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# TRAINING ENGINEERS IN PIPELINE INTEGRITY

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## ABSTRACT

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In pipeline engineering you don't need anything at all! You don't need qualified engineers, you don't need quality systems, you don't need risk management, you don't need safety audits, you don't need inspections, you don't need training. You don't need anything! Until something happens... then you need everything.... Got the message?

Pipeline integrity means pipeline safety and security, and it is currently a 'hot' topic following numerous high profile and tragic failures.

The integrity of a pipeline is critically dependent on its engineering. and managing risks. This paper explains the increasing importance of training and shows why it is essential that a pipeline's management and engineers understand many aspects of pipeline engineering to be able to understand a pipeline's integrity needs. Additionally, the paper outlines the integrity training needs for pipeline engineers.

## 1. INTRODUCTION

We live in an ever-changing world, and as individuals we must live with change. In our work place we accept downsizing, re-engineering, etc., and in the oil business we accept the fluctuating price of oil.

We are experiencing change in the pipeline business (1,2): poor quality materials and a lack of understanding of major risk meant that 30 years ago, and before, we needed standards that ensured we had good quality pipe, careful routeing, etc.. But now we know that in-service defects (damage, corrosion) fail pipelines and cause casualties (see Section 2). Hence, a pipeline's 'integrity' is dependent on the design, operation and management of a pipeline.

Consequently, we have seen in the past few years the publication of regulations and standards that formally require pipeline operators to 'manage' their pipeline's integrity and have in place formal risk management plans that clearly mitigate and control risks (see Section 3).

Our engineers now need to know how pipelines fail, how to assess damage and risk, and produce integrity plans. This knowledge is relatively new to the pipeline business, although the methods and protocols have been available for decades.

Hence, we need to rapidly train our engineers in these 'new' integrity protocols.

### 1.1.Training

The two most important specifications when recruiting professional staff are usually qualifications and experience. In the pipeline business we rely on academia to provide the basic qualification and all-too-often rely on other companies to provide the experience. Is this sensible and sufficient? Probably not, as engineers receive little or no training in pipeline engineering at graduate or post graduate levels [1], and our oil and gas majors are continually going through 'downsizings' and early retirement programs that ensure large losses in pipeline skills and experience. More important, these programs target the older staff that we have relied on to mentor the young engineers and help them gain experience.

Has your company a structured training program? Has your company a commitment to training engineers in integrity, particularly updates on all the recent technical advances (e.g. smart pigging), management changes (e.g. management systems) and code updates (e.g. ASME B31S)?

This section will focus on the increasing importance of training, and its value to pipeline companies.

#### 1.1.1 Recruitment & Retaining Staff

Good, forward-thinking companies invest in their people, and part of that investment is training. This makes business sense; a study released in 1999 by The Gallup Organization showed clearly that employer-sponsored training and education is a major attraction for people looking for jobs. Also, workers say they are more likely to remain with companies that invest in such programs.

In 1999, a review by the UK's Institute of Personnel & Development showed staff training to be the key to retaining skilled employees, and in 1999 a survey by the American Management Association showed that investing in employees

[1] This is changing. The University of Newcastle, in the UK, has a Masters Program on Pipeline Engineering (Section 4). Log onto www.ncl.ac.uk for more information. Also, the ASME has a Pipeline Engineering Sub-Division that is active in pipeline engineering education and conferences. Log onto www.asme.org for more information.

 

skills through training is a more effective tool for retaining staff than purely financial incentives.

### 1.1.2 Intellectual Capital (1 -4)

Many of our newer companies have values in excess of their earnings or values shown on their balance sheet. In some cases the company value is less than 10% the stock market value. Where does the other 90% come from?

We now have a switch from 'physical capital' to 'intellectual capital'. This is because knowledge is now a major source of competitive advantage in all industries. World -class companies must operate in a continuous improvement environment - in such an environment, knowledge and brainpower are the company's greatest assets:

i. INTELLECTUAL CAPITAL - TANGIBLES - includes legally recognised intellectual property such as copyrights, patents, brand names, trademarks, etc.. They can be accounted for using historical data, but most companies exclude brand names from a balance sheet.

ii. INTELLECTUAL CAPITAL - INTANGIBLES - includes employee know-how, capability and the knowledge carried in heads.

iii. ORGANISATIONAL CAPITAL - includes intellectual capital but also management and organisational culture.

iv. VALUE? The market value of a person is mainly determined by a combination of the knowledge the person creates and owns. A company's worth is an accumulation of its employees' knowledge. The market value of a company is determined - in large part - by the intellectual capital, as perceived by the investing public. Exxon's intellectual capital has been valued at 72% of its market value. Dupont was valued at 84%. Coca Cola was valued at 96%. Intellectual capital is often termed as 'goodwill' or 'intangible asset/value' in the financial books, but it is worthwhile considering your own company's worth, and deducing its intellectual capital worth.

Unfortunately, it is a fact that the intellectual capital of the oil and gas business continues to 'leak into other industries at an alarming rate' (4).

The 'developed' western world populations are ageing as birth rates fall (5). Massive skills shortages are looming which are already very evident in the marine industries. The issue is not new, but becoming more important by the year. For example, in the UK across all industries 25,000 engineers retire annually and only 12,000 graduates replace them. In one major contractor, for the past decade the average age of senior engineers and project managers has been moving upwards - it is now 49 years and increasing by about one year in every two. Estimates suggest that the offshore oil and gas industry could lose over 50% of its most experienced workers by 2007 (5).

Hence, we must preserve and grow our intellectual capital, by refining our business processes, exploiting technology, and cultivating an environment that promotes creation, collection and sharing of knowledge. This is partly achieved by having well-trained staff, under continuous development programmes, but would also include research programmes and involvement in industry initiatives, such as code writing.

## 1.2 TRAINING ENGINEERS

### 1.2.1 Safety

Training of engineers is not only a business investment – it is essential for safety.

A study (6) conducted at the Swiss Federal Institute of Technology in Zurich analysed 800 cases of structural failure in which 504 people were killed, 592 people injured, and millions of dollars of damage incurred.

When engineers were at fault, the researchers classified the causes of failure as follows:

| | |
|---|---|
| • Insufficient knowledge | 36% |
| • Underestimation of influence | 16% |
| • Ignorance, carelessness, negligence | 14% |
| • Forgetfulness, error | 13% |
| • Relying upon others without sufficient control | 9% |
| • Objectively unknown situation | 7% |
| • Imprecise definition of responsibilities | 1% |
| • Choice of bad quality | 1% |
| • Other | 3% |

Clearly, we must ensure our engineers have both knowledge and an understanding of all influences on plant, and this is best achieved by training. To ensure the engineer is always up-to-date, the training must also be part of a continuous development process, which would include attendance at conferences, involvement in research, etc.. However, this paper is focussed on the training element of this development.

### 1.2.2 Legal And Professional Requirements To Train Engineers

Engineers have a legal duty to exercise a 'standard of care' when carrying out their duties. An engineer would be failing in this standard of care if they did not having learning and skill ordinarily possessed by other engineers (7). Consequently, a company not training its engineers to reasonable and recognised standards would also be failing in its 'duty of care' to the general public and its workers.

Additionally, our professional bodies (e.g. ASME) require that engineers perform services only in areas of their competence, and they need to continue their professional development throughout their careers. This presents us with difficulties; as companies change, and are downsized, re-engineered, etc., the engineer is often faced with multi-disciplinary problems and duties, and a shortage of time to train.

### 1.2.3 Cost

Courses on pipeline integrity cost between $1000-$2000 (2002 costs) for one to three day courses. Add-on costs would be lost time and subsistence, and these are usually the major costs.

Value? An understanding of pipeline integrity can help assess pipeline defects and avoid unnecessary repairs which can cost $100,000s. It can help planning of inspections and maintenance that could avoid, for example, expensive smart pig runs which can cost $1,000,000s. Last, and most important, it can avoid pipeline failures that can cost lives and $10,000,000s.

## 2. PIPELINE SAFETY AND INTEGRITY

Pipelines are a very safe form of energy transportation, but we must constantly review our pipeline's operation to ensure we maintain this high level of safety. This means we must maintain 'integrity'. To understand how we can maintain our pipeline's integrity, we need to know what fails our pipelines. If we can prevent the causes of failure, we can stop failures.

### 2.1 IN-SERVICE DEFECTS FAIL PIPELINES

What fails a pipeline today? Figure 1 shows that the major cause of pipeline failure for liquid and gas pipelines in the USA is 'outside force' (often termed 'third party damage' or 'external interference').

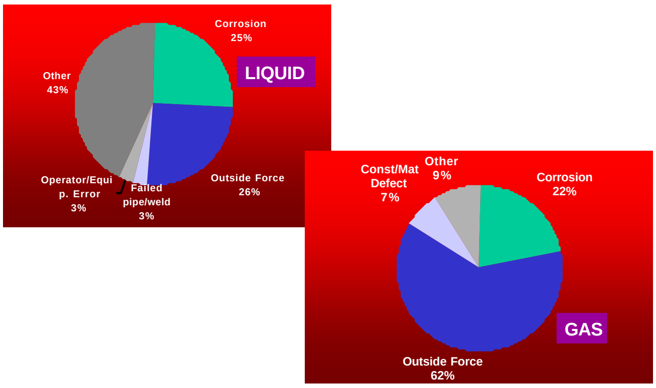


**Figure 1. Causes of Pipeline Failures in the USA in 2001 (data from USA Office of Pipeline Safety, (8))**

Failure data from other regions such as Western Europe also show outside force to be the major cause of failure, followed by corrosion. Therefore, if we are to improve the integrity of our pipelines we need to reduce outside force failures and corrosion, and focus our design and operation on achieving this reduction.

This is supported by the most recent, and serious (multiple fatality) failures in the USA; they appear to have been caused by deterioration (corrosion or outside force), rather than faulty design, Figure 2.

The point to make is that our basic design may be sound, but it is how we care for our pipelines during their life that is the new 'key' to their safety. Therefore, we need to focus on operational practices to improve safety.

**Figure 2. Recent USA Pipeline Failures (8)**

### 2.2 WHAT IS PIPELINE INTEGRITY, AND INTEGRITY MANAGEMENT?

Pipeline integrity is ensuring a pipeline is safe and secure. It involves all aspects of a pipeline's design, inspection, management and maintenance. This presents an operator with a complex 'jigsaw' to solve if they are to maintain high integrity, Figure 3.

Pipeline integrity management is the management of all the elements of this complex jigsaw: the management brings all these pieces of the jigsaw together.

### 2.3 THE NEED FOR AN 'HOLISTIC' APPROACH TO PIPELINE INTEGRITY

Pipeline failures are usually related to a breakdown in a 'system', e.g. the corrosion protection 'system' has become faulty, and a combination of ageing coating, aggressive environment, and rapid corrosion growth may lead to a corrosion failure. This type of failure is not simply a 'corrosion' failure, but a 'corrosion control system' failure. Therefore, an engineer must appreciate the system to prevent failure; understanding the equation that quantifies failure pressure is just one aspect. Figure 3 summarises the many aspects of pipeline integrity that need to be appreciated to be able to manage a pipeline effectively and safely.

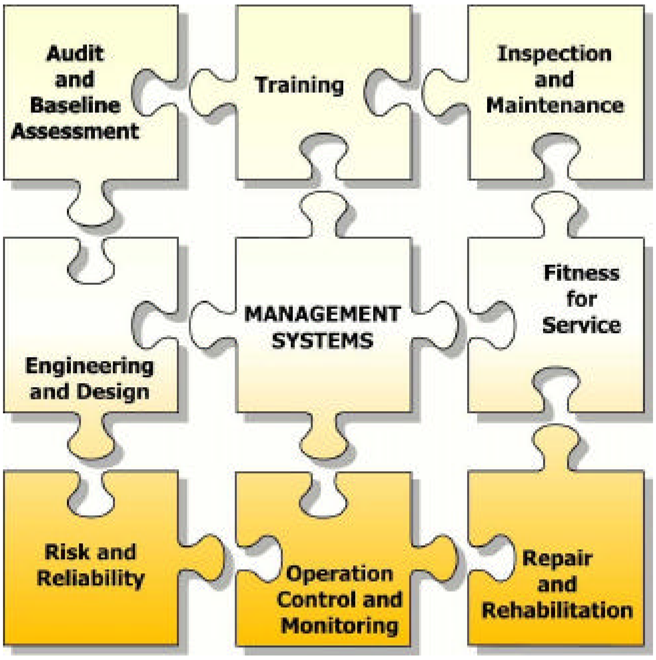


**Figure 3. The Pipeline Integrity 'Jigsaw'**

**Figure 4. Gas Pipeline Failure in North America (8)**

Additionally, failures affect the surrounding people and environment; therefore, an appreciation of the consequences of failure is essential, Figure 4. This means an understanding of risk analysis.

The need to understand the many aspects of pipeline integrity means that a holistic approach (Figure 3) to pipeline integrity training is needed. This approach will allow a company to present a training course that will provide the engineer with all the necessary skills to assess pipeline integrity.

## 3. THE MOVE TOWARDS REGULATING AND STANDARDISING PIPELINE INTEGRITY

### 3.1 REGULATION

In 2000[2], the U.S. Department of Transportation (DOT) proposed regulations that require pipeline integrity validation through inspection, testing, and analysis of pipelines that run through or near high consequence areas (HCAs) (9). HCAs are defined as populated areas, commercially navigable waterways, and areas that are unusually sensitive to environmental damage.

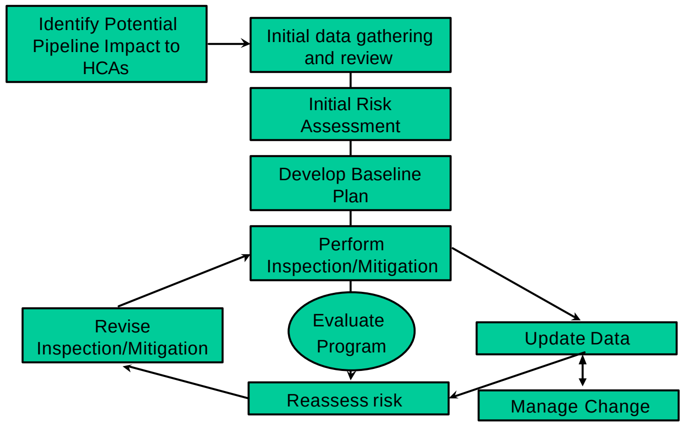


**Figure 5. Framework for Pipeline Integrity Management from API 1160 (10)**

The DOT's Office of Pipeline Safety (OPS) now expects operators of HCA pipelines to have an integrity management program that continually assesses and evaluates the integrity of HCA pipelines. These programs would be applied on the basis of either prescriptive requirements from OPS or risk-based decisions made by the pipeline operator.

### 3.2 STANDARDISATION OF PIPELINE INTEGRITY MANAGEMENT FOR LIQUID LINES - API 1160

The American Petroleum Institute (API) has developed an industry consensus standard that can provide a basis for a company's approach to satisfying the proposed DOT regulation.

[2] A 'final rule' applying to hazardous liquid pipeline operators was issued in 2000; operators are required to perform a 'baseline assessment' of their pipeline system by e.g. smart pigs, hydrotesting, etc.. Baseline assessment must include identification of all pipeline segments, methods to assess integrity, schedule for integrity assessments, and explanation of all risk factors. Additionally, operators must maintain a written integrity management plan.
A 'final rule' applying to gas pipeline operators is expected to follow closely the new ASME B31.8 Appendix on pipeline integrity (see below).

This standard is titled "Managing System Integrity for Hazardous Liquid Lines" ( API Standard 1160-2001) and was published in November 2001 (10).

API 1160 gives guidance on developing Integrity Management Programmes. An outline of the suggested API framework is given in Figure 5.

These programmes must:

- Identify & analyse all events that could lead to failure,
- Examine the likelihood and consequences of potential pipeline incidents,
- Examine and compare all risks,
- Provide a framework to select and implement risk mitigation measures,
- Track performance.

The programme starts with a good pipeline design and construction, satisfying all other legal and code requirements, and:

- It is flexible,
- It is built on trained people, using defined processes,
- It should be tailored to an operator's needs,
- An integral part is a risk assessment, and this is a continuous process,
- It should use new technology,
- It should be externally audited,
- There is no 'best approach'.

We can see that training is an important aspect of pipeline integrity management, and that any integrity engineer must understand and appreciate such matters as risk assessment and mitigation, failure causes and basic pipeline engineering.

3.3 STANDARDISATION OF PIPELINE INTEGRITY MANAGEMENT FOR GAS LINES – ASME B31

The American Society of Mechanical Engineers (ASME) has rapidly produced an integrity management appendix for its ASME B31 code: 'Managing System Integrity of Gas Pipelines', ASME B31.8S-2001 (11). It is applicable to onshore pipeline systems constructed with ferrous materials that transport gas, and became available in April 2002.

This supplement requires all 'threats' to a pipeline to be evaluated. Threats are: Time Dependent (e.g. external corrosion); Stable (e.g. manufacturing-related defects); Time Independent (e.g. outside force).

These threats are appraised using a risk assessment. This assessment must include the evaluation of 'impact areas', i.e. the area around a pipeline that might be affected by a failure. This includes a consideration of the consequences of a failure with respect to:

- Population density,
- Proximity of the population to the pipeline (including consideration of manmade or natural barriers that may provide some level of protection),
- Proximity of populations with limited or impaired mobility (e.g., hospitals, schools, child-care centers, retirement communities, prisons, recreation areas) particularly in unprotected outside areas,
- Property damage,
- Environmental damage,
- Effects of unignited gas releases,
- Security of gas supply (e.g., impacts resulting from interruption of service),
- Public convenience and necessity,
- Potential for secondary failures.

The risk assessment allows a prioritization of pipelines/segments for scheduling integrity assessments and mitigating action, such as inline inspection or pressure testing.

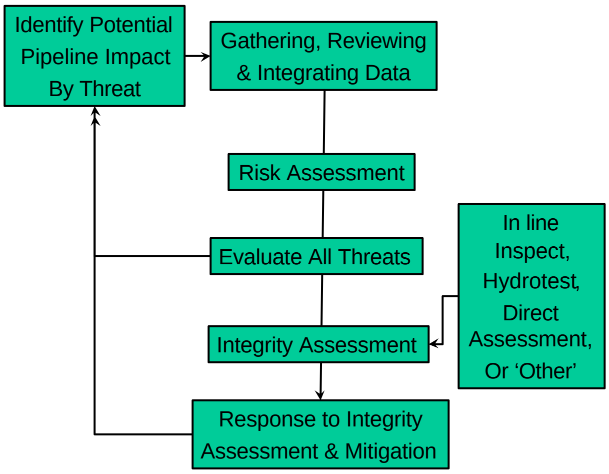


**Figure 6. Framework for Pipeline Integrity Management from ASME B31S-2001 (11).**

## 4. TRAINING ENGINEERS IN PIPELINE INTEGRITY

### 4.1 BASIC CONSIDERATIONS AND BASIC NEEDS

The author regularly works as a consultant on integrity problems for pipeline companies around the world. He also presents pipeline integrity training courses in North and South America, Europe, the Middle East and the Far East. Using this experience, a training needs list for pipeline engineers involved in a pipeline's integrity is detailed below. First of all we will consider the basic needs for training and some general considerations.

#### 4.1.1 Some Considerations

The first point to make is that training serves little purpose unless it has a clear purpose (see Section 4.5). The increase in importance and interest in integrity and risk gives pipeline integrity training three clear purposes: safety (Section 2); satisfying regulations/codes (Section 3); and increasing company value (Section 1.1.2) .

The second point to make is that integrity is a team effort – it requires many skills or access to skills. It is not simply a question of doing a calculation on an area of corrosion, nor is it simply a run by a 'smart' pig. It is the bringing together of all the elements of the jigsaw in Figure 3.

The third point to make is that pipeline integrity is both a business and corporate issue, and hence its accountability and responsibility must reside with senior management. Its importance and complexity cannot be simp ly delegated.

The final point is simple: we need to be able to answer the question *'how are you training your engineers in pipeline integrity?'*. It is a valid question for any stakeholder in a pipeline's safety to ask, both before OR after a pipeline fai lure.

4.1.2 Experience

Engineering experience, or access to experience, is also important, but it should be remembered that some engineers with 20 years experience have, in fact, one year's experience repeated 20 times. Indeed a major conclusion from the integrity training courses conducted to date has been the general absence of wide ranging experience, and the absence of an in-depth understanding of pipeline integrity in most of the oil and gas majors.

4.1.3 Hindsight

We all know that hindsight is a precise science. A problem we all have is that we never think that accidents will happen. We decide not to renew our car breakdown insurance (Who needs it? Cars are so reliable now.)… the following week our car breaks down in the middle of the Mojave Desert. We decide to start buying cheaper computers (Why pay $2000 for a Dell, when I can get the same specification on a machine built by the guy in our local mall for $1000?), and they start crashing and losing all our work, and the guy from the mall has moved (quickly).

When the accident happens we will pay just about anything to remedy it, and we quickly realize our errors. It is exactly the same with pipeline failures. Try and think ahead.

4.1.4 Basic Needs

The integrity training needs can be divided into two areas:

i. Basic pipeline engineering knowledge,
ii. Pipeline integrity knowledge.

Basic pipeline engineering knowledge will include an understanding of pipeline design, operation, maintenance and inspection. This can be achieved through a combination of training courses and on-the-job experience. Alternatively, staff can attend dedicated university courses on pipeline engineering such as the Masters course at the University of Newcastle, UK[3].

We will assume that pipeline companies train their engineers in general pipeline engineering, and now focus on pipeline integrity training.

API 1160 (see Figure 5) implicitly gives us some guidance on pipeline integrity training needs, but any pipeline integrity course must cover:

[3] www.ncl.ac.uk/pipe.eng

- Basic Pipeline Engineering (including regulations, design, pipeline stresses, hydrotesting and pipelines' safety record),
- Engineers' Responsibilities (including ethics),
- Pipeline Defects and Why Pipelines Fail,
- Fracture Mechanics and Fatigue[4],
- Assessment of Pipeline Defects (corrosion, gouges, dents, cracks and weld defects),
- Fracture Propagation and Arrest,
- Setting Smart ('intelligent') Pig Inspection Levels,
- Setting Inspection & Maintenance Priorities,
- Pipeline Repair and Rehabilitation,
- Risk Analysis and Integrity Management, and
- Pipeline Management Systems.

If the course needs to cover offshore pipelines in detail, then an appreciation of pipeline spans, stability, buckling and interaction with fishing gear is also needed.

There are both publications (e.g. 12-14) and courses available that cover all the above aspects, but note that companies need to check both the credentials (are the speakers suitably experienced and well-known?) and independence (are the speakers trying to sell something other than education?) of these course organizers/presenters.

4.2 APPRECIATION OF INTEGRITY CODES AND GUIDELINES

There are a number of codes, specifications and guidelines available to assist engineers when they are appraising pipeline integrity. Hence, engineers must have an appreciation of these documents.

Figure 7[5] gives a sample of the codes and guidelines that are available (15 -18). Codes such as ASME B31.8 give some guidance, e.g. on crack arrest criteria. We have already mentioned API 1160 as a general integrity management document, but standards such as API 579 and BS 7910 (15, 16) give specific assessment methods for a variety of defects detected in structures.

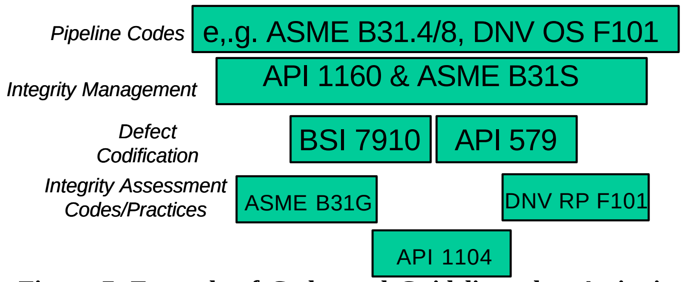


**Figure 7. Example of Codes and Guidelines that Assist in Integrity Assessments**

[4] Recent engineering graduates will often have covered these items.
[5] For further information on the standards in Figure 7, logon to the ASME, API, BSI and DNV websites.

The pipeline industry has further developed its own guidelines such as the Appendix G to ASME B31 (17), which gives assessment procedures for corrosion in pipelines.

Finally, there is an industry-sponsored project[6] nearing completion in the UK supported by 14 companies, including many of the oil and gas majors (19-21). This project will produce a manual for assessing all types of defects in pipelines, and will specify all the available 'best practices'.

## 4.3 CHANGING HOW WE VIEW RISK

We can see from Figures 5 and 6 that an assessment of risk is the new 'key' to pipeline integrity.

Risk should be identified and managed at all levels in a company, but it should start with corporate management, as the senior executives enable policies and projects.

The designers, engineers and operators collectively design, construct, operate and maintain the pipeline, but it is corporate management who control finance, set objectives and assign responsibilities. This is an important point – senior executives should be aware of pipeline risk, as they are accountable, and engineers should ensure their executives and management are aware of all risks.

The risk posed to population and environment by a pipeline is a function of its failure probability and its consequences of failure. Clearly, it is part of the integrity management of a pipeline, Figure 3; therefore, this risk is managed by good operational and design practices. For example, damage to the pipelines can be prevented by good surveillance, and liaison with those who might damage them.

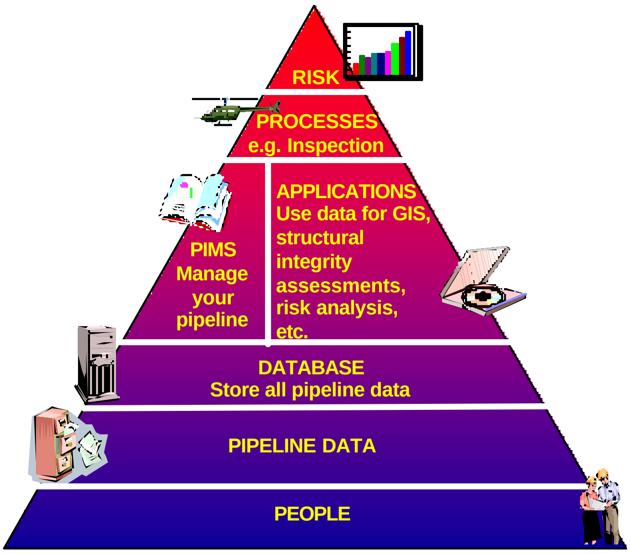


**Figure 8. Managing Pipeline Risk – The Risk 'Pyramid'**

Also, corrosion can be prevented by effective corrosion protection systems, and detected by using intelligent pigs.

Pipeline risk management starts with good staff and management, dealing in good quality data, usually accessible from a database. This database can be accessed by 'applications' such as Geographic Information Systems (GIS), but structural assessments will also need the data. Overall, these applications and assessments will be managed by some type of pipeline integrity management system (PIMS), and the data and analyses can be used to monitor and control the risk posed by the pipeline to surrounding population and society.

Figure 8 shows the position of risk assessments in controlling pipeline risk. The control of pipeline risk is a complex and wide ranging exercise: it is not simply a risk analysis software package. The risk analysis calculation is one part of the process of identifying and quantifying risk which includes management, databanks, inspection strategies, etc., and all parts of the pyramid in Figure 8 need to be understood and in place to allow risk to be quantified and controlled.

Consequently, a HOLISTIC approach is needed to managing pipeline risk – it is not simply the purchase of an expensive risk analysis program, or a catchy new mission statement declaring an environmentally friendly strategy.

## 4.4 CHANGING HOW WE MANAGE DATA

Every year we have more and more pipeline data to manage. These data are key to helping us monitor and review our pipeline's integrity and risk of failure (see above). How good is our data and how good is its management?

Data Management Association International[7] provide information on quality of data. For example, a 2001 Price Waterhouse (PWC) survey showed that only 1 in 3 companies were "very confident" about the quality of their data. A third of the companies had to scrap IT systems that did not work. PWC concluded that often the software was not the problem, but rather inconsistent, duplicate or error-filled data. Additionally, almost half of the respondents said senior management did not place enough importance on data management issues.

The world produces between 1 and 2 exabytes ($10^{18}$ bytes) of unique information per year, which is ~ 250 megabytes for every man, woman, and child on earth. Printed documents of all kinds comprise only .003% of the total. Unfortunately, in a typical IT organization, less than 10% of data collected is used: 90% is just a cost to the company.

Worldwide we created more information in the last 3 years than in all of previous recorded history. The literature tells us that the average volume of data usable for analysis per company will grow by x3000 in the next 4 years, and the number of users of that data in your company will grow by x4 in the next 4 years.

Hence, if we want to effectively manage our pipeline risk we need to both organize and standardise our data management, otherwise we will not be able to assess, monitor or control risk.

Currently, there are two basic data management approaches (IT people would call these 'domains'):

[6] For further information logon to www.apancl.co.uk

[7] www.dama.or

i. In the *application*[8] *domain* the database and data management functions are dependent on, and an integral part, of an 'application', e.g. a Geographic Information Systems (GIS), where special software uses the data. The data reside within the application. These are the most common in our business.

ii. In the *warehouse domain* the database and data management function is independent of any application. The data is contained in a 'warehouse' that can be accessed by any application.

The *application domain* creates a situation whereby data is "locked in" to an application and cannot be accessed by other applications. For example a database built up in a GIS application, may not easily be accessed by a risk assessment application. This may also 'lock' a pipeline operator to the application vendor: a situation many now find unacceptable.

The solution, to the inherent failings of *application domain* data management, is to manage information independent of any application so that it is available to a wide variety of users and applications. This approach is the data warehouse domain data management environment. It is based on the simple principal that (software) applications and pipeline data have differing ownership and life spans: data must last forever and resides within a pipeline operator, whereas applications are continually being updated/changed and are the property of a software vendor. This also means the skills and knowledge base of the people responsible for each will also reside in different locations.

There are now several initiatives in the pipeline business that are attempting to standardize how we manage our data. The 'PODS' initiative in the USA (22) was the first step: the USA pipeline industry is building its databases in accordance with a company-wide or industry-wide standard to allow operators to compare their own performance with comparable companies or across the pipeline industry'. The Pipeline Open Data Standard (PODS) is managed by, and for, the pipeline industry (22). The 'ISPDM' initiative in Europe is providing further (similar) advances (23). This industry standard pipeline data management project is a $1milllion project supported by the European Union, and due to finish at the end of 2002.

## 4.5 KEY MESSAGES FROM AN ENGINEERING TRAINING COURSE

A pipeline integrity training course must have the following objective and goal:

i. *Objective* – To understand the cause, behaviour, assessment, mitigation, management, and the consequences of defects in pipelines.

ii. *Goal* - To give course attendees a sound, holistic understanding of defects and failures in transmission pipelines, and the knowledge to allow their assessment, mitigation and risk management.

A pipeline integrity course is like any other engineering course; it is aimed at educating an engineer, to allow continued or improved safety of engineering plant. And this is the key message – a pipeline integrity course is a safety course, and this is the first of ten key messages engineers should obtain from the course:

1. ALWAYS THINK SAFETY – Pipeline codes are safety standards, and an engineer's prime role in any industry is to ensure safety. Additionally, they have a professional and legal duty to put safety first (see below).
2. PIPELINES ARE SAFE – But their management can make them unsafe. Pipelines fail for a reason, and most of these reasons can either be avoided or mitigated. Let's improve our pipeline's safety every year.
3. PIPELINE DESIGN CODES ARE 'DAY 1' CODES – A pipeline designed and built to code will be very safe on its first day in service; however, after day 1 the pipeline's management dictates its safety, not the design code. Therefore, good managers and good management systems[9] are the key to pipeline integrity. This means a continual appraisal of technical issues such as smart pigging, risk management programs, correct routeing, etc., to achieve high integrity, but remember - only good management will guarantee integrity.
4. DO NOT DO THE 'MINIMUM' - Codes. Regulations, etc., are minimum requirements. Aim to do more than your peers.
5. USE A HOLISTIC APPROACH - Pipeline Integrity Management must consider all aspects of our pipeline system, as it is an integrated process, where all elements affect safety. We must apply holistic solutions.
6. CHANGE IS DIFFICULT – It is difficult to change pipeline engineering practices in companies, because it is difficult to change people. However, as pipelines age we must continually change our approach to pipeline integrity.
7. CALCULATIONS ARE NOT ENGINEERING - They do convey the thought process and design intent, and are an essential part of any engineering appraisal. The quality, etc., of calculations indicates the level of care and diligence; however, calculations substantiate, but do not substitute, for judgement (7).
8. DO NOT AUTOMATICALLY SELECT THE LOWEST BID – Pipeline integrity will require hiring equipment and help. This will mean placing contracts, with differing vendors offering differing prices and services. Do not let your contracts department automatically accept the lowest price - a trained monkey can select the smallest of three objects. An engineer can select the safest and best.

[8] DATABASES – these are large, commercial software packages that can be used across a company, and by other companies. They resemble a 'warehouse' where we can store data.
APPLICATIONS – companies are using these data in 'Applications' such as GIS, and risk analysis programs: these Applications are constantly changing and improving, but our data must remain constant. As an industry, we will not usually develop Applications, so we need not concern ourselves with them, but we must organise our ever-increasing data for their use.

[9] Management Systems are covered in Reference 13 or logon to www.apancl.co.uk for similar publications.

9. ENGINEERING RESPONSIBILITY - It is an engineer's responsibility to ensure that any integrity or risk assessment is correct. He/she should use the best possible practices available, check calculations, inputs and assumptions, and use all available data (historical, current and circumstantial): inspection data, operations records, maps, etc., may give more information about the risks, causes, etc.. An appreciation of the wider practical issues, and an understanding of all engineering aspects of the problem are required. This will require excellent data management support and internal communications.
10. PROFESSIONAL AND PERSONAL INTEGRITY – Engineers performing integrity assessments, where decisions can effect company profits, career progression, environment, etc., must put safety first, and remember that engineers have professional (institutional requirements), legal ('standard of care') and ethical (moral) criteria to also satisfy in all aspects of their work (1,2).

And we will end this section by helping the manager whose task it is to justify all the above training requirements, by quoting Mark Twain… *"There is nothing training cannot do. Nothing is above its reach. It can turn bad morals to good; it can destroy bad principles and recreate good ones; it can lift men to angelship."*

It can also make your pipeline safer!

## CONCLUSION

There is now a real need to train pipeline engineers in all aspects of pipeline integrity. This requires a holistic approach that covers a wide range of engineering topics that can be represented by the pipeline integrity 'jigsaw'. Pipeline integrity management brings together all these topics.

This paper has highlighted the urgent need to train our engineers, and listed the requirements and contents of a pipeline integrity course.

We will end by repeating the abstract… *In pipeline engineering you don't need anything at all! You don't need qualified engineers, you don't need quality systems, you don't need risk management, you don't need safety audits, you don't need inspections, you don't need training. You don't need anything! Until something happens... then you need everything....*

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Western Regional Gas Conference. Anthony Tetto Senior Utility Consultant Loss Control. A E G I S. Complacency, Short-Cuts-Failure to Follow Procedures.Â  The following examples occurred when gas company employees lost respect for natural gas, became complacent or did not follow procedures. These are difficult â€œLessons Learnedâ€, but if we donâ€™t learn from history we may be destined to repeat past mistakes. Incident (2004)Company Retention $5M. A contractor working on a highway reconstruction project struck the service line to a house, causing the service line to separate from a compression coupling near the gas main. The gas company was called at 11:15 am; a serviceman arrived on the scene at 11:45 and immediately called for a crew.