: many have extensive university lecturing experience and many years experience in the pipeline business.

Students

We train all nationalities, and can present the course through interpreters. Our Defect Assessment in Pipeline Course Notes are in Spanish and English.



Industry Accreditation
Our courses are recognised by many industry organisations for continuing professional development.



Approved Training Provider

Joint Industry Project The Pipeline Defect Assessment Manual (PDAM)



BACKGROUND

The Pipeline Defect Assessment Manual ('PDAM') is a 473-page engineering manual that details the 'best practices' in pipeline defect assessment, and provides users with detailed procedures, methods and equations for the assessment of defects such as corrosion, gouges and dents. It gives definitive guidance on the assessment of defects in pipelines.

• BP plc • BG plc • Centro Sviluppo Materiali SpA (CSM) • Chevron Energy Technology Company (a division of Chevron U.S.A. Inc.) • CNRI • Det Norske Veritas (DNV) • Exxon Mobil • Gaz de France • GE Power Systems Oil & Gas PII Pipeline Solutions • Germanisher Lloyd • Health and Safety Executive • MOL Hungarian Oil and Gas plc • Petróleo Brasileiro S.A. (PETROBRAS) • PROMIGAS S.A. E.S.P. • Saipem UK Limited (a member of Saipem ENI Group) • Shell Global Solutions International B.V. • SNAM Rete Gas SpA • Statoil ASA • Toho Gas Company Limited • Total E&P UK plc •

The manual was produced in 2003, but the Joint Industry Project is continuing; this allows the manual to be continually updated.

THE PIPELINE DEFECT ASSESSMENT MANUAL

The past 40 years has seen the development of numerous methods for assessing the significance of defects in pipelines. Some of these methods have been incorporated into industry guidance, others are to be found in the published literature. However, there is no definitive guidance that draws together all of the assessment techniques, or assesses each method against the published test data, or recommends best practice in their application.

PDAM presents a considered view of the 'best' currently available methods for assessing the significance of defects in oil or gas, onshore or offshore pipelines manufactured from steel line pipe. The 'PDAM' project has four products:

1. PDAM: The Pipeline Defect Assessment Manual containing the detailed methods needed to assess a variety of defects in pipelines.
2. REVIEWS: Sixteen pipeline defect assessment literature reviews which were researched and written to provide a sound technical basis for the recommended methods in PDAM.
3. CALCULATIONS: Thirty spreadsheets covering the methods in PDAM.
4. DATA: Thirty spreadsheets containing the full scale test data that form the bases of many of the recommended methods in PDAM.

TYPES OF DEFECT CONSIDERED IN PDAM

PDAM contains guidance for the assessment of the following types of defect:

• defect-free pipe • corrosion • gouges • plain dents • kinked dents • smooth dents on welds • smooth dents containing gouges • smooth dents containing other types of defects • manufacturing defects in the pipe body • girth weld defects • seam weld defects • cracking • environmental cracking • interaction between defects of similar and different types • leak and rupture • fracture propagation •

PDAM considers longitudinally, circumferentially, helically-orientated defects subject to (static and cyclic) internal pressure, in-plane bending, axial force, and combinations of these loads.

THE EXTENDED PDAM PROJECT

The PDAM project has been extended to ensure that the PDAM is maintained and updated in line with developments in the published literature and comments from the users of PDAM. New sponsors can join the existing sponsors of the extended PDAM project for GBP £20,000 (twenty thousand pounds sterling). Sponsors of the extended PDAM project will receive all of the deliverables of the PDAM project. Additionally, sponsors will benefit from receiving regular (annual) maintenance and update of the PDAM and from having an influence over the future development and improvement of the PDAM.

PDAM considers longitudinally, circumferentially, helically-orientated defects subject to (static and cyclic) internal pressure, in-plane bending, axial force, and combinations of these loads.

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