ISSUE 01 • 2012
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oil & gas

Rising Confidence

market Unconventional Energy Rush
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integrity Best Practice Solutions
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GL Noble Denton

Got trouble offshore? Get James onboard

James is one of GL Noble Denton's senior offshore engineering consultants based in Malaysia. His skills save our clients a fortune and protect their reputations too. He's valued as much for his 10 years of hard-earned hands-on experience as his academic abilities in research and analysis.

James advises on a variety of projects, from high-seas ship salvage and major bid support, to warranty surveys and leading-edge floatovers. His proudest moment so far is flying over the Bunga-Orkid A platform, having seen the project through from concept drawings to completion.

- **Has more than 10 years experience in offshore engineering**
- **Has helped clients across the world from Thailand to Turkmenistan**
- **Has made hundreds of oil and gas assets safer and more efficient**
- **Is learning Mandarin Chinese**

James is one of the thousands of dedicated experts our clients count on every day

Learn more about him here **www.gl-nobledenton.com/James**

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GL Noble Denton is the independent technical advisor to the oil and gas industry

To Our Readers

Pekka Paasivaara

The oil and gas industry has been through considerable change over the past year. We have witnessed environmental incidents, political uproar and financial instability in key markets all around the world. At the same time, cautious optimism increasingly took hold across the sector. Shale gas exploration in the US, for example, is experiencing extraordinary growth (p. 8). According to *Big Spenders*, the Economist Intelligence Unit's 2012 report on the future of the sector, commissioned by GL Noble Denton (p. 12), US shale plays have become a magnet for many oil companies.

After a period of volatility, the US comeback is but one of the major shifts taking place in the global oil and gas industry. China is also striving high, intending to take the lead in the global oil and gas construction market over the next decade (p. 14). At GL Noble Denton, we expect to grow together with China and have doubled our local team accordingly over the past three years.

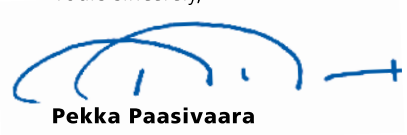
Recent industry incidents – be they in the Gulf of Mexico or the North Sea – have underlined the importance of up-to-date technology and standards focusing on asset safety and assurance. How can we collectively break the cycle of catastrophic incidents caused by our operations? This was the key question addressed at a recent conference held at GL Noble Denton's Spadeadam test site, highlighting operational risks and offering best practice solutions (p. 30).

As the oil and gas industry continues to focus on risk, GL Noble Denton is proud to have worked with a number of key clients to apply best practice in safety, integrity and performance across their operations. To minimise the risk of excavating near gas pipelines, GL Noble Denton and UK's National Grid introduced a new data sharing system (p. 20). Another GL Noble Denton software solution helps companies with metal pipe distribution networks plan and prioritise how and when to replace their pipes with advanced plastic piping. The solution combines mains replacement management with network planning and design software.

Corrosion remains one of the great natural enemies to any metal industrial asset, and GL Noble Denton is proud to be a leader of thought in this area. Find out about modern corrosion management schemes and whether they are really fit for their purpose (p. 34), and learn how chemical analysis enables investigations of material defects and component failure (p. 46).

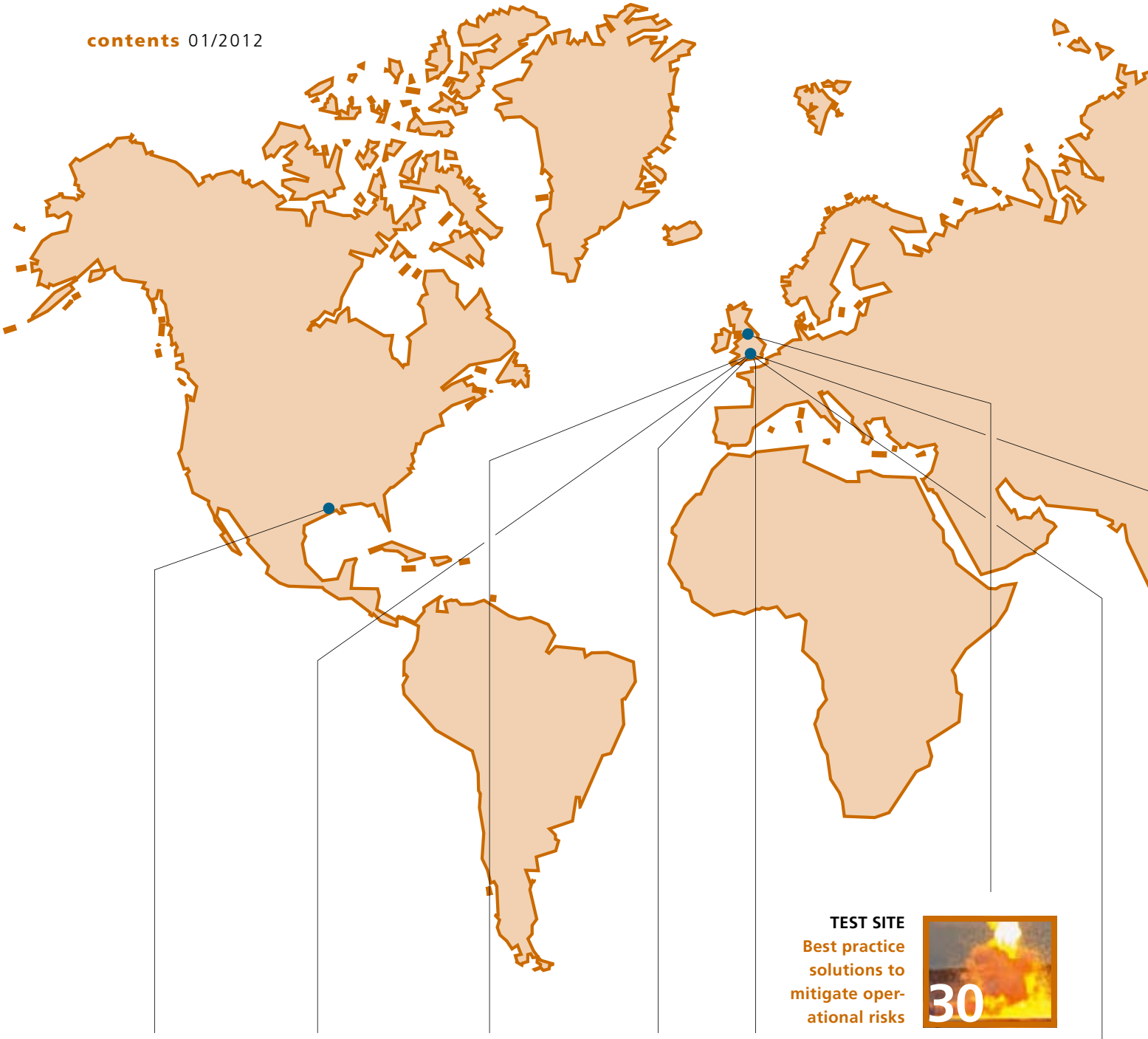
At GL Noble Denton we are convinced: To find constructive answers we must first understand the question. What is your question for us? We are prepared to listen.

Yours sincerely,



Pekka Paasivaara

Member of the Executive Board, GL Group

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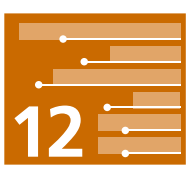
Hot topic of the US oil and gas industry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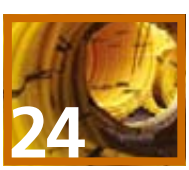
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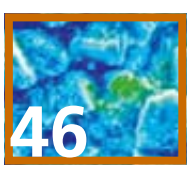

ANALYSIS
When the chemistry is right

ASIA
China is getting ready as a major energy supplier

GL Noble Denton in Brief

- GL Noble Denton is a **TECHNICAL ADVISOR AND TRUSTED PARTNER** for the oil and gas industry.
- The Oil & Gas business segment of the GL Group helps to design, build, install and operate onshore, maritime and offshore oil and gas assets to ensure **SAFETY, SUSTAINABILITY AND SUPERIOR VALUE.**
- GL Noble Denton is the **MERGER BETWEEN GERMANISCHER LLOYD'S OIL & GAS BUSINESS AND NOBLE DENTON**, a premier provider of life-cycle marine and offshore engineering services. Since January 2010, they have been offering their services as GL Noble Denton.

GL Noble Denton is a full-service provider with broad upstream and midstream competence **FOR THE COMPLETE ASSET LIFECYCLE.**
GL Noble Denton combines excellent engineering and analytical skills with operational experience of offshore, maritime and onshore oil and gas assets. The Oil & Gas business segment of GL employs **MORE THAN 3,000 ENGINEERS AND EXPERTS IN 80 COUNTRIES.**

We have strong expertise in complex oil and gas assets such as MODUs, FPSOs, pipelines, subsea systems, OSVs – and assurance, asset integrity, safety and risk, marine operations, project management and software services to match. The scope of technical services includes safety, integrity, reliability and performance management.
GL Noble Denton is **A TRULY INDEPENDENT ADVISOR** without any vested interest in selling a design, installation, fabrication or equipment.

GL Noble Denton services oil and gas clients in onshore production, onshore pipelines, storage, import terminals, LNG, refineries and petrochemicals, distribution networks as well as mobile offshore drilling units, mobile offshore production units, fixed platforms, subsea, risers and flow lines, offshore support vessels, tankers and shipping and offshore pipelines. We oversee and support the full lifecycle of an asset from project concept to decommissioning. The business segment has **A GLOBAL REACH IN THE OIL AND GAS CENTRES** of the world.

GL Noble Denton
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market

The Americas, Asia-Pacific and Europe: As a world-class technical service provider for the oil and gas industry, GL Noble Denton shows presence on a global scale.

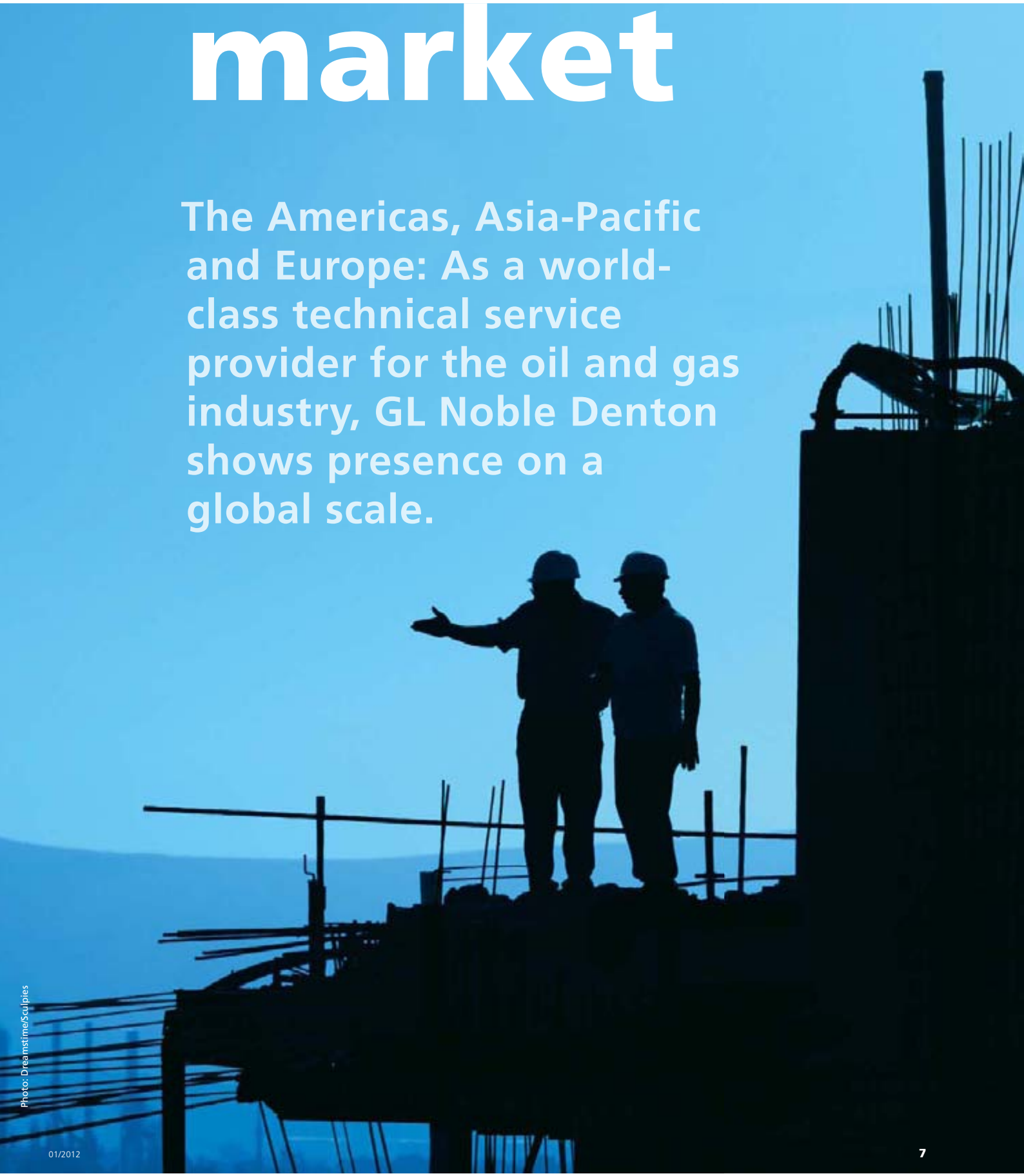


Photo: Dreamstime/Sculpies

Drilling Rig. **Unconventional gas projects are booming.**

Exuberant Optimism

Shale gas is the hot topic of the US oil and gas industry. While some experts believe unconventional gas may secure the nation's energy supply for centuries, others remain sceptical

There is no doubt that if the believers are right, North America will soon be rid of its energy worries for generations. The current unconventional energy rush, which will unquestionably be a hotly debated subject at the Offshore Technology Conference (OTC 2012) in Houston, seems to support that notion. Furthermore, relative independence from energy imports would put US foreign policy in a comfortable negotiating position with oil and gas exporting nations on issues touching the United States' national interests.

"But we aren't quite there yet," says Arthur Stoddart, GL Noble Denton's new Executive Vice President for the Americas Region who will take office on 1 May, at the height of the OTC. True – the shale gas revolution has transformed the US natural gas market over the past five years in a way few could have imagined, dramatically altering the supply landscape and depressing gas prices.

The rapid development of projects like the Marcellus, Barnett, Haynesville and Fayetteville shales has created a ripple effect that has spread across the global energy industry. Europe, Poland and Ukraine have emerged as a focus for shale gas exploration. Even oil and gas companies with no exposure to unconventional energy sources have been affected by its speedy rise.

ABSTRACT

- Unconventional gas is now approaching 30 per cent of total US natural gas output, transforming the global supply situation
- Differences of opinion exist regarding the future economic viability of shale plays

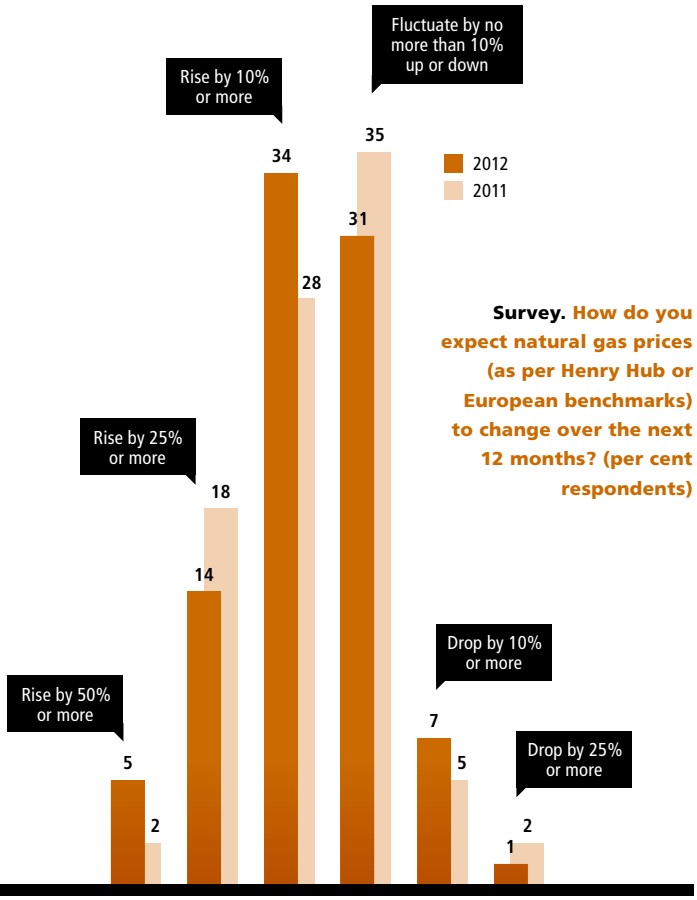
Nevertheless, the scale of the ramp-up bears examination. A decade ago, gas from shale accounted for barely two per cent of US natural gas production. Today it is approaching 30 per cent and rising. The price impact has a significant bearing on the industry. The surge in production has forced US domestic natural gas prices to plummet below four US dollars per million BTU (British Thermal Units). This price level, however, is considered too low to justify many large, gas-related investment projects. The advent of substantial domestic gas supply has rendered a number of North American LNG projects uneconomic, with majors like ExxonMobil spending billions building LNG receiving terminals that may never reach their intended capacity. Despite these signs, 53 per cent of worldwide respondents to the

second Economist Intelligence Unit's survey "Big Spenders" believe gas prices will rise over the next twelve months (see graph right). The study gives an outlook for the oil and gas industry and was commissioned by GL Noble Denton (read also page 12).

Perfect Storm

The foundations of this unconventional "revolution" were laid in the US, where advances in technology such as horizontal drilling and hydraulic fracturing have dramatically increased production. Unconventional US output soared to 10 billion cu ft/day in 2010, around one-quarter of the country's total. By 2035 this proportion could rise to one-half, according to the U.S. Energy Information Administration.

Oil companies active in this terrain acknowledge the transformative impact of unconventional energy on the industry, particularly natural gas. "We are in the midst of a structural revolution," says Thomas Ahlbrandt, the former



Survey. **How do you expect natural gas prices (as per Henry Hub or European benchmarks) to change over the next 12 months? (per cent respondents)**

Source: Economist Intelligence Unit

Shale Gas. **The natural gas is stored in shale formations.**

Photos: Dreamstime/Andrewmits/Homydesign

vice president of exploration at Falcon Oil & Gas. "There are now three times the number of gas wells being drilled compared to oil wells. The debate is no longer: 'Are we running out of gas?' The debate is: 'Do we now have 100 or 200 years of gas supply in the US?'" North America's unconventional revolution rests on a confluence of favourable factors – a "perfect storm" in the words of one executive. Most important is the strong geological resource base, estimated by the U.S. Energy Information Administration (EIA) at 862,000 billion cu ft. Also important are the US's provision breaks, a stable regulatory regime, private ownership of mineral rights and the existence of a strong service industry.

Shale plays are attracting oil companies in troves.In the Eagle Ford play, 1,010 drilling permit applications ▷

▷ were filed for the Texas play in 2010, a tenfold rise on the previous year. In 2011 the Texas play attracted more than 2,000 permit applications.

A number of companies are already investing in the region. Talisman Energy's North American operations, for example, are principally focused in the Eagle Ford and Farrell Creek shale plays, with plans to build significant liquids and shale projects. Its objective in North America is to become a leading, returns-focused shale gas producer.

Meanwhile, in western Canada and Alaska, ConocoPhillips has invested in a number of opportunities, with focus on the Deep Basin and central Alberta, where the company has utilised various shale gas production methods, thereby opening up substantial opportunities in proven trends, such as the light-oil Cardium Formation.

"North America has seen the bulk of the activity so far, since that region has a well-developed oil services industry – rigs and crews – and an extensive pipeline network to move the products to market," says Shell's Mr Henry.

"At Shell, we are looking into the opportunity worldwide, including interests in China, eastern Europe, South Africa. These plays need to be drilled to delineate the potential, and the industry at large will need to build up the services and pipeline infrastructure in these new regions," he adds.

Resource. **The total shale gas potential of all basins in the USA is about 500 to 1,000 tcf.**

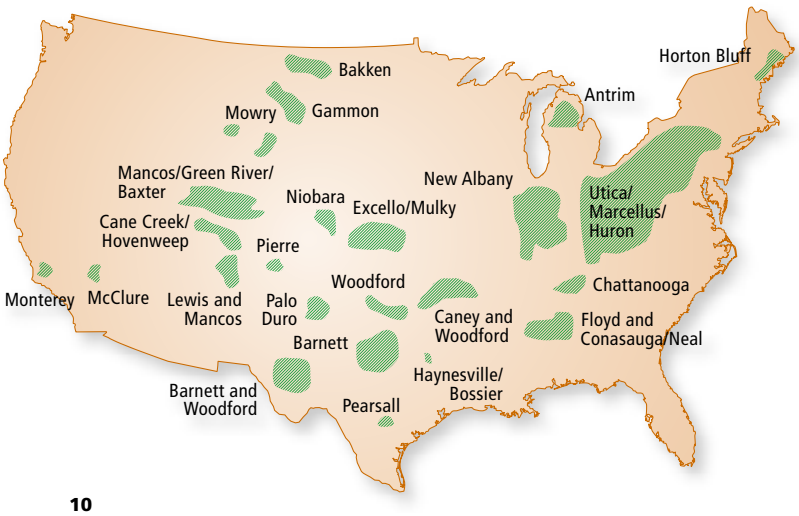


Photo: Dreamstime/Anthony Aneese Totah Jr

Houston. **The Offshore Technology Conference (OTC) is the foremost annual event for the global oil and gas industry.**

However, some senior executives caution that shale plays may not be as economically competitive as advocates make out – highlighting the point that unconventionals is one area where oil industry consensus is distinctly lacking. "Over time, if you look at the marginal cost of producing shale in volume, only the very best properties in the big shales in Haynesville, Barnett and Horn River can be produced for US$4. Everything else is in the range of US$5.5 to US$6," says Mr Sheldon.

America Alone?

There is widespread doubt whether the unconventionals revolution can be exported outside North America. The perfect storm that made these developments scalable realities in the US is not evident in other geographies. Furthermore, the technologies that made the rapid US advance possible – horizontal drilling and fracking – have drawn increasing criticism. Meanwhile, there is concern that the depletion rates of unconventional fields are much faster than those of their conventional counterparts. Whereas

US-focused players are bullish about unconventional plays, European industry executives are notably more cautious.

Investment in Unconventional Gas

Inflation is having an impact, particularly in the new unconventional plays that are revolutionising the industry. In the US, E&P companies have responded to inflation in the oilfield services sector with steadily rising capex spend on liquids-rich plays such as the Permian and Eagle Ford basins in Texas, and the Bakken in North Dakota.

The migration to liquids-rich projects has served to heighten competition for staff and equipment on these fields. The result is that companies are factoring in much larger capex spend in 2012. For the industry as a whole, cost inflation could lead to 10-12 per cent growth in spending in the next 12 months in the region and high single-digit increases annually through to 2015.

Strong project economics has incentivised greater spend on shale plays compared with conventional natural gas projects, which are still compromised by the generally weak price environment for gas. Hess, a significant US-integrated company active in the Bakken shale, is meanwhile spending nearly half of its US$7.2 billion capital budget on unconventional development, up from 16 per cent two years ago. With Bakken production alone expected to more than triple to 120,000 barrels per day by 2015, Hess sees unconventionals contributing 40-50 per cent of its production and reserve growth over the next five to seven years.

Despite the rapid advance of unconventional energies in North America, its capacity to transform the long-term global natural gas supply picture is still unproven. The horizontal drilling and fracking technologies that have brought these volumes of unconventional gas on stream remain highly controversial. And the conditions that have made these projects viable in the US are not easily replicated in other geographies. Time will tell whether the reality of unconventional gas will deliver the potential. □ **AMO**

SPENDING. Unconventional projects will absorb a larger proportion of corporate capex in 2012.

A variety of quotes and information for this article was sourced from the Economist Intelligence Unit.

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Americas under New Leadership

ON 1 MAY, Arthur Stoddart will take office as GL Noble Denton's new Executive Vice President for the Americas Region.

He is taking over from Dr RV Ahilan, who has been leading the region in an interim capacity since November of last year. The existing management team within the Americas **WILL REPORT DIRECTLY** to Mr Stoddart and he will become a member of the GL Noble Denton Management Board.

Mr Stoddart has **EXTENSIVE EXPERIENCE IN THE OIL AND GAS INDUSTRY** and has successfully run the UK business under the Advantica brand from 2009, and then within the GL Noble Denton structure since 2010. **UNDER HIS LEADERSHIP,** GL Noble Denton has seen a transformation of the UK business, with the recent renewal of the National Grid contract, growth of the Gas Consulting Practice and a continued increase in profitability.

Fig. 2: Which of the following do you believe represent the main barriers to growth for your company in the next twelve months? Select up to three. (per cent respondents)

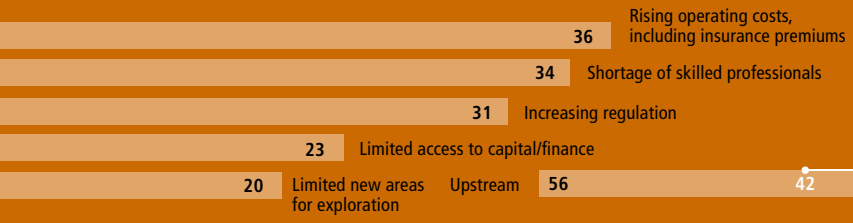
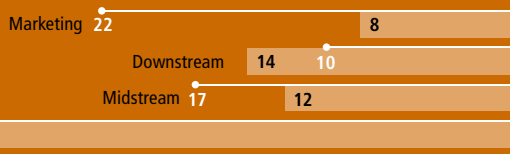


Fig. 3: Which segment of the industry do you expect to see the strongest business growth in the next twelve months?
Select one. (per cent respondents, 2011 figures in white)



Big Spenders: Oil and Gas Executives Highly Optimistic

According to a new Economist Intelligence Unit report commissioned by GL Noble Denton, oil and gas industry leaders are highly optimistic for industry growth this year

Oil and gas executives have forecast improved performance and higher levels of capital expenditure this year, despite concerns over global economic instability, according to a new report on the future of the sector commissioned by GL Noble Denton.

"Big Spenders: The outlook for the oil and gas industry in 2012" is the Economist Intelligence Unit's second annual barometer for the sector. It gathers the views of nearly 200 board-level oil and gas executives and policy makers to provide a concise summary of the opportunities and pitfalls that oil and gas professionals should look out for this year.

Companies Prepared to Spend

Big Spenders reveals that 82 per cent of oil and gas industry leaders are either highly or somewhat confident about the business outlook for their company in 2012, compared with 76 per cent last year. Just eight per cent of those polled described themselves as pessimistic over performance this year (see Fig. 1).

Meanwhile, North America has been tipped as the region with the greatest confidence in oil and gas industry growth over the next eleven months according to the report. Growth in the area's unconventional gas market and a return of drilling activities to the Gulf of Mexico are beginning to give a boost to the region's oil and gas industry.

Findings from the research also show that nearly two thirds (63 per cent) of executives plan to invest either somewhat or substantially more over the next year (see Fig. 4). This implies significant opportunities for GL Noble Denton to develop new business as industry activities ramp up.

There remains a caveat to the high levels of confidence revealed in Big Spenders, however: if global economic conditions deteriorate, oil and gas companies will have to scale back their spending commitments where they can do so without creating damage to their wider portfolios.

Other key findings from the research, as reported by the Economist Intelligence Unit, include:

- **Rising operating costs emerge as the top barrier to growth –** more than 50 per cent of respondents say they expect an increase in wages over the next twelve months. Furthermore, 54 per cent of respondents expect the cost of contractors to increase, compared to only eleven per cent anticipating a decline.
- **Risk remains a key challenge** – an overwhelming

ABSTRACT

- Oil and gas industry confidence is rising
- Increasing costs and regulation are both affecting the prospects of the industry

majority of respondents (82 per cent) either strongly or somewhat agree that regulatory issues have become more important in the post-Macondo period. Increasing regulation is regarded by 31 per cent of respondents (Fig. 2) as the main challenge for their company over the next twelve months.

- **Skills shortages are becoming more acute** – according to the Economist Intelligence Unit's research, this issue comes out of the survey as one of the major obstacles to growth over the next twelve months. Last year, skills issues came fifth on the list of barriers and were only identified as a top-three issue by 25 per cent of respondents. This year, the issue has risen to second on the list, and has been identified as a key barrier by 34 per cent of respondents (Fig. 2).

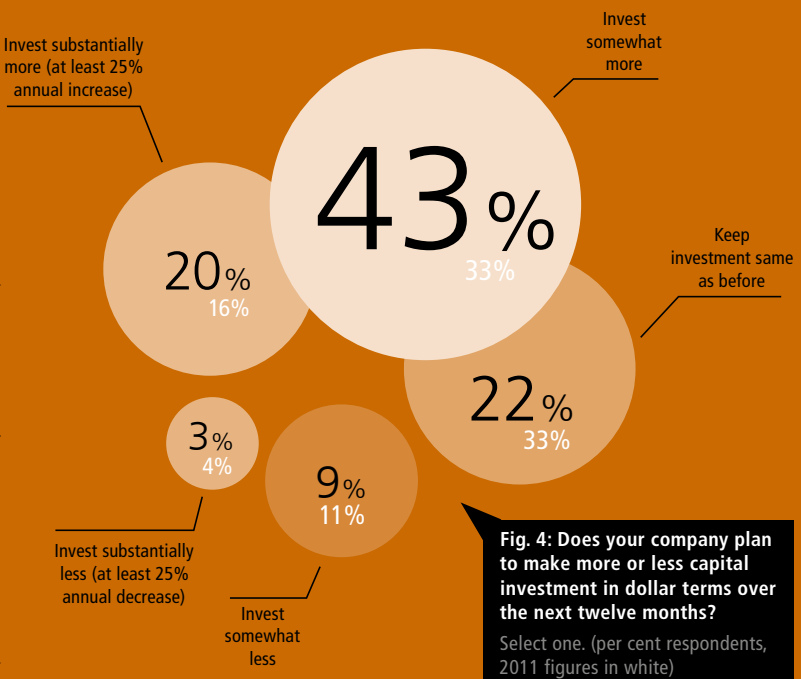


Fig. 4: Does your company plan to make more or less capital investment in dollar terms over the next twelve months?
Select one. (per cent respondents, 2011 figures in white)

Pekka Paasivaara, member of the GL Group Executive Board, said: "The second annual Economist Intelligence Unit oil and gas industry barometer sends a clear message: Companies are preparing to spend big in 2012, despite a slower growth in demand for oil and gas during the second half of last year, and concerns over the future of the global economy.

"But this doesn't mean that our clients are sanguine about their prospects for the year ahead. Findings from the report highlight a wealth of barriers to success, from rising operating costs to the worry of an impending shortage of skilled professionals and an uncertain regulatory environment in the post-Macondo era.

"While capital expenditure looks set to take off, industry leaders will need to invest selectively this year, keeping operating risks low during a period of prolonged uncertainty. Their success will be defined by an ability to develop innovative approaches to operating more safely, efficiently and sustainably than ever." □

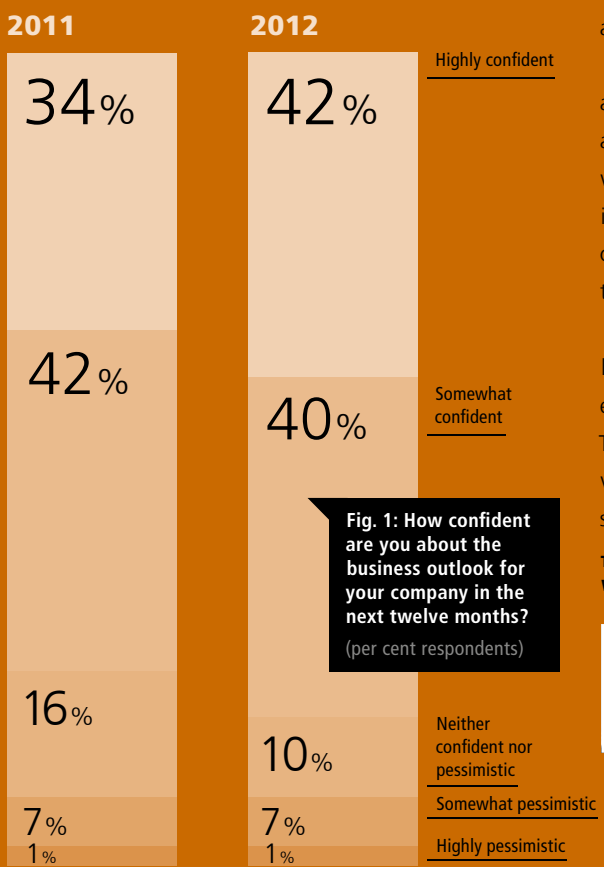


Fig. 1: How confident are you about the business outlook for your company in the next twelve months?
(per cent respondents)

Data source of all diagrams: Economist Intelligence Unit

BUSINESS OUTLOOK. "Big Spenders" is the second Economist Intelligence Unit report which analyses the oil and gas industry.

THE REPORT CAN BE DOWNLOADED FROM:
WWW.GL-NOBLEDENTON.COM/EN/EIU-REPORT-2012.PHP

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Asia Ascending

While shale gas in the United States may soon cover much of the nation's domestic energy need, Asia is emerging as a major energy supplier to the world. China is getting ready to rival the US as a fossil fuel superpower

Dragons. **Roles among Asian oil and gas nations are shifting.**

Major shifts are taking place in the oil and gas industry; not least in Asia. National oil companies (NOCs), once bystanders rather than drivers, are now the key players in the market, as the region strives to sustain its growing demand for energy. The future role of China is still open; but the ambitions of the earth's most populous nation are staggering: China aspires to take the global lead in exploration and production.

Chris Webber, a Senior Editor of the Economist Intelligence Unit, summarises the results of a recent survey on oil and gas professionals' predictions for the future: "National oil companies now control about 80 per cent of the world's oil, so the private sector's links with these organisations couldn't be more important. Unfortunately, however, the relationship seems to be going in the wrong direction. Last year, 25 per cent of companies said they expected to see a more favourable approach to working with international governmental companies and NOCs. This year, that figure has dropped to just 15 per cent."

ABSTRACT

- National oil companies currently control more than 80 per cent of the world's oil
- China's expansion course has raised fears of destabilisation in the Asian oil and gas industry

At the Singapore International Energy Week in November 2011, GL Noble Denton hosted an exclusive dinner and round-table discussion for representatives of well-known international oil companies, technical suppliers and industry associations. The attendees offered strong opinions on where the industry is heading.

Profit-Driven Innovation

One consensus amongst the participants: State-owned oil companies have played a leading role in developing Asia's growing profile in the international energy market over the past decade. While they were once viewed as the international oil companies' (IOCs) sleeping partners, they now rival roaming oil

Expertise for Asia. **Richard Bailey, GL Noble Denton's Executive VP for Asia Pacific.**

majors in the acquisition of steady supplies for the region's fast-growing consumer economies.

But the role of the IOCs is not dead yet, according to discussion among the attendees at the round-table event. While the NOCs might now own the majority of reserves, IOCs pioneer the technology needed to access them. "The political and non-commercial nature of NOCs restricts them," said one attendee from a leading fabrication company, commenting on the Asian market in particular. "They tend to be more risk-averse and trail behind IOCs when it comes to developing new methods and technologies for production."

China's Intent

Perhaps the most startling estimation to be given during the round-table discussions was that of China's intent to develop an 85 per cent share in the global oil and gas construction market over the next decade. "This is a great example of how China's move to ▷

Photo: Dreamstime/Lavoview

Thirsty. Major international oil companies believe their technology leadership will always be in demand in Asia.

▷ dominate the market could drastically change the Asian oil and gas industry in the short to medium term," said an industry expert. "Korea and Singapore form Asia's centres for oil and gas construction today because they are able to deliver better capacity and quality than China. As soon as China sorts out its quality issues – which I'm sure it will – that balance is likely to change considerably."

NATIONAL OIL COMPANIES. Oil companies fully or majority-owned by a national government.

Some attendees agreed that the impending rise of China in the Asian oil and gas industry is likely to have a significant commercial impact on other countries and might destabilise the region. Others felt that China's intent on growth is less likely to impact upon its neighbours. "China's approach to developing a greater presence in the oil and gas industry is naturally defensive. It has too many oil and gas interests outside of Asia to become aggressive in its approach to the local market," said a director of an engineering and construction company with significant operations in the region. "Singapore and Korea may have to invest more heavily to secure their seat at Asia's future energy table, but China's growth is unlikely to push them out of the market altogether."

While the topics discussed during the round-table event clearly demonstrate the Asian oil and gas industry's significant growth potential – both in demand and supply – they are also reflective of a market that meets obstacles during rapid expansion. China's place in the Asian energy market remains difficult to predict, leading the round-table attendees to offer conflicting opinions on how heavily its neighbours will be impacted by China's growth.

Support for Clients

Richard Bailey, GL Noble Denton's Executive Vice President for Asia Pacific, said: "The discussions raised around the tables at this event have reconfirmed underlying concerns with the region's oil and gas industry, all of which are linked to the rapid expansion that we are experiencing. The Asian oil and gas industry is clearly focused on its future challenges and opportunities that lie ahead, and GL Noble Denton continues to support its clients in developing the innovative solutions they need to meet the region's evolving energy demands." □ **RC**

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We Expect to Grow Together with China

Three questions to Mr Wu Yi, General Manager, GL Noble Denton China

Ready to Serve China. **GL Noble Denton's Shanghai General Manager Wu Yi sees enormous business potential in China.**

ENERGIZE: **Mr Wu, you joined GL Noble Denton in 2008. How has the business developed since?**

WU: In April 2009 we registered our industrial division in Shanghai as an independent company to ensure smooth and flexible business operations. We put more effort into proactive sales and, as a result, from 2009 to 2011 an annual growth rate higher than 50 per cent was achieved each year. Benefiting from China's economic growth, we also expanded our business beyond industrial inspection into such areas as construction monitoring, transportation and installation, dynamic positioning, marine consultancy and assessment, marine warranty onsite surveys, engineering services, pipeline management software, etc. The team has expanded from 27 to over 60 staff members.

ENERGIZE: **Which of the GL Group's offshore, maritime, and onshore services do you consider to be key business segments and revenue drivers in China?**

WU: Besides our traditional offerings of inspection and construction monitoring, in recent years we have focused our efforts on supporting China's offshore sector. Our dynamic positioning and engineering services have started to yield profits for us and have increased our visibility among existing and potential clients who are learning more about our services and expertise. Our uniqueness lies in our current position as a full-service provider for the entire lifecycle of oil and gas assets. New initiatives, including a competence centre we plan to set up in Shanghai, will help us share our experience and expertise with clients in China.

ENERGIZE: **What are the prospects and opportunities for the Chinese oil and gas market?**

WU: In general, I am very positive about the Chinese market and we expect to grow together with China as the country is building up its offshore capability. China plans to have the total manufacturing capacity of Chinese shipyards cover 80 per cent of the global offshore newbuilding volume by 2015, compared with the current percentage of around 30 per cent. CNOOC has announced investments totalling 30 billion euros in offshore newbuilding and deep water exploration projects by 2015. Therefore, we are sure the Chinese market presents plenty of opportunities for us. The international service providers will have a bigger role to play as Asian countries, including China, will continue to see a robust growth in their energy markets and need to have up-to-date technology and standards to support their growth. □ ZL

software

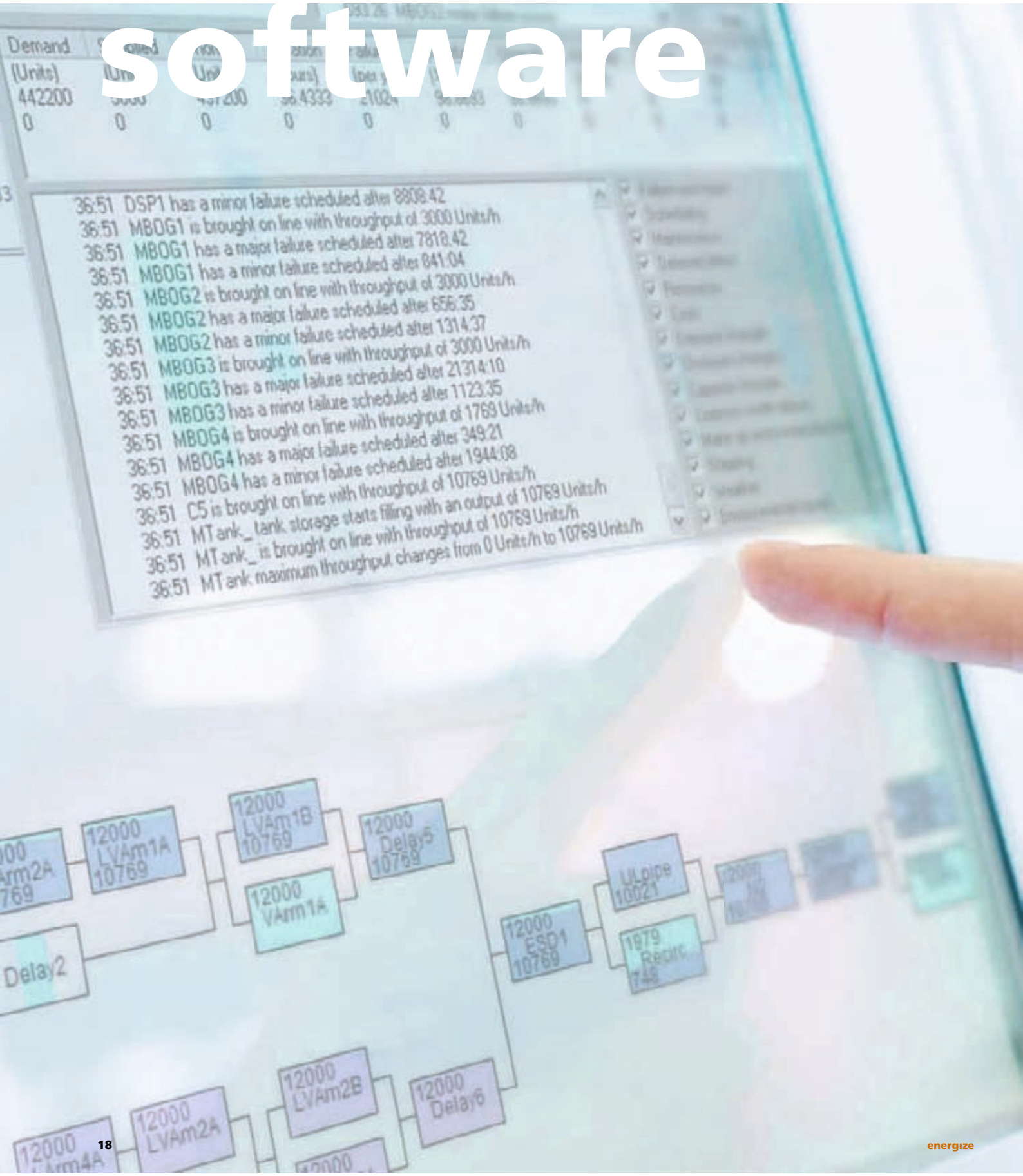
Demand
(Units)
442200
0
36:51 DSP1 has a minor failure scheduled after 8808.42
36:51 MBOG1 is brought on line with throughput of 3000 Units/h
36:51 MBOG1 has a major failure scheduled after 7818.42
36:51 MBOG1 has a minor failure scheduled after 841.04
36:51 MBOG2 is brought on line with throughput of 3000 Units/h
36:51 MBOG2 has a major failure scheduled after 656.35
36:51 MBOG2 has a minor failure scheduled after 1314.37
36:51 MBOG3 is brought on line with throughput of 3000 Units/h
36:51 MBOG3 has a major failure scheduled after 21314.10
36:51 MBOG3 has a minor failure scheduled after 1123.35
36:51 MBOG4 is brought on line with throughput of 1769 Units/h
36:51 MBOG4 has a major failure scheduled after 349.21
36:51 MBOG4 has a minor failure scheduled after 1944.08
36:51 C5 is brought on line with throughput of 10769 Units/h
36:51 MTank_ tank storage starts filling with an output of 10769 Units/h
36:51 MTank_ is brought on line with throughput of 10769 Units/h
36:51 MTank maximum throughput changes from 0 Units/h to 10769 Units/h
12000 LVArm1A 10769
12000 LVArm1B 10769
12000 Delay5 10769
12000 VArm1A
Delay2
12000 ESD1 10769
ULpipe 10021
12000 LVArm2A
12000 LVArm2B
12000 Delay6

Photo: Dreamstime/Niderlander

Beneath the Surface

A new data sharing system helps to assess and minimise the risk of excavating

Just crossing the street where you live or driving to work you'll pass over pipes and cables delivering gas, electricity and other utilities into homes and businesses. These pipes deliver vital services and need to be maintained carefully throughout their operational life. In addition, they may also lie in the vicinity of other utilities, which face their own maintenance programmes, or be disturbed by unrelated street, construction or demolition work.

In the past, communication and information sharing between utilities and third parties excavating in the vicinity of existing pipelines have been problematic, which can result in damage to services. Such damage to infrastructural assets is costly in time and money, for all stakeholders.

ABSTRACT

- EAGLES is a collaboration between National Grid and GL Noble Denton
- The automated plant enquiries system promotes safe working, reduces damage to assets and avoids incidents

Historically, there have been few effective ways to integrate, share, reuse and effectively communicate knowledge held by both owners of underground assets and third-party enquirers. This has all too often resulted in additional excavations to locate pipelines, increasing costs and perhaps causing unnecessary traffic congestion and upset to the public.

In addition, damage to a pipe may set off a chain reaction, causing knock-on effects to connections or service pipes inside a building away from the point of damage; for example, of leaking gas seeping into underground spaces and cellars.

Dial Before You Dig

Owners of these assets and third parties concerned with planning, organising and supervising work near such services must be fully aware of what lies beneath the surface before they start digging.

The scale of the issue is huge. In the UK alone, the total length of buried pipes and cables is estimated at about four million kilometres, and some four million holes are cut into the UK road network each year in order to install or repair buried service pipes and cables. However, a solution has been developed, and can be used effectively on any utility service system around the world.

"To minimise communication failures and create a mutually beneficial knowledge link between asset owners and

Groundwork. **Without knowledge about the exact location of assets damages are more likely.**

enquirers, GL Noble Denton and British-based utility company National Grid have developed EAGLES (Electricity And Gas Location Enquiry System), a web-based service designed to share information of what lies hidden below ground," says Dr Neil Brammall, Senior Consultant with GL Noble Denton's Software Solutions unit, and an expert on mapping software and its applications for the utilities industry.

With fast automated responses to enquiries, EAGLES is focused on damage prevention to operating assets (electricity, gas, or water pipelines and associated infrastructure) owned or operated by utility companies operating distribution or transmission systems. The system has been used internally by National Grid since November 2009, and there is an aspiration to make the system available for self-service use during 2012.

The risks of poor communication between contractors and asset owners are clear, with construction staff working "blind" with no (or outdated) asset plans and without relevant safety information. EAGLES, however, delivers a quick, automated response to enquiries about the location and type of assets buried below the surface.

EAGLES. The Electricity And Gas Location Enquiry System is an automatic risk-based assessment of asset location enquiries.

Automated Risk Assessment

"Having advanced knowledge of potential threats posed to assets by third-party activities is critical to asset owners being able to offer useful information and safety guidance to construction planners and excavators," says Dr Brammall.

Effective sharing of information between the asset owner and enquirers creates a "virtuous circle" of communication that provides advanced warning of potential danger to the asset owners and timely, expert advice to excavators.

Using complex software and a large geographic information system (GIS) database, EAGLES can record, track and store this information for use by any utility or ▷

Photos: Dreamstime/Lunamarina, iStockphoto/Paul Vasarhelyi

network operator to safely and efficiently undertake roadworks. EAGLES' automated assessment and prioritisation system allows third parties to submit details of planned works, which is then available to the asset owners, providing advanced warning of risk where necessary.

"This is where EAGLES resolves the problem," says Dr Brammall. The EAGLES expert system assesses this information against asset information, including the asset type and such details as pressure/voltage, material, diameter and depth; information which can be brought into play when assessing what is a "safe" distance for a given type of work.

EAGLES uses mapping information from the UK government's Ordnance Survey mapping agency to mark up work locations while geographic information sourced from the client is used to pinpoint an asset's location.

The data provided to EAGLES is used to answer four key questions:

- **What:** The precise nature of the works (including related activities including heavy plant crossing, temporary storage, etc.)
- **Where:** The proximity of the works to assets
- **When:** The work start date allows smarter resource management for any follow-up work
- **Who** is the undertaker of the works known, competent entity or an individual building a kitchen extension onto a house?

Having processed this raw data, the EAGLES expert system executes an automated risk assessment of works against

Data. EAGLES uses mapping information from the UK government's Ordnance Survey mapping agency to mark up work locations. The total length of buried pipes and cables in the UK is estimated at about four million kilometres.

Photos: Dreamstime/Lunamarina/Skopal, iStockphoto/Paul Vasarhelyi, Ordnance Survey UK

assets and, for "low-risk" enquiries, responds automatically with maps and guidance. "High Risk" works are flagged up and forwarded to qualified personnel employed by the asset owner, who will then investigate further before informing and working with third-party enquirers on developing site-specific solutions.

The email communication includes instructions and guidance relevant to the activities specified, and scaled asset location maps covering the area affected by the proposed works. By sharing this information, safe working for the onsite contractors is promoted and accidents avoided.

This "virtuous circle" of communication gives contractors greater confidence to carry out the work safely, while the utilities (asset owners) benefit from advanced knowledge about what work will be carried out, and can support and advise as necessary, improving risk management and customer service.

EAGLES Software

Ultimately, the EAGLES software solution is about assessing complex GIS data against damage prevention business rules and providing timely information to the asset owner and third parties. Objective, transparent and repeatable criteria are applied to the assessment of risk associated with working in the vicinity of utility services.

The EAGLES system has been used by National Grid in the UK to process over 100,000 third-party enquiries, with nearly half of those enquiries considered to cause no risk (or a low risk), and therefore requiring no further intervention. The average time in generating a response from a submitted enquiry is less than 30 seconds.

EAGLES' fast response capability provides an effective way for excavators and asset owners to share and update relevant information, thereby helping to reduce third party damage. "The technology and methodology can be rolled out across the gas and electricity industries and to other utilities and operators of applicable transmission and distribution networks," says Dr Brammall.

For utilities, an automated assessment provides valuable early warnings of risk, leading to a more efficient execution of works. As Dr Brammall says, "This automated prioritisation of enquiries, and the ability to deal with low-risk enquiries fully automatically, is the key benefit of the EAGLES system."

By using EAGLES in advance of any excavation, third parties benefit from receiving useful safety information quickly. National Grid and other utilities benefit from receiving an up-front assessment of risk in order to plan, support and advise as necessary saving time, money and enhancing safety. □ **BMM**

NATIONAL GRID. The international electricity and gas company is providing energy to customers across Great Britain and the United States' Northeast.

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Uninterrupted Supply – Strategies in the Pipeline

Thousands of kilometres of ageing metal pipe carrying gas for domestic and business customers are being replaced with a new generation of plastic pipes, in a very organised, strategic way

Replacement. **The cost of distribution mains replacement needs to be carefully managed.**

Uptime MRP. **Key software tool to support distribution companies.**

Companies with metal pipe distribution networks need detailed planning to prioritise how and when pipes need replacing. Using a combination of mains replacement prioritisation, network planning and design software, GL Noble Denton has developed a solution to support gas distribution companies.

The two key software tools are Uptime Mains Replacement (MRP) and SynerGEE Gas. Uptime MRP is a powerful decision support tool for operators of gas distribution networks. It helps to reduce operating costs and enhance safety and reliability, supplemented by SynerGEE Gas, a system modelling and simulation tool. "By integrating these two software tools, the status of pipes designated for replacement in a project is automatically updated in SynerGEE Gas ready for processing and modelling," says John Scrivener, Business Development Manager, Oil & Gas at Software Solutions.

In busy cities, for example, digging up roads is costly and needs to be carefully planned. However, the time and cost involved in cutting an open trench in busy streets to replace gas main distribution pipelines can be minimised by having an effective long-term replacement strategy that considers issues as varied as future demand (from planned housing estates, hospitals or similar infrastructure). "Including such game-changing parameters in the Uptime MRP and SynerGEE calculations at an early planning stage, will allow for predicted capacity increases, or reductions, in the future," says Mr Scrivener.

Network Integrity

Pipeline owners' operations and engineering staff are responsible for overseeing the integrity of gas distribution pipelines, while the company itself faces pressure to ensure its system's integrity through investments funded by its customers, the gas owners, or shippers. "Knowing when and where to invest in the network is key to ensuring proper reliability at a cost-effective price to customers," says Mr Scrivener.

Uptime MRP software provides the strategic management capability to manage risk and select the most effective replacement strategy that keeps pace with the ageing of a client's overall pipeline network.

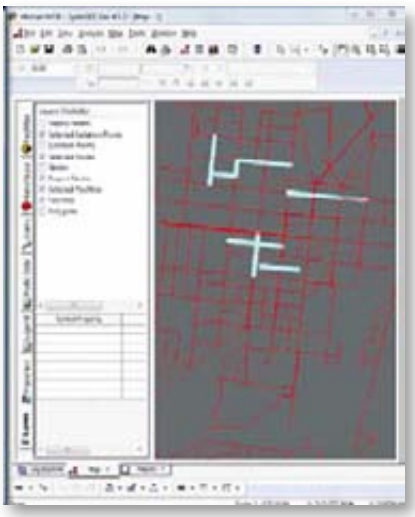
For the asset integrity management planner, Uptime MRP provides:

- Assesses the present condition of pipelines in terms of susceptibility to leaks
- Calculates the risk of incidents posed by ageing mains
- Predicts the rate of change in condition and risk over time and future deterioration

ABSTRACT

GL Noble Denton provides a software solution supporting operators of gas distribution pipelines to find an effective long-term replacement strategy

Roadworks. **Using MRP software can lead to a cost reduction of up to 30 per cent.**



Mains. **Geographic information is sourced from client company databases.**

- Evaluates and compares different multi-year replacement programmes
- Facilitates replacement strategy development based on criteria such as length, expenditure, material, age, operating pressure and diameter
- Assigns a "replacement year" to each main
- Uses native GIS tools to manage inputs and results in an open environment

SYNERGEE GAS. The tool models and analyses closed conduit networks of pipes, regulators, valves, compressors, storage fields and production wells.

Geographic information, including surface maps of roads and buildings, and network plans are sourced from client company databases.

Ageing pipes may have been repaired many times and be susceptible to further leaks or even failure. Metal pipes were first used in Europe in the late 19th century, and have been replaced with plastic, polyethylene pipes of varying diameters between 63 and 450 millimetres since the early 1970s.

Metal pipes are still used by the industry, but only for specific reasons where a high degree of stiffness is required. Such pipes are used when a pipeline is slung across roads and rivers under a bridge or as risers in tall buildings and skyscrapers.

Replacement Management

Uptime MRP enables users to get a quantitative measure and understanding of a pipeline's condition and operating risk. "It provides a risk analysis solution that integrates a number of attributes about a particular section of pipe, such as potential hot spots that could lead to leakage from natural forces from floods to frost and include consequences that might impact customers," says Mr Scrivener.

Using data from Uptime MRP, SynerGEE Gas allows users to model large, complex integrated multi-pressure level systems offering full control over gas constraints (gravity, heating value and viscosity), equations of state, friction factor calculations and heat transfer constants.

In the gas pipeline industry, this knowledge helps operators make crucial decisions to ensure their networks' safety and integrity. Also, armed with this data, planners are able to cut capital spending and reduce risk. With the integration of Uptime MRP and SynerGEE Gas, pipes have

their changing status automatically updated in readiness for processing by ADM, an Automated Design Module incorporated into SynerGEE Gas.

ADM recommends replacement pipe sizes, whereas MRP assumes the costs for a like-for-like pipe replacement size in its calculations. For example, the network may contain a 150 mm cast main, and MRP will assume a 150 mm pipe is to replace the existing main. ADM, in turn, may suggest that a 63-millimetre plastic main may be the appropriate size/material for the replacement, thus reducing the cost of the project.

Client Benefits

When planning a gas mains replacement programme, the pipeline owner must consider several issues. The first job is to understand which part of the network needs removing and develop a systematic strategy to replace metal mains based on an assessment of the pipe's condition and the risk of failure it poses.

Uptime MRP is used to reduce capital expenditures by calculating how much replacement or refurbishment is required to manage risk, maintain consistent system performance levels and demonstrate regulatory compliance. Cost savings are realised through several routes. By replacing mains before they become maintenance problems through, for example, requiring frequent emergency leak repairs. Also, by creating timetabled replacement strategies with corresponding cost estimates the asset owner is in a strong negotiating position with replacement contractors.

Software Solutions' clients report that MRP can lead to a replacement cost reduction of up to 30 per cent and repair prevention savings of up to 60 per cent by keeping on top of asset deterioration.

SynerGEE Gas operates in single-pressure level networks using data and criteria supplied by the asset owner. Information commonly inputted into the model includes:

- Current and possible piping configurations
- Load distribution including the design criteria of maximum and minimum allowable velocity for the pipes
- Pipe installation parameters including internal diameter, material type and installation cost per unit length

Using this data and criteria, the software determines which set of pipes most economically satisfies specified pressure and velocity constraints. SynerGEE Gas and its ADM component logically select pipe sizes so that the gas flows consistently throughout the system, and allows decisions to be made including:

- Determining a low-cost design for new service areas or major mains replacement efforts
- Analysing system design and avoiding over-engineering
- Identifying the incremental cost by designing to a higher minimum pressure

Adaptable

Together, Uptime MRP and SynerGEE Gas are powerful support tools that enhance safety and investment decision-making ability. "The combination can be used on any size pipe, internal pressures or length of pipe. The tools are also adaptable for use by water utilities," says Mr Scrivener.

Uptime MRP and SynerGEE Gas are a long way from the traditional paper map pinned to an office wall with coloured pins indicating leaks, corrosion hot spots or previous repairs. But using similar raw data, this software's risk-based approach allows companies to flag up future issues allowing for cost-effective replacement and safe pipeline operations. ◻ **BMM**

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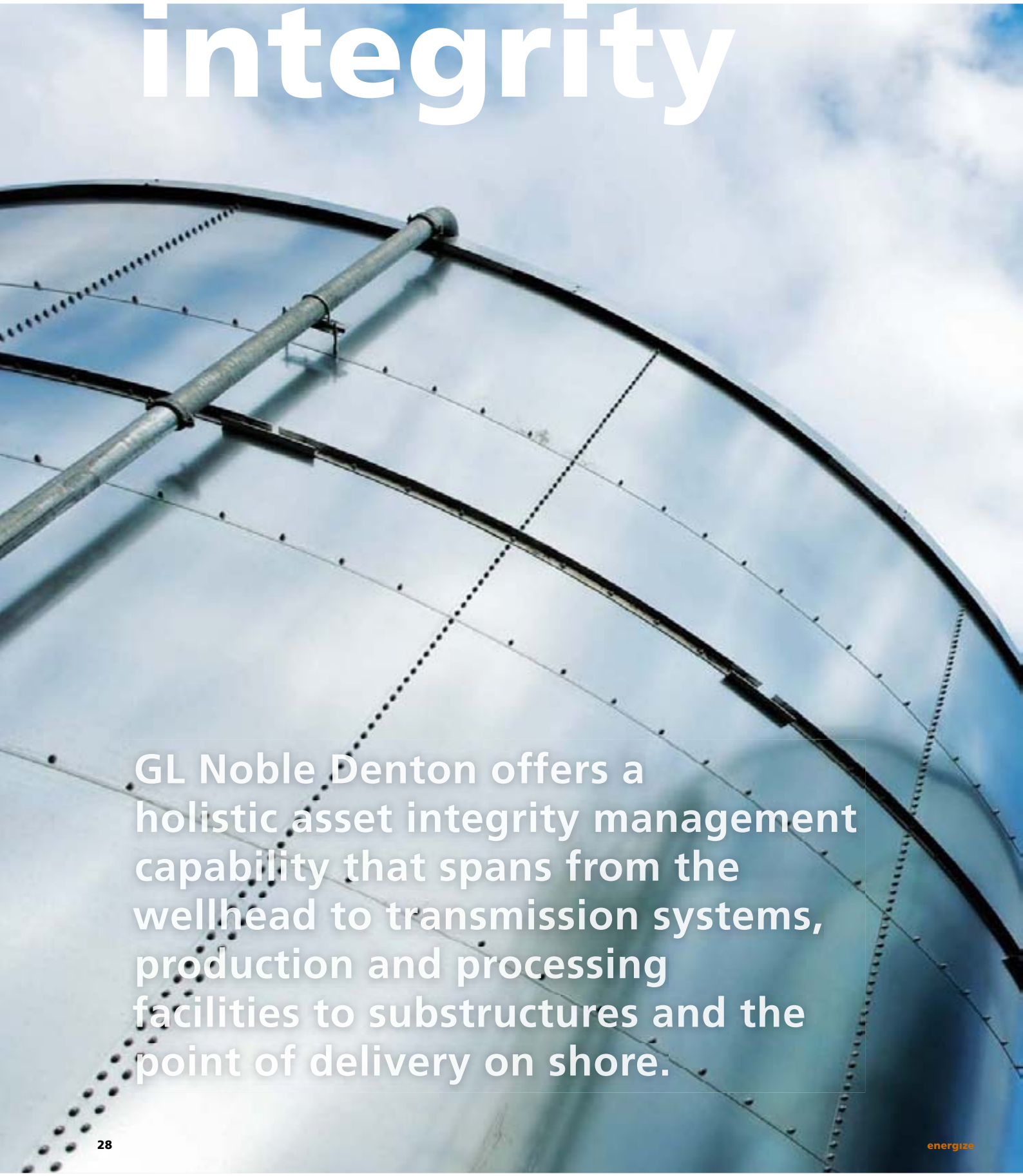
integrity



GL Noble Denton offers a holistic asset integrity management capability that spans from the wellhead to transmission systems, production and processing facilities to substructures and the point of delivery on shore.

Photo: Dreamstime/Lush

Catastrophic Events: Breaking the Cycle

A conference focused on major accident hazards took place at GL Noble Denton's Spadeadam test site, highlighting operational risks and offering best practice solutions for their management

ABSTRACT

- The oil and gas industry has a stringent approach to health and safety
- The aim of the conference at the Spadeadam test site is to avoid major accidents by sharing of information

Situated on 35 hectares of high-security Ministry of Defence land in a remote location in Northern England is one of the oil and gas industry's most valuable facilities. GL Noble Denton's Spadeadam test site is designed to carry out large-scale hazard tests on oil and gas assets of all types and sizes, helping operators to validate models and design codes, and obtain accurate test measurements by simulating real-world environments.

It is here that more than 50 of the oil and gas industry's safety and risk leaders gathered for an inaugural conference on major accident hazards in November 2011. The event, hosted by GL Noble Denton in association with the Institution of Gas Engineers and Managers (IGEM), set out to discuss one of the sector's most relevant and fundamental questions: How can we collectively break the cycle of catastrophic incidents caused by our operations?

The conference also provided delegates with a unique opportunity to witness the destructive force of the major hazards that they spend their professional lives working to prevent. Nine large-scale experimental demonstrations were shown by GL Noble Denton Spadeadam's team of engineers and scientists over the two-day event, each attached to a realistic industry scenario to help delegates

High Pressure. **Fire caused by a valve spindle. Ignition of an escape of a valve spindle at 30 bar.**

put some perspective on the conference's crucial discussions and debates.

Catastrophic Amnesia

A study into the recurrence of oil and gas accidents presented to the conference by Dirk Roosendans, Total Petrochemicals' Manager for Health and Industrial Safety, revealed the importance of sharing knowledge: "The oil and gas industry's stringent approach to health and safety means that a large amount of information is made available following an incident with the specific aim of avoiding repetition," he said. "So, why don't we use it effectively to stop accidents from happening again?"

Roosendans said the lack of information sharing could be explained by the fact that most oil and gas professionals will rarely or never experience a major accident hazard personally in their careers, making the risk of a hazard more of a concept than a reality: "After 20 years of a major ▷

Bang Box. Natural-gas-vented explosion.

Demo. An attack on a steel pipeline conveying propane at two bar.

accident occurring, it begins to disappear from our corporate memory," he explained. "Most of us will never experience a pool fire or vapour cloud explosion in our careers, so we don't find it easy to prepare for the risk or follow the guidelines that have been published to mitigate their recurrence."

Peter Bamforth, Safety Engineering Manager at the BG Group, agreed, adding that employees often lack a personal frame of reference when it comes to catastrophic incidents. "The true root causes of incidents are generally people, and the difficulty with that is they can often be far removed from the incident when it occurs. For example, competent operators may work with poorly designed facilities for years before an incident occurs and, by that time, those responsible for the design may have moved on. That's why it is so important that everyone across the company, from engineers to finance teams, has a consistent understanding of how important our safety culture is and the events that we are trying to avoid," he said.

SAFETY ISSUES. Effective communication between the management and employees is most critical during oil and gas asset design.

Leading by Example

The BG Group runs regular major hazards awareness courses at GL Noble Denton's Spadeadam test site in an effort to educate its employees: "We started off by bringing our senior management team to Spadeadam and showing them some large-scale demonstrations as part of the awareness course. They were so affected by their visit that they insisted that their direct reports also attend," Bamforth said. Delegates at the conference agreed that an organisation's leadership behaviours are key to ensuring that safety is taken seriously throughout its workforce.

Chris Murray, Chief Executive of Xoserve and a member of the National Grid leadership team, emphasised the role of a company's senior management in instilling a culture of safety leadership. "We need to ensure that employees don't look the other way when a potential hazard faces them because they've not been given the confidence to speak up or they feel that the senior management is difficult to get in front of on a day-to-day basis," he said. "A zero per cent accident rate is achievable in every company. All accidents are avoidable and only zero is an acceptable number. No matter what the incident or who's involved, you can always do something to improve safety," he added.

Professional Audience. Gathering for dropped-object demo.

Discussion among delegates at the conference also identified that miscommunication between management and its employees on production versus safety issues was most critical during oil and gas asset design.

"One cycle that the oil and gas industry needs to break is that of the continual missed opportunities for risk reduction in the early stages of design. We need to get out of the mindset that safety-related changes are possible in equal weight at any stage of an asset's design. As time and financial pressures begin to apply in the later design stages, the balance between production and safety become more complicated for everyone involved," conference facilitator Lee Allford summed up.

The conference identified the significant progress that operators are making towards mitigating the risk of major hazards. However, the safety and risk professionals attending the conference agreed that it would only be by continually sharing this best practice and discussing new safety initiatives that the oil and gas sector would be able to break the overarching cycle that causes accidents and loss of life. □ **RC**

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An Explosive Impact

Mike Johnson. Principal Consultant for Safety and Risk.

In his presentation **"HOW BAD EXPLOSIONS CAN GET"**, GL Noble Denton's Principal Consultant for Safety and Risk, Mike Johnson, shared the findings of his 30-year career researching the mechanics of vapour cloud explosions.

CITING EXAMPLES OF INCIDENTS IN PORT HUDSON in 1970, Jaipur in 2009 and the 2005 Buncefield explosion, which caused the largest fire in Europe since World War II, Mike put to delegates that the widespread destruction caused by vapour cloud explosions is the result of a transition from "deflagration" combustion to "detonation" combustion within the explosion. A deflagration is characterised by relatively modest overpressures, while the characteristics of detonation are far more violent, often leading to widespread destruction.

Mike explained that **TRANSITION OCCURS** when flame speeds are above the ambient speed of sound, generating shock waves sufficient to initiate detonation. He demonstrated to delegates the point of transition between deflagration and detonation in a series of slow motion videos of experiments that he has conducted at GL Noble Denton Spadeadam over the past ten years.

"The outcome of the experiments often depended on the fuel we used," said Mike, whose research has found that **EVIDENCE OF THE TRANSITION TO DETONATION** can also be seen in the aftermath of a vapour cloud explosion: "When we looked at the trees and lamp posts left behind in a number of incidents, we saw that they were either bent or levelled to the ground pointing towards the detonation source. This allowed us to pinpoint the exact location of detonation."

So is the case for vapour cloud detonation proven and accepted by the industry? Not entirely, Mike said. "Some industry professionals and **ACADEMICS STILL DON'T BELIEVE** that the transition between deflagration and detonation is possible in practical conditions, and that alternative combustion mechanisms exist. But, I can't see how high flame speeds can be generated in a vapour cloud explosion without a transition from deflagration to detonation occurring."

Corrosion Management – the Illusion of Control?

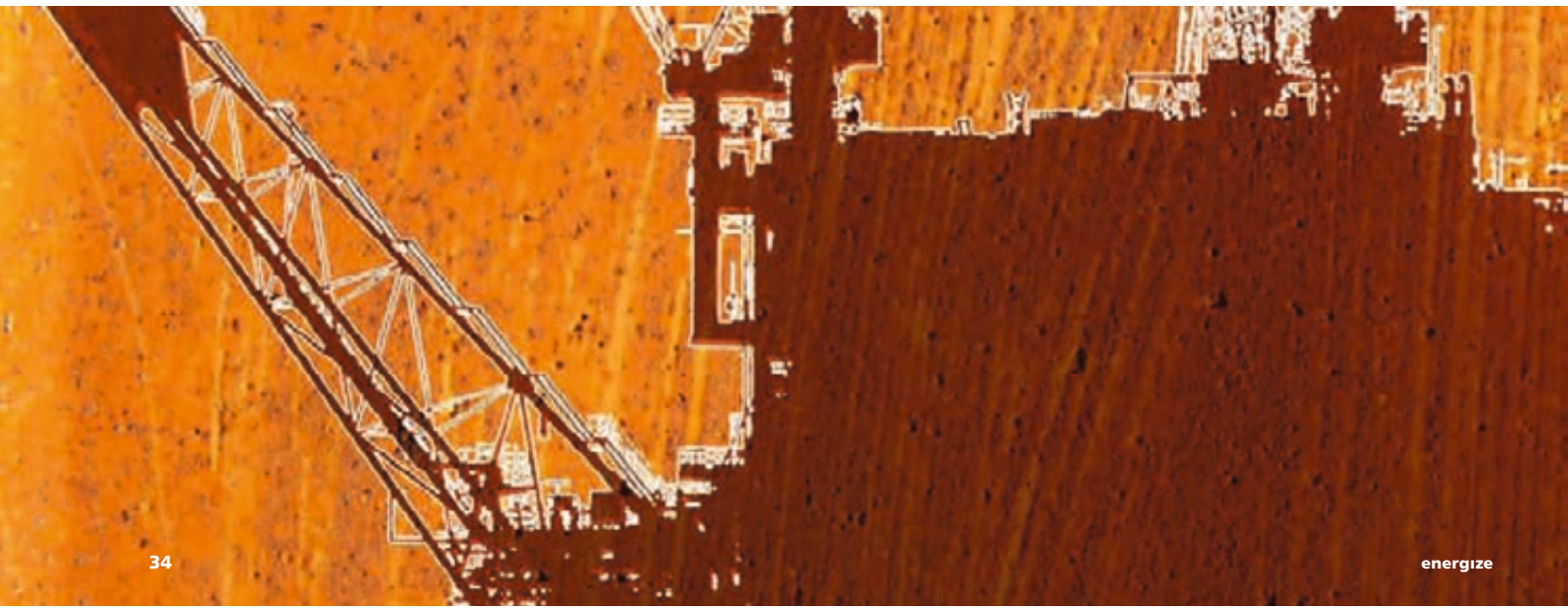
Modern corrosion management schemes serve the purpose of preventing premature asset failures. Why then does corrosion still occur and cause loss of availability?

Corrosion has been a problem ever since man learned to refine and work metals. In recent times, science has made great advances in understanding the causes of corrosion and developed many techniques for preventing or slowing its attack. But the enormous risk potential inherent in complex modern industrial assets requires proactive thinking to anticipate problems before they occur – and accounting for the human factor.

The Search for a Strategy

Corrosion management as a formal concept began to be formulated in the 1990s, but official guidance did not appear until the 2001 issue of the UK HSE document "Review of Corrosion Management for Offshore Oil and Gas Processing". This document, which proposed a formal approach to corrosion management based upon risk assessment, defines corrosion management as: "Corrosion management is that part of the overall management system which is concerned with the development, implementation, review and maintenance of the corrosion policy."

The document was completely revised in 2008 and published by the Energy Institute as "Guidance for Corrosion Management in Oil and Gas Production and Processing" along with an accompanying "Corrosion Threats Handbook". Most oilfield operating companies have also produced their own corrosion management guidance aligned with the companies' integrity management practices. Simi-



Damage. **Corrosion is the natural enemy of metal.**

lar philosophies have been devised for pipeline corrosion management. All these systems share common approaches since in most cases they are adaptations of safety management systems developed for process facilities. Construction and operation of a corrosion management system generally contains the following stages:

- Produce policies and objectives
- Derive an organisation and assign responsibilities
- Conduct a corrosion risk assessment (CRA) and plan control measures
- Implement the control measures and analyse corrosion data
- Determine if the corrosion control methods are effective by monitoring and inspection
- Review the overall success of the corrosion management system
- If not fully effective, revise the system to improve performance
- Periodically undertake an external audit of the system and revise according to auditors' recommendations

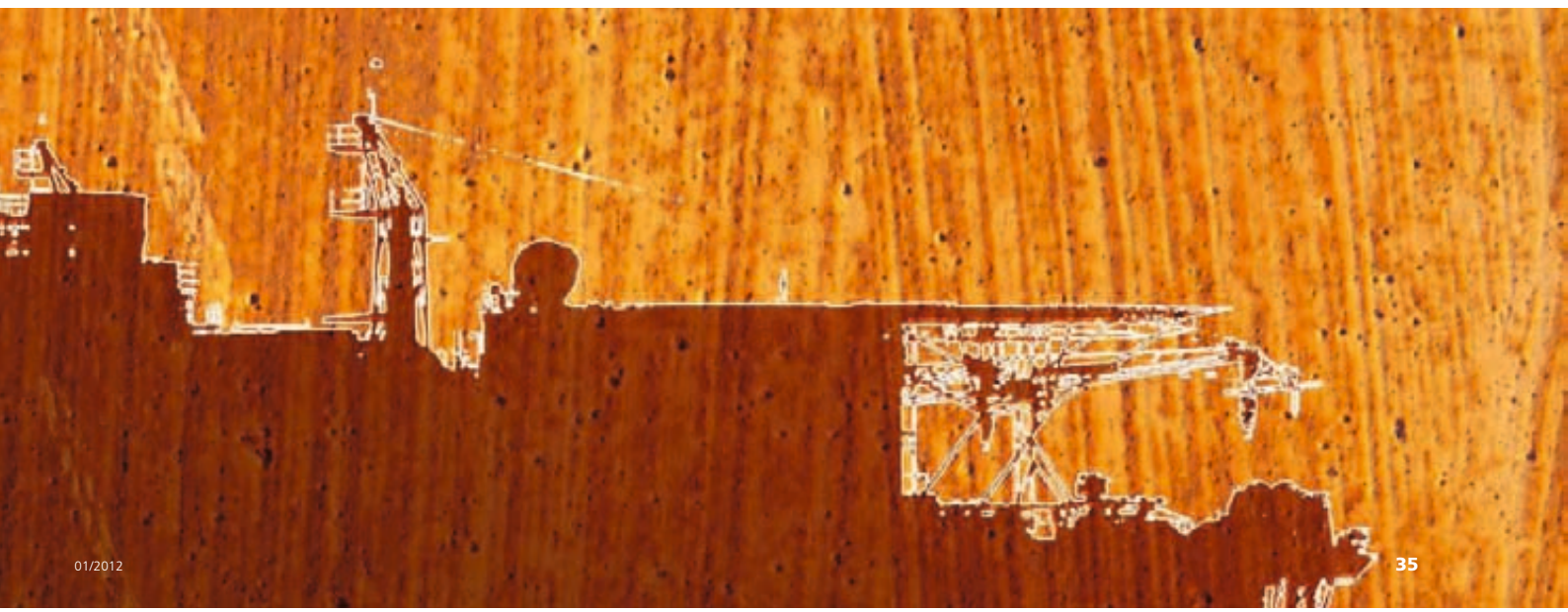
In most cases the system is assessed applying key performance indicators (KPI) that monitor the most critical corrosion control measures. These include parameters such as the number of corrosion monitoring probes operational, corrosion inhibitor concentrations and the number of planned inspections performed.

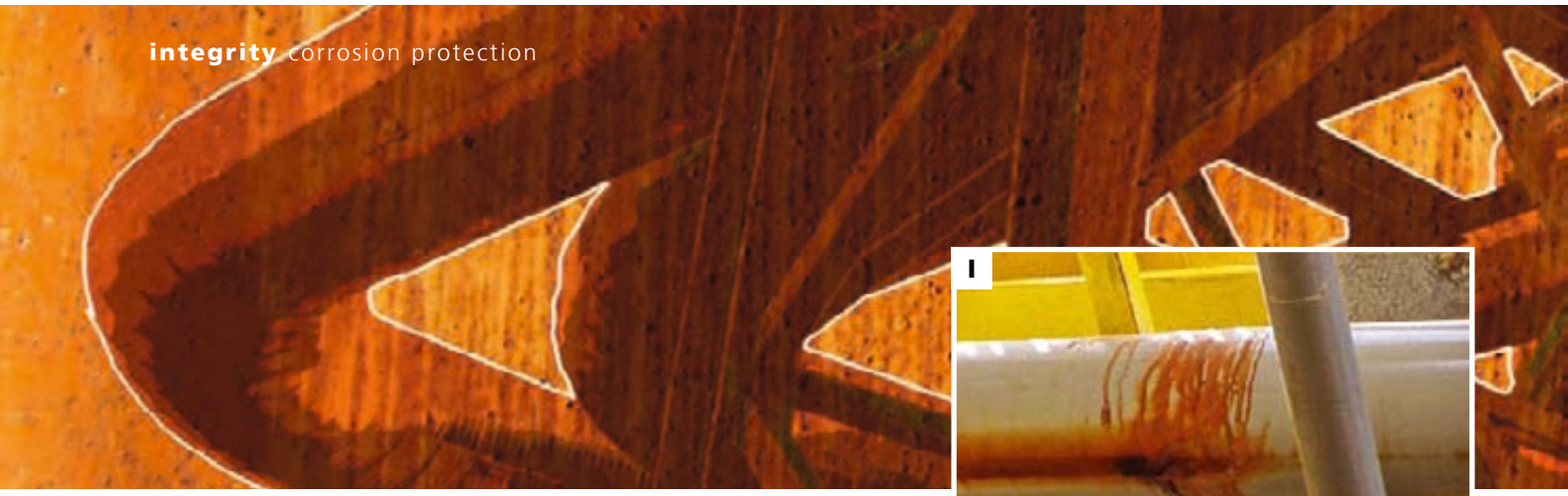
ABSTRACT

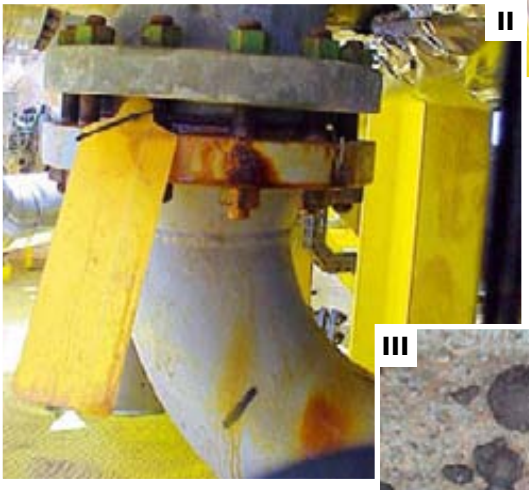
- Corrosion management is the development, implementation, review and maintenance of corrosion policy
- Any scheme for facilities must account for human factors and local conditions

Rust Never Sleeps

As the oil and gas industry now has reliable technologies for preventing corrosion and has devised sophisticated corrosion management systems, it might be thought that corrosion problems can now be consigned to history. In fact the recent HSE KP3 report on asset integrity states: "The introduction of corrosion risk assessment (CRA) and risk-based inspection (RBI) has offered an opportunity for operators to apply sound ▷







I. Corrosion awareness training is an important part of management schemes.

II. Bolted connections are a common problem area.

III. Even severe internal corrosion can remain undetected until failures occur.

> corrosion science and engineering to the identification of potential problem areas and to target inspections in an intelligent and defined manner… [Yet] coherent corrosion management programmes have not been developed and implemented. The result is a continual increase in inspection and corrosion problems which the industry is struggling to break through. […] Whilst CRA and RBI are good in theory, inspection programmes can fail to deliver the required performance due to lack of commitment by the company…"

Issues with CM Schemes

In spite of state-of-the-art corrosion management protocols and associated software, corrosion continues to be an issue. One reason is that only corrosion specialists see corrosion as important, while both the management and staff of hydrocarbon facilities normally regard it as a minor irritation. Corrosion failures generally take some time to occur and until severe damage is present don't interfere with the operation of equipment. Most people don't intuitively associate corrosion with a safety hazard. Thus, without sustained corrosion awareness campaigns, corrosion management activities will be neglected.

A good example is the importance of corrosion inhibitor availability. Inhibitor availability is the proportion of time that a corrosion inhibitor is actually being delivered into the system to be protected. In systems highly prone to corrosion availabilities of >90 per cent are often specified so, in theory, if the corrosion inhibitor pumps fail or the inhibitor tanks are emptied, production should cease until the inhibition system is restored. In practice, industry surveys have shown that for oil producing facilities it is extremely rare for production to cease when inhibitor is not available.

The management is clearly prepared to accept the risk of a future corrosion failure and its consequences in order to assure production now.

Another issue is that while many modern process facilities have corrosion input at the design stage and are frequently designed for ease of inspection, older facilities lack these advantages as corrosion, if considered at all, was seen as an operational issue that did not impact upon design decisions. It is extremely difficult to implement modern corrosion management practices in old facilities, which are probably more prone to corrosion. This leads to criticism from the safety authorities. Corrosion management programmes, usually produced by a central function, frequently fail to address the actual situation or condition of the facility and to obtain local asset commitment.

Deceptive KPIs

The review process inherent to all conventional corrosion management schemes can lead to false assumptions, especially where facilities do not have significant corrosion threats. The usual response to perceived shortcomings is to add more KPIs or other control measures. This often leads to KPI fatigue where operational staff realise that all of the KPIs cannot be met due to resource constraints, and concentrate on the ones that can be achieved. On the next audit the auditor will declare that corrosion is not being adequately controlled when in fact corrosion control is adequate. For this reason it is good practice to have regular KPI pruning to ensure they do not grow out of control.

The recent UK HSE document HSG254 recognised that there are issues with the correct specification and monitoring of KPIs for safety management; the same issues exist for corrosion management. Many corrosion management schemes concentrate on inspection. KPIs are devised to cover the frequency of inspection and whether inspections have been performed. Unfortunately, inspection KPIs are a lagging indicator, detecting corrosion only after it has occurred. A corrosion management scheme needs to include leading indicators such as the performance of active corrosion control measures and corrosion monitoring results to allow the onset of corrosion to be detected and preventative actions taken.

PROBLEM. Adding more key performance indicators often leads to KPI fatigue: the operational staff concentrates on the ones that can be achieved.

Any corrosion management scheme for hydrocarbon facilities must account for human factors and local conditions. A management plan may be entirely technically correct but fail to be implemented because the staff cannot comprehend what is required, do not believe corrosion is important, or the plan involves a complete change in working practices. Equally it is counterproductive to produce a plan requiring extensive inspections on a facility where inspection is difficult to perform, there is a shortage of inspectors, or advanced inspection techniques are not locally available. □ TI

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PE pipes and fittings play a key role in operating gas and water distribution systems safely, reliably and economically, and enjoy an excellent performance track record. Key to the success of PE pipeline systems is the ability to quickly form reliable, endload-resistant fusion joints with a strength equivalent to the parent pipe materials with a minimum design life of 50 years. Operators of PE pipeline assets report that the main threat to PE pipeline integrity other than third-party damage is poor fusion jointing. Inadequate workmanship in the field can lead to premature failure with catastrophic consequences. This is a particular concern for gas distribution lines. Axial or bending stresses caused by thermal expansion or contraction, or ground movement will increase the risk of failure of substandard joints.

To reduce the risk, installers must be trained appropriately. This article provides an overview of key parameters influencing butt fusion and electrofusion weld performance, typical failure modes seen in the field, and preventative actions that can help mitigate the incidence of failure. GL Noble Denton has over 40 years' experience in PE pipeline technology and routinely conducts incident reports and independent forensic failure analyses of PE pipe systems.

ABSTRACT

- PE has revolutionised low pressure pipe system design on a global basis
- Key to the success of PE pipe systems is the ability to form endload-resistant fusion joints with strengths equivalent to the parent pipe materials

The Fusion Process

There are three main types of fusion joint geometry: butt weld, socket joint and saddle joint. In butt fusion welding, the two ends of the pipes to be joined are trimmed flat and square to each other and then heated using a flat heater plate under controlled temperature, time and fusion pressure.

Avoiding the Pitfalls of Fusion Welding

At the 2012 Pipeline Technology Conference in Hanover, GL Noble Denton presented a comprehensive overview of current research into distribution pipeline safety

In electrofusion welding, the pipes are inserted into injection-moulded PE fittings with embedded heating wires. The terminals for electrical connection are located on the outside of the fitting. When energised by a controlled electrical power source for a pre-defined duration, the embedded wires produce the necessary heat to melt the plastic and, once allowed to cool, form a welded joint. Successful jointing of PE pressure pipes using these methods requires strict control of the parameters and conditions. For a safe gas supply, joints must be totally reliable. In reality, aerospace levels of reliability and ease of installation are expected of low-cost labour working in muddy site conditions in all weathers.

Another difficulty is that reliable inspection of polyethylene pipe joints using NDT is difficult, since radiography and ultrasound cannot reliably detect key issues that ▷

Polyethylene Piping

OVER THE PAST 60 YEARS, PE materials have evolved with advances in polymer science.

Today's highly engineered bimodal PE100 now provides exceptional balance of strength, stiffness, toughness and durability consistent with the demands of long-term gas and water pressure containment, ground loading and the service environment. In particular, PE offers advantages, such as:

- Economical, high-volume manufacture – extrusion, injection moulding
- Design flexibility – easily shaped
- Integrated design – multifunctional, ready-assembled components – couplers and fittings
- Low material cost
- Light-weight design – ease of transport and handling
- Flexibility – ease of transport and handling, use in conjunction with trenchless technologies, and resistance to seismic activity
- Relative ease of jointing (compared to metallic pipe systems)
- Squeeze-off for emergency gas flow stop
- Corrosion and good chemical resistance
- Biologically inert capabilities
- Toughness, impact resistance, abrasion resistance and long-term durability – technical lifetime of >50 years
- Low-temperature performance
- Leak-free fusion jointing – low maintenance costs
- Low-friction bore – no scale build-up and efficient flow of transfer medium
- Environmental benefits – recyclable

Photo: Dreamstime/Darknightsky

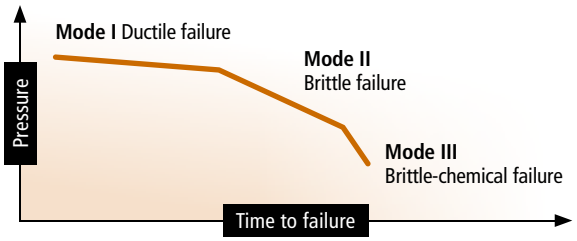

Figure 1. Failure modes of PE pipe – internal hydrostatic pressure testing.

▷ are known to affect PE joint quality, such as fine particulate contamination, cold fusion in butt welds and misalignment and contamination in electrofusion joints. New developments such as ultrasonic phase array and microwave methods have not yet proved sufficiently reliable or cost-effective for field implementation.

It is therefore a fundamental requirement to employ simple in-field quality assurance and process control techniques. This must be underpinned by a commitment to thorough workforce training. Furthermore, there must be continual investment in equipment to ensure tooling is fit for purpose. Finally, the culture adopted by an organisation must drive behavioural change so joint installers will take responsibility for the quality of their workmanship.

Polyethylene Failure Modes

The long-term durability of PE pressure pipe is dependent upon its ability to inhibit stress crack growth (SCG), one of three major failure modes for PE pipe, as shown in Figure 1.

Mode I failure results in yielding and reflects a material's propensity to undergo large-scale, irreversible "plastic" deformation when under stress. The mechanism results in localised expansion of the wall section and final rupture of the deformed zone (Figure 3).

Mode II failure is associated with creep, creep rupture and SCG. Creep is time-dependant, non-reversible deformation under constant tensile stress. Creep rupture, the terminal event of the creep process, is a measure of the time the material takes to fail. Creep rupture can be accel-

Photo: Dreamstime/Darknightsky

Figure 2. Sequence leading to SCG.

Figure 3. Ductile failure of PE pipe under internal hydrostatic pressure.

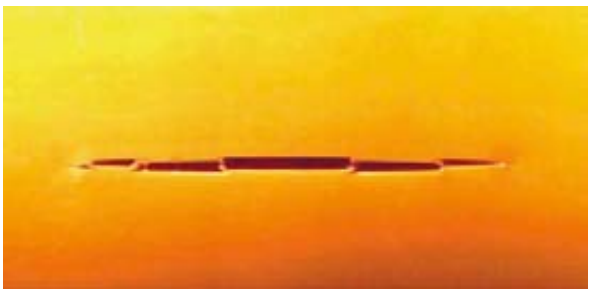

Figure 4. Brittle failure of PE pipe – slit type fractures.

erated by temperature, stress concentrations, fatigue and the chemical environment (Figure 2).

Mode III failure is related to degradation and embrittlement of the plastic due to thermo-oxidation with time.

The general mode of field failure reported for PE pipe is brittle SCG through the pipe wall due to formation of stress concentration defects in the fusion zone. These cracks can initiate at microscopic stress-raising flaws, inherent in the basic pipe product or, more likely, from defects. These brittle mechanical failures are typically slit-type fractures that lie parallel to the pipe's extrusion direction. Circumferential hoop stress in the pipe wall is the driving force for crack opening (Figure 4). Circumferential cracks can also be initiated on either the outside or inside surface of pipes due to secondary stresses such as bending or impingement on the material. Visually, brittle cracks are typically smooth, featureless and devoid of any yielding and deformation process. They are initiated at stress concentrations within a material structure, which may be inherent flaws, or defects such as residual stress, contaminants, inclusions or surface scratches. SCG due to the presence of stress concentrations can also occur in all fusion joints (Figure 5).

Causes of Failure

A clean and uncontaminated surface is the single most important factor in achieving a good bond between two surfaces to be jointed. Contamination can compromise fusion integrity and particles can act as stress concentration sites, the precursors to SCG.

A common failure mode of butt fusion joints is the initiation of SCG at stress concentration defects at the fusion weld. Secondary bending stresses, typically misalignment, uneven support or pivot points drive crack propagation circumferentially round the joint until it becomes unstable, resulting in a transition to fast crack growth and catastrophic failure (Figures 6,7). There are many procedural factors that can affect weld quality:

- **Fusion pressure** is an important parameter in the butt fusion process since it produces the mixing of molten materials to form the joint. ▷

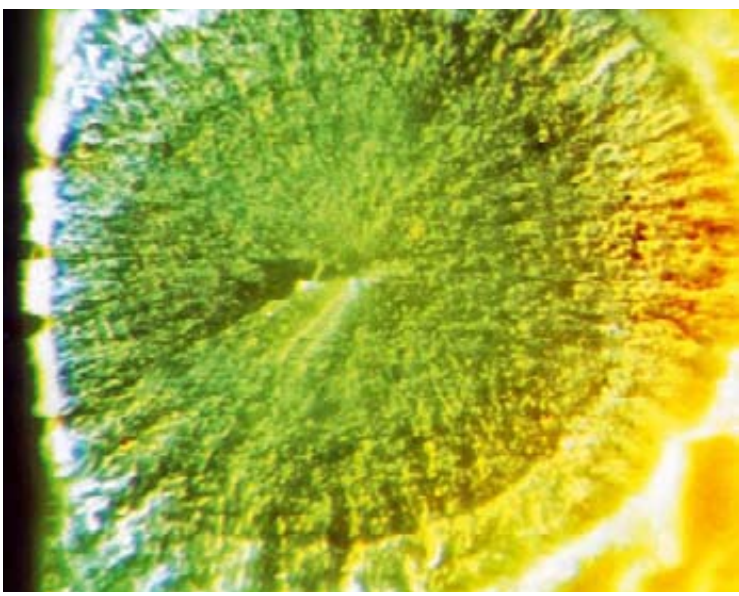

Figure 5. Brittle fracture surface.

Figure 6. Catastrophic failure of a butt fusion joint.

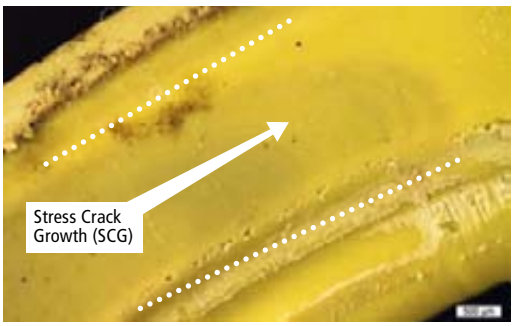

Figure 7. SCG preceding catastrophic fracture of complete joint.

Figure 8. Tensile testing of an electrofusion weld specimen.

- **Drag pressure** is the pressure required to overcome both the weight of the pipe and the friction within the butt fusion machine.
- **Melt temperature.** The fusion temperature currently used in butt fusion is 233 °C which is sufficient to melt the material but not high enough to cause thermal degradation.
- **Pipe-end preparation (trimming) and contamination.** The pipe ends must be completely trimmed before making the joint.
- **Pipe alignment** impacts on drag pressure and thermal contact between the pipe and heater plate. Especially when jointing long lengths of pipe, improper alignment will compromise the joint integrity.
- **Heat soak time** is the amount of time for which the pipe ends are in contact with the butt fusion heater plate.
- **Dwell time** is the time taken to remove the heater plate and bring the pipe ends together to complete the joint. This step must be completed as rapidly as possible.

PTC.
The Pipeline Technology Conference in Hanover is a platform to promote the exchange of technology news and innovative concepts.

Quality Assurance and In-Process Control

The "Achilles heel" of the PE system is at the point of installation. In-field quality control is extremely important because there are no non-destructive methods available to check joint quality on PE systems. Ultrasonic and radiographic techniques will not detect small inclusions such as dust or "cold joints" where fusion is incomplete but no air gaps are present.

The only other method of inspection is by observation to reduce procedural defects whilst providing a means of auditing the fusion process. Some of the practices adopted include:

- **Automatic butt fusion equipment** controls a number of important fusion parameters and removes potential procedural problems associated with operator error. It is mandatory within the UK gas networks. Data acquisition allows details of the welding operation to be retained for quality assurance purposes.
- **Bead inspection** can provide significant information on joint quality. The size and shape of the bead can indicate errors with procedural factors. The technique is discussed in detail in BS EN 120077.
- **Bend back test.** Removing a section of bead with a debeading tool and bending it back on itself will reveal any slit defects. Fine dust particles trapped within the joint can act as a barrier to fusion. This test is mandatory for UK gas networks.
- **Destructive testing.** A randomly selected butt joint can be destructively tested in order to assess joint quality. Samples are subjected to tensile tests in accordance with BS ISO 139538.
- **Equipment maintenance.** The equipment used for PE construction requires periodic maintenance. The manufacturer's maintenance schedule should be strictly adhered to.

Photo: Dreamstime/Darknightsky

Electrofusion

The electrofusion fitting is designed with special "cold zones" located in the centre of the fitting and at each mouth where the pipe enters. When the fitting is energised, the molten plastic is contained within the joint by the cold zones, and due to thermal expansion a melt pressure is built up. This promotes the mixing of pipe and socket material and, when cooled, makes a strong fusion joint.

Insufficient insertion of the pipe into the socket bore or misalignment of the pipe and socket are potential causes of thermal degradation, void creation and incomplete fusion leading to SCG and premature joint failure. In order to negate these possible failure modes, the pipe must be aligned by clamps and restrained during the fusion cycle.

Contamination due to careless handling is also a major issue that can lead to premature failure of electrofusion joints. Pipe cleaning and preparation has traditionally been achieved by scraping, a method that again implies certain risks if not performed diligently. This has driven the development of peelable PE pipe consisting of a core PE pipe and a sacrificial polypropylene (PP) skin. Removing the skin exposes the core PE pipe. PE-core pipe can be joined using EF technology without scraping. Peelable PE pipe reduces surface damage and improves the efficiency of pipeline installation.

Monitoring

New developments to improve field conditions and promote good practice include the use of remote cameras that can remotely monitor and record the quality of joint workmanship in the field. The very fact that the operator knows that joint quality is being inspected provides an impetus to comply with good practice and ensures a strong, ductile weld (Figure 8).

Conclusion

The greatest threat to the integrity of polyethylene pipelines other than third-party damage is fusion joint quality.

The factors contributing to premature joint failure are a combination of poor training and awareness, non-compliance with industry good practice, and lack of robust in-field quality assurance and spot-check auditing methodology.

Front-end investment to combat these issues would be a cost benefit in terms of reducing the risk to public health. The commercial benefits would be greater assurance in pipeline lifetimes of 100+ years. □ **CC**

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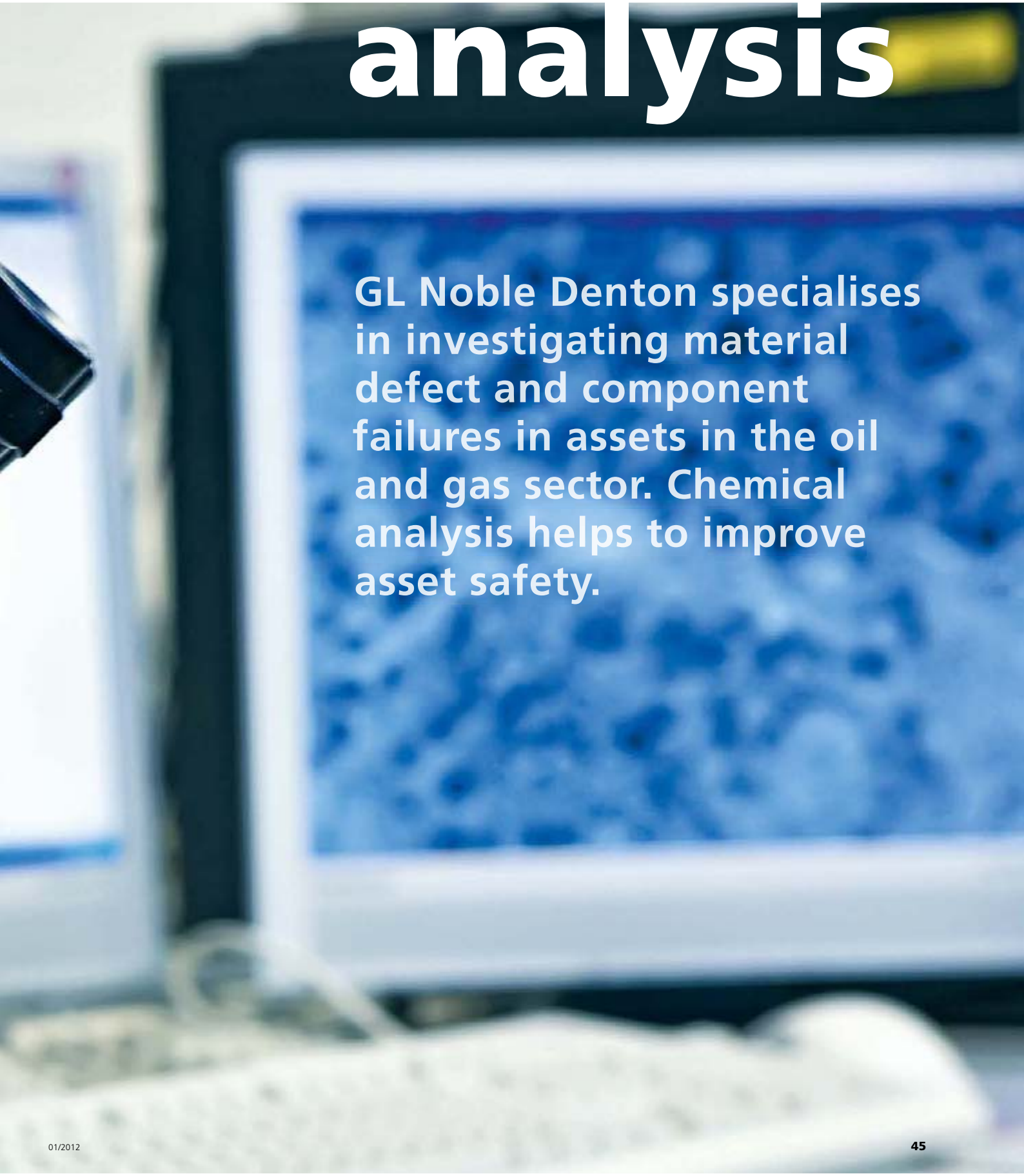
Photo: Dreamstime/Franz Pfluegl

analysis



GL Noble Denton specialises in investigating material defect and component failures in assets in the oil and gas sector. Chemical analysis helps to improve asset safety.

When the Chemistry Is Right

The analytical expertise of GL Noble Denton's chemistry experts is indispensable in investigations of material defects and component failures in oil and gas assets, from offshore drilling platforms to processing plants and distribution networks

GL Noble Denton applies chemical analysis to many important areas in the gas and oil sector, such as health and safety at work, environmental protection, investigation of incidents, identification of materials, studies of polymer degradation/oxidation, phase equilibria, thermodynamic and kinetic reactions, and quality control.

Failures or non-compliances with specifications may result from failing materials, a chemical process fault, or contamination of the manufacturing equipment or the raw materials used. Gas pipelines may deposit liquids and/or solids in addition to the fluid they are designed to carry. Filters may block up with debris from an upstream process or due to chemical or physical reactions in the pipeline or storage vessel. Contaminants may be hazardous with respect to handling, replacement and disposal. Symptoms are generally reported when a component stops working or behaves differently due to blockage, corrosion, leakage, sticking of seized parts, etc. Metals and alloys used in the construction, fabrication and components of pipelines and appliances may corrode or fail for various reasons. Surface coatings may fail due to photochemical oxidative degradation, thermal degradation, moisture absorption causing blistering or disbonding, or chemical reaction of gas components with those in the coating composition.

ABSTRACT

- Photochemical oxidative degradation. The gradual decomposition of a polymer exposed to ultraviolet radiation (sunlight) and oxygen, which cause the molecular chains to break, thereby weakening material strength

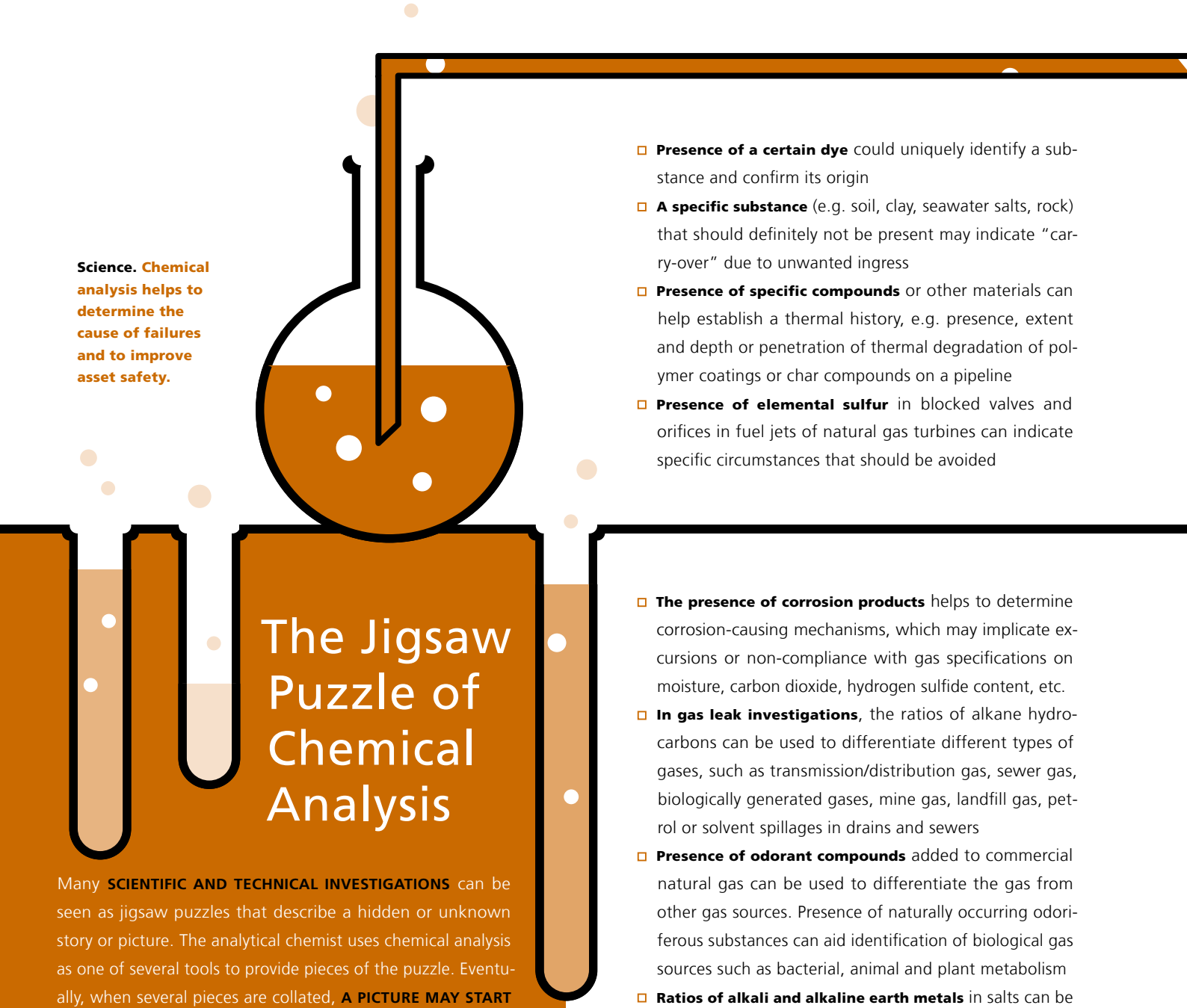
Investigation begins with inspections at the operators' premises and various symptomatic observations are recorded. Some tests are carried out on site and samples may be collected for analysis in the laboratory.

Understanding the Question

When carrying out investigations or obtaining evidence to answer a specific question, it is important for the client and the analytical chemist to understand the original question and the significance of what a particular chemical analysis test result could achieve. This helps to avoid costly "blanket analysis" requests where endless amounts of testing could provide little or no value in answering the original question. Tests and results aimed at providing a definitive conclusion should be considered prior to chemical analysis. This might involve looking for evidence of the presence of "a pin in the haystack" or "markers" providing the crucial evidence of trace amounts of a substance in a complex mixture. Alternatively, the question could focus on one or more major components. Examples include:

- **Part per million concentrations** of a specific antioxidant in a lubricating oil could help identify one of several potential lubricating oils that could have entered a section of an asset due to error, a breakdown, etc.
- **Traces of mercury** in debris could indicate a filtration system was not working correctly. Absence of mercury in process water could indicate compliance with the discharge consent of a water treatment plant

Science. **Chemical analysis helps to determine the cause of failures and to improve asset safety.**



The Jigsaw Puzzle of Chemical Analysis

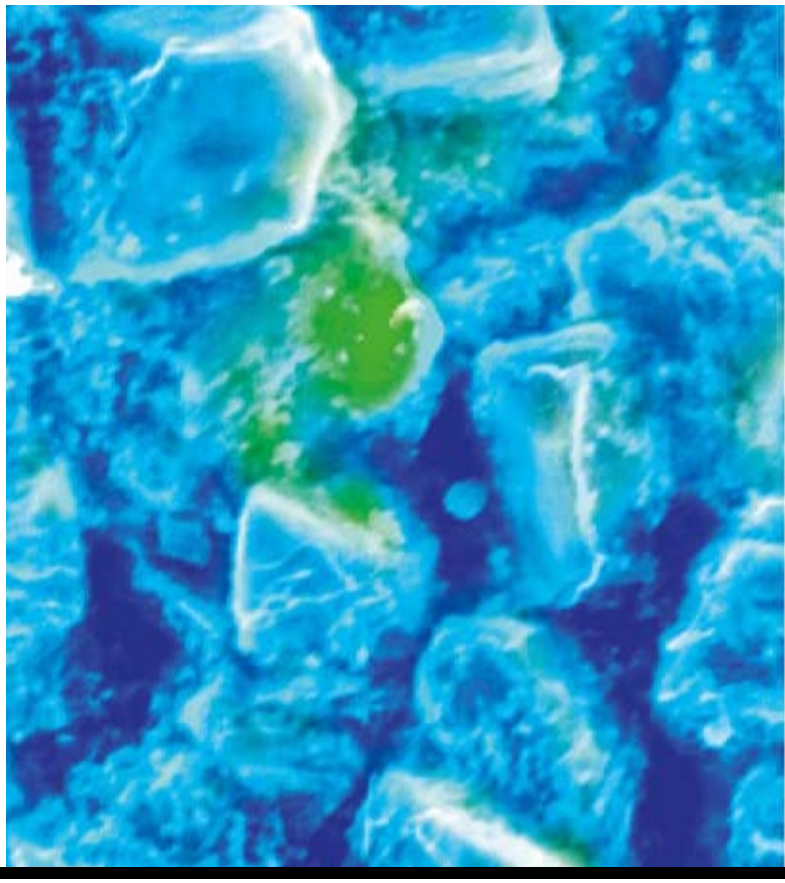
Many **SCIENTIFIC AND TECHNICAL INVESTIGATIONS** can be seen as jigsaw puzzles that describe a hidden or unknown story or picture. The analytical chemist uses chemical analysis as one of several tools to provide pieces of the puzzle. Eventually, when several pieces are collated, **A PICTURE MAY START TO EMERGE;** once sufficient pieces exist to complete the puzzle, the original question can be answered.

Further pieces of the puzzle may or may not add value and the investigation could stop **WITHOUT ADDITIONAL COST.** In some cases, one piece of the puzzle may be all that is necessary to address a specific question. In other cases, several pieces combine to strengthen conclusions.

- **Presence of a certain dye** could uniquely identify a substance and confirm its origin
- **A specific substance** (e.g. soil, clay, seawater salts, rock) that should definitely not be present may indicate "carry-over" due to unwanted ingress
- **Presence of specific compounds** or other materials can help establish a thermal history, e.g. presence, extent and depth or penetration of thermal degradation of polymer coatings or char compounds on a pipeline
- **Presence of elemental sulfur** in blocked valves and orifices in fuel jets of natural gas turbines can indicate specific circumstances that should be avoided
- **The presence of corrosion products** helps to determine corrosion-causing mechanisms, which may implicate excursions or non-compliance with gas specifications on moisture, carbon dioxide, hydrogen sulfide content, etc.
- **In gas leak investigations**, the ratios of alkane hydrocarbons can be used to differentiate different types of gases, such as transmission/distribution gas, sewer gas, biologically generated gases, mine gas, landfill gas, petrol or solvent spillages in drains and sewers
- **Presence of odorant compounds** added to commercial natural gas can be used to differentiate the gas from other gas sources. Presence of naturally occurring odoriferous substances can aid identification of biological gas sources such as bacterial, animal and plant metabolism
- **Ratios of alkali and alkaline earth metals** in salts can be used to differentiate (or identify) a particular seawater, groundwater or potable water source

Chemical Analysis and How Is It Carried out

Chemical analysis looks at the chemical composition of any material such as a metal/metal alloy, simple or polymeric inorganic or organic solid, liquid or gas. Materials can exist as pure elements (e.g. iron) and pure compounds ▷



X-RAYS. SEM/EDX analysis of 5-micron mercury sulfide particle in an iron oxide matrix found in gas filter units. Elemental mapping at high magnifications revealed the presence of trace quantities of mercury sulfide, which could not be detected by other techniques.

▷ of a number of elements (e.g. iron carbonate, ethyl alcohol, benzoic acid, petrol, etc); and also as simple or complex mixtures.

Chemical analyses can be simple or complex, depending on the original question that needs to be answered and the number of substances present. Consider a mixture of water, rust, rock, salt, oil, glycol, iron sulfide, iron oxide and iron carbonate. The original question may be: "Is there any salt present, and if so, how much?" Analysing for salt only would answer this question. But if the original question required a breakdown of all major and minor components, the mixture would first need to be separated into suitable fractions for subsequent analysis by appropriate techniques.

The techniques used for separating mixtures can be as simple as manual separation with tweezers and examining the sample under a stereomicroscope at low powers. Magnets are useful in separating magnetic particles from non-magnetic particles. Particles with different densities can be separated by adding them to inert liquids of different density; dense particles sink while less dense particles float. More complex separation methods are filtration, distillation, dissolution in acid or alkali and extraction with suitable solvents. A mixture of rock and salt can easily be separated by adding water to dissolve the soluble salt and filtering off the insoluble rock. The salt is isolated by evaporation of the water extract. Suitable chemical analysis techniques are then used to determine the mineral compositions and identity of the rock type as well as the composition of the salt, which may be a mixture of chlorides and sulphates of sodium, magnesium, potassium and calcium, or pure sodium chloride. If the mixture was a dirty sludge due to the presence of oil, another solvent such as cyclohexane would be needed to clean the rock and extract the oil for analysis by another technique. In a quantitative separation process the percentage weight of each fraction is recorded. Following chemical analysis of the individual fractions, a more detailed quantitative analysis of all fractions is possible.

Chemical analysis can be routine or non-routine and a range of tests may be needed to provide sufficient information. Even development and validation of a new test, highly specific to identify a particular substance, can be explored if it will provide a confident answer. Chemical analysis results alone may provide sufficient information or they may contribute to a larger pool of evidence from several other disciplines such as engineering, metallurgy and physics.

Types of Chemical Analysis

Chemical analysis can be divided into two main classifications: wet chemical analysis and instrumental analysis.

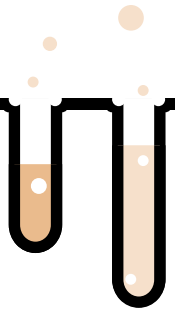
WET CHEMICAL ANALYSIS

This involves classical wet chemistry procedures that include spot tests, which are often carried out in test-tubes,

SEM/EDX Analysis

A DOMESTIC GAS CONSUMER'S FIRE exhibited a severe white soot-like powdery deposit on the glass front of the fire such that the flame couldn't be seen.

SEM/EDX analysis showed that the white deposits consisted of hydrated silica – H_2SiO_3 caused by the combustion of the vapours of organic silicone compounds in the flame where the silica deposited out as a white fumed solid. There were **TWO POTENTIAL SOURCES OF SILICONES:** the air and/or the gas supply. Air and gas samples were taken on adsorbent tubes and GC-MS analysis carried out. The presence of several silicones was confirmed in the house air but not in the gas supply.



volumetric titrations, gravimetric and colorimetric analyses. The substance under investigation can be tested for physical properties such as colour, odour, hardness, consistency, melting and boiling points, refractive index, density; and for chemical properties such as effect on heating or burning, pH, solubility in water, acid, alkali or any number of inorganic and organic solvents. Flame tests for specific elements can be quick, simple and conclusive. For example, where only two possibilities existed a chlorinated rubber O-ring can be quickly differentiated from a natural rubber O-ring by burning a few milligrams in a Bunsen burner flame and allowing the combustion gases to impinge on red hot copper metal. A blue-green flame would indicate the presence of chlorine in the chlorinated rubber and the analysis and differential identity of the rubber would be complete. There would be no further need for any other analysis unless the question had additional requirements, such as filler content and identity. Thousands of qualitative and quantitative test tube and paper strip dip tests exist for the analysis of different substances or classes of substances. Wet chemical analysis generally requires large samples (several grams/millilitres) but many micro-analytical tests are applied to small sample sizes (milligrams) including tests under a microscope when the sample is limited. Some wet chemical analysis is destructive; if the sample is limited, careful decisions need to be made which destructive tests would maximise the information gained.

II INSTRUMENTAL CHEMICAL ANALYSIS

This uses instruments designed to look at physical, chemical, electrical, magnetic and spectroscopic properties of the atoms in molecules in pure substances and mixtures. A range of chemical analysis techniques exist, each with its own instrumentation, usually connected to a computer for operation, data acquisition, processing and reporting.

Some types of instrumental analyses can be used to analyse extremely small amounts of substance (e.g. a few milligrams to micrograms). Even if the technique/test is destructive, there is often sufficient material left for further tests for examination by third parties for reproducibility. Some instrumental techniques are non-destructive so the sample can be preserved if it is important not to destroy evidence.

II.I DIFFERENTIAL SCANNING CALORIMETRY DSC

DSC measures energy changes that occur when materials are heated. Small samples (~10 milligrams) are heated from liquid nitrogen temperatures (-197 °C) to several hundred degrees Celsius in an atmosphere of flowing gas (air, nitrogen, oxygen). Materials that undergo changes in physical or chemical state will either absorb (endothermic) or emit (exothermic) energy. A plot of energy flow against temperature is known as a thermogram. Melting range, ▷

▷ melt enthalpy, per cent crystallinity, degree of cure, glass transition temperature, thermal degradation or oxidative characteristics are useful diagnostic parameters when comparing different polymers that may be the subject of a failure or incident investigation.

Standard reference materials are used for DSC comparison. A reference material could be an elastomeric or plastic component, e.g. an O-ring, diaphragm or seal from an appliance such as a gas meter that has not failed in service. Comparison could reveal that the failed component has different DSC properties to the non-failed component (e.g. a different Tg). This evidence, together with other, complementary evidence from further chemical and physical tests is used to identify causes of failure such as a faulty batch, incorrect or accidental selection of material not fit for purpose, thermal or oxidative degradation, contamination, etc.

II.II INFRARED SPECTROSCOPY

Infrared spectroscopy studies the vibrational energies absorbed by the bonds between atoms in the molecules of compounds. A plot of amount of energy absorbed against wavelength is referred to as an infrared spectrum. Groups of specific atoms called functional groups such as OH, COOH, COOR, NH_2, NO_2, etc., absorb at unique infrared wavelengths and are diagnostic spectral features in the spectrum identifying the presence of a particular functional group. The fingerprint region of the spectrum ~1,500–500 cm^{-1} is uniquely different for each compound and helps to differentiate compounds.

SPECTROSCOPY. Analysis of the energy radiated by a substance to determine its composition and properties.

The use of reference spectra of standard reference materials allow spectra of unknown ones to be compared manually or by computer using spectral library searches against data bases containing spectra of different compounds such as pure chemicals, minerals and polymers. Identification of materials by infrared spectroscopy usually requires samples to be in a pure form and can require chemical clean-up and separation for good library search matches. Libraries of plastics, elastomers and other polymers are useful in classifying an unknown polymer. Elastomers can be identified by comparing the infrared spectrum of their pyrolysates (products of thermal degradation) against standard reference spectra.

Materials can be presented to the spectrometer in all physical states: gas, liquid or solid. Very small amounts of just a few milligrams of solid and liquid can be handled. Sample sizes down to 10 microns can easily be analysed and identified using an infrared microscope. A classic example of infrared microscopy is the identification of different fibres in forensic analysis. The individual layers of multi-layered polymers used in corrosion protection can be identified by infrared microscopic examination of microtome-thin cross-sectional slices. Some reflection accessories produce spectra that are essentially surface-sensitive and represent the first few microns of a surface. It is possible to identify layers on surfaces that are only several microns thick, e.g. varnish coatings, bloom finishes or surfaces contaminated with foreign substances.

Mistake. **Historical yellow polyethylene gas service pipe with black outer layer of lead and lead sulfide. Due to the black discoloration, the live gas pipe was misidentified as a water pipe and was cut open causing a gas leak. Lead pigments are no longer used in modern polyethylene pipes.**

II.III SCANNING ELECTRON MICROSCOPY – ENERGY DISPERSIVE X-RAY ANALYSIS SEM/EDX

This technique uses an electron microscope to examine bulk samples at low and high magnifications. Small particles or selected areas of interest can be examined. When samples are bombarded with an electron beam, the atoms emit X-rays that are characteristic of each element. An X-ray detector counts the X-rays and produces an X-ray spectrum. It is possible to obtain both topographical information such as details of a fracture surface, and chemical state information such as elemental composition. Elemental mapping and line scans allow spatial distribution of elements and compounds to be shown in a graphical format. Different colours can be assigned to differentiate different elements. Line scans can show sharp differences in chemical composition at interfaces/boundaries, layers, etc.

II.IV GAS CHROMATOGRAPHY – MASS SPECTROMETRY GC-MS

The GC-MS technique uses chromatography to separate simple and complex mixtures. As little as 0.01 microlitres (~10 micrograms) of a mixture of organic compounds can be separated into individual compounds. The mass spectrometer detector (MS) generates a mass spectral "fingerprint" used to identify and quantitate each compound present. GC-MS is sensitive and can detect concentrations ranging from per cent to parts per billion (ppb) – ideal for providing evidence of the presence of trace components. Small samples (milligram to microgram) can be pyrolysed at several hundred degrees Celsius. The thermal degradation products are then separated to produce a GC-MS pyrogram, highly characteristic of a particular polymer. Adsorption tubes that contain adsorbent material such as Tenax, silica gel or charcoal are used to sample atmospheres such as air or gases. Trace components in air or in natural gas are trapped and concentrated on the adsorbent tube and subsequently thermally desorbed to produce a GC-MS analysis allowing compounds to be identified.

Depth Profile

INFRARED SPECTROSCOPIC MEASUREMENTS through the wall of a 10-year-aged PE pipe showed the presence of oxidised surface which penetrated to a depth of approximately 2.5 millimetres.

In the oxidation of PE in the presence of sunlight, oxygen from the air attacks the polymer backbone of the PE hydrocarbon structure to produce hydroperoxides. These hydroperoxides decompose and further react with the formation of a mixture of carbonyl compounds such as esters, aldehydes, ketones and carboxylic acids. The carbonyl group (C=O) absorbs infrared radiation at approximately 1,700 cm^{-1} which can be **DETECTED IN THE THROUGH-WALL SPECTRA,** the intensity of which gives an indication of the penetration with distance through the wall.

Summary

Chemical analysis is an essential science applied to the gas, oil, water and electricity sectors for various purposes including quality control, corrosion control, evaluation of kinetic and thermodynamic properties of materials and their interactions with each other within transportation, distribution and storage systems, and in utilisation. A large range of chemical analysis techniques are available that include both on-site and laboratory-based methods. Depending on the techniques and methods used, it is possible to obtain compositional analyses from percentage levels down to part per trillion concentrations. Without chemical analysis and its ability to study materials at a macroscopic, microscopic and atomic level, data critical for failure and forensic investigations would not be available. □ **DR**

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projects in brief

Expertise New Dynamic Positioning Base Supports Norway-based Oil Companies

stavanger To meet the growing demand for dynamic positioning (DP) services in the North Sea and broaden the reach of the company's global offshore offering, GL Noble Denton has established a dedicated DP team at its offices in Stavanger, Norway. The company already serves a wide range of clients from its DP centres in Aberdeen, Houston, Singapore and Abu Dhabi, and has ambitious plans for growth from its new Norway base.

Dynamic positioning control is a computerised system used on a vessel to maintain its position and heading. Although these systems are state of the art, regular trials and inspections are necessary in order to ensure the safety and upkeep of the technology. GL Noble Denton provides a full range of technical and assurance services to operators across the world, including: failure mode and effects analyses (FMEA), proving trials, annual DP trials, DP operational procedures, competency assurance and capability analysis. The company provides these services for a wide variety of offshore support vessels, from large drill ships to smaller high-speed offshore crew boats.

Commenting on the opening of the Stavanger DP base, GL Noble Denton's Director Bob Thomson said: "As the number of Norway-based oil companies expands in this sector, the level of DP services that they require will also intensify." For further information please watch the animated DP video at: **www.gl-nobledenton.com/en/marine_consulting/DynamicPositioning.php**.

Photo: Dreamstime/Nightman1965

OSV. GL Noble Denton's DP team in Norway have secured a number of major projects, including annual DP trials.

Engineer. Country Manager Tekena Dokubo.

West Africa New Presence for Services and Software Solutions

lagos GL Noble Denton has opened its first base in West Africa with operations in Lagos, Nigeria. The move reinforces the company's commitment to developing its presence in the region, where the oil and gas industry has recently increased its efforts to access the considerable hydrocarbon reserves available in the Gulf of Guinea.

GL Noble Denton's Nigerian operations will develop the company's growing reputation for providing services and software solutions to aid international and local oil companies in developing and operating safer and more efficient assets in West Africa.

Nigeria is the tenth-largest oil producer in the world, and the most prolific oil producer in sub-Saharan Africa. The country has proven oil reserves of more than 37 billion barrels, and an estimated 187 trillion cubic feet of natural gas reserves. The country is the ninth largest natural gas reserve holder in the world and the largest in Africa.

Nigeria. The oil and gas sector's activities are increasing rapidly.

Innovation Pipeline Industries Guild Award

london GL Noble Denton has won the coveted Utilities category of the 2012 Pipeline Industries Guild Awards. The award honours an innovative beam drilling system, which is used by UK gas network operators to secure drilling equipment onto gas pipelines more safely and efficiently. The Beam Drilling System initiative was developed jointly with National Grid and maintenance specialist ALH Systems Ltd.

Honoured. GL Noble Denton Senior Engineer Dave Gregory.

Transnet Simulation Software for Multi-Product Pipeline Training

johannesburg Transnet, South Africa's principal petroleum and gas pipeline operator has awarded a significant contract to GL Noble Denton to provide its Stoner Pipeline Simulation (SPS) software for use on Transnet's multi-product pipeline.

The software will be used to deliver in-depth training programmes to Transnet employees who will operate the company's new 550 kilometre multi-product pipeline (NMPP). SPS uses state-of-the-art simulation to allow operators to replicate a variety of scenarios that the pipeline may experience during its life cycle.

The software will be tailored to Transnet's individual training requirements and configured to accurately re-create any aspect of the NMPP. It will allow the pipeline's operators to learn to recognise potential technical problems with the pipeline; respond to emergency situations; and develop an understanding of the dynamic operation of the pipeline in a virtual environment. The system will also provide full management of the training records for each operator.

Support. GL Noble Denton's SPS helps to operate pipelines efficiently.

Shell Inspection Services Framework Agreement for Shell's Extensive Global Portfolio of Projects

the hague GL Noble Denton has been awarded a four-year enterprise framework agreement (EFA) to provide inspection services for Shell's extensive global portfolio of projects in select locations.

GL Noble Denton's network of highly qualified inspection engineers will have the opportunity to work alongside Shell's project teams to inspect on- and offshore equipment globally. They will supplement Shell's procurement process to ensure that goods acquired by Shell are compliant with the highest industry safety and efficiency requirements across their life cycle.

GL Noble Denton's Senior Vice President for Technical Assurance, Paul Shrieve, said: "GL Noble Denton's position as a market-leading technical assurance services provider has been further recognised by this agreement, and we are delighted to have the opportunity to develop a closer relationship with Shell. With a presence in more than 80 countries across the world, we are well placed to support the company wherever it is operating, and our independence will allow us to deliver unbiased advice, aiding Shell's continued drive to operate the oil and gas industry's safest assets."

Photo: Dreamstime/Erik De Graaf

Facility. GL Noble Denton supports Shell with worldwide inspection services.

dates

Conferences & Fairs

MAY

09.05.2012
Gas Industry Awards
London, UK

24. – 25.05.2012
European Dynamic Positioning Conference
London, UK

JUNE

04. – 08.06.2012
World Gas Conference
Kuala Lumpur, Malaysia

13. – 15.06.2012
5th Annual Pipetech World Summit 2012
Istanbul, Turkey

18.06.2012
An Audience with Nick Winser
London, UK

AUGUST

28. – 31.08.2012
Offshore Northern Seas (ONS)
Stavanger, Norway

OCTOBER

08. – 11.10.2012
Gastech 2012
London, UK

23. – 26.10.2012
30th International North Sea Flow Measurement Workshop
St Andrews, UK

Ceremony. Over 600 gas professionals are expected.

Offshore. New developments in DP systems.

Fair. Kuala Lumpur Convention Centre.

Venue. Grand Cevahir Hotel & Convention Centre

Talk. National Grid's Executive Director Nick Winser.

Event. Leading biennial energy meeting.

Networking. Natural gas industry's premier event.

Platform. Subsea measurement challenges.

IMPRINT

energize oil & gas, issue no. 01/2012, April 2012 **Frequency** energize oil & gas is published four times a year **Published by** Germanischer Lloyd SE, Hamburg, Germany **Editorial Director** Dr Olaf Mager (OM), Corporate Communications **Managing Editor** Anne Moschner (AMO) **Authors of this issue** Rob Coveney (RC), Tim Illson (TI), Zhang Li (ZL), Bruce McMichael (BMM), Dr Chris O'Connor (CC), Derek Robson (DR) **Design and production** printprojekt, Schulterblatt 58, 20357 Hamburg, Germany **Layout** Lohrengel Mediendesign **Cover photo** BP p.l.c. **Translations** Andreas Kühner **Printed by** Media Cologne Kommunikationsmedien GmbH, Luxemburger Straße 96, 50354 Hürth, Germany **Enquiries to:** Germanischer Lloyd SE, Corporate Communications, Brooktorkai 18, 20457 Hamburg, Germany, Phone: +49 40 36149-4509, Fax: +49 40 36149-250, E-Mail: pr@gl-group.com

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GL Noble Denton

Conscientious? It ought to be Saikat's middle name

- Kept a cool head in Qatar for a three-month Galiom engagement
- Led an industry-first integration between Galiom and Oracle ERP
- Implemented the most Galiom modules for a single client in Malaysia
- Is a leading light in Kuala Lumpur's Indian culture

Saikat is one of our highly valued software implementation consultants. With over 10 years in the industry, he supports major Galiom installations in the Middle East and Asia Pacific. The GL Noble Denton asset integrity management solution, Galiom helps improve asset reliability and reduce major accident risk.

Ask Saikat what aspect of his job he enjoys most and he'll reply client interaction, because requirements capture is a large part of the role. But it's certainly not all, since he sees the entire project through to acceptance testing and end user training. So, when Saikat leaves site, he only ever leaves delighted customers.

Saikat is one of the thousands of dedicated experts our clients count on every day

Learn more about him here **www.gl-nobledenton.com/Saikat**

twitter
Follow us **@glnobledenton**

GL Noble Denton is the independent technical advisor to the oil and gas industry

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