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The Challenge of Change in Engineering

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ABSTRACT

This paper considers some of the challenges facing engineers and the pipeline industry as we experience business and social change, and we look to change some of our pipeline engineering practices.

These challenges range from maintaining our safety standards to furthering technologies to allow cost reductions. However, as an industry we will fail all our technical challenges if we do not retain our best staff, and manage them effectively.

Therefore, this paper considers some of the changes needed in the people and management side of our industry, before challenging current basic pipeline construction practices.

1. INTRODUCTION

The pipeline industry is like any other modern industry; recent years have seen massive commercial and managerial changes such as volatile oil prices, large oil and gas majors merging, and the collapse of one of our biggest companies (Enron) (1). This change will continue and we must not be surprised or alarmed; as Mario Andretti said *'If things are under control, then you're just not going fast enough'*.

This change will continue to be driven by the volatile oil price and global recession, the need to improve investment returns, industry consolidation, the pace of technological change, workforce demographics and an uncertain world order (2).

We are also faced with increased long-term demand for energy; world energy use will continue growing rapidly until at least the year 2020, particularly in developing nations. International energy outlooks estimate that overall energy consumption will rise 60% up to 2020. Faster-than-average growth is expected for developing nations (121%), world natural gas use (104%), and world net electricity consumption (76%).

Fossil fuel will continue to dominate up to 2050 (3) with natural gas the fastest-growing component of primary world energy consumption (more than doubling during 1997-2020), but oil is expected to remain the major energy source.

Meeting this demand will not be easy, as our reserves and future energy sources can be in distant and difficult environments, and there is a need for technological advances to allow economic development and transportation. Also, the current world recession means demand will be erratic and fluctuate; the International Energy Agency is predicting a low (0.8%) growth in oil and gas demand in 2002 and the World Bank concludes that mid-2002 may see a recovery in the global economy, but the risks posed to this recovery *'are the gravest in a decade'*.

Consequently, we are now an industry faced with wholesale change, uncertainty and increasing (albeit fluctuating) demands on our engineering. How can we survive this environment?

This paper considers change in all aspects of industry. It considers the challenges we are facing, starting with how we should change our engineers and management, and then it considers how to fund the innovations that will help us change our engineering practices. This is important, the key to pipeline integrity is well-trained and well-managed staff. Therefore, this paper emphasizes the importance of understanding changes in both our engineering staff and management.

Finally the paper considers some of the possible changes we could introduce into our business to reduce construction costs while maintaining safety. However, the paper starts with a reminder that we all need to change and that our primary focus in pipelines is our staff and safety.

2. ARE YOU READY FOR CHANGE?

The oil and gas business will change fundamentally in the coming years; we are already seeing the diminishing power of OPEC, as Russia (third largest oil producer after Saudi Arabia and USA, and non-OPEC) steps up its production, and the huge new reserves being found away from OPEC countries (e.g. Alberta, Canada) are likely to change both oil price and commercial power.

Change is a continuing fact of life; for example, the Victorians and those who lived through the Second World War experienced great change. Today, we are again seeing the pace of technological, political and economic change increasing. This leads to uncertainty; for example, companies that attempt to set out ‘10 year strategies’ are now viewed with humour, as we know (certainly since September 11^{th}) that our world can change in an instance.

We experience change in all aspects of our lives, but often do not notice its true effects. Consider your home and family and what you might think is ‘good’ technology:

- Central Heating. 40 years ago most homes in the Western World were small and not centrally heated, and therefore the family had to live in one room – the room with the coal fire. Now, central heating allows the family unit to be dispersed all over the house; we no longer have to sit together.
- Microwave Cookers. Traditionally, a family has sat down and had meals as a group, to ensure hot, safe food. Now, microwave cookers and convenience food allow members of a family to eat whenever they want; we no longer have to sit together to eat.
- Electronic Games. We no longer have to sit together to play.
- Cell Phones. We now no longer have to be together at all!

Hence, we should not be surprised when our environment changes in business.

3. CHALLENGES FACING OUR ENGINEERS

Currently, there is a major shortage of good quality engineers in our business. This has been the case for many years. To attract young talent we must offer an attractive career, including financial reward. Reference 1 covered the changing priorities of today’s workers, and how to make careers more attractive, so it is not covered here. However, there are real challenges facing our engineers ranging from continuous updates to their skills to ethical issues. This section covers several of these issues.

But first of all, let us start off this section by saying that all engineers are stupid. Why? We take the most difficult subject options at high school (science subjects), take one of the most difficult and intense degrees at university (engineering), work on low pay for many years to gain professional accreditation, and by the time we are 40 years of age, we hope to become a project manager on a salary that would make a 30 year old lawyer laugh. We accept poor working conditions, save money on projects that goes to support lavish corporate headquarters, attempt to train ourselves in new technology in our own time, support professional institutions that give us little in return, ‘carry’ old style managers who could not manage to find a drink in a brewery, and work on projects that have high accountability and responsibilities, but little financial reward. Engineers are stupid.

Therefore, we have to change, and hopefully the sections that follow will help….

3.1 A Lifetime of Learning and Training

3.1.1 Training

Engineers are strange professionals; we are expected to be at the forefront of technology and innovation, yet most of us do not have systematic and structured training. Engineers are very computer literate, but how many have ever undergone training on the use of computers? *'Not needed'* I hear you say *'we learn on the job'*. OK, but this culture unfortunately covers many other technical areas.

Consider a study (4) conducted at the Swiss Federal Institute of Technology in Zurich. They analyzed 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:

CAUSE	%
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%

Table 1. Causes of Failures, when Engineers were at Fault

It is not only engineers making these mistakes; a recent report (5) on a fatal (4 fatalities) rail crash in the UK in October 2000 concluded a major cause of the accident was an incomplete appreciation of the risks presented by cracks in the rails by the company that owned the rail infrastructure.

The above main causes are difficult to forgive – training may have prevented them. Therefore, we must ensure our engineers are well trained, and have a continuous professional development, and start to turn around the recognized lack of training and development in recent years, and our dwindling numbers (see below) (2,6).

A new survey has revealed skill shortages in many areas of engineering, with a great need to educate engineers, and teach them greater flexibility – '*multi-skilling is almost axiomatic to meet the changing demands of the industry*' (7). Reference 7 also highlighted the absence of structured training provision in companies, and training is still viewed as a cost rather than an investment, with companies expecting others to train their workforce.

Training also makes business sense; according to a 1998 USA survey (8) by The Gallup Organization, employer-sponsored training and education is a major attraction for young staff looking for jobs, and workers say they are more likely to remain with companies that invest in such programmes. Also, in 1999 a survey by the American Management Association showed that investing in employees' skills through training is a more effective tool for retaining staff than purely financial incentives.

3.1.2 Intellectual Capital (9,10)

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' [2]. 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 (see below). For example, to make an automobile takes 40% ideas, skills and knowledge and 60% energy and raw material. To make a computer chip takes 98% ideas, skill and knowledge and 2% energy and raw material. Human capital has become crucial to the success of business (11).

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%.

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'* (3), and we have an ageing, old workforce, giving age demographics described as *'disturbing'* (12).

Hence we have the dual problem of a workforce that is decreasing, and becoming very old! We have an average age in the offshore oil and gas industry of 49 years, with a tight distribution around this average due to minimal hiring during the downsizing era (2), with a 'young' worker being 43 and an 'old' worker being 55. With early retirement still popular, we could lose half of our experienced workforce by 2007.

The effect of these age demographics is tighter intellectual capital in companies. Hence, we need to be highly integrated and collaborative – organisations need to enhance their intellectual assets and competences regardless of its source or ownership (2).

We need to preserve and grow our intellectual capital, by refining 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 and accelerated

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[2] Intellectual capital is generally considered only the intangible assets of a firm, such as patents, processes, staff knowledge and goodwill, but we will consider items such as patents as having tangible value in this paper.

development programmes (2), but would also include research programmes and involvement in industry initiatives, such as code writing.

3.1.3 'Downsizing'[3] and Corporate Knowledge

Management consultants may move into our company, and start suggesting 'improvements' or 'rightsizing' the work force. Reference 1 recognises the important role of management consultants and suggests the optimum way to use management consultants, but all companies should carefully check that their suggestions are not short term fixes. Consider a hypothetical situation; a management consultant coming into my home, after I have told him/her that I have problems paying all the bills.

The consultant will review my home, and first of all would suggest that my wife is a major overhead – everything she does (cleaning, cooking, sex, etc.) can be outsourced. She must go. The children… they need rationalizing and re-engineered. Yes, they are important for a family unit, but… do you need all of them, and… do you really need them for 24 hours a day? So, they all go, but I can have them for 12 hours every weekend. The house is a deficient business process – why own a property when you can rent a smaller apartment, thus releasing capital to pay for further consultancy? What about Grandma and her flat over the garage? It is so difficult to let go of people you've known for a long time, but I'm told that this is business, and I could probably find a younger, cheaper grandma, with better short term memory, on a lease basis … bye bye grandma. Then the pet dog… a waste of money, with no resale value, and its constant attention-seeking can distract me from major issues. I hesitate, but the consultant tells me to make and execute decisions quick, and be seen to be decisive by subordinates. So, I shoot the dog in the front of the kids. Grandma's cat is not even discussed. Bang – in front of Grandma. In a constructive moment, and to satisfy my longings for a pet, the consultant suggests a cost-neutral solution; I should diversify and have a pet chicken – it will provide eggs on a regular basis, and if times become hard, I can eat it.

Therefore, the consultant's solution to my family budget problems is that I live alone, in an apartment, with a pet chicken. Beware management consultants.

In many situations, downsizing is vital for an organization's survival; if we do not make a profit we will not have a future. Similarly, redundancies are now a fact of everyday life, so we now have to live with both downsizing and redundancy.

Unfortunately, both can be badly handled:

- downsizing is now sometimes called 'dumbsizing'; research has shown that only 12% of downsized companies subsequently increase market share and most have below average share performance (13).
- when times are good our senior executives tell us that their staff are their greatest asset, but when times are bad the same staff become their greatest liability.

It is worth noting that companies are making the same mistakes today, as they made a few years ago during their last 'downsizing'; they are forcing staff, with critical knowledge and corporate memory, to leave, and they learn too late that such knowledge is irreplaceable (14-16).

The costs can be huge; the government enquiry following a railway crash in the UK, where 31 people were killed, heard evidence that specialists had lost their jobs in previous years leaving middle managers with little understanding of the jobs their staff did each day, and new recruits to jobs where safety was a key element, had little experience, and inadequate training (14). The same

[3] See also Section on 'Loyalty', later.

industry has a major skills shortage exacerbated by insufficient training levels, and additionally engineers are turning their back on an industry that now has a poor image (16).

It is worth noting that staff who possess the most valuable knowledge may not be the people you think are your star performers (15). The quiet mentors, and staff who do not brag about knowledge but possess huge amounts, may be your stars. If you have to lose these staff ensure their knowledge is transferred before leaving, or hire them back as consultants.

It is an interesting thought, but in this century our limitations will not be computers and communication capabilities (they will rapidly advance), but rather learned principles, experience, values and information. These will be the future performance differentiators in the oil and gas business (2).

If we need to downsize, or reorganise, we should not leave it solely to our human resource (HR) department; most people in HR have little knowledge of business, or managing corporate change (17) and they tend to be 'generalists', lacking technical abilities.

The old quote (Paul Goodman) *"Few great men would have got past personnel"* is dated; the impact of a good HR department and HR staff on the bottom line is not disputed, but they are usually poorly qualified (they have diplomas of sorts, but no truly senior qualifications), with little exposure to business (17); consequently, they cannot be compared with the likes of the Chief Financial Officer or Chief Engineer in a company who are highly qualified and experienced in their areas.

3.2 Accountability

Another new challenge facing our engineers is the increasing, and disturbing, movement of corporate responsibility onto engineering staff. Liability claims for engineering errors may well now be systematically aimed at engineers rather than corporate entities.

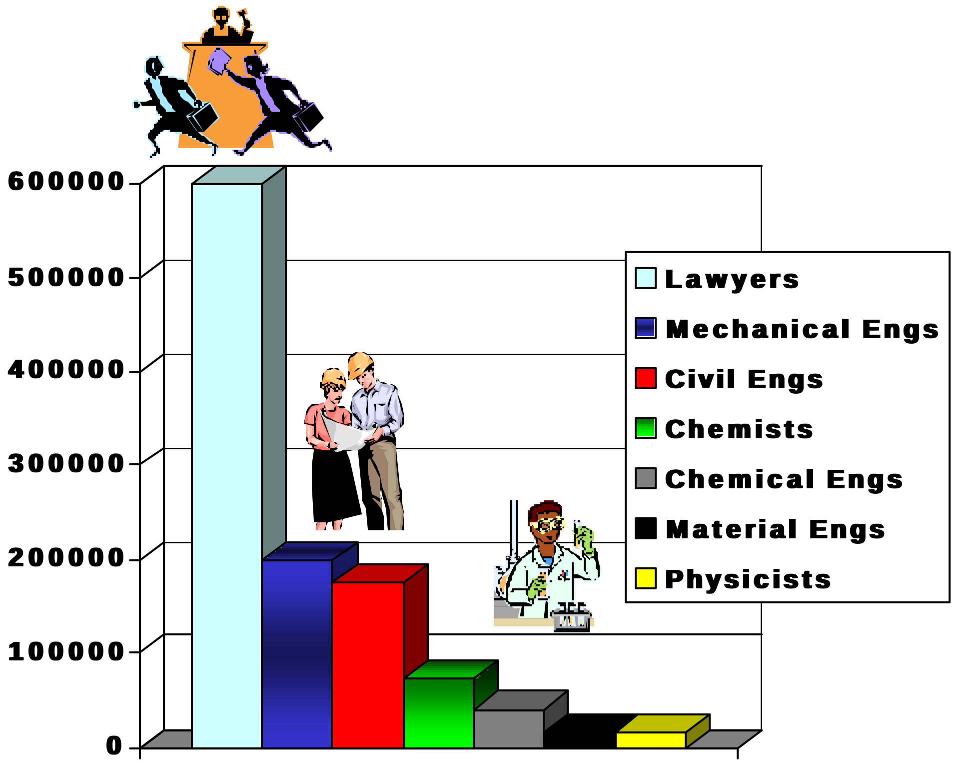

Figure 1. Number of Legal and Technical Professionals in the USA in the late 1990s (19).

Engineers have long accepted responsibility for errors, and should be well aware of their 'duty (or standard) of care' as a professional (18). However, we need our engineers to be innovative, and break down barriers, so we must not create a risk-averse culture, and not allow engineers to be continually exposed to the fear of litigation. Therefore, companies must provide an environment that allows engineers to innovate safely, and this is achieved by ensuring all risks associated with a project have been demonstrably recognized and evaluated.

This is a real fear, and we should all take note of changes in professional numbers; Figure 1 shows career statistics (19) from the USA. The number of lawyers in the USA now outnumbers the total number of engineers and scientists.

We know how effective lawyers are at creating work and markets to satisfy both their increasing numbers and financial needs. If their next target is engineers and engineering, we can expect future bright young graduates to quickly realize that law is a safer option than engineering, for obvious reasons. Therefore, we can help prevent this happening by ensuring our engineers are well and continually trained, Table 1.

3.3 Socio, Eco and Human Rights Responsibilities

Our oil and gas majors now work all over the world. They have to balance social, economic, ecological and business issues/needs:

i. **Global Energy** – the world needs energy to grow, particularly the Third World,

ii. **Local Economies** – small developing countries need their skills and risk money to explore and produce oil and gas on their soil,

iii. **Exploration and production** - invariably will cause some intrusion into eco systems and local customs,

iv. **Commercial** – they need to make a profit to satisfy shareholders – i.e. you and me.

Unfortunately, they are often faced with working for/in countries that have a history of socialistic economic support who need outside energy investment, but are uncomfortable when faced with the high profits required to undertake the investment risk (20).

This can lead to accusations of foreign companies 'stealing' natural resources. Our majors can be faced with a country where officials gain political credibility by claiming foreigners are 'stealing' the resources, but are ignorant of investment risk compensation, and the fact that our majors are making a profit not for themselves, but their shareholders, and any of us can be a shareholder.

However, this does not mean that the majors can operate without clear ethical standards. These standards will affect their engineers; engineers are being asked to work in countries and environments that can be both controversial and sensitive. This can create problems for our engineers:

i. **Social & Environmental Concerns** - Pipelines can run through important ecological areas, and industrial developments in previously rural environments can lead to work, tradition, social and health changes.

ii. **Political Instability and Human Rights Violations** - Pipelines can be laid in politically unstable/corrupt areas. Wealth created can lead to sustained instability, and increased chance of sabotage, environmental disasters, etc.. Revenues generated by governments from pipelines are not guaranteed to be used to alleviate poverty, etc.; they may be used for military purposes.

iii. **Disproportionate Power** - The largest oil company in the world - Exxon Mobil - had (1996) annual profits four times the budget of Cameroon and 40 times the budget of Chad.

iv. **Ethics of the Majors (21)** – Between 1982 to 1992 Shell's subsidiary in Nigeria spilled ~ 1.6 million gallons of oil in Niger Delta, most from leaking pipelines, causing water pollution and death of fish, mangroves & tropical forests. In 1997 the Wall Street Journal reported Exxon's chairman as advising developing countries to avoid environmental controls otherwise they would lose foreign investment.

v. **Ethics of Engineers**[4] – Engineers have professional obligations, and must satisfy the ethics policies of their professional institutions. An engineer's prime responsibility is to the safety of the public and environment. Loyalty to their company comes after these responsibilities.

In the past, the cynics have said it is only unethical if you get caught. We cannot live like this. Clearly, companies need to have a clear ethical approach to business[5], otherwise they will not be able to satisfy an engineer's personal responsibilities and conscience. Employers need to be demonstrably ethical, rather than have an ethics policy that is never applied, other than on their websites.

[4] Ethics, in this context, means professional standards – log on to www.onlineethics.org.

[5] In the UK, there is an 'FTSE4Good' index that ranks the listed companies in order of ethical practices (environment, human rights, etc.), and allows investors to consider 'ethical' investments.

4. CHANGE IN OUR SENIOR MANAGERS

4.1 The Need for Personal Change

Reference 1 gave us some guidance on how managers can be an active part of the change in our business, by ensuring that they both change and understood change. The former political leader Nelson Mandela says, *'One of the things I learnt when I was negotiating was that until I changed in myself I could not change others'*. Mahatma Gandhi said something similar: *'We must become the change we want to see'*. This can be difficult; many change agents find their biggest obstacles are the same people who initiated the change in the first place (22).

Understanding change and anticipating its benefits may also pose problems to managers; as the philosopher Immanuel Kant said *'The human mind can never arrive, by pure thought, at truths about concepts… of which it has no experience'*.

4.2 Continuous Change?

Employers should beware of continuous change, merely for change sake. Change must have a clear purpose, as staff can initially build up a resistance to change, but later become 'resigned' to it.

When we introduce change we do not want a 'resistance' movement forming that prevents the change; we want employees to actively participate, criticize, and be part of it all. People are resilient and they can withstand all the associated pain, and we often hear staff say that some of the changes are 'torture'. This is interesting; Amnesty International reported in 1998, that people could withstand extreme torture… once. This is because they have never experienced it before, do not know what to expect, and don't know what comes next. The second time they are faced with it, they know the pain, they know what is coming next, and they succumb.

4.3 Dealing with the 'New' Worker

Managers will usually deal with two types of worker in our business: the 'company' person (staff directly employed by a corporation), or the 'freelance' person. Traditionally, we deal with the company person – the man or woman who is committed to a career in a single organization. This is changing; in the USA over 30 million workers are now freelance, outnumbering workers in the manufacturing and civil service sectors (23).

This change has been caused by many factors, but it is mainly brought about by workers thinking about their careers, and taking ownership of it. This seems an obvious thing to do, but it is only a recent development; it is a fact that most workers spend more time planning their annual holiday than planning their careers (24).

The freelance worker is simple to employ, simple to manage, and simple to let go. They have decided on their career course and the control mechanism. But how does the manager deal with the company man/woman, and how can we both incentivise and retain their skills?

Managers must realize two things in dealing with their staff:

i. **New Staff and the Power Shift -** We are witnessing a change in power in large organizations; the new worker does not see his/her career revolving around the organization, they see the organization revolving around their career (25). This means that the new worker is more demanding, requesting career breaks, training, equity in the company, ethical practices, etc.. A manager needs to respond to these new requirements.

ii. **Old Staff and Reality Checks** - Staff in large organizations with long service are slowly realizing that there is life outside their organization. Unfortunately, until these staff are faced with radical corporate change, or the threat of redundancy, they have never considered alternative paths. They also now realize that the longer they stay in a large organization, the higher the chance of being made redundant.

Therefore, today's manager must adapt to the 'new' worker, and also the changes occurring in existing long standing staff. Otherwise, he/she will be faced with purely freelance workers. This may not be a problem to a large organization, if the freelance workers are good, and in many cases it is the best course, but it will almost certainly lead to that function being totally outsourced, as there is little to justify it as an in-house resource, or 'core' skill.

A manager should not resort to any practice that alienates staff. The old attitudes such as *'Sure, you may not like working here, but we pay your rent'*, or *'when I was your age, I was grateful to just have a job'*, are defunct. Similarly, the corporate manager who is merely a 'functionary' (a manager who helps drive the mythical corporate organization, rather than the business) will disenchant a worker, as they will immediately see any work request from that manager to be either of little consequence or pure bureaucracy. It is these type of functionary managers that are to blame for the saying *'if at first you don't succeed - try management'.*

Finally, what is the future for the corporate manager if he/she does not get it right? In his book 'Free Agent Nation' (25), Daniel Pink says, that in a world of free agents, *'most managers are toast'.*

4.4 Changing the Manager to a Leader

Major change in an organisation will require first class managers and their biggest challenge is likely to be helping their companies to adapt to a competitive environment that is neither stable nor predictable.

In a successful company, a senior manager may have historically been rewarded for successfully managing the day-to-day operation of his/her department, but organizations are now looking for something more - innovation in their managers. Our managers must always be aware of the day to day business deliverables, but we now also need managers who can both make the existing systems work well, and also ask if the systems could be better.

How can we change a management steeped in an old culture such as meeting simple annual targets through micro-management? The answer is by changing the manager into a leader. This is important; as Warren G Bennis says *'Failing organizations are usually over-managed and under-led'.*

We know that 'classic' management involves: planning, organizing, leading and controlling. But during change we need some managers who focus on 'leading'.

MANAGER	**LEADER**
Is a copy	Is an original
Administers	Innovates
Maintains	Develops
Focuses on systems	Focuses on people
Relies in control	Inspires trust
Has short range view	Has long range perspective
Asks how and when	Asks what and why
Has his/her eye on the bottom line	Has his/her eye on the horizon
Accepts the status quo	Challenges the status quo
Is the classic good soldier	Is his/her own person
Does the right thing	Does the thing right

Table 2. Differences between Managers and Leaders

Table 2 is from the investment bank, Credit Suisse First Boston (CSFB); it is now focusing much of its management training on leadership development (26). Here we see the fundamental differences we are seeking in leaders. We can argue each item in Table 2, and we can argue the detail, but the table tells us we have a major challenge in changing our management. Of course we need our 'standard' manager, to deal with our day-to-day chores, but if we want one of our existing managers to become a 'leader', Table 2 tells us to take that person out of the day-to-day management.

An example of how a leader would differ from a manager is that the leader would challenge any change that may demoralize staff. A good example is the 'competency-based' interviews that are still popular and being peddled by management consultants. These are interviews where a candidate for a job is assessed against a generic list of agreed competencies, none of which ask the most important question *'can this person actually do the job'*? Staff know this, but managers seem blind. Similarly, managers who are still obsessed with meetings and committees are now viewed with suspicion – communication channels and platforms are essential for both our managers and leaders, but our new workforce expect something a little more dynamic. Remember, Rome did not create a great empire by having meetings - they did it by killing all those who opposed them.

Note that when selecting or expecting leadership, the people in a company currently 'at the top', are not necessarily the best qualified; they may merely be the best connected.

There is a good example of changing from a manager to a leader. The England football team recently appointed a Swedish manager. The appointment of a 'foreign' manager was greeted with some dismay by the English press. However, the new manager transformed the team into winners, and his management approach was immediately analysed (27). His approach was to challenge the way the team had previously been managed; he left the day to day work (the 'coaching') to other staff, but instead he focused on strategy, and ensuring all his players can do and know their roles, and are aware of all others roles, and the overall team plan and vision. He is a listener – unusual in football management - and the overall effect is success. Also, according to John Adair, professor of leadership studies at Exeter University, UK, the new manager *'simply conveys to the players that they are great. It's a message they haven't heard before'*.

Some other lessons can be learnt from former great leaders (28):

i. Martin Luther King was a fine speaker, yet if you analyse the text of his *'Free at Last…'* speech it says very little. The key is in the storytelling, and that the leader embodies the story in his/her own life.

ii. Successful leaders do not surround themselves with 'yes' men; instead, they surround themselves with 'constructive dissenters' who – when the time comes – are prepared to tell them that they are crazy.

iii. Leadership qualities vary with timing and situations. For example Winston Churchill was acknowledged as a fine leader during wartime, but was voted out of power immediately afterwards. Similarly, the managers who were successful during rapid growth may not be suited to managing a rapid downturn (29), and managers who have been successful in large corporations or a civil service where organizational and political skills are essential, may be highly inappropriate in a more commercial environment, where business acumen is paramount.

Finally, leaders can abuse their position, so ensure controls are in place! Martin Luther King, Jesus Christ, Gandhi, Mandela, are all acknowledged as great leaders, and they changed the world for the better. Other 'great' leaders – Hitler, Stalin, Bin Laden – had the opposite effect, and so we must be aware of the power that comes with leadership; leaders can save or kills us (28).

4.5 Eliminating the Blame Culture

There is still a tendency to 'blame' all company wrongs on the next management level above, and there are organizations that cannot tolerate a single failure. This results in no manager taking a risk, and problem solving being replaced by back stabbing and moaning.

The solution is a management aimed at taking reasonable risks in its approaches to problems, and all levels telling the level below, *'we're no longer micro-managing, just tell us how it should be done*', and the lower level taking ownership and responding, not back stabbing.

And any mistakes should be without blame; in his book 'On Becoming a Leader', Warren Bennis points to Ten Factors for the Future that all leaders will need to possess, one of which is *'Leaders embrace error. Mistakes are the signposts of learning'*. Indeed, one thing that all leaders have in common is that they fail, either partially or totally (in their business life, personal life, etc.) so we should not seek the perfect leader.

Therefore, managers must live with mistakes, but they must also come to terms with 'empowerment' of their staff. Empowerment of subordinates has long been on the wish list of management, but has it been implemented? Empowering subordinates means 'letting go' and allowing employees to make mistakes (30) - a difficult thing to do for a traditional manager.

5. SOME CHANGES NEEDED IN THE OIL AND GAS MAJORS

The previous sections have discussed some changes needed in the people and management side of our industry. There are also some important changes needed in our oil and gas majors. Reference 1 covered many of these, but several more warrant attention.

5.1 The Pipeline Industry And The New Technologies Needed

We need technology to help us in many areas, e.g. explore deeper reserves, design stronger pipelines and to detect premature ageing of our assets. But we must take care not to waste technology:

i. **it is how people use technology that makes it meaningful and of benefit.** Consider the ever-present PC on our desks. They can create two extreme problems for people: those adverse to computers make little use of them, whereas the technophiles amongst us are addicted. How much time is wasted on answering useless email in your office? Email is a classic example of too much information and not enough intelligence (31).

ii. **it must fit our changing world -** consider the USA's purchase of 20 stealth bombers (that cannot be detected by radar) for $46billion. How much use have they been in a region such as Afghanistan that has no radar for them to avoid, and no targets for them to bomb?

iii. **it must have a clear purpose** – there is no point designing a hammer if there are no nails.

The pipeline technology conferences in Brugge and Calgary in 2000 presented many new technologies, and Reference 1 presented a summary. Of current interest is our drive to exploit our reserves, in particular deep water, we will need many technologies (2):

- Reservoir management – discrimination of oil, gas and water, with reservoir performance measured in real time
- Fewer wells/reservoirs – deepwater will mean fewer wells, producing at higher rates using infrequent and low costs interventions.
- Smaller fields – there are more smaller fields to develop than large ones. We need extended tie-backs, minimal facilities, and remote operation
- Composite materials – for use on production platforms and vessels
- Well bore information – system control telemetry, real time communications.
- Flow assurance – technologies are needed for predicting was and hydrate formation, with chemical and mechanical technologies developed to alleviate flow assurance problems.
- Semis vs. Spars – as we go deeper and deeper, the spar platform is being preferred to the semi submersible because the facilitate the use of surface trees and have a good design history. However, the semis submersible do not incur the technical issues of going deeper and deeper (they're insensitive to depth), and they could overtake spars as the preferred technology.
- Reduced cycling time – we need to reduce deep-water project time with, for example, parallel drilling and production.

It should be pointed out that many of our challenges over the next decade will be in keeping our existing (old) systems running safely. Hence, companies should be actively looking at technologies and practices that focus on 'old' pipelines.

All the above technologies are aimed at cost reduction, without reduction in safety or efficiency.

5.2 Who Should Pay for Technology?

The oil and gas majors must take the lead in any change on our industry. Why? Because they have all the power. Reference 1 highlighted the fact that to further technologies in our business, the majors must finance more research, as they are the main beneficiaries. Unfortunately, they have not been doing this, and there has been a decline in their funding of research and development programmes. From 1987 to 1997, the US Department of Energy estimated that Research and Development spending by operating companies was reduced by about $1billion, and more recent estimates have updated this figure to $2billion (2).

Reference 1 reported the high profits being made by the oil and gas majors with the high oil price, and Table 3 provides an update; the oil and gas majors are huge corporations growing at an awesome rate. Based on 2000 figures, Exxon Mobil is now the world's biggest corporation, with the world's biggest profits of $17.7billion, a staggering increase of 124% over 1999.

These huge profits are not confined to the company – the top executives are reaping huge rewards in the oil and gas companies; in 2000 the CEO of BG in the UK saw his rewards package increase 419% in the year (32).

It is not all good news. Our biggest oil and gas companies can make mistakes, and mistakes can be expensive. For example, Enron led the way in the mid-90s, in changing the energy industry from the old staid, regulated business to a modern free-market industry (it was the first on-line trader – the natural way to trade commodities). It failed spectacularly at the end of 2001.

RANK		**COMPANY**	**REVENUE**	**REVENUE**
1999	**2000**		**($billion)[6)]**	**%CHANGE FROM 1999**
3	1	Exxon Mobil, USA	210	+28
11	6	Royal Dutch Shell, UK/Neth	149	+42
17	7	BP, UK	148	+77
50	14	TotalFinaElf, France	106	+135

Table 3. The World's Largest Corporations in 2000 (33)

However, the large and consistent profits recorded by our oil and gas majors, mean that they have no excuse for any errors made in pipeline safety.

[6] Billion means 1,000,000,000

5.3 Cyclic Culls – Effect on Staff

In good times we find a shortage of skilled staff, and in bad times we shed them. This served the oil and gas majors well during the 1990s, as they kept their profits to themselves, and treated their staff and service suppliers like their oil and gas – commodities. A down turn in 1998/9 meant further reductions, but in 2000/1 we have seen a sudden upturn, and a high demand for skills.

This cyclic culling means that staff realize they are as much a commodity as the product, and they associate price drops with layoffs. They have seen this before, and the tremendous recruitment drive now underway as oil prices soar will not fool the more experienced staff. They know that any promised career path will be as fickle as the price of oil, and hence we should not be surprised to see an abundance of staff entering our business solely to make a quick dollar (34).

5.4 Cyclic Culls – Effect on Suppliers

The service sector suffers greatly from downturns in the market place, as they are squeezed on price. Consequently, many service companies are looking to diversify both in terms of services-offered, and geography. This means they can select who they can do business with, and may soon ignore their more fickle clients – the oil and gas majors.

But what about ‘relationships’? Surely past business working leads to loyalty and has some currency? Unfortunately, the industry practice of commodity-based purchasing means the only relationship existing is on paper (34).

5.5 Corporate Culture

A study in the USA’s Personnel Journal showed that executive job interviewees asked about ‘corporate culture’ nearly as much as job benefits (34% compared to 36%).

The study defined corporate culture as the corporate identity – it encompasses all the factors that determine how the staff in a company think and act – both as individuals and groups. It is very much an ethos rather than a written policy, and staff will have difficulties defining it, but it is a execution of and combination of (35): vision (long termism); commitment (determination to deliver at all levels); objectivity (no private agendas); planning (as Yogi Berra puts it – *‘if you don’t know where you’re going, you’ll probably end up someplace else’*); discipline (methodically implement your strategic plan); buy-in (everybody must be involved); consistency (even attention to all departments); continuity (it must be bigger than an individual – who might leave); patience (be realistic on timelines); and resources (developing a culture takes time, people and money).

If you want to determine your company’s culture, or how it is viewed by staff – ask the staff. Senior or middle managers tend to have a very positive view of company culture, usually obtained from fellow managers, but employees on lower levels are much closer to reality and see the company from its underbelly.

What are the most common weaknesses in corporate culture and how can they be remedied (35)?

i. **Communication**. The single greatest weakness in most corporate cultures is that employees do not feel they know what is going on in the company; they rely on the company grapevine for the big news. This is probably because the most common form of communication in a large company is the memo; the memo is a poor form of communication as not everybody reads a memo, and staff are now inundated with information, and they find it difficult to register it all in their memories. A memo is only a delivery device, it is not a message; a better way of communicating is through two way channels, where senior executives can repeat themselves to reinforce messages, and also be seen to be open to cultivate trust in staff of all levels.

ii. **People management skills**. In many companies, managers are promoted based on time-served and functional skills. Neither are management qualifications, and the new manager is likely to behave as his/her previous (bad) managers have, as they have come up through the same system.

Middle managers are more often than not a barrier that blocks any vision from reaching lower levels. If your department heads are incompetent, your best intentions will never reach the rank and file (30).

5.6 Loyalty ('friendship or duty towards something or somebody')

Loyalty is like credibility – it is hard to build up (12). This is particularly true where a company has previously cut staff during a downturn.

How do you build loyalty in a company? Well, in changing times, it is easier to reduce or even kill loyalty than maintain it. In the 1998/9 market downturn the author instigated staff cuts in his own company, and like others who have been through a staff-cutting exercise witnessed how much is gained short term by cost savings, but also now knows how much is lost longer term due to the effect on moral of surviving staff, and the permanent loss of skills that cannot be replaced easily when the market picks up.

Downsizings are an excellent way of wrecking both employee loyalty and any corporate culture of trust. Next time you are faced with a downsizing, consider this quote from Bob Palmer, CEO of Rowan Corporation, *'Money is easier to find than people'*; it is important to hold a company together during good and bad times.

But how can we keep staff loyalty during these changing times? As Palmer *says 'If you want an employee to be loyal to you, you need to be loyal to the employee, it's that simple'.*

Again, we need to change; staff know that words such as *'pride, commitment, teamwork'* are words that managers use to get them to work for free. Instead, we must offer tangible benefits for loyal staff. Hence, policies and procedures must be in place that give staff confidence that any loyalty they show will be rewarded. For example, longer notice periods, company equity schemes, and other rewards for competence and commitment.

6. CHANGE IN PIPELINE STANDARDS

6.1 Pipeline Standards are Safety Standards

We will always build our pipelines to the highest standards. The most extensively used pipeline standard is ASME B31. The origins of this standard lie in the American Standards Committee (now called the American National Standards Institute) who many decades ago initiated 'Project B31' at the request of the American Society of Engineers. The industry's objective then was to make a major contribution to improving public safety by understanding the causes of failures and establishing guidance, procedures, and methods for reducing pipeline failures.

ASME B31.8 (the code for gas lines) was first developed in 1955; it is interesting to note that industry concerns when the 1955 Code Committee first developed standards for gas pipelines remain the major concerns of operators today — maintaining the safety of the pipeline system while economically transporting natural gas.

Therefore, our design codes are safety codes, and they have helped our industry produce safe and cost effective pipelines. But are they sufficient and can they be changed? And why does there seem to be an upturn in pipeline failures? We can assess their sufficiency by returning to their original intention – reduce pipeline failures.

6.2. In-service Defects Fail Pipelines

What fails a pipeline today? Figure 2 shows that the major cause of pipeline failure for onshore gas lines in Europe is third party damage.

Original material or construction defects are not the major cause. Therefore, if we are to improve the safety of our pipelines we need to reduce third party damage failures, and prevent corrosion, and focus our design on achieving this.

The most recent, and serious (multiple fatalities) failures in the USA appear to have been caused by deterioration or damage, rather than faulty design, Figure 3.

CAUSE	Number
Hot Tap By Error	5%
Ground Movement	6%
Corrosion	15%
Construction/Material Defect	18%
Third Party Activity	50%
Other/Unknown	6%

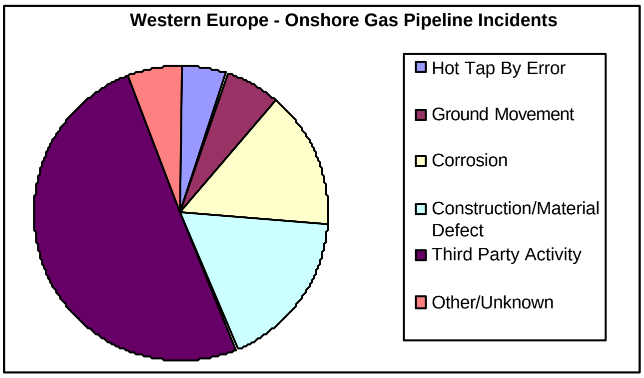

Figure 2. Causes of Gas Pipeline Failures in Western Europe (data from the European Gas Incident Group)

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 3. Recent USA Pipeline Failures (36) in Bellingham, 1999 (top) and New Mexico, 2000 (bottom) (Images courtesy of the National Transportation Safety Board, USA)

6.3 Linking Design Codes to Operational Practices

We clearly need to put more emphasis on operational practices in our design codes. In the USA, current deficiencies in ASME B31 are being addressed both by ASME (see below) and by regulation. The absence of clear guidelines on in-service inspection has led to new regulations; the USA Office of Pipeline Safety (OPS) requires operators of liquid pipelines that pass through populated areas, commercially navigable waterways, and areas that are unusually sensitive to environmental damage, to have an integrity management program that continually assesses and evaluates the integrity of 'high consequence' pipelines. OPS will soon issue equivalent guidelines for gas lines.

Such programs would include internal inspection, pressure testing, data integration and analysis. These programs would be applied on the basis of either prescriptive requirements from OPS or risk-based decisions made by the pipeline operator.

6.4 The Major Change Needed in Our Standards

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, decent routeing, etc.. But now we know that in-service defects fail pipelines and cause casualties. This leads to the first major change we need to introduce into our standards - better operational practices – and this will satisfy the historical safety intent of our standards. The publication of API 1160, and the soon to be published integrity appendix to ASME B31.8 is the start of this change (see later), but this change must be accompanied by a better understanding of new management methods and staff skills and expectations.

7. CHALLENGING CURRENT PIPELINE DESIGN AND CONSTRUCTION PRACTICES.

There used to be a saying: *'pipeline engineers are like surgeons – they bury their mistakes…'*. Not very complementary, but it could have been worse – we could have been grouped with lawyers. Fortunately, the pipeline industry has progressed; with our new and better materials and methods available for better constructions we bury few mistakes.

We will now consider some pipeline design and construction practices, and see if there is scope to change them, with a cost benefit for the industry, but no reduction in safety.

We will consider the following:

- Pipeline Design Factor
- High Grade Steels
- The Pre-Service Hydrotest
- Multiple Changes to Design Parameters
- Defect Assessment
- Pipeline Integrity

The following sections are not intended as a justification for adopting or changing any of the above; the intention is to demonstrate how current practices can be challenged, and how we are slow to change them.

7.1 Pipeline Design Factor

Could we reduce construction costs by increasing our design stresses (and hence reducing wall thickness and material costs)? The answer is 'yes' if we can demonstrate that safety is not compromised. We can do this by first understanding the background to our design limits, then presenting a technical argument for raising the design stresses, but demonstrably maintaining our safety standards.

7.1.1 Basis of Design Factors

Most pipeline codes around the world limit the design stress to a percentage of the linepipe's specified minimum yield strength (SMYS). 72% is usually the maximum permitted, although codes in North America specify higher (80% SMYS).

The concept of basing design stress on a percentage of SMYS was the judgment of members of the pressure piping committee of the American Standards Association (ASA) in the 1950s. It was decided that a 1.25 factor applied to the (assumed) 90% SMYS mill test that linepipe was usually subjected to, would give an acceptable safety margin. Hence, a design factor of 72% SMYS was proposed. An 80% SMYS maximum design stress was eventually added to ASME B31.8; this adopted a similar safety factor approach, only this time the 1.25 factor was applied to a field hydrotest of 100% SMYS, to give 80% SMYS maximum design stress.

Therefore, our current maximum design factors are historical artifacts, not a safety or structural parameter. This is not a dismissal of the importance of the design factor, merely a factual perspective.

7.1.2 Raising Design Factors

We have been slow to adopt higher design factors[7], e.g. 0.8. This is because design stress or design factor have traditionally been viewed as a key parameter in assuring pipeline safety; however, the only failure modes addressed explicitly by the design factor are yielding and burst of the defect-free pipe under internal pressure. The rupture of defect-free pipe is not a credible failure mechanism and we can see from Figure 2 that most failures are caused by external forces such as equipment impact.

Therefore, if we want to improve safety we should not decrease design factor – we should improve our in-service inspection and surveillance.

Indeed, we have evidence that high stress pipelines can be safely operated. Many 1000s of km of pipelines in the USA operate at stresses above 72% SMYS, some as high as 85% SMYS. These lines are known as 'grandfather' lines, as they were allowed to maintain these high stress levels by the USA Office of Pipeline Safety because they were operating at these levels before the enforcement of regulations that limited design stresses to 72% SMYS.

A report by the USA Department of Transportation, *'A Safety Evaluation of Gas Pipelines Operating above 72% SMYS'*, in August 1987 provided the data to support the above concession. The three companies in the USA operating lines above 72% SMYS had reportable incidents per mile (since 1970) in the range of 0.5 to 0.1 the incidents for pipeline segments operating below 72% SMYS.

7.1.3 Safe Operation of High Stress Pipelines

The key to safe operation of a pipeline is a safe design AND safe operating practices. High design stresses do not fail a pipeline – damage does. Therefore, it is possible for us to operate a high stress pipeline (e.g. 0.8 design factor), with a higher safety level than a 0.72 design factor line.

The advancement of analytical risk models, and our understanding of reliability methods, now allow us to objectively determine the effect of changing design parameters on safety. These new models give us another tool to add to our pipeline engineering toolbox.

Pipeline engineers have long known that a design gives us only a 'day 1' safety guarantee; it is how we manage, maintain and inspect our pipeline that determines the safety of the line throughout its life.

Figure 4 summarises this philosophy; it is possible to design a high stress pipeline that provides safer operation throughout its life, compared to a lower stress pipeline, by combining all our key design and operation parameters.

[7] Maximum design stress/SMYS.

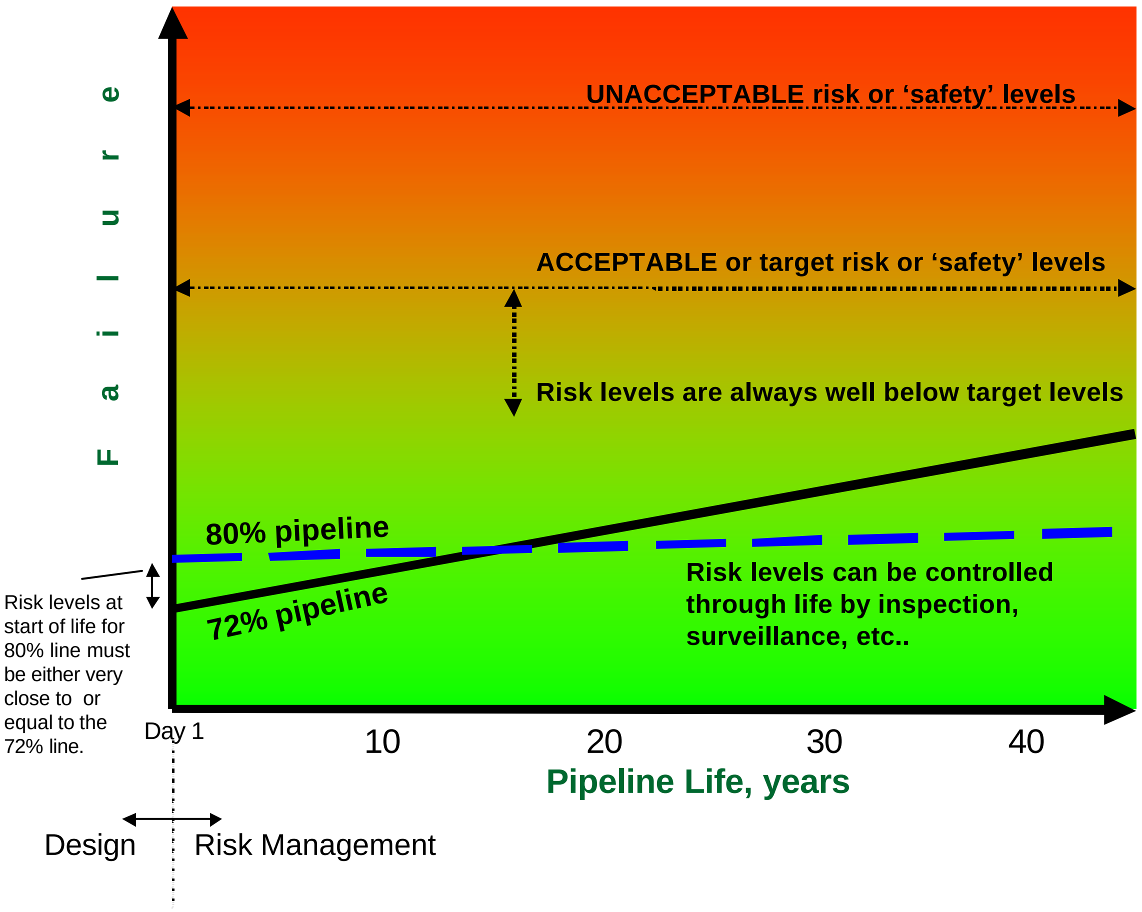

Figure 4. Controlling Risks in a Pipeline Throughout Life.

Risk and reliability methods provide the analytical tools for quantifying the effects of all these parameters. Because these methods quantify safety we can use them to ensure that a pipeline starts life at an acceptable risk level and that the risks are controlled throughout life, Figure 4.

Consequently, risk and reliability methods now give the pipeline industry the capability of understanding the combined impact of all pipeline parameters on the safety of a pipeline, and the industry does not need to take a narrow view on any single parameter, such as design factor.

We will experience a resistance to risk methods, as they 'admit' our pipelines pose real risks to the general public. However, this is a sound, honest engineering approach, which recognizes that we are both minimizing pipeline risks and costs, and recognize that we will never reduce risk to zero, even if we spent a billion dollars per kilometer building a pipeline.

7.2 High Grade Steels

We need larger and higher stresses pipelines to make the transportation of some of our more distant reserves economically viable. Increasing the diameter of a pipeline for a given grade of steel will result in:

- increased weight,
- increased line pipe cost,
- increased transportation cost,
- increased construction time and costs.

All of these issues can be resolved through the use of a high grade steel, such as X80, but there has only been limited use of X80 (in Canada, Czech Republic, Germany and the UK).

At the 16th World Petroleum Congress, Andy Jenkins of TransCanada PipeLines said. *"World energy consumption is expected to increase more than 50 per cent by 2020…Technology will be at the forefront of pipeline development, including new laying technology, automated mechanical welding, quality assurance techniques, higher grade steels such as X80 and X100 grades, online pipeline data and global positioning systems to improve record and data management."*

Jenkins said that by using high-pressure transportation and higher grade steel, significant cost reductions can be achieved in transportation costs. *"Despite the premium, cost reductions of 30 per cent have been gained when using X100 steel".*

There are few technical reasons for resisting the use of X80 materials; it is listed in the major linepipe standard, API 5L, and has been used in onshore gas projects totaling about 500km. It can be welded, field bended and has adequate toughness properties for oil and lean gas pipelines. Therefore, its use should become more extensive. There is limited information on X100 (or higher) material but it is likely to require more development work to ensure adequate toughness and strain capacity in high pressure and high strain applications.

7.3 Hydrotesting Pipelines

Before we put a pipeline into service we prove the structure by applying a high stress – the hydrostatic test.

Actually, we have been proof testing structures for centuries. In our own experience we know – as children - that if you want to go ice-skating on a frozen pond, it is best to send the fat kid onto the thin ice first. If the ice holds, we go skating, if the ice fails, we lose the fat kid….

In the middle ages, civil engineers would build bridges, but would not be able to calculate their true strengths. Therefore, they would invite the local army battalion to 'open' the bridge by marching across it with its horses, cannons, etc.. The army thought they were part of a celebration – in fact they were the proof load.

The concept and value of hydrostatic testing of transmission pipelines started in the early 1950s when Texas Eastern Transmission Company in the USA wanted to rehabilitate their War Emergency Pipelines and convert them to gas (37). Before any testing, these lines failed frequently in-service because of original manufacturing defects in the pipe. Battelle Columbus Laboratories in the USA suggested that these lines should be hydrotested prior to conversion. The lines failed '100s of times' on test, but never in-service from manufacturing defects[8].

Typically a pre-service hydrotest will be conducted at a pressure of 1.25 times the maximum design pressure. The hydrotest is now widely accepted as a means of:

- checking for leaks,
- proving the strength of the pipeline,
- removing defects of a certain size (the higher the stress level in the test, the more defects likely to fail),
- 'blunting' defects that survive, and this increases subsequent fatigue life,
- reducing residual stresses, and

[8] It is interesting to note that many 1000s miles of pipelines have since been tested, and there has never been a subsequent in-service rupture from manufacturing/construction defects (37).

- ‘warm prestresses’ defects that survive, and this improves their low temperature properties.

The above list is impressive, but how useful is the hydrotest today? We know that it was originally used to detect (by failing) original manufacturing linepipe defects, but modern linepipe is usually free from these older type defects, and linepipe is now highly quality assured before delivery to site.

This begs the question – ‘*when did we last see a failure from a linepipe defect on hydrotest?*‘ Certainly, we may have leaks at flanges, or even leaks at construction girth welds, but it is now highly unusual to have a linepipe failure on test.

Therefore, it could be argued that the prime role of the hydrotest today is a leak test, not a strength test. If we can accept this changed role of the hydrotest, it is feasible to replace it with a different test, e.g. a low pressure air test, merely to detect leaks.

Often, the hydrotest is a legal requirement, or is used as part of the commissioning phase of a pipeline, and in these cases it would be difficult to replace it with alternatives. Also, if a pipeline fails shortly after commissioning and it has not received a hydrotest, there could be major liability problems between operator, linepipe manufacturer and operator. Nevertheless, the absence of failures of linepipe on hydrotest give support to the argument that the pre-service hydrotest is now primarily a leak test, and could be replaced by alternatives.

7.4 Multiple Changes to Pipeline Design and Construction Practices

It is possible to introduce technical innovation into construction practices. For example, higher design stresses and pipe grades should become the norm soon. However, there will be resistance to these changes (Figure 5) if they are collectively applied. This is because there is considerable complexity is combining new parameters. For example, a pipeline project that used X100 linepipe, at 80% SMYS, at high pressure, transporting rich gas, would be a highly cost effective system. However, the combination of all these ‘new’ parameters will create complexities, e.g. the ability of high grade steels to arrest running fractures when transporting rich gas at high pressures is not well understood, and would be a barrier to this innovation combination.

Therefore, we should exercise some caution in multiple applications of innovation, and ensure we have a technical understanding of any complexities caused by their interaction, Figure 5.

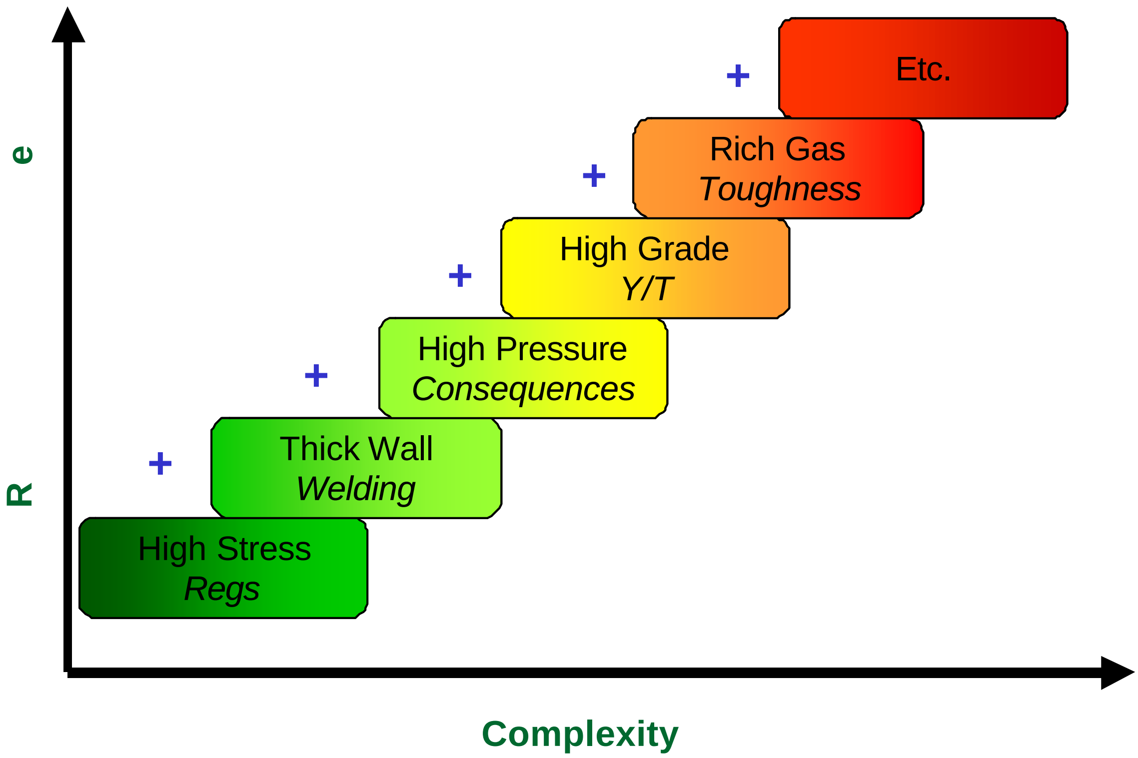

Figure 5. Resistance to Change with Increasing Complexity of the Change(s)

7.5 Changes in Defect Assessment in Pipelines

During the fabrication of a pipeline, recognised and proven quality control (or workmanship) limits will ensure that only innocuous defects remain in the pipeline at the start of its life. These control limits are somewhat arbitrary, but they have been proven over time. However, a pipeline will invariably contain larger defects at some stage during its life, and they will require an engineering assessment to determine whether or not to repair the pipeline. This assessment can be based on '*fitness for purpose*'[9], i.e. a failure condition will not be reached during the operation life of the pipeline.

Engineers have always used fitness for purpose – in the early days an engineer's intuition or direct experience could help when a defect was discovered in a structure, and there were many 'rules of thumb' developed. We are now better positioned in structural analysis, and we have many tools available that can help us progress from these early days. And remember that 'rule of thumb' was derived from a very old English law, which stated that you could not beat your wife with anything wider than your thumb….

7.5.1 Assessment Methods

Fitness for purpose is not intended as a single substitute for good engineering judgement; it is an aid. The fitness for purpose of a pipeline containing a defect may be determined by a variety of

[9] Note that 'fitness for purpose' may have a legal and contractual meaning in your country. For example, in the UK, a consultant engineer is expected to exercise 'reasonable skill and care' in his/her work; however, a contractor carrying out a construction has a fundamentally different obligation – he/she is obliged by law to warrant that the completed works will be fit for their intended purpose. Therefore, if a consultant gives a warranty for fitness for purpose (on the completed works) and they are not, he/she will be liable even if he/she has used all reasonable skill and care. The damages from a breach of warranty are different from those of negligence. Check your liabilities on your professional indemnity insurance.

methods ranging from previous relevant experience, to model testing, to '*engineering critical assessments*', where a defect is appraised analytically. These critical assessments can be by:

- Generic methods (38,39),
- Traditional pipeline industry methods (40-42),
- Recognised pipeline codes developed using the traditional methods (43,44),
- Publications from pipeline research groups (42, 45-47),
- 'Best practice' publications emerging from Joint Industry Projects (e.g. 48-50).

7.5.2 Recent Work

The more recent work has shown these old (40-42) methods to still be applicable to many newer pipeline applications, but there has been a heavy reliance on experiments, and more recently numerical analysis. There has been little fundamental work reported, and this is a major, serious and somewhat puzzling omission. It is unreasonable to expect that 30-year-old methods will be applicable to newer (e.g. X100 grade) steels, thicker wall (e.g. deep water pipelines approaching 50 mm in thickness), and higher strains (deep water and arctic conditions will give rise to greater than 1 percent strains).

The past 10 years has seen a near obsession with proving that these old methods are either:

i. highly conservative, or
ii. applicable to newer materials or applications via ad hoc, simple testing or numerical analysis.

This is the wrong approach; new methods should be developed. In some cases the old methods are not conservative, and are not theoretically applicable to newer, thicker materials (50). A more quantitative, explicit understanding of the material toughness is required. Certainly, provided that low constraint and high toughness conditions prevail, experiments will show them to be reasonable (or conservative) in these newer materials and geometries. Derivatives of the older methods that are biased towards the behaviour of modern, high toughness line pipe steels will not be applicable to older line pipe. Without methods that quantify the effects of constraint and toughness, there will be a reliance on experimental validation for all new applications and materials, and empirical constraints.

Therefore, we need more fundamental research into the way pipelines fail, and a movement away from the older methods, that have served us well in the past, but may be found wanting in newer pipelines and designs.

7.6 Changes in Pipeline Integrity

The safety of pipelines is our main focus, both as an industry and as engineers. We have recently seen major change in the USA in how pipeline integrity is regulated and standardized, as a result of a number of high profile and tragic failures in gas and liquid lines in the USA, Figure 3. API 1160 (51) is a new pipeline integrity management standard for liquid lines, and ASME is to publish (52) an integrity appendix for B31.8 (gas lines). We now have formalized pipeline integrity management with the intention (53) of:

- Accelerating the integrity assessment of pipelines in areas where failures would have a high consequence,
- Improving operator integrity management systems,

- Improving government's role in reviewing the adequacy of integrity programs and plans, and, and
- Providing increased public assurance in pipeline safety.

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 6. Pipeline integrity management is the management of all the elements of this complex jigsaw; the management brings all these pieces of the jigsaw together. Therefore to appreciate and ensure pipeline integrity, a 'holistic' approach is needed, requiring a number of skills. These skills will need to be continually updated, and therefore training is a key input into integrity (54). The need for wide ranging training in pipeline engineering has been identified (17), and the industry must start to both formalise and quality assure this training.

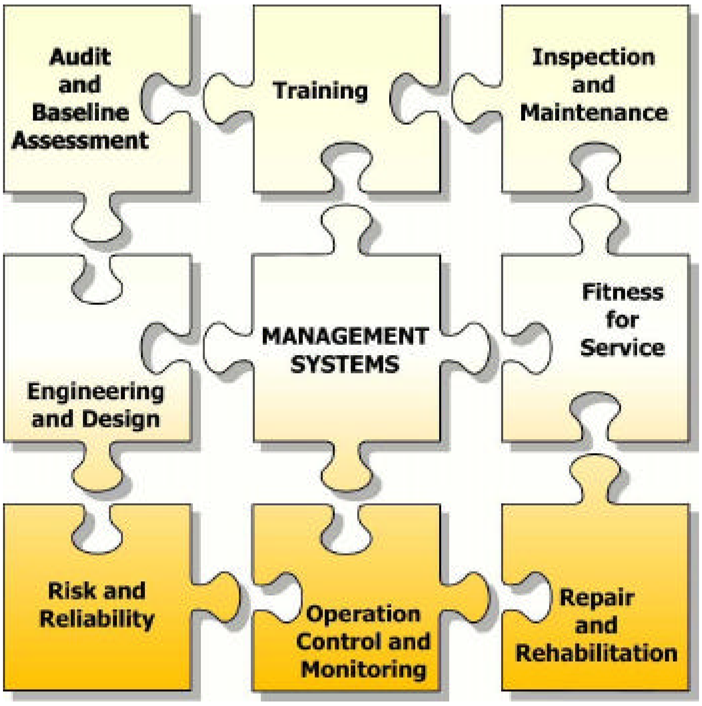

Figure 6. The Pipeline Integrity 'Jigsaw' (54)

A problem we have now is that we are downsizing our skills base in pipeline companies, and this may lead to us losing essential integrity skills. The skill gaps can be filled with consultants, but companies must be confident that the consultants:

i. Are qualified for the complex and multiple skill task, and

ii. Are independent.

Figure 6 helps us assess the required capabilities of both in-house staff and consultants in integrity. Independence is a 'hot' topic in our industry at present, with the demise of Enron raising questions of the role of one of their major consultants (Arthur Anderson) who both audited their financial accounts and supplied financial consultancy. Other companies are now looking to separate their auditing and consultancy services.

We can have a similar situation in pipeline engineering. Construction companies may well help with engineering audits, then bid for any resulting rebuilds. This could lead to both professional and financial conflicts of interests.

In pipeline integrity, there are now many companies that are offering consultancy. Operators should be confident that an independent, holistic service is being offered; for example it is reasonable for inspection ('pigging') companies to offer follow-on integrity assessment services, as this offers customers a more complete service. However, as a conclusion from a follow up service may be a recommendation for further inspections, there could be conflicts of interest. There is no evidence of this; however, would you ask a barber if you needed a haircut?

Finally, it needs to be emphasised that the integrity of our existing pipelines has to be our main priority, both as engineers and an industry. We know why pipelines fail, and we know how to mitigate against these failures. We can now train our staff in integrity and we have standards and methods to help us manage integrity. Combine these with the large profits being recorded by our oil and gas majors, and we conclude that, today, there are very few excuses for pipeline failures.

8. SUMMARY

This paper has presented the author's personal views on some of the challenges facing our industry. It has focused on the people and management side of the business, as most of these challenges will be experienced by all levels of staff and all parts of our industry.

It is now time for all of us to accept change, and remember… change is inevitable, except from vending machines….

ACKNOWLEDGEMENTS

The author would like to thank his colleagues at Penspen Andrew Palmer for contributing to this paper. This paper is partly based on the author's management course 'Changing to a New Business' which has been presented to a large number of staff in oil and gas majors. Their contributions are also acknowledged. Contact phil.hopkins@apancl.co.uk for further details on this course.

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