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The Skills Crisis in the Pipeline Sector of the Oil and Gas Business

by

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ABSTRACT

Oil prices are now (July 2008) passing the $US140/barrel mark, and the demand for fossil fuels is predicted to increase rapidly over the next 25 years. The oil majors, such as Exxon Mobil, are recording record profits, and pipelines, the international oil and gas transportation system, are expanding.

We would expect this successful and growing oil and gas industry to be attractive to young staff, but it is not: the average age of a worker in the business is over 50, and we are producing less and less engineers in the developed world.

This paper investigates the problem of the ageing workforce in the oil and gas industry and the pipeline business, and attempts to explain why the industry is unattractive to young engineers, and the resulting importance of recruiting new staff and training existing staff.

It then covers the current education and training of pipeline engineers, and notes that the situation has been summarised in one review as 'dire'. The current courses offered by universities on pipeline engineering are reviewed, then the education requirements for pipeline engineers are listed.

It concludes that there is labour and skills crisis in the oil and gas sector, and there are very limited formal education and training courses for pipeline engineers. It suggests that the industry and universities must work together to attract young people to tailored courses that satisfy skill shortages. Industry must take the lead and invest in universities willing and able to offer pipeline engineering education.

The paper emphasises the role of structured, modular learning packages for both university courses and continuous professional development. The Internet offers unlimited facilities for distance learning, and today's students and existing staff expect and need modern learning methods.

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1. INTRODUCTION

1.1 The Oil and Gas Business… Boom

The oil and gas business is big, and is becoming bigger, as oil prices soar, Figure 1, and demand for energy increases. Consider these facts from the US Energy Information Administration [1][1]:

- world energy demand will grow by 55% between 2005 and 2030;
- fossil fuels will remain the primary sources of energy, accounting for 84% of the overall increase in demand from 2005 to 2030;
    - global oil demand will rise from 83 million barrels of oil per day (mb/d) in 2004 to 118 mb/d in 2030;
    - global demand for natural gas will rise from 100 trillion cubic feet (tcf) in 2004 to 163 tcf in 2030;
    - coal consumption will increase from 114.4 quadrillion Btu in 2004 to 199.0 quadrillion Btu in 2030.

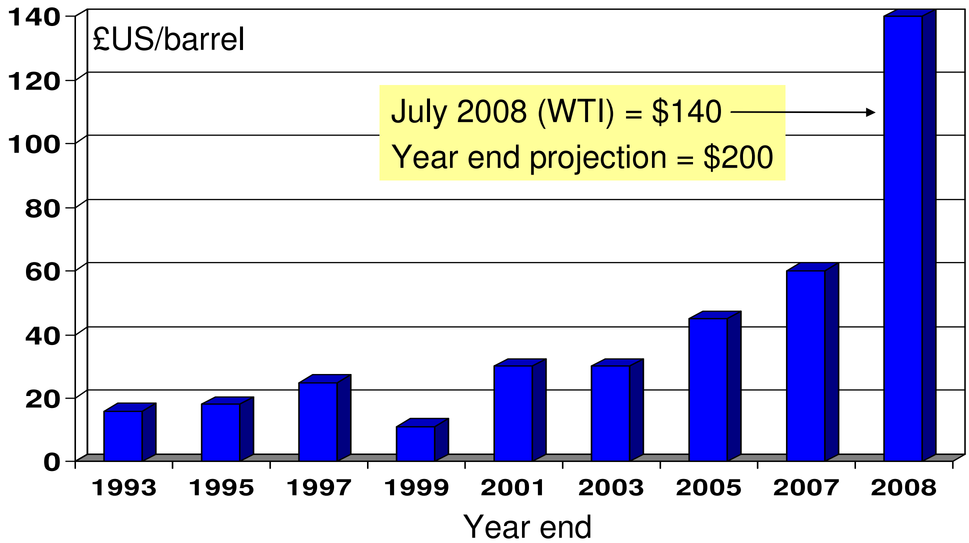

Figure 1. Rising Price of a Barrel of Oil.

This expanding industry is also highly profitable: Exxon Mobil, the world's largest non-government owned oil group, announced profits of $US40.6 billion in 2007, the largest profits ever by a listed company. Shell also announced a record profit for a British

[1] Billion = 1000,000,000. Trillion = 10^{12}. 1 cubic foot = 0.0283 m^3. Quadrillion = 10^{15}. 1 Btu = 1,055 J.

company in 2007: $US25 billion. These profits are expected to continue into the foreseeable future, as the average price of a barrel of oil continues on record highs of $US66 in 2006, $US72 in 2007, and over $US100 in the first quarter of 2008, Figure 1. In July 2008, the price of a barrel of oil passed $US140, and these high prices are predicted to continue for many years, Figure 2.

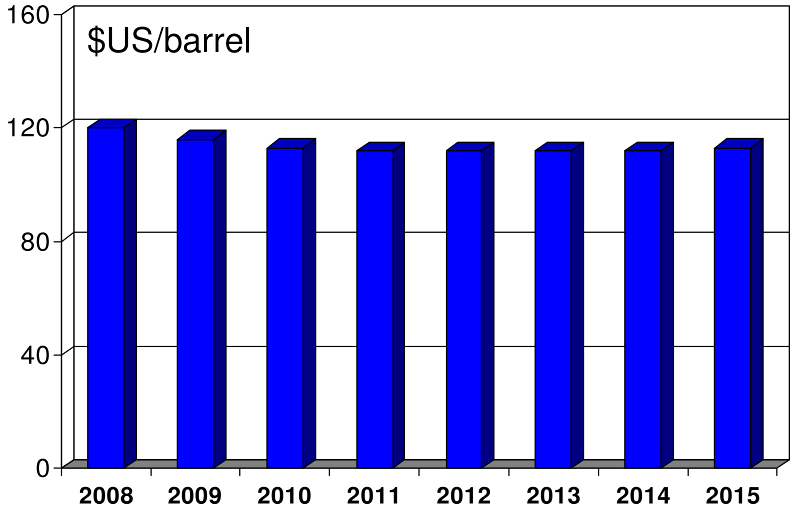

Figure 2. 'Futures' Price of a Barrel of Oil (NYMEX, May 2008).

1.2 Pipelines in the Oil and Gas Business… Boom

To support this growth in energy demand, pipeline infrastructure has grown by a factor of 100 in approximately 50 years. It has been estimated that world pipeline expansion will be in the order of 7%/year over the next 15 years [2]. This means over 8000km/annum of pipelines being built in the USA alone, at a cost of $US8 billion/annum [3].

Internationally, 32,000km of new pipelines are constructed each year: this is a $US28billion business, and 50% of these new builds are expected in North and South America [4]. Additionally, 8,000km of offshore pipelines are being built per year: this is a $5billion business with 60% in NW Europe, Asia Pacific, and the Gulf of Mexico.

Figure 3 shows the predicted 157,000km of onshore pipeline systems to be built in the next 5 years (2008-2012) at a cost of $US178billion.

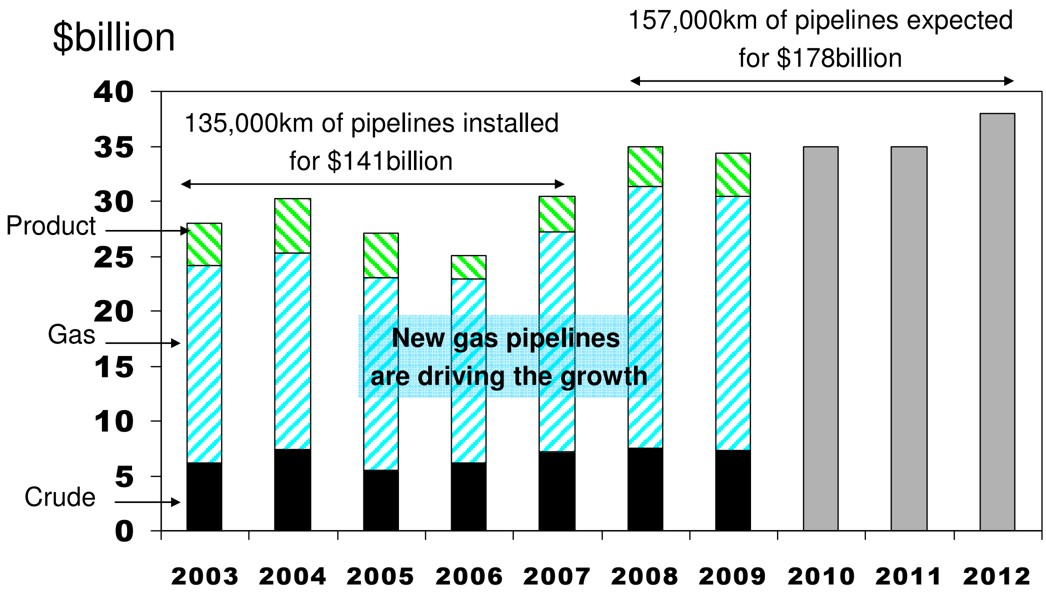

Figure 3. New Onshore Pipeline Constructions [4, 5].

1.3 Engineers in the Oil and Gas Business… Recession

The oil and gas business is a highly profitable business, and will continue to be profitable into the foreseeable future, but it has major problems with its workforce. Consider these diverse facts and quotes [6, 7] related to the oil and gas business:

- In the USA there are 1,700 people studying petroleum engineering in 17 universities, compared to 11,000 in 34 universities in 1993;
- *"There has never been a time when our industry so needs outstanding talent. Older professionals will need to be replaced in a few years. At the same time we have seen a drop in students taking science-based programs in the United States'*, Rex Tillerson, CEO, Exxon Mobil;
- *"We need to convince young people that a technical career in this industry is both stimulating and worthwhile – meeting challenges that matter to the world'*, Jeroen van der Veer, CEO, Shell;
- The average age of an American oil worker is over 50, and the average age of a worker in major oil and gas operators and service companies is 46 to 49 years of age.

Fossil fuels are essential, and the oil and gas business relies on engineers for everything from safety to profits, but the simple fact is that this business faces a crisis. It is not attracting new engineers, and much of its workforce will soon retire. Why has this situation arisen, and how can it be resolved? This paper attempts to answer this important question, and discusses how education and training can play key roles. The paper focuses on engineers, but there is also a shortage of good pipeline technicians and operators.

2. THE SKILLS GAP, AND CRISIS INDICATORS

2.1 Ageing Workforce in the Industry [6, 8 – 11]

The oil and gas industry workforce is old: a 'young' worker is about 43, and an 'old' worker is 55. Their average age is about 50 and their average retirement age is 55; therefore, it is obvious that the industry faces a major skills crisis in the next 5 to 10 years, as more than half the experienced workforce will leave the industry.

It is all skills levels that are ageing. In the UK, the mean ages of Chartered engineers and Incorporated engineers is 55, whilst the mean age of Engineering Technicians' is 50. Over 25% of the Chartered Engineers are aged 65 or over.

2.2 The 'Missing Generation'

We are all aware of the 'missing generation' in the oil and gas industry. The workers who trained in the 1960s and 1970s are approaching retirement; but the new, young generation attracted to the industry by the current boom and huge salaries are still too young to replace the retirees. Replacement takes time: it takes about 3 years for new staff to become familiar with the industry, and about a further 10 years to gain a professional discipline [6].

2.3 Increasing Global Demand for Skills

The skills problem is becoming even larger: we need to replace the missing generation, plus introduce another generation to meet with increased demand for skills. This is because new oil and gas finds will require huge workforces; for example, Brazil's Tupi field is equal to all the reserves in Norway. Also, the shift from the rapidly depleting older fields in the Middle East, to the new discoveries in places such as Canada, will create a global recruitment problem.

Reference 6 quotes, *"Faced with one of the biggest periods of expansion in its history, the global oil and gas industry is already being held back by its failure to attract, recruit and retain highly skilled staff. This is true from rig workers to senior scientists and engineers. Through short-term thinking and a belief that required staff can be bought, the oil and gas industry has stretched its resource base to breaking point."*

2.4 Reduced Number of Engineers in the Industry

There has been a lack of training and development in recent years, and there are many reports on the dwindling number of engineers in the business [12 – 16]. In the UK, the total number of registered engineers has fallen to 25,000, or by 8%, in the past decade [11].

In 2007, the UK's Association of Consulting Engineers (ACE) commented, *"There are currently 20,000 unfilled jobs in the consultancy and engineering sector. 13% of all jobs are currently vacant; highest numbers of vacancies are at engineers' level and especially so for civil, electrical and mechanical".*

2.5 Short Term Fixes

Many companies are having to boost their work force with workers on highly priced, short term contracts, or tempting back retirees. This is a short term fix, of no longer term strategic value to a business.

Similarly, companies are recruiting staff from developing countries who are maintaining their production of good quality engineers. Again, this is a short term fix, as the engineers recruited from these developing countries create a skills gap in the country they are leaving, and many will eventually return home.

2.6 Loss of Skills and Cost of Products

There is an accepted shortage of all key skills in the industry. The impact in the pipeline business is manifesting itself in the cost of pipelines; for example, the nominal price for a mile (1609m) of 36 inch (914mm) diameter pipeline in the USA had risen from $US1.5million/mile in 2003 to $US2.5million/mile in 2005, primarily due to the increase in the price of steel ($650/t to $US1300/t) and a scarcity of qualified workers [17]. Recent data in the Oil and Gas Journal give the following increases in costs for building pipelines [18]:

	2006 (US$/mile)	2007 (US$/mile)
Materials	728,000	>1,000,000[2]
Labour	629,000	1,000,000

The increase in labour costs is attributed to a shortage of highly skilled tradesmen (welders, sideboom operators, etc.), an ageing workforce, fewer young people entering the field, and many competing projects. The effect is that the cost of building a pipeline has nearly tripled in the past four or five years from approximately $1,000,000/mile to $3,000,000/mile [18].

[2] Mainly due to rising costs of steel.

It is not just the oil and gas business that has this age problem, and lack of new blood; for example, in the UK across all industries 25,000 engineers retire annually and only 12,000 graduates replace them.

2.7 Lack of New Blood

In the UK, a recent survey [19] on the oil and gas business revealed that more than three quarters of companies in the oil and gas business are having difficulty recruiting staff (both managerial and technical), and part of the problem was the industry's poor image (job insecurity, old employment practices, lack of experienced staff).

Many developed world countries are also faced with a decline in the number of school-leaving-age pupils: in the UK there will be a decline of about one in six in that age range over the next decade [11].

2.8 Decline in Engineering Graduates

The total number of UK engineering and technology graduates over the last six years has remained stable [11, 20]. However, the growth in other degree subjects has resulted in a decline in the overall share of all students: a decline from 9% to 6% [8]. Additionally, new engineering/science graduates are decreasing by 3% every year in the UK. A report in 2007 [21] demonstrated that students in the UK are opting out of science, technology, engineering, and mathematics subjects at university, and similarly there is a decline in high school students taking these subjects.

The UK's Royal Academy of Engineering in 2007 gave a more telling commentary of engineering graduates: *"Between 1994-2004 the number of students embarking on engineering degrees in UK universities remained static at 24,500 each year even though total university admissions rose by 40% over the same period. Further, after completing their studies less than half of UK engineering graduates subsequently choose to enter the profession".*

2.9 Other Issues for the Industry

References 3, 10 and 11 have covered the many problems with the oil and gas business, and the pipeline business, and hence the reader is directed to these publications for further reading.

3. BARRIERS TO SOLVING THE SKILLS CRISIS

3.1 Status Quo

The old age profile in the oil and gas business, and a continuing emphasis on experience, compared to other industries, will certainly deter the entry of young professionals. Consider the view of a young engineer entering the business [3]:

- The majority of the workforce is twice your age [9]; they are also almost all males [11], and 97% are white [22].
- You will not be allowed to work on any really exciting technical challenges early in your career: those go to the 'experienced' hands.
- You will need at least 10 years of experience to be considered for any mid-level technical or managerial position.
- No one is going to go out of their way to share his/her knowledge with you. You are expected to learn by 'putting in your time'.
- You will be laid off: probably more than once.

Engineers rightly value experience, and reward experience. But we must take care not to become obsessional about experience, and we must not always value experience above other attributes such as a willingness to learn, a willingness to change, and new knowledge. These latter three attributes are often offered by younger staff, and missing in experienced staff.

3.2 The Volatility of the Industry

We are currently in a boom period in the oil and gas business, mainly due to the price of oil being over $140/barrel[3], but it is only eight years ago that the price of oil was down at $U10/barrel. Downsizings of companies in the service sector were both common and severe in the late 1990s. We all know that downsizings are an excellent way of wrecking both employee loyalty and any corporate culture of trust.

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 early 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 now we have seen an upturn since 2001, and a high demand for skills.

[3] The 'futures' market (e.g. NYMEX) predicts high prices for many years to come – see Figure 2.

Cyclic culling of staff means that staff realise 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 [16].

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.

3.3 Are Engineers Valued?

3.3.1 Professional Engineers and Technicians

Salary reviews are difficult to perform and report, with differing definitions of professions, differing analysis, and differing sample sizes leading to conflicts and inconsistencies between differing reviews; however, this section attempts to show some salary data for engineers.

Engineers’ salaries are reviewed every year in the UK [22, 23]: the average salary in 2005 for a chartered (professional) engineer was £53,067 ($US106,000), and the median was £45,500 ($US91,000). These compare very well with other UK salaries for workers with a university degree, Figure 4.

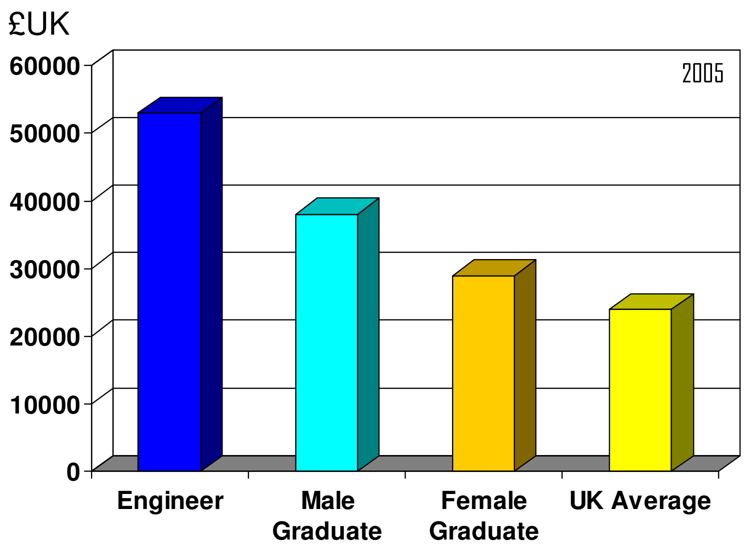

Figure 4. Comparison of Salaries in the UK for all Age Groups [23[4]].

In 2007, the mean salaries for professional engineers in the UK were [11]:

- Chartered engineer = £UK54,000
- Incorporated engineer = £UK44,000
- Engineering technician = £UK34,000

The USA Department of Labor publishes industry-specific salaries. In May, 2006, the mean annual salaries for professional engineers in the pipeline business was $US70,000 to $US90,000. Engineering technicians had mean salaries of $US53,000 to $56,000.annum.

Unfortunately, the salaries for engineers do not compare favourably with other professions. In the UK (2007) [11], Figure 5.

[4] Data (other than professional engineer) from UK government statistics (www.statistics.gov.uk).

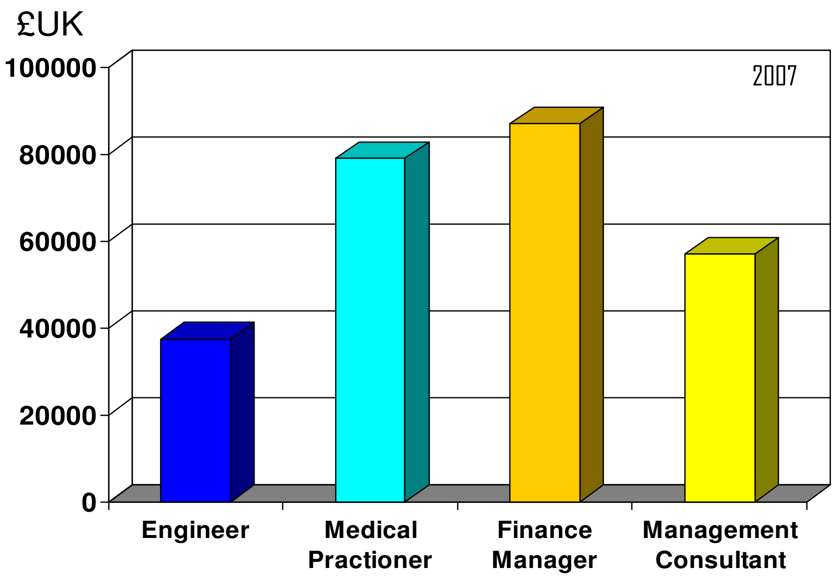

Figure 5. Median UK Salaries in 2007 [11].

3.3.2 Starting Salaries for Graduate Engineers

Median starting salaries for graduate (holding a bachelor degree) engineers in the UK (2007) are between £UK22,500 and £UK23,000, but these salaries are well below starting salaries in investment banking (£UK36,000) and consulting (£UK29,000) [11].

A UK salary review by the Association of Graduate Recruiters in 2007 showed a median starting salary for a graduate of £23,500, but previous reviews showed that the starting salary for UK mechanical engineering gradates is below that of new graduates choosing other careers in: consulting; legal work; general management; actuarial work; financial management; marketing; and IT.

3.3.3 Exodus of Young Engineers from the Profession

Professional engineers will have higher salaries that some professions, but they have the opportunity to work in the highest paid sectors (finance, IT, etc.). Newly graduated engineers, or students entering university, will look at the top paid sectors of industry, and conclude that engineering is well paid compared to some sectors, but is well behind the commercial, IT, legal and financial sectors. Engineering cannot compete with these sectors, and this is reflected in the fact that 29% of engineering graduates are recruited by the financial and consulting sectors each year in the UK [11].

3.3.4 Is Engineering Attractive to Young People?

A 2007 Institution of Engineering and Technology study in the UK showed that engineering failed to make the top 10 career choices among a group of 14 and 15- year-olds: the top three were: lawyer in first place; teacher in second place; and professional sportsperson in third.

Why do young people find engineering unattractive? A press release by the UK's Institution of Mechanical Engineers (IMechE) in March 2005 summarised the crisis of young people not entering engineering. IMechE said that UK companies are 'crying out' for their skills, but believed students are not going into the field of engineering because it did not pay well as a career. They reported that students were not entering mechanical engineering because students had the views summarised in Table 1.

View of Student	% with this view
Engineering paid a poor salary	55.4%
Few career prospects	14.5%
Engineering was boring, in comparison to other careers	13.5%
Engineering degrees are more costly/longer	16.6%

TABLE 1. Young Persons' Views on Engineering.

The first, and major, view in Table 1 is supported by the previous data, and the IMechE also quoted a survey that had shown that the engineering sector would see an annual increase of 2.5% in salary, compared to the national median increase of 4.8%.

This poor image and salary progression contrast with the forecast that there will be a 24.2% increase in vacancies in the mechanical engineering sector, the third biggest after logistics and consulting.

3.3.5 Employing Local Nationals

State-run companies in the Middle East and Asia have identified the reliance on expatriate workers, and the need to develop their own skills base. These countries/companies are now systematically employing nationals, with the intention of replacing the existing foreign and ageing workforce, Figure 6.

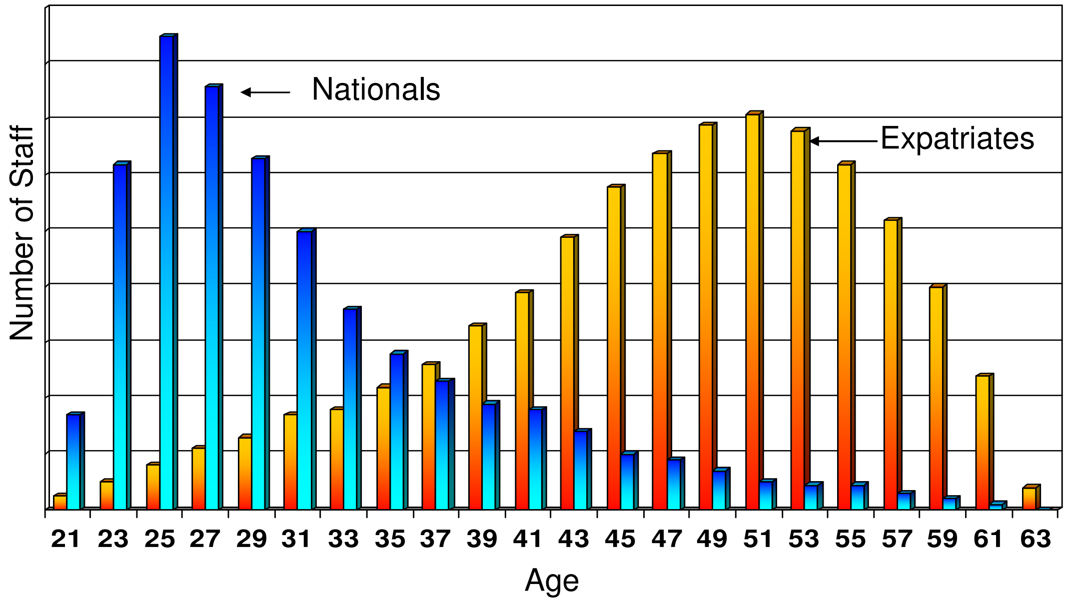

Figure 6. 'Push' by Middle East and Asian Countries to Replace the Expatriate Workforce with Nationals [6].

This means organisations have to make large numbers of new recruits 'job ready' quickly [6], but this influx of inexperienced, albeit able, staff require training, mentoring, etc., by the older, existing expatriate workforce. There latter workers are overworked, short staffed, and many may be looking forward to retirement; therefore, they are unlikely to be able to spend the necessary time with new staff to help them develop quickly.

3.3.6 Societal Values

Society continues to value and pay other professions (lawyers, accountants, city analysts) more than engineers and scientists. If this continues, society must accept a decrease in both quality and safety in our engineering structures. A young person will consider engineering (difficult degree syllabus, slow promotion, relatively low pay to other professions, threat of jail if things go wrong…), reject it, and choose an easier, better paid option.

Similarly, society must review its double standards; it accepts high fees from some professions (e.g. from lawyers), under-performance by others (bankers), poor performance (financial advisers), and incompetence (pension fund management), but aims to imprison lower-paid engineers if they make minor errors, albeit with great consequences (see below).

The prime role of engineers is safety; however, engineering is now seen as a price-driven commodity. This means that engineering and engineers are viewed as the 'lowest of three prices'. Quality is becoming secondary.

3.4 Industry Image

Oil and gas brings many benefits to society, and is an essential part of modern-day living: we cannot survive without it. In recent years, many scientists have highlighted the impact on our environment of burning fossil fuels: this impact can be highly damaging, particularly on our climate, and have long term consequences to our planet.

Over the last two decades, scientists have observed a slight increase in temperature on the surface of the earth. Some attribute this to an increased concentration of 'greenhouse gases' in the atmosphere. The most important greenhouse gases are: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. The main greenhouse gas of concern is carbon dioxide, and fossil fuel burning releases large quantities of carbon dioxide.

The previous section has noted that the engineering profession has a poor image with young people, Additionally, many young people will not be comfortable working in an engineering industry that might be seen to be destroying the planet.

Engineers will continue to have an essential and high profile role in the future energy business. The move to cleaner fuels, alternative energy forms, and the need to keep ageing assets working safely all require engineers: this should be attractive to young people. Accordingly, there is an urgent need to 'sell' engineering, the oil and gas industry, the crucial role engineers will pay in both the oil and gas industry, and in cleaner fuels, to school children and undergraduates. These messages need to be delivered by knowledgeable career advisers, and bespoke, stimulating academic courses.

3.5 Responsibilities[5] and Liability

Engineers must act in a responsible manner, otherwise they are liable to prosecution; indeed, a recent court case in the USA saw pipeline engineers serve jail sentences following criminal proceedings due to a pipeline failure.

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[5] See References 16 and 24 for commentaries on ethics in engineering.

Punishment for serious mistakes is – of course – acceptable and necessary. However, staff taking on these increased responsibilities and consequences must be rewarded accordingly, otherwise they will see the safest job in a courtroom is not engineering, but law!

It is reasonable for society to expect its engineers to be trained and competent. Now, governments are requiring that engineers should be demonstrably trained and competent, Figure 7. For example, the USA Pipeline Safety Regulations Federal Register Part 49 CFR §192.763 (*Pipeline integrity management in high consequence areas*) states:

- Training (i) Supervisory: '*An operator's integrity management program must provide that each supervisor… has appropriate training or experience in the area for which the person is responsible…'.*
- Training (ii) Persons who evaluate: '*An operator's integrity management program must provide criteria for the qualification of persons who review or analyze results from integrity assessments and evaluations…'.*

Figure 7. The Training of Engineers is Becoming a Regulatory Requirement.

Consequently, our business is now formally requiring we train our engineers correctly and comprehensively. Life-long learning is a legal requirement, and standards are being produced to help pipeline engineers meet these expected competencies [25].

3.6 Are Engineers Partly to Blame?

Are engineers partly to blame for the profession being unattractive and (relatively) poorly paid? Surprisingly, yes. There are many reasons for this:

- Engineering is now a vocational profession: we enjoy being an engineer, and we believe our work is important, and sometimes accept remuneration and work conditions that other professions would not accept. This is particularly true of the pipeline business, where some of the major contracts are now in locations that are war zones (Iraq), politically volatile (Venezuela), and with social unrest (Nigeria). Would a lawyer accept these assignments at engineers' rates? They would not. Why? Well, we all know that the hard work of an engineer will certainly be rewarded on arrival in heaven, but lawyers know they are not going there....

- Engineers are poorly supported by their expensive professional institutions and societies. These bodies are neither dynamic nor high profile, and seem unable to impose any control over pay and status.
- Engineers are obsessed with saving money. The problem is, they do not seem to realise that part of these savings come out of their own pocket. Let me give you an example. Engineers and their companies bid for engineering work, and often the price submitted is assessed by fellow engineers. The obsession with saving money, can drive prices down, and the rates paid to engineers on a project can come under scrutiny. Engineers have no professional pay rates: it is a market rate. This rate is constantly squeezed under competitive bidding, but this bidding is controlled by engineers on the other side of the negotiating table!

4. HOW CAN EDUCATION AND TRAINING HELP?

This paper has presented exhaustive data to show the reader the skills crisis in the oil and gas business. How can we improve and attract skills in our industry? The previous section has shown that many things have to change before we can attract new, young staff (image, remuneration, job security, etc.), but this section will focus on education and training.

4.1 Change is Essential and this Requires Training

The engineering profession is under increasingly pressure to change [26, 27] for a variety of reasons; for example:

- The environmental and economic problems facing the global society need new solutions;
- New discoveries, powerful computers, and fast communication systems have revolutionised the profession;
- The traditional boundaries between mechanical, civil and electrical engineering no longer exist, and should not exist.

Indeed, the USA's National Academy of Engineering reported in 2004 and 2005 the important decision-making role engineers have in society and the need for engineers to have broad, flexible perspectives: integration of skills is essential. This will need learning tools and easily accessible, searchable, knowledge bases.

4.2 Training is Good Business

Reference 12 noted that employer-sponsored training and education is a major attraction for young staff looking for jobs. Workers say they are more likely to remain with companies that invest in training programs. Additionally, investing in employees skills through training is a more effective tool for retaining staff than purely financial incentives.

4.3 Overview of Training Tomorrow's Engineers

Is the present education and training system failing industry? Andrew Furlong, of the UK's Institution of Chemical Engineers commented on the *"looming skills gap in science and engineering"* in 2007 and expressed concern about meeting the UK's need of 2.4 million new science and technology graduates by 2014.

Most commentators believe a radical rethinking of strategy is needed. One view is that the main requirements that must be implemented for the successful training of tomorrow's engineers are [26]:

- UNIVERSITIES: Universities must have education and courses that bridge cultures across the world as growing internationalisation is reflecting the global nature of business.
- MODULAR: Modular training courses and infrastructures offer convenient, efficient, flexible, life-long learning.
- PRACTICAL: Learning must have a practical orientation, where there is an integration of education and application.

4.4 Do we know what Young People and Engineers want?

The above three requirements present a challenge: at present we do not have training that satisfies these requirements in either the oil and gas industry, or the pipeline business.

One of the problems we have in the education business is that we have a poor knowledge of our customers' needs and requirements. Today's students and young engineers want flexible, efficient, rapidly-accessible, up-to-date learning, but often we give them what middle-aged, male engineers or academics believe they need.

A Master (MSc) programme in pipeline engineering was launched in 2000 in the UK. Paper mail shots, posters, etc., were sent out and displayed. Yet, all the students who applied for the course came via the internet, having discovered the course on the university's website. The 'client' was not on any paper mail list, did not look at posters, and investigated further education in parallel with buying their music from eBay, booking a flight on expedia.com, and reading their favourite newspaper – all on-line. The client was surfing the web for his/her future education course, while the university were pinning posters to university noticeboards!

Similarly, today's students and young engineers want materials quickly, and in electronic format. They want material that can be quickly interrogated by search facilities, they want good visual materials, up-to-date information, and instant, remote access to the learning materials whenever they need them. Future classroom-based teaching, and library-based references needs to adapt to the new students, or risk becoming unused or even obsolete.

4.5 Do we know what the Industry wants?

Many academics have a view of industry that is dated: many view industry as wanting the best students, with the highest grades, from the best universities. This view is wrong. A

2006 survey by YouGov in the UK revealed employers have different views on job applicants, Figure 8.

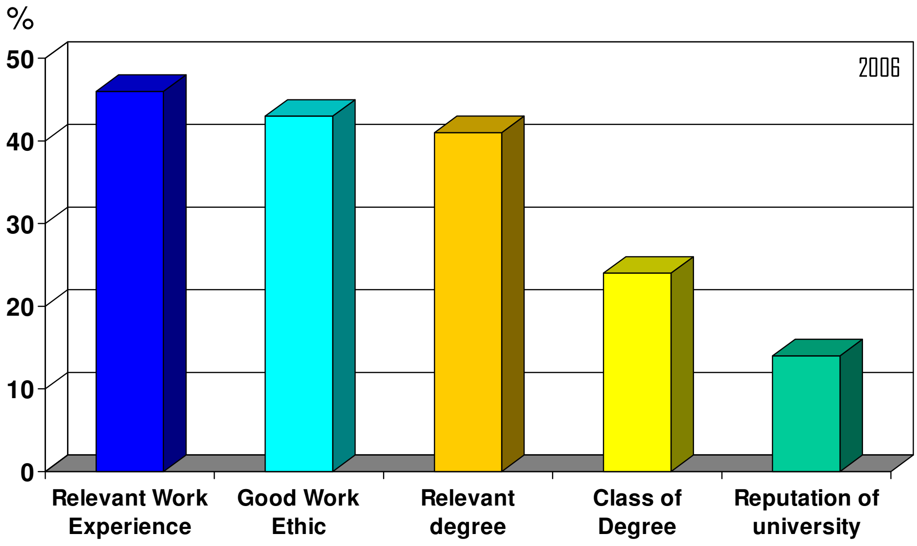

Figure 8. What an Employer looks for in an Employee.

This review revealed that employers are looking for graduates with a degree that fits the job advertised, and they have only a relatively minor interest in class of degree or standing of the university. Additionally, three quarters of employers thought that students who have gained work experience during their university studies will settle more easily into the world of work. Conversely, 52% of employees thought that students without this work experience would enter the world of work with unrealistic expectations, and would struggle to deal with pressure of work, time management, professional behaviour, etc..

Conclusions? Universities need to provide degree courses highly relevant to industry, and should actively encourage or organise work experience for their students.

4.6 Alliances between Academia and Industry

We cannot expect universities to know what an industry needs. Universities are battling for funding, competing for students, and are facing their own challenges. They are as busy as any other industry.

If we want academia to meet our needs, we have to inform them of our needs, and actively support them in their provision of education, research and training that solves our skills problem.

A joint endeavour between industry and education must be realised if we are to have viable products and solutions, and it is industry that must be proactive.

4.7 A New Learning Approach to Overcome the Old Barriers

A four tier approach to improving our intake of good young staff, and training our existing staff, is needed.

4.7.1 Tier 1: Working with Schools

We need to attract good young students into our universities, and stop the decline in engineering graduates: engineering graduates from UK universities are decreasing by 3%/annum. A partnership of industry, professional institutions, schools' career advisers, and universities is needed.

4.7.1.1 Taking the Lead with Schools

The lead should be taken by the professional institutions and societies: the UK's Engineering Education Alliance (EEA) [27] concluded that there are many initiatives underway to encourage young people into engineering, but there is no 'single point' of contact or reference. Additionally, they concluded that the effort that is made to encourage our school leavers to enter engineering 'lacks direction' [27].

4.7.1.2 Science Teaching in Schools

The IMechE considers qualifications in Mathematics and Physics as 'essential' for a high school student interested in becoming a professional mechanical engineer, along with additional subjects such as Chemistry. The EEA considers Mathematics, Design and Technology, and Science as the key building blocks.

These essential requirements are problematic; for example, the number of high school students taking physics as a major is declining in the UK. The UK's Institute of Physics attributes this fall to poor careers advice, and insufficient qualified physics teachers in UK schools. Indeed, Physics was not in the top ten subjects studied by UK high school students in 2004.

The number of high school students in the UK taking 'A-levels' (the examination taken by 18 year olds and a requirement for university entry) in Physics has halved since 1982, and the numbers taking Chemistry A-level have dropped by 37% in the same period. UK university departments covering these now 'unpopular' sciences are decreasing: the Institute of Physics states that, since 2001, 30% of university Physics departments have either merged or closed.

4.7.1.3 Drop the 'Hybrid'

Schools are guilty of diluting science skills with hybrid science courses (combinations of science subjects): Andrew Furlong, of the UK's Institution of Chemical Engineers said in

2007 *"…(hybrid) science is not preparing students for further study and is leaving big gaps in essential knowledge. Pupils must be allowed to study single-science options like Chemistry and Physic'".*

4.7.2 Tier 2: Working with Universities

Industry needs to work closely with universities and build new courses that are tailored to the industry needs, and attractive to young people. The universities can then ensure academic standards are met.

4.7.2.1 Stop the Decline

There is a decline in engineering at universities: figures published recently (2008) in the UK by its university entrance body ('UCAS') showed that the number of applications for degree courses for the 2008/9 academic year have increased by 8% compared to 2007/8, but applicants for Mathematics, Physics, and Chemistry degrees have all decreased, as have applicants for Mechanical, Civil, Chemical, Electrical, Electronic, and Aeronautical engineering degrees.

4.7.2.2 Drop the 'Hybrid'

Many first engineering degrees are being 'diluted' by the inclusion of topics that are considered more attractive to younger people (marketing, management, IT, etc.), at the expense of more traditional engineering topics [28]. Institutions that accredit these degrees need to question this type of change.

However, the universities are only reacting to what they see as market forces, and the wishes of their entrants. This dilution continues into postgraduate degrees, where many masters programmes offer various engineering courses 'with management'. Is there a world shortage of managers? Engineers need management training – but do they need it in their early 20s? The end products of some of our degrees are new engineers with a bias away from engineering, and a view of engineering that leans to IT, management, etc., rather than the traditional subjects. Is this what industries need?

4.7.2.3 The Oil and Gas 'Degree'?

Universities also need to consider how they present oil and gas engineering, and pipeline engineering at both undergraduate and post graduate level. The market needs these engineers, and they are not emerging from our universities. Industry needs to talk to universities!

Pipeline engineering is poorly presented at universities. Undergraduate engineers should be offered both oil and gas, or pipeline, engineering options in their final year of study. The oil and gas industry needs to help universities develop materials for these options, educate the academics, and be seen by the students to be actively supporting the options.

4.7.3 Tier 3: Modular Learning

Engineering is rapidly changing, and engineers need to keep pace with all technical changes. This is not possible without life-long learning. Additionally, the days of a 'job for life' are over. All engineers need to be highly trained, to be able to move between jobs. Structured modular training courses can provide this learning.

Globalisation, fierce commercial competition, and changing technologies require engineers to be quick to react. Similarly, engineers need to have easy and quick access to new knowledge. This can be achieved now: the modern methods of flexible working can allow us to take modular courses. This can give us the vital work-life balance we all now see as essential.

Staff no longer want to spend long periods away from home and workplace; they would rather embark on modular learning where they select suitable training packages from a comprehensive list, and participate in that learning programme in their own time.

The oil and gas industry, and academia need to work together to produce and offer this modular learning. Modules related to current and future industry issues should be on offer. This will require universities and industry to be flexible in both providing learning and providing students.

4.7.4 Tier 4: Distance Learning (e-learning or Virtual Learning Environments)

Universities need to offer residential, part time, and distance learning packages for all their possible customers (undergraduate, post graduate, and continuing professional development). This flexible, distant learning approach is in line with the changing work place, and the expectations of both the young and old today, and will appeal to both young engineers wishing to enter the oil and gas industry, and existing staff in the industry.

The internet offers the platform for both modular courses and distance learning. Distance learning formats can be easily produced, albeit at a price, but the distinction between campus learning and distance learning is fast disappearing with the advent of 'virtual learning environments' (VLE).

VLEs are internet-based 'platforms' – software that organises all the information needed for distance learning. The platforms can be commercial (you pay) or 'open-access' (free), and allow staff and students to log-on and access all course materials, bulletin boards, chat rooms, information updates, announcements, libraries, etc., in an easy, user-friendly web page format.

There are a number of commercial VLEs [29]: we now have the technology to offer distance learning to the oil and gas industry. Now, we need to:

- Produce the learning modules;
- Produce experienced staff to supervise the modules and students;
- Place the modules on a suitable platform;
- Manage and maintain the learning.

4.7.5 Barriers and Solutions

What are the barriers to this four tier approach? There are several:

- Professional institutions and societies must reverse the decline in engineering graduates by improving the image of the profession, lobbying for higher pay particularly for new starters, etc..
- Industry must commit to both support and participate in modular learning packages;
- Distance learning modules must be produced under partnerships between industry and academia;
- The industry must produce teaching staff to supervise these learning modules;
- An infrastructure must be put in place to give access to these modules;
- The whole process needs to be managed and examined.

5. SOME 'QUICK FIXES'?

We have a shortage of engineers in the oil and gas business, and we will need to quickly train our engineers to help fill this shortage. There are some obvious 'quick fixes':

- RETENTION: Retain existing staff, and develop all staff. We lose staff for reasons. Understand these reasons, fix any problems, and make sure we offer the most attractive employment packages: this will allow us to retain and recruit the best staff. These packages can include long term incentives, relocation compensation, wide-ranging benefits, flexible working (for example, 9-day fortnights), etc..
- THE BOTTOM LINE: Often, money is an issue. Pay your best staff high salaries. If your best staff are leaving to join your competitors because of poor salaries, you are a second class business. And remember: money is easier to acquire than talent, and replacing talent is expensive.
- LEARNING CULTURE: Encourage managers to both train themselves and train their staff (see next section). All companies must develop a 'learning' culture, where learning and education is seen as a key business driver and differentiator.
- MENTORING: Senior employees have traditionally mentored younger staff; unfortunately, these older staff are now too busy to help with mentoring. The skills shortage means our older staff are working at full pace up to the day of their retirement – and beyond. Mentoring and coaching have become history, and the traditional 'apprentice' model is breaking down [6]. This needs to change: management must allow senior staff to devote time to mentoring younger staff. Many companies will be uncomfortable with this investment as there is no guarantee that the mentoring time spent on younger engineers will not be lost by the engineers leaving in a highly competitive market.
- ATTRACT SCIENTISTS: Young entrants to engineering do not need to be graduate engineers: science graduates can be trained quickly in engineering and fill some of these gaps. Clearly, we need to offer courses to allow these science graduates to gain engineering skills (see next section).
- ATTRACT WOMEN: We all know that we are not attracting enough women into the oil and gas business. We need to make the business attractive to all entrants. Companies need to aggressively recruit more women, and ensure the industry is attractive by clearly showing there are no 'glass ceilings', and eliminating all potential barriers by, for example, offering flexible working arrangements, and

attractive childcare and maternity benefits, as key selling points. The pipeline business has to be more attractive to all entrants than rivals such as the legal profession, banks, etc..

- LATE RETIREMENT: We have a large group of older, retired workers who can be both encouraged to return to work that they are already skilled to perform, or to perform duties after appropriate training. For example, the increasing demand for workers in all business sectors in Australia, combined with the dramatic drop in fertility rates in Australian women, has meant that the Australian Government is actively recruiting older workers [30]. Many 'older' workers are actually only older than 55. With life expectancy approaching 80, 55 is young! Again, to attract older workers, we will need to be flexible: an older worker may not want to spend five days a week in the office, or long periods away from home. It should be emphasised that a policy of delaying retirements, and contracting back retirees has a 'limited shelf life' [6]: these staff must be replaced quickly.
- ATTRACT MINORITY GROUPS: In some countries the engineering profession is dominated by the 'white male' [31]. In the USA *"Only about one student in 25 from the African-American, Latino, and American Indian communities have taken the appropriate coursework to enter schools of engineering"* [31]. We need to work on encouraging engineering in these minority groups.
- FLEXIBILITY: 'Home working' can be very attractive to both employees and employers. Employers need to be careful with home workers: sometimes the home environment is not suited to work, and can also lead to a feeling of isolation by both the worker, and his/her workers back in the company office. But home working has changed: it can now be better/more efficient than the office; for example, online services may be more efficient at home (home bandwidths can be faster than in some offices). New software provides low cost, internet-based video conferencing, replacing the old style, clumsy and expensive video conferencing kits from the 1990s. All you need is a PC, webcam, and microphone. Finally, allowing staff the option of, say, one day per week working from home gives a worker flexibility in his/her working week.

The above 'quick fixes' require human resource departments to work harder in their recruitment policies, working arrangements, and training programmes.

Figure 9. The Pipeline Industry needs some 'Quick Fixes' to solve its Skills Crisis.

6. EDUCATION AND TRAINING OF ENGINEERS

6.1 General Competencies for Engineers

When we educate our engineers we must ensure they emerge from their studies with all the required competencies. Engineers need far more than technical expertise: they need knowledge and understanding. The Engineering Council in the UK oversees professional engineering standards in the UK, and they consider that engineers need four competencies:

- Knowledge and understanding;
- Application to practice;
- Leadership and management;
- Interpersonal skills.

Indeed, an engineer is considered competent if they have *the 'required theoretical and practical knowledge and sufficient experience to carry out work safely'* [32].

6.2 Competencies for Pipeline Engineers

Reference 32 gives a general overview of the required competencies of pipeline engineers, Table 2. The 'core' competencies are listed, along with the other competencies that pipeline engineers may need, depending on their post and position.

ACTIVITY	TASK
1. Health, Safety and Environment (Core)	Legislation awareness; Risk assessment; Use of permit to work system.
2. Operations	Identification and assessment of pipeline route; Leakage survey of pipelines; Pig launching and receiving operations; Site work involving excavation and reinstatement; Isolation of mechanical plant; Isolation of electrical plant; Completion of physical decommissioning of pipeline; Purging of pipelines/pipework; Undertake hot working on operational pipeline; Hydrostatic testing of pipelines; Drying of pipeline prior to commissioning; Recommissioning of pipelines; Operate fire and gas detection systems; Operate emergency shutdown systems; Emergency response; Use of portable gas detection equipment; Use of breathing apparatus; Use of security systems; Driving (cars and light vehicles).
3. Mechanical Maintenance	Maintenance of pipeline sleeves; Maintenance of pipeline valve and actuation systems; Examination and maintenance of filters; Examination and maintenance of pig traps; Maintenance of heaters; Maintenance of lube oil systems.
4. Electrical and Instrument Maintenance	Site testing and maintenance of electric motors; Maintenance of standby generation equipment; Maintenance of electrical switchgear and UPS system; Maintenance of metering UPS systems; Maintenance of gas quality monitoring systems; Maintenance of compressed air systems; Maintenance and use of electrical equipment for hazardous areas; Maintenance of uninterrupted power supply (UPS) and DC equipment.
5. Specialist Services	Specialist surveys to detect coating anomalies; Specialist repair of pipe coating anomalies or reinstatement of coating following pipe repair; Specialist inspection of CP system; Examination of pipework/equipment to identify defects which could lead to failure of pressure containment; Carry out internal/in-line inspection of pipelines; Specialist measurement, recording and assessment of defects in pipewall.

TABLE 2. List of Pipeline Engineering Competencies [32].

More detailed requirements, particularly for engineers directly involved with the operation and maintenance of a pipeline, can be found in Reference 25. The purpose of this American Society of Mechanical Engineers (ASME) standard is to establish requirements for the qualification and management of qualifications for pipeline personnel. The implementation of this standard is intended to help minimise human error that would impact the safety or integrity of a pipeline. It is worth noting that the standard clearly places a duty on the employer: *'Employers shall be responsible for identifying training needs and providing appropriate training for individuals requiring or maintaining qualifications'.*

6.3 The Role of Institutions and Societies

Professional institutions and societies have a major role to play in training our engineers. Unfortunately, most of these organisations do not have pipeline engineering as a specific area of interest; for example, the IMechE in the UK has a 'Pressure Systems Group' that has some connections with pipelines, but it is mainly aimed at pressure vessels and piping.

An exception is the ASME: it has a Pipeline Systems Division, and is committed to support the *'education and timely, in-depth exchange of technical information among researchers and engineers'*. It actively seeks novel research in pipeline engineering and awards an annual prize for the outstanding research work. Also, it has a highly successful biennial conference, and has organised and financed a video-conference between universities involved in pipeline engineering education.

6.4 Public Training Courses

Many companies offer short (up to five days) public training courses on a wide range of pipeline engineering topics. There are regular public training courses held in Amsterdam, Houston, Kuala Lumpur, Calgary, etc., on such topics as: Onshore and Offshore pipeline engineering; Pipeline defect assessment; Pipeline inspection; Pipeline repair; Corrosion assessment; Risk management.

These short courses are popular, and play an important role in training staff in the pipeline business. Some are highly reputable, but they are not regulated, accredited, examined, or co-ordinated.

6.4.1 The Cost of a Public Training Course

The cost of these training courses can be high, but this cost if often negligible compared to the loss of time, and expenses associated with an engineer attending the course. Hence, the focus of a manager approving a training course should not be its cost, but its value.

The value is assessed by the quality of the course, and – most important of all – the quality of the trainer.

6.4.2 Checking the Course

There is a need to be cautious with these training courses, the trainers, and providers. The 'training industry' is big business, and sometimes quality is sacrificed for profit. Engineers and oil and gas companies should carefully check the training courses on offer. There are some very good courses, and some awful courses, on offer, Figure 10. A simple checklist would be:

- Is the training course agenda coherent and logical (or just a list of lectures by lecturers who are cheap and available that week)?
- Is the training course established and provided by a credible organisation (or put together by a provider with no knowledge of the business, with no other related offerings)?
- Are the course materials coherent, thorough, and up-to-date (or fragmented (a 'bag of bits'), dated, and lacking depth)?
- Is the course well-attended, and can references be provided?

It is essential to check the above items with previous attendee of courses: they give the best assessment.

6.4.3 Checking the Trainer

The most important item on a training course is the trainer. A poor trainer is a dangerous trainer. A checklist for a trainer would be:

- Is he/she qualified? (e.g. is the trainer a professional/chartered engineer?);
- Is he/she credible? (e.g. has the trainer a CV that gives confidence in his/her abilities?);
- Is he/she 'well known' (e.g. is the trainer recognised by peers in this topic area, and is he/she known to be a key figure in that topic?);
- Is he/she experienced in the topic? (an 'experienced'; engineer would need more than 10 years in the topic subject to be considered competent to be a sole trainer);
- Is he/she 'in touch' with the topic? (e.g. is the trainer currently involved with the topic?);
- Is he/she clearly part of the industry and this topic (e.g. is the trainer a leading member of committees or organisations who lead in the topic field?).

Figure 10. Public Training Courses are available in Pipeline Engineering, but how good are they?

6.5 Current University Courses in Pipeline Engineering

Nationally, and internationally, the pipeline industry is poorly served by academic organisations; however, some universities (for example, Newcastle, UK; Calgary, Canada; Rio, Brazil) are now providing formal learning programmes in oil and gas pipelines. Additionally, some universities conduct ad hoc research into pipelines, some have centres of expertise in testing (for example, University of Gent, Belgium), and some universities have dedicated posts in pipeline engineering (for example, University of Loughborough in the UK has a professorship in pipeline technology).

This section briefly describes the pipeline training programmes offered in four countries: Brazil, Canada, UK, and USA.

6.5.1 Brazil

Since 2000, the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), has offered undergraduate and graduate programs on pipeline engineering. The programs offer seven independent modules, open to students of sciences and engineering at three levels: undergraduate (senior level); extension (continuing education); graduate (MSc and Postgraduate Certificate).

The modules are: Mechanical Design; Pipeline Hydraulics; Topics in Pipeline Design; Pipeline Structural Integrity; Topics in Pipeline Operation; Topics in Pipeline Construction, Installation, and Maintenance; Seminars.

6.5.2 Canada

The Faculty of Engineering at University of Calgary, Canada established a new centre known as the Pipeline Engineering Centre in 2003. This Centre's goal is to provide support and direction to industry in pipeline engineering. The centre addresses pipeline engineering education and research.

Training at Calgary involves the development of graduate classes in the pipeline engineering area, the establishment and running of short courses, the development and delivery of training courses, and the hosting of seminars and workshops.

Memorial University of Newfoundland gives undergraduates an opportunity to study offshore oil and gas topics in their Faculty of Engineering and Applied Science (www.engr.mun.ca/undergrad/oil.php), and they are introducing offshore pipeline systems classes.

6.5.3 UK

6.5.3.1 London

University of East London[6] offers a 'Pipeline Technology and Network Management' masters programme. It is based on three modules: Fluid mechanics (40 hours of lectures); Management of sewerage systems (40 hours of lectures); Management of water supply networks (40 hours of lectures).

It is biased towards potable water and sewerage pipelines. The university also conducts research work on pipelines; primarily, water pipelines and non-metallic pipeline materials.

6.5.3.2 Cranfield

Cranfield University offers an 'Offshore and Ocean Technology' masters programme, with an option in 'Pipeline Engineering'. The course comprises 10 one-week assessed modules, a group project, and an individual project. Students complete eight 'core' modules: Project Management; Corrosion in the Offshore Environment; Subsea Oil and Gas Exploitation; Offshore Pipeline Design and Installation; Materials in the Offshore Environment; Safety, Risk and Reliability Offshore; Fracture Mechanics; Underwater Vehicles and their Applications. They select two others from: Offshore Structures and Environmental Forces; Diving Science and Technology; Underwater Technologies; Underwater Optics, Acoustics and Control; Offshore Renewable Energy: Technology; Offshore Renewable Energy: Management; Reliability Engineering and Asset Risk Management; Offshore Structural Integrity Monitoring.

[6] Log on to http://www.uel.ac.uk/pipeline/about.htm for information on the course.

Clearly, this course has an offshore structures bias, with limited pipeline engineering.

6.5.3.3 Newcastle

University of Newcastle[7], UK started a master degree program in ‘Pipeline Engineering’ in 2001, under the guidance of a combined academic and industry steering committee. Its aim is simple: to equip the next generation of pipeline engineers with appropriate qualifications, Figure 11.

It is designed to meet the specific requirements of the oil and gas sector, covering both high-pressure offshore and onshore pipelines. A unique feature of this programme is the high level of participation by the pipeline industry in specifying the curriculum, and in providing a larger number of visiting lecturers. The one year residential MSc programme has the following modules: Fundamentals of Pipeline Engineering; Design and Construction; Asset Management; Economics for Pipeline Engineers; Hydrocarbon Processing and Production; Corrosion and Corrosion Control; Materials and Fabrication; Dynamics of Offshore Installations; Pipeline Structural Integrity; Civil and Geo-technical Engineering; Safety and Environmental Engineering.

The course now attracts over 35 students per year.

The masters programme will offer distance learning options in 2008: in particular, a ‘Certificate of Pipeline Engineering’ can eventually be offered, if industry provides the necessary funding. This Certificate will be awarded after a student successfully completes a distance learning course (over the internet) covering several modules from the residential MSc course. The distance learning students will be required to pass examinations during a summer school at the university, and complete an assignment during their studies.

The first module of this Certificate course in available and its 29 lectures are considered to cover the essential skills needed in pipeline engineering: Introduction to Oil and Gas; Exploration to Refining; The Petroleum Business; The Transmission of Energy; History of Pipelines; Types of Pipelines; Line Pipe; Corrosion and Coatings; Pipeline Pressure and Stress; Pipeline Safety and Why Pipelines Fail; Design Basics; Design – other considerations; Valves; Fittings and Plant; Pumps and Compressors; Pipeline Hydraulics; Onshore Pipeline Routeing; Onshore Pipeline Construction and Commissioning; Field Welding; Offshore Engineering; Offshore Pipeline Routeing; Offshore Pipeline Construction; Pipeline Testing; Pipeline Operation; Pipeline Inspection and Monitoring;

[7] Log on to http://www.ncl.ac.uk/pipe.eng/ for information on the course.

Pipeline Decommissioning and Abandonment; Risk, Safety and Environmental Issues; Project Engineering, Control and Finance; Engineers' Ethics and Responsibilities.

It should be noted that University of Newcastle teaches ethics and responsibilities, as it requires its students to be aware of current issues, and the wider global implications of being an engineer.

Figure 11. University Courses in Pipeline Engineering are Emerging.

6.5.4 USA

A recent review [33] of pipeline engineering training and research in the USA concluded that the current situation was 'dire'. It also quoted an older review [34, 35] of pipeline engineering research and education in the USA in 1996-7: this earlier review showed that 12 out of 225 universities[8] in the USA offer pipeline-related undergraduate courses, and 15 pipeline-related graduate courses. Only University of Missouri in Columbia offered an introductory course exclusively on pipelines. This course closed in 2001 when the course leader retired. Its content was: Introduction; Single phase incompressible flow of Newtonian fluid in pipe; Single phase compressible flow in pipe; Non-Newtonian flow in pipe; Flow of solid/liquid mixture in pipe: slurry flow; Flow of solid/air in pipe pneumotransport; Flow of capsules in pipe-capsule pipelines; Pipe, fittings, valves and pressure regulators; Pumps, blowers and compressors; Flow meters, sensors, pigs and automatic control systems; Protection of pipelines against freezing, abrasion and corrosion; Planning, construction, and operation of pipelines; Structural design of

[8] 35 out of the 225 universities responded to a questionnaire.

pipelines: load considerations and pipe deformation/failure; Economics of pipelines; Legal, safety and environmental issues on pipelines; Code, standards and government regulations.

University of Missouri in Columbia considered that due to the importance of fluid mechanics or hydraulics to pipeline engineering, logical platforms for launching a pipeline engineering curriculum are programs of ‘hydraulics’ or ‘fluid mechanics’ that already exist in many civil engineering or mechanical engineering departments.

6.5.5 Other Locations

Other universities may be offering Pipeline Engineering courses. For example, it is understood that University of Petroleum & Energy Studies, Dehradun, India offers a pipeline engineering programme to ‘MTech’ level. The syllabus is covered in four semesters: Transport phenomena; Basic of petroleum refining and petrochemicals; Numerical methods in engineering; Risk analysis and management; Structural engineering and vibration in pipelines; Project and material management operations and economics; Pipeline systems engineering. Petroleum transport systems and operations; Defect assessment and maintenance in pipelines; Offshore pipeline systems; System analysis and optimization; Pumps/compressors; Database management systems; ERP system. Hazards, safety and environmental management; Process modelling and simulation; Pipeline network analysis; Petroleum law policy and contracts; Enterprise systems management and its application to petroleum sector; Project, internship, and seminars.

6.6 Pipeline Integrity Training

A major area of interest in the pipeline business is ‘integrity’. ‘Integrity’ will have different meanings in different sectors of the petroleum business: most pipeline engineers will consider integrity to mean pipeline structural soundness, but to a customer, it may mean ‘billable quality’ of product, or to a control room it may mean operational stability.

The USA’s Department of Transportation considers [36]:

- the term ‘integrity’ means that a pipeline system maintains its structural integrity and does not leak or rupture;
- ‘integrity management’ encompasses the many activities pipeline operators must undertake to ensure that releases do not occur.

Ensuring a pipeline is safe and secure, with no release of product, requires many aspects of pipeline engineering, ranging from corrosion control to internal inspection; consequently, pipeline integrity covers most of the general pipeline engineering disciplines listed above. A pipeline integrity engineer requires wide pipeline engineering knowledge.

The key elements of pipeline integrity training can be summarised by reference to two key pipeline integrity documents: API 1160 [37] and ASME B31.8S [38]. These two documents give guidance on managing the integrity of liquid and gas pipelines, which requires:

- Understanding of general pipeline engineering (see Section 6.5);
- Evaluation of pipeline 'threats' (incidents that can cause pipeline failure, and why pipelines fail);
- Risk analysis and assessment (determining probability of failure, consequences of failure, and acceptable levels of risk);
- Understanding of pipeline inspection, surveillance, testing, and monitoring;
- Ability to conduct structural assessment of pipeline damage such as corrosion, mechanical damage, etc., and understand how this damage changes with time, and appropriate remedial measures.

7. DISCUSSION

The oil and gas industry is booming, oil prices are at record highs, and profits are soaring, yet companies in the industry are now suffering from past downsizings and lack of recruitment. Combine an ageing workforce, with a poor image associated with engineering, and environmental damage, and it is not surprising that young staff are not attracted to the industry.

Companies are starting to develop their own people [6]:

- Shell has opened a training centre in the Netherlands (Learning@EPICentre) with a capacity to train 270 students/day;
- Exxon Mobil's Upstream Technical Training Center in Houston will train more than 4000 students/annum;
- BP has established a Projects Academy, in conjunction with MIT.

These initiatives are needed, but they will not be sufficient to solve the skills problem. Previous publications [3, 10, 11] have shown the ageing profile of engineering staff in the pipeline industry, and the alarming loss of skills. More recent publications [39, 40] have emphasised this loss: 40 to 60% of skilled staff in the oil and gas industry are approaching retirement, and will do so in the next five years. This latter observation lead to a worrying conclusion: the industry is haemorrhaging intellectual capital. There is an urgent need to retain skilled staff and train new staff [39, 40].

It is worth noting that talent in no longer a national asset: it is a global commodity [39] that attracts worldwide competition. This can lead to a 'drain' on national talents, through international channels. This loss of talent can:

- affect operational management; and
- affect a company's or region's ability to understand, and change with, the market.

An extra dimension is that both clients (e.g. pipeline operators) and contractors (e.g. engineering design companies) are suffering talent and skill shortages: this could lead to the 'blind leading the blind'! There are solutions; for example [39, 40]:

- Use new sources of talent; for example from developing nations. These nations are producing a greater proportion of engineering and science graduates than the developed world. Indeed, Western Europe is seeing a decline in these graduates (the UK now produces more 'media studies' graduates that physics and chemistry graduates [38]). Obviously, recruiting from these new sources may leave skills gaps in those regions, and this has to be considered.

- Increase incentives for staff, such as remuneration, flexible working, etc..
- Develop links with universities to develop new talent.
- Manage knowledge by capturing existing knowledge, and sharing it with all generations of engineers.
- Increase productivity using more efficient business and working systems.

To meet this challenge of skills shortages we need to both train and retain! Otherwise both safety and profits will suffer. Academic courses aimed at sectors of the oil and gas industry, continuing professional development, and accessible training, particularly distance learning, need to be at the forefront to help to maintain skill levels.

7.1 The Start of an Exciting Era in Pipeline Engineering

The difficulty in attracting staff is contrasted by the fact that the pipeline industry is probably entering its most exciting era, and this era will need highly skilled engineers. Here are some of the challenges that will both excite and challenge tomorrow's engineers:

- AGEING ASSETS: A great challenge in the next decade will be the maintenance and management of ageing pipelines; for example, most of the USA's huge oil and gas pipeline system is over 40 years old.
- 'UNCONVENTIONAL' OIL AND GAS: There is a major move towards extracting oil and gas from all viable sources: today's high costs for oil and gas mean that previously uneconomical sources are now economical. The days of obtaining vast quantities of 'easy' oil have passed, but we can obtain similar quantities of oil and gas from more difficult, more expensive sources. Oil and gas exist in shales, in low permeability rocks ('tight gas'), and in 'oil sands' in huge quantities. The USA Government estimates that oil shales contain one trillion barrels of oil in the USA alone – four times Saudi Arabia's proven reserves. Canada's vast oil sands are thought to contain as much oil as Saudi Arabia's 'conventional' sources. These new sources will require many new engineers and many new skills.
- CARBON CAPTURE: Electricity generation using fossil fuels generates carbon dioxide (CO_2). The use of cleaner fuels (e.g. using clean coal technology) and the capture of the emissions provide the most significant means of reducing the emissions. The CO_2 would be sequestrated from carbon-burning industrial plants, and stored in geological structures such as saline aquifers or old oil and gas fields.

The CO_2 will need to be transported in large quantities, in pipelines. CO_2 is a difficult fluid to transport (e.g. it needs to be transported at very high pressures), and there is an urgent need to design and develop CO_2 pipelines if carbon capture is to become a reality, and help prevent climate change. Governments are already committing to reduce CO_2 emissions: the UK is committed to reduce its CO_2 emissions by 60% by 2050.

- HYDROGEN ECONOMY: Developed nations rely heavily on oil, gas and coal, but hydrogen is the most abundant element in the universe and can be used for a fuel. Countries are looking at long distance hydrogen pipelines as an alternative fuel supply to natural gas, etc.. Hydrogen can be transported as a liquid (e.g. by trucks and tankers) or as a gas (by pipeline). Pipelines offer the most economical transport mode, but hydrogen is a problem fluid to transport; for example, it embrittles many steels. Much work is needed on hydrogen pipelines before the new 'hydrogen economy' arrives, but BP is now planning a $US1 billion plant in California to obtain hydrogen from petroleum coke.
- BIOFUELS[9]: Sustainable biofuels (for example, bioethanol obtained from sugar cane) are alternatives to fossil fuels, without the damaging levels of CO_2 emissions. These fuels will be ethanol, methanol, etc., and new pipelines will be needed to transport both the raw products and the new fuels to/from their refineries. The biofuel industry is already with us: Brazil intends to power 80% of its transport fleet with ethanol derived mainly from sugar cane within five years.
- SABOTAGE/TERRORISM/THEFT: the world's oil and gas pipelines pass within and across regions that are poor, politically unstable, inhospitable, corrupt, or prone to terrorist attacks. Consequently, pipelines and facilities such as pumping stations are vulnerable to attack, sabotage and theft. The world's pipeline system is growing; for example, Saudi Arabia has 20,000km of pipelines and this length may grow to 96,700km in the future [42]. This may be a big, easy target for terrorist attack: the Cano Limon pipeline in Colombia was attacked 170 times in 2001 by a terrorist group, despite the heavy and constant presence of armed guards. Theft of products from pipelines and vandalism are also problems: the Niger-Delta region of Nigeria recorded the deaths of about 5000 people from oil pipeline 'vandalisation and explosions' in 2000 [43]. Technology can help; for example, satellite surveillance is a practical solution today, as is the use of more sophisticated leak

[9] A 'biofuel' is a liquid or gaseous fuel produced from 'biomass'. Biomass is a product of agriculture, forestry or related industries, as well as the biodegradable fraction of industrial and municipal waste [41].

detection systems and remote sensing devices to detect tamperings on the pipeline. But it is worth noting that in Russia, Gazprom have an armed force protecting its pipelines, and over $170million has been invested in safeguarding the Baku-Tblisi-Ceyan pipeline, including a 700 person security force in Georgia [4].

- DEEPWATER/HOSTILE ENVIRONMENTS: The next decade will see a huge increase in exploitation of reservoirs in deepwater, in the Gulf of Mexico, and off the coasts of Brazil and West Africa. Our technologies work well in 1000m, even 2000m water depths. But some of our deepwater exploration will take us beyond 3000m and onto 4000m. These depths require new technologies and new skills.
- WATER: One third of the world's population does not have a safe water supply: this leads to 25,000 people dying per day because of poor water quality. Here are some more shocking facts: in the next 24 hours, 4,000 children will die from diarrhoea caused by unclean water and poor sanitation; at any time, half the population of the developing world are suffering from water-related diseases; one billion people have no source of drinking water [44]. New pipelines can help solve the water problem. This will require huge investments, huge infrastructures, and international co-operation. The politics will not be easy: in 1995 the World Bank viewed 'water' and its effects on world peace, and it stated that in the past wars had been fought over oil, but the future wars could be over water.

7.2 Academia and Pipeline Engineering

Industry and academia need to partner and work together to ensure that young engineers are attracted to the industry, and courses are tailored to satisfy the new skills needed. Additionally, industry and academia need to review how they train their staff: a combination of modular learning and distance learning is the modern, convenient and quick solution.

Section 6 has listed the requirements for general pipeline engineering education and training. These requirements should be satisfied by the above combination of modular, distance learning. The pipeline business needs to invest in this learning now.

Universities now need to actively teach pipeline engineering. This will require universities to offer pipeline engineering at both undergraduate level (probably as a final year option), and post graduate level (masters and doctoral). This will cater for an industry need: there is a real international need for pipeline engineers, current and imminent vacancies, and the potential for a highly rewarding career.

It will not be simple, and there are three reasons for this:

- Universities and their staff are under increasing pressures to deliver their current programmes, and attract more funding. This means their focus will not be on a 'new' idea, such as pipeline engineering. Indeed, universities, certainly in the UK, are obsessed with research and published papers. This obsession is required as their annual funding is dependent on their research: the importance of teaching, and an academic's ability to teach, are distant memories in these ivory towers [45]. Industry needs to take great care before investing even a single dollar in a university, without assurances that the dollar will be used in teaching, and not contributing to some academic's standing within his or her pet subject.
- Universities have little or no knowledge of pipeline engineering. They do not have pipeline engineering research facilities, staff with pipeline engineering backgrounds or expertise, nor pipeline engineering journals, books[10], etc.. We can never have a university course on pipeline engineering until we have university staff with pipeline skills.
- Universities need to have a research basis for any new technological area. This means that a university will need a core research programme in pipeline engineering, if it is to provide staff, materials, project ideas, etc., to pipeline engineering students. Consequently, an investment in both pipeline engineering research and education is needed if a university is to succeed in training tomorrow's pipeline engineers.

This will require industry to actively support universities in recruiting staff, and setting up courses and facilities. If industry does not help academia, academia cannot deliver. 'Industry' can be any organisation ranging from an oil and gas major, to a professional society; for example, the American Society of Mechanical Engineers (Pipeline Systems Division) has a programme that financially supports the exchange of academics in universities involved in pipeline engineering.

Consequently, the oil and gas business must:

- Seek universities willing to initiate pipeline engineering education and research;
- Assist these universities in setting up a range of courses: undergraduate, graduate, and continuing professional development;
- Provide resources (staff, finance, and course contents);

[10] Reference books for pipeline engineering are now being published in response to an industry need [46 - 56].

- Accept university staff on secondments, and provide their own staff to assist universities;
- Provide research ideas, mentoring of university staff, and supervision of research projects.

If the oil and gas business does not do the above, the current ‘dire’ situation will continue.

8. CONCLUDING COMMENTS

8.1 The Skills' Crisis

We have staff shortages and a skills crisis in the oil and gas industry, and in the pipeline engineering business. A recent publication [57] by the private equity company 3i, listed facts that summarised the crisis:

- In the UK, the percentage of school leavers studying engineering has lately been reported to be around 8% compared with 15% in France, and 33% in China.
- In 2004, the UK produced around 24,500 graduate engineers and the US produced 70,000. In comparison, India produced 350,000, and China produced 600,000.
- The oil and gas majors had collectively displaced more than 1.1 million employees since 1984. There is a particular shortage of workers in the core 30 to 45 year old range, because of the recruitment freezes the majors implemented over the past two decades.
- In the UK, the number of people employed directly and indirectly by upstream oil and gas companies shrank from around 360,000 in 1997 to 270,000 by 2001.
- The Independent Petroleum Association of America records a massive drop in upstream employment from more than 700,000 in 1992 to just over 250,000 in 2004.

Engineers are important: bad engineers can create an unsafe environment in the oil and gas business. With no engineers, an unsafe environment is guaranteed. There are engineers, technicians, and operators available, but good quality, experienced staff are in short supply. Indeed, in many regions we have an adequate supply of 'entry level' engineers, but this will not solve the problem of the shortage in skilled and experienced staff [58].

The 1980s and 1990s was a time the industry went through poor times, with significant effects [59]; for example, in this period the number of petroleum engineering graduates dropped by 88%. The industry and engineering remains unattractive, yet it offers decades of employment, in companies that record the highest profits in the world.

Now, the industry needs to urgently attract new, high quality, staff to replace an ageing workforce. The average age of engineers in the industry is now over 50; and there is now a big gap between the 'baby boomers' and engineers with 10 years experience or less [59].

The oil and gas industry will face fierce competition from other industries; for example, the demand for skilled staff in the renewable energy sector has increased by 60% over the past two years [60]. Also, the nuclear industry in the UK will need up to 13,500 graduates and technicians over the next 10 years, and this number does not include the expected higher demand that new builds will create [61].

The image of the industry, and the type of work on offer, is important for recruitment: younger workers are looking for 'brand' recognition and a positive company reputation, whereas engineers in mid-career are seeking interesting work, and development opportunities [58].

And finally, it is worth noting that we are not rewarding engineers in simple financial terms: this will ensure some of our best engineers will be lost to other industries or specialisations. Consider a review by the UK's Institution of Engineering and Technology [62]: the IET concluded that engineering consultancy rates are actually dropping in the UK, and lagging behind other disciplines such as 'change management', Figure 12.

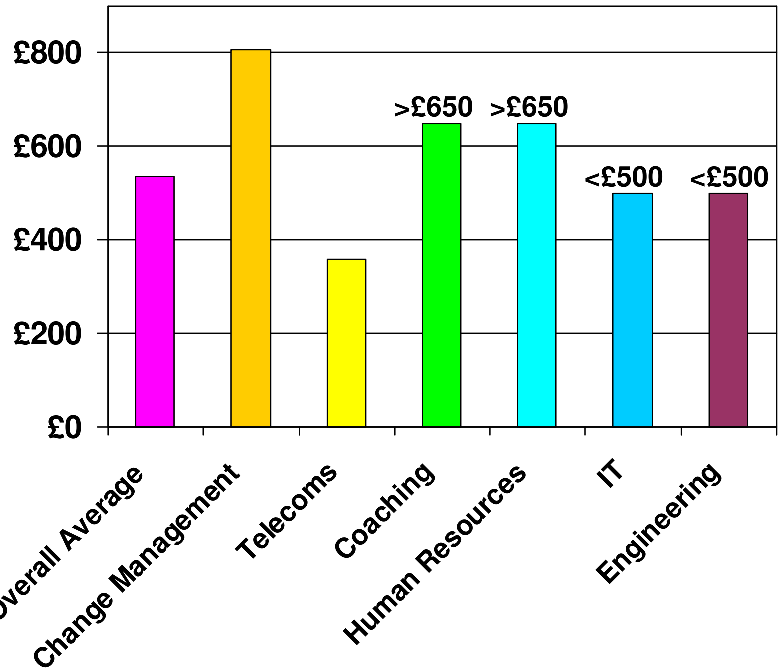

Figure 12. Daily Rates for Consultants in the UK (2008 survey [62]).

8.2 Education, Training and Mentoring in the Oil and Gas Industry

The industry needs to continuously educate and train its existing staff, but the training must fit in with the new working methods of staff, such as flexible working and work-life balance.

The industry is entering a period of great technological challenges: our new oil and gas reserves are in difficult (deepwater) or hostile (arctic) environments. Also, the increasing cost of conventional oil will take us into unconventional sources (oil sands, shale gas, etc.) requiring new technologies and new skills. These challenges require the industry and its staff to adapt, change, develop, and expand into new skills areas.

These challenges will not be simply solved by new university courses or bespoke training courses. The solution rests in a co-ordinated approach to staff education, training, and development. We all know that a raw engineering graduate is of little use in a company; they require training. Then, 'trained' is not enough: an old army saying is *"'trained' doesn't mean ready"*. An engineer is 'ready' for unsupervised decision-making after an intense period of on-the-job training and organised mentoring, Figure 13.

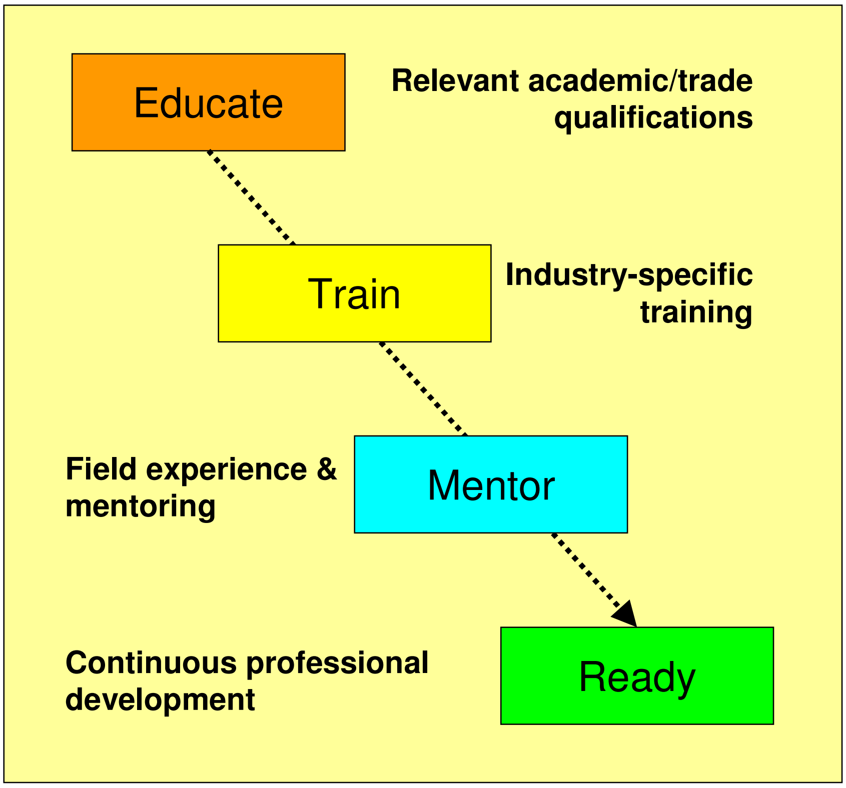

Figure 13. The Essential Development Steps for Engineers.

The above problems can be solved by:

- Industry and universities working together to bring young people to attractive, tailored courses that satisfy skill shortages. Industry must take the lead and invest in universities willing and able to offer pipeline engineering education. Students appreciate 'hands-on' and industry involvement in courses [59]. To remain globally competitive, the engineering sectors in the developed world need to attract careermovers and people in their twenties and thirties as well as highly motivated young people [11].

- Structured modular learning packages need to be offered to existing staff to allow continuous professional development. The Internet offers unlimited facilities for distance learning, and today's students and existing staff expect modern learning. It is a 'now' generation: going to a library is time-consuming, a chore. The internet and intranets can offer instant access to information and knowledge. This is an important point: the current baby boomers in the business have benevolent temperaments that want to transfer all their knowledge to younger staff, but today's younger generation has a *'just-in-time, just-as-you-need-it'* outlook [53]. This may not be ideal, but all learning packages must recognise this.
- The oil and gas industry needs to be as enthusiastic about developing and buying training and learning packages, as it is when buying new IT systems, or gleaming HQ buildings. They are a fraction of the price, better value, and attractive to all staff. This is an important point: our limitations in the oil and gas industry, and the pipeline sector, over the next ten years will not be computers, communications, finance or technologies. It will be learning, experience, values, and information: the successful companies will be investing in these.

8.3 Education and Training in the Pipeline Business

The 'mid-stream' (pipeline, gathering and processing, LNG) part of the oil and gas industry employs about 13% of all employees in the industry [58]. Some parts of the mid-stream business are optimistic they can meet the challenges of skill shortages, but others are highlighting shortages in skills from project managers to technicians: *'When you are building a pipeline, you need trained people'* [58]. Recent interviews [63] with companies in the transmission and distribution pipeline business have forecast a boom in the business, but *'the shortfall will be the people'*.

This is not simply a problem of staffing: it is also a safety issue. The Health and Safety Executive in the UK is responsible for pipeline regulations and safety, and it has said [64] that loss of expertise and corporate knowledge/memory is putting pressure on pipeline safety. Consequently, our education and training courses are a safety issue.

This paper has covered the status of education and training in the pipeline business: the situation has been described as 'dire', and there is an urgent need for universities to offer pipeline engineering courses at undergraduate, graduate, and professional development levels. These courses will require funding and active support from the oil and gas industry.

Some countries are attempting to guide its pipeline industry with its training requirements; for example, ASME B31Q-2006 [25] aims to minimise the role of human error in pipeline failures. It contains general and specific requirements that pipeline operators and regulators can apply to qualify individuals who perform safety checks, maintenance tasks, and other work on gas and hazardous liquid pipelines.

8.4 Actions for the Oil and Gas Business

Many companies have a skills shortage and do not have the infrastructure to train engineers, with many replacing highly tenured staff with entry level workers [58], yet we are facing a period of business expansion. This is not a sustainable position.

The oil and gas business needs to:

- Retain existing staff, and attract new staff, by providing a secure, rewarding and flexible workplace.
- Seek universities willing to initiate pipeline engineering education, and assist them in setting up a range of specialised courses: undergraduate, graduate, and continuing professional development.
    - Provide resources (staff, finance, and course contents) for these education courses. Additionally, the industry needs to accept university staff on secondments, and provide their own staff to assist universities.
    - Provide the universities with research funding and ideas, mentoring of university staff, and supervision of research projects. This will require the formation of centres of excellence in selected universities.
- Aggressively and quickly invest in learning packages or initiatives that relate to the skills needs of staff.
    - Train existing staff by offering learning programmes and packages (either in-house, or public).
- Develop staff by allowing more experienced staff the time to do mentoring.

The above actions will require huge commitment and financial investments, and the oil and gas majors must take the lead. As the price of a barrel of oil approaches $US150, there is absolutely no excuse for financial caution.

8.5 Can we Wait?

Most of the readers of this paper will be engineers, so they will appreciate figures more than words. Consider these facts [11] from the UK that cover all aspects of the engineer ‘food cycle’:

- SCHOOLS: figures from the UK government show the number of school leavers will decline by 16% by 2018, so all industries will be short of local employee ‘feedstock’.
- APPRENTICESHIPS: Engineering apprenticeships currently have a completion rate of 3 in 5.
- ENGINEERING GRADUATES: We produce many graduates, but 29% of all our graduates here in the UK leave university to join the finance/commercial sector, not engineering.
- UNIVERSITIES: 50% of all engineering post-graduates in UK universities come from outside the UK.
- THE PROFESSIONS: The number of registered engineers has fallen by 21,500 in the past decade.

A shortage of good engineers will create an unsafe environment in the oil and gas business. This means that lives will be lost. It is essential to take ‘decision-makers’ in our industry to the field, and show them an offshore platform in its ‘tertiary’ stage: ageing, rusting, and containing highly pressurised and hazardous plant that needs extra attention and care. Take them to a refinery, where some of the plant will be over 50 years old. Take them to an ageing pipeline, and show them the corrosion and the peeling coatings. All these ‘problems’ are easily managed and solved by qualified engineers.

And finally it is worth noting that engineers cannot make mistakes: the cost is too high. Can you imagine if engineers had made the same naïve, short-sighted mistakes that our bankers and financial ‘experts’ made leading up to this (2008) year’s ‘credit crunch’? If we engineers had made mistakes on this scale in the oil and gas industry, we would all be in jail.

The skills shortage crisis in the oil and gas business is real: it has now moved on from a ‘people’ issue in companies, to a strategic issue. A solution needs to be found today: we cannot wait.

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