In Brief...
GAS PROCESSORS ASSOCIATION EUROPE
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A NEW ERA FOR AN OLD TECHNOLOGY?

UCG Technology is not new, but as the world is looking towards Clean Coal technologies, UCG, coupled with Carbon Capture and Storage (CCS), offers huge potential as a method of exploiting large coal resources on land and offshore.

Underground Coal Gasification

Ten years ago, the term "underground coal gasification" (UCG) was virtually unknown, other than to a small circle of people involved in its operation and development. Now, thanks to the work of the UCG Association, there is a proliferation of UCG projects around the world.

Feasibility studies, commercial research and potential projects are currently underway in the majority of countries with large indigenous resources: Australia, South Africa, USA, China, India, New Zealand, Hungary, Canada, Western Europe and the UK.

Investment funds are being raised and the technique is now being recognised as a major future source of clean, affordable energy.

In Britain, officials hope the process will provide access to vast coal reserves under the North Sea, and in the last year eleven licences have been granted in the UK for energy to be obtained from coal using the UCG method. In Eastern Europe interest continues due to the ever increasing concerns relating to security of supply.

What is Underground Coal Gasification (UCG)?

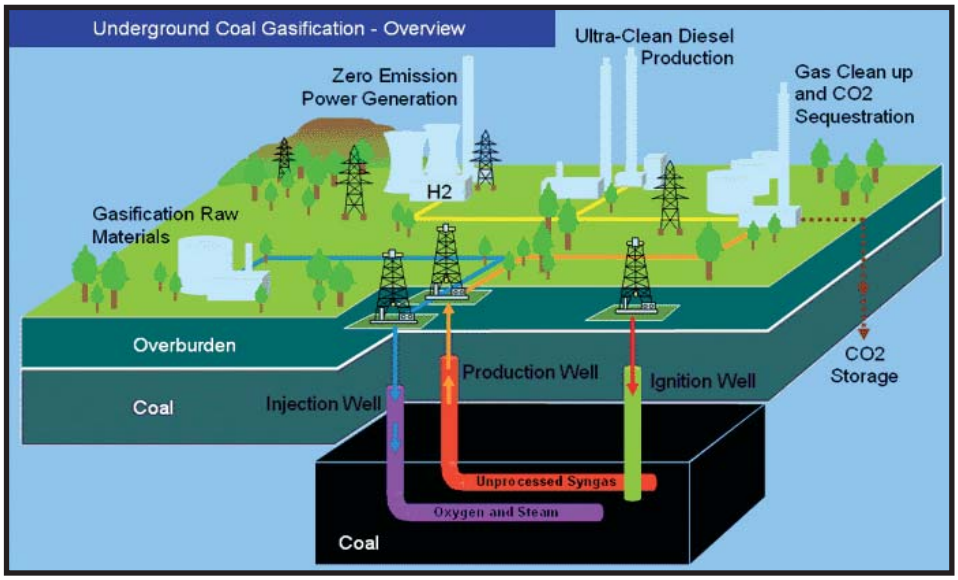
UCG is a method of converting unworked coal, while still in the ground, into a combustible gas suitable for industrial heating, power generation or the manufacture of hydrogen, synthetic natural gas, diesel fuel or chemical feedstock. The basic UCG process, pioneered by the Soviets in the 1930s, has two wells drilled into the coal, one for injection of the oxidants, another to bring the product gases to the surface, while ensuring the stability of partial combustion and the integrity of the reaction chamber under the high temperatures generated during the process. Improved drilling capabilities have allowed access to the coal, regardless of depth.

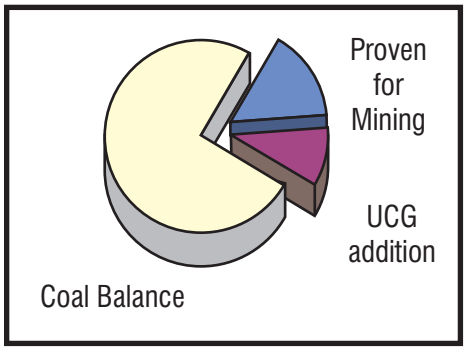
Most trials have been at depths around 100m, working at, or just below, the hydrostatic pressure, to limit gas leakage into the strata. In Europe tests have been conducted as deep as 1200m. At the shallower depths, air is the most cost-effective oxidant. At greater depths, say below 300m, the balance moves in favour of oxygen plus steam.

Major advances in the technology, due to horizontal and directional drilling techniques, plus greater knowledge of site selection criteria, hydrogeology, advances in seismic studies and environmental impacts - which are fully manageable with the right coal and overburden structures - make the practice safe, reliable and the economics attractive. As UCG is best suited to very deep, inaccessible coal, experts believe UCG can substantially increase recoverable coal reserves globally.

World Resource 5-8000BT
- **Proven Reserve (2005) 909BT**
- **Est. UCG addition 600BT**

There are many environmental benefits to the UCG process since no coal is brought to the surface; reduced emissions, soiling of the landscape, fugitive dust, noise and disruption to the surface. Also Capex and Opex are lower with no requirement for surface gasifiers, less costly clean up, smaller more efficient separation plant, lower capture costs and the ability to produce hydrogen in bulk quantities. The composition of syngas and the high pressure available, suggests that a range of CO_2 capture options could be considered; there is currently research in Europe for the CO_2 to be reinjected into the gasified coal seam or into adjacent coal seams for permanent storage or to enhance coal bed methane recovery or EOR *continued on page 2*



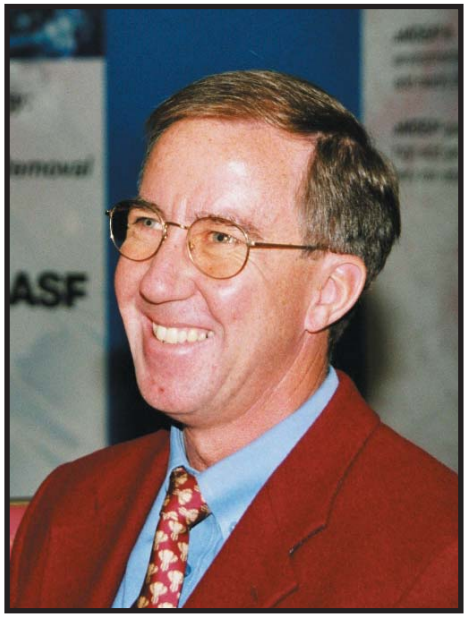


View from the Top

Over the past month, the headlines have been dominated by the oil pollution in the Gulf of Mexico, caused by the loss of the Deepwater Horizon semi-submersible drilling rig. At the time of writing, the blame game is in full swing, with politicians on both sides of the Atlantic voicing strong opinions on the subject, and Tony Hayward, BP's CEO, has been grilled by a Congressional Committee. Shouting may be good (domestic) politics, but the reality is that although BP seems to have been unfairly cast as the only villain of the piece, they are the only ones who are able to deliver a solution. This is surely one dispute where pouring oil on troubled waters doesn't have much chance of success!

So why are the energy companies trying to drill in ever deeper water? What encourages them to push the drill pipe through 1,500m of seawater before the bit even starts to bite? One factor will certainly be the potential profits to be made. However, another important factor must surely be America's seemingly insatiable demand for energy.

Somewhat optimistically, President Obama has just suggested that *"this is the time to end America's century-long addiction to fossil fuels"*. At first sight, "addiction" may seem to be a strong word to use, but under closer scrutiny the energy and illegal drug industries appear to have much in common. The narcotics "industry" in the US is a large, successful, consumer-driven business, albeit illegal. There are clearly safety issues associated with the acquisition and processing of the raw materials, and also the safe distribution of the finished product. In light of these similarities, the President seems to have hit the nail on the head.



GPA Chairman Justin Hearn

So will the US really be able to reduce its dependency on fossil fuels? Can Joe Public be persuaded to give up his energy-intensive lifestyle? Is the addict going into "rehab" anytime soon? The signs for an imminent cure are not very encouraging, but perhaps by switching the addict to a less damaging "drug" - like from heroin to methadone - we can still make some progress. What if the US could replace *domestic* coal with *domestic* gas in power generation?

At the GPAE's May Conference in Vienna, the emerging role of "unconventional gas" was discussed. In the US, increased shale gas production, made possible by improved horizontal drilling and "fraccing" techniques, has already led to reduced imports of LNG. So, increased domestic gas production is already contributing to US energy security. Ironically, it is the unfortunate result of BP's attempts to extend the boundaries of drilling technology in search of oil and gas in the deepwater Gulf of Mexico that is presently causing so much anger in the US.

In a related development, it was announced this week that Siemens will be supplying five gas-fired power stations to a US utility company. They will replace coal-fired units that began operating in the early 1950s. Per kWh generated, the new gas-fired generators will reduce CO_2 emissions by 60%, and NOx by 95%, compared to the coal-fired units. In addition, nearly all of the sulphur and all the mercury emissions will be eliminated.

Gas-fired power plants can take as little as two years to build on brown field sites, with existing utilities and access to the grid. Siemens believe that the switch to gas-fired power stations is mainly driven by regulation, and the realisation that spending hundreds of millions of dollars on the back end of an old coal power plant is simply not worth it.

This deliberate move from coal to gas in the US power generation industry is encouraging, and gives us reason to hope that a similar trend will begin in Europe. In Britain, the security-of-supply argument for coal, compared to gas, is barely credible when 50% of the coal supply presently comes from Russia. In addition, CCS technology is perceived - even within our industry - as not yet state-of-the-art. For many, the phrase, *"clean coal"*, is still an oxymoron!

As gas processors, we can be sure that, despite the current political rhetoric, the demand for natural gas will increase as the potential alternatives are presently perceived as too dangerous (nuclear), too dirty (coal and, to a lesser extent, oil) or too unreliable (wind / solar). It is our challenge to help assure the supply. *Justin Hearn*

Continued from Page 1

Ongoing Developments and Projects

Studies have been growing in pace and number over the past few years, with more than ten new feasibility studies initiated between 2007/9. The rate of new projects continues to increase and now include commercial scale projects in Australia, Canada, USA and New Zealand. In 2009 the first UK offshore licence for UCG was issued; these now total eleven, plus one in Ireland, and there are indications that the countries of Eastern Europe will soon also undertake commercial UCG activities.

UCG is especially suitable for low-rank coals like lignites and sub-bituminous coal, which produce less heat when burned due to their high ash content, and are highly polluting. This has driven a lot of recent investigation in India where the ash content (35% to 50%) is a major technological limitation to their coal development. South America is keen on UCG for fertilisers, others for power generation. The resultant UCG Syngas has many application options, which is also a major factor of the process and the global appeal.

There is no doubt that UCG technology is one that has the potential to play a significant role in the future global energy mix for many. The need for cleaner indigenous energy not only impacts on a nation's commercial prosperity, there is also a direct impact on all aspects of the social economics and development of emerging nations. For those with few other indigenous sources of energy, UCG has much to offer. *Julie Lauder - The UCG Association*

GPA Europe Technical Conference, Paris

Advances in Process Equipment

The first paper of the morning session in Paris, *Application of Nitrogen Refrigeration Turboexpander /Compressors to Large Scale LNG Trains*, was presented by Joe Kugler of Air Products & Chemicals Inc.

Joe outlined the constraints of using proven and available equipment used in the development of the AP-X® process cycle to enable the maximum capacity of a single train of the APCI C3-MR process to grow from 5 MTA to 8 MTA. This involved using the largest heat exchanger designed and manufactured by APCI and combining it with a nitrogen instead of Mixed Refrigerant subcooling system. The nitrogen recycle refrigeration system has been used in hundreds of air separation liquefaction units worldwide, albeit not of the size required for the AP-X® process. The process required 4 x 7 MW companders operating in parallel for each of the six trains for Qatar to provide a total of 25MW of refrigeration per train.

As the compander size was a step-out from previous experience, engagement of the customer early in the design concept was vital. The need for the use of outside consultants to review key aspects of the design, along with component testing, cryogenic and full load testing was emphasized.

The need for support to the customer during construction, installation, commissioning and start up was stressed.

Dr Hans Kimmel of Ebara International Corporation presented the next paper, *Thermo-Fluid Dynamics and Design of Liquid-Vapour Two-Phase LNG Expanders*, co-authored by Simon Cathery of Costain Energy and Process. Hans outlined the Euler Turbine

Dr Hans Kimmel

Joe Kugler

Equation dating back to 1756 and described the development of Ebara two phase LNG expanders. Base load LNG plants have typically liquefied natural gas at high pressure and subcooled the LNG prior to reducing the pressure across a Joule Thomson valve before passing to storage. This leads to a vaporisation loss and liquid phase expanders have been used to reduce this loss, although they have needed to be operated against a back pressure valve to prevent vaporisation in the expander, still resulting in a vapour loss. Ebara have developed the liquid-vapour two phase expander to negate the need for a back pressure valve and so increase overall LNG process efficiency. The units were first used in a nitrogen rejection unit in Poland, and have subsequently been retrofitted in a number of LNG plants. Hans' presentation showed the detail design of the expanders, with the amazing shapes of some of the components which clearly go well beyond what Euler could have imagined back in 1756.

Dr Roger Dambach of Cryostar SAS presented the third morning paper, *Reliable criteria for the selection of flashing liquid expanders (FLE)*. Roger's presentation described Cryostar's work to investigate the most suitable turbine technology for use in FLE service for LNG and mixed refrigerant (MR) service.

From in-house experience Cryostar investigated three different technologies in the development of FLE for LNG. These are multi-stage FLE (derivative of the reverse centrifugal pump), impulse wheel FLE (derivative of the Pelton turbine) and single-stage radial inflow FLE (derivative of API 617 turboexpander).

Cryostar's conclusions are that the multi-stage FLE should not be further

Dr Roger Dambach

considered because of its limited ability to recover work from the flashed gas. For the impulse wheel FLE option, the difficulty of wheel material selection and ability to maintain homogeneity of the two phase fluid within the FLE, were cited as problems still to be overcome. Roger asserted that Cryostar's conclusion is that the single stage radial inflow FLE is the best performing and most qualified concept currently available to the LNG industry.

The first paper following the coffee break, *Low Cost, High Efficiency CO_2 Compressors,* was presented by Peter Baldwin of Ramgen Power Systems, USA. CO_2 compressors using current proven technology represent approximately 33% of the capital and operating cost of an amine based carbon capture and storage system. Due to limitations in allowable pressure ratio for high molecular weight CO_2, eight stages of compression are needed

Peter Baldwin

GPA Europe Technical Conference, Paris

for overall pressure ratio of 110-140:1, and ten for a ratio of 200:1. The Ramgen design is seeking to overcome this limitation. Another advantage of the Ramgen design is that a very high proportion of the input energy is recovered at 500°F as opposed to 200°F with conventional technology, much more suitable for integration with the amine unit. To address the two key objectives of the US Dept of Energy for CCS, lower costs and improved efficiency, Ramgen is developing a unique shockwave compression technology based on proven supersonic aircraft inlet design. The principal advantage is that it can achieve very high efficiency at very high single stage compression ratios of up to 10:1, and Ramgen has demonstrated the performance of a single stage design on air at a compression ratio of almost 8:1, a world record performance. On review of the results, the US DOE has authorized the next phase of work to begin in the development of a CO_2 specific design for pilot scale feed. In late 2008, Dresser-Rand Inc announced that it had made an investment in Ramgen Power Systems to support further development and commercialisation of the technology.

The next paper, *An Overview of Compression Options for FLNG*, was presented by Tom Fuggle of Dresser-Rand, UK. Tom broadly reviewed the requirements and challenges for compressor selection for an FLNG project in which he covered the three main process refrigeration options of Nitrogen, Mixed Refrigerant and Cascade. The importance of definition of the compressor duty, the compressor performance map, the compressor configuration, series and parallel operation and train size was stressed. The need to match and integrate the compression equipment with the selected process, the optimization of the equipment to improve efficiency, flexibility and availability in order to maximise LNG production was highlighted.

Tom demonstrates the effective use of a simple visual aid

As usual the presentations lead to an intense and revealing Q&A

The wide range of compressor drive options was described, comparing the use of generators and electric motors versus mechanical drives and the critical selection parameters of efficiency availability, weight and space requirements were covered. The influence of the above selection parameters on compressor train configuration, number of units and sparing philosophy, along with flexibility of operation and availability was outlined. As gas turbines are most often selected for offshore applications, a summary of various gas turbine drive options was described and compared to highlight the importance of packaging to improve availability and minimize effects of varying ambient conditions on the plant operation. The role and importance of maintenance, condition monitoring and service contract possibilities on availability and reliability in reducing operational risk was covered. Finally the impacts of the above factors on CAPEX, OPEX and hence project financial viability were summarized.

The final paper of the morning session, *Optimisation of Large Gas Compression Systems for Gas & Condensate Fields using "Integrated Asset Models"*, was presented by Dr Sib Akhtar of MSE (Consultants) Ltd. Sib described the challenges of design and specification of compressors for large gas fields characterised in early field life by high reservoir pressures and where plateau production rates are maintained by drilling additional wells. As the reservoir pressures decline during the life of the field, compressors are needed to maintain pipeline pressure and maximise production. The compressor basis of design is often difficult in early stages of a project, and, if not done well, can seriously affect the life costs of a project.

Sib recommended that design of gas compressor systems for gas and condensate fields should include future upgrade requirements during Concept Design, FEED and equipment design and specification. He recommended that the compression system should be developed using Integrated Asset Models that can be used to examine various different compressor design configurations in order to optimise the solution. The development of such models using GASMAN ™ to examine reservoir, wells and wellhead performance, pipeline network and compression systems was described. Examples of large UK gas fields that required additional compression during project life were described and a number of large international projects where GASMAN™ models for compression systems were developed were detailed. *David Healey*

Tom Fuggle gets animated

A welcome return for Dr Sib Akhtar

GPA Europe Technical Conference, Paris

After the buffet lunch, the afternoon session opened with a paper from May-Britt Hägg, from the NTNU Chemical Engineering department in Norway, entitled *Challenges related to optimised membrane modules for natural gas sweetening*. Commercial membrane modules for natural gas sweetening are either made as spiral-wound membranes (cellulose acetate and its derivatives) or hollow fibres made from polyimides. New materials with optimised separation properties for CO_2 removal from natural gas are continuously in focus for research. Several materials, such as Nanocomposites, facilitated transport membranes and carbon membranes with both high selectivity and high permeance for CO_2 have all been documented on a laboratory scale. Improved separation properties will reduce membrane area and loss of methane. The challenge is to scale-up the membrane from the laboratory to the pilot plant scale despite the lack of facilities and funds.

The preferred configuration for membrane modules are hollow fibres, due to their high packing density (permeation area). There is a significant challenge to convert the optimised separation properties obtained in the laboratory from flat sheet membranes to hollow fibres – even using the same type of material. Durability of the membrane towards components such as H_2S and higher hydrocarbons may easily be tested in the laboratory, but their long term durability needs to be proved in a pilot plant. Another major challenge is that high pressure test rigs simply cannot be placed "just anywhere". May-Britt estimated that it would take another ten years of slow but steady progress to get from the lab and into a commercial application.

A quiet chat over lunch

Next up was Tom Cnop, from UOP N.V. in Belgium, with a paper entitled *Separaex Membranes for Natural Gas Treating – a novel design to reduce footprint and weight*. Tom explained that membrane technology had been widely used for separation acid gases such as CO_2 and H_2S from natural gas due to their cost effectiveness, reliability, ease of operation and their suitability for remote installation, both on and off-shore. Typically, membrane elements are installed in series in a membrane tube, and multiple membrane tubes are installed in parallel to form membrane skids. The size of the skids is controlled by the height and shipping limitations of the particular project. For large systems, the amount of pipework, together with the structural steel to support the membrane modules, adds footprint and weight to the overall membrane installation.

UOP has responded to this challenge by developing a novel system for membrane assembly called "Multitube". The Multitube is based on a compact design within a pressure vessel containing a plurality of membrane tubes and flow adaptors, simplifying the process stream connections. This increases the membrane packing density, reducing footprint and weight. A 7-tube unit has now been successfully tested at a natural gas plant. This success means that membrane systems will become even more attractive for large projects, whether onshore or offshore.

Taking us up to the coffee break was David Averous, (co-authors Florian Picard and Gilles Aubert) from Fives Cryogenie, who talked about *Ensuring the reliability of aluminium platefin heat exchangers.* David first provided some background, explaining that aluminium brazed plate fin heat exchangers (PFHE) have been extensively used in the cryogenics industry, in particular gas processing applications such as LNG plants. The complex technology of PFHEs offers a high degree of heat transfer capacity and a large range of operating pressures, but requires highly skilled design. Optimal design

May-Britt Hägg

Tom Cnop

GPA Europe Technical Conference, Paris

David Averous

Speakers, Session Chairmen and Programme Co-ordinator

leads to some difficulties because any hydraulic or thermal perturbations in one stream will be directly propagated to the others through the aluminium core matrix, and could directly impact on the mechanical integrity of the exchanger. This is particularly true for off-design and nonsteady state conditions.

David went on to describe the implementation of several sophisticated methods for modelling the operation of PFHEs, including thermo-hydraulic analysis and mechanical stress studies. Fives uses in-house computational tools to highlight the physical phenomena inherent in the behaviour of PFHEs during both normal and abnormal operating conditions. The results of these calculations lead directly to improvements in the reliability of the exchangers, and also fine-tune the standard design rules.

Fourth on the programme was Dag Kvamsdal, (co-authors Mauritz Talseth and Fredrik Carlson) from Cameron Process Systems, Norway, who presented *Design and verification of internals used for high pressure gas scrubbing*. Dag explained that the design of efficient high pressure gas scrubbers (demisters) is a real challenge. New high pressure scrubber designs should be compact, robust and use internals that have been verified at real flow conditions. It is common that internals used in high pressure gas scrubbing are often verified at low pressures, with model fluids or air and water test rigs. Dag explained why this procedure was often inappropriate for modelling the actual fluids at high pressures, and was a poor basis on which to base process guarantees. It has been found that only by testing at high pressures with real fluids are satisfactory designs achieved, due to the difficulty of predicting the fluid behaviour at higher pressures. This is mainly due to the reduced density differences at higher pressures and also the reduced surface tension. Computational Fluid Dynamics (CFD) is used to design the internals for high pressure scrubbers, but has its limitations.

Dag Kvamsdal

Liberato Ciccarelli

Rounding off the afternoon was Liberato Ciccarelli, from ENI, Italy (co-authors Alberto Ansiati of TEA Sistemi and Umberto Spinelli of Wringing srl) who explained the challenges of *Experimental efficiency determination of a solid separator device – the wringing separator*. Liberato explained the problems resulting from the entrainment of small iron oxide particles (c. 6μm) from pipelines in the natural gas streams flowing through them. These particles can compromise the performance of downstream recompression equipment and block tubes. These blockages can often lead to process upsets in amine and glycol plants. For this reason, ENI E&P adopted a "wringing separator" that is able to remove all particles above 1μm. They have been particularly effective in the Mellitah plant in

GPA Europe Technical Conference, Paris

Libya, where solids are removed from the gas arriving from the Wafa field.
However, following pigging operations, many of the rust particles exhibit a diameter below 1μm, making their removal more difficult. In an attempt to solve this problem, a new model of wringing separator has been developed and tested in the TEA Systems facilities in Pisa. In the experiments, two different types of particle were used; iron oxide and furnace residue, which have different "granulometries". The tests were performed on two different types of wringing separator – the "multi principle" and "standard principle" types, with air flow rates between 60 to 350 m^3/h, and a particle concentration of 1-2 g/Sm^3. The "multi principle" type has numerous spirals slotted together to form one main spiral, whereas the "standard principle" type has three separate spiral elements placed in parallel. The tests demonstrated that the two separators offer similar separation efficiencies; they are also both able to separate a wider range of iron oxide particle diameters. In conclusion, the tests show a similar behaviour between the two configurations when considering the pressure loss between the separator inlet and outlet. It is expected that these improvements will be useful in upgrading the current generation of wringing separators at Mellitah.
This brought the afternoon session to a close. *Justin Hearn*

GPA Europe Knowledge Session, Paris

Mass Transfer

The session was presented by Martin Copp (Sales Manager Europe) and Claire Haycock (senior process engineer) from KOCH-GLITSCH (packed tower product).This session looked at the main considerations for selecting the appropriate internals for any mass transfer application and focuses on the importance that column internals (distributors, supports, collectors, etc.) have on the efficient operation of packed mass transfer columns.
KG presented the differences between trays, random packing and structured packing, and highlighted the importance of liquid distributor design for each application. The mass transfer mechanisms are different for each family:

- Trays consider continuous liquid against dispersed vapour
- Packing considers continuous vapour with dispersed liquid.

They then introduced the motion effect with an impressive video from their test centre, showing a real column subject to rolling and pitching. In a floating unit, static tilt is the worst condition for heat and mass transfer, as inclination provokes by-pass of gas. This is obvious for trays, which are not used in floating units. Structured packing is preferred to random packing in floating units; however the research and development in this domain is on-going, and the speakers could not say too much about new results (random packing) and development.
The speakers gave us a clear review of mass transfer devices; they introduced their future challenges (motion), and they replied to all the questions with emphasis and clarity. This session was really appreciated by the audience, who expressed their satisfaction with long applause.
GPA Europe would like to thank Koch-Glitsch Engineering services for their support of the knowledge sessions and the two presenters. *Loïc Barthe*

Claire Haycock

Recipients of the GPA best paper award (see page 14) as well as bringing honour to GPA Europe enjoy pleasant company at the Annual Convention in the USA!

STOP PRESS

GPA Europe announces the best paper awards for 2009. The winner is Luke Addington for his paper presented at the Spring conference in Sitges, Spain, titled *An Evaluation of General "Rules of Thumb" in Amine Sweetening Unit Design and Operation.* This paper borne out of "real world" observations regarding the validity or otherwise of some motherhood and apple pie statements in this area was not only well presented and received but full of useful guidance. Luke has also presented this paper at the US Annual Convention already and since one of the bonuses of receiving this award is GPAE financial support to present the "Best Paper" at the annual convention, this honour will go to the second placed Kees Smit who presented *Pitfalls in the Design and Operation of Mol Sieve Units for the Removal of Water and Mercaptans.* Clearly a common thread can be seen which is that papers coming out of Operational experience are very well received if somewhat rare.

GPA Spring Conference, Vienna

Under the grey, May skies of Vienna, the Danube was unfortunately not blue, but the GPAE Spring Conference at the Hilton Vienna Danube hotel brightened the gloom and provided a tantalizing glimpse into the world of Unconventional Gas, a probable, not-so-distant future source of feed for the Gas Processing Industries.

The morning programme of papers was opened by Luisa Shelenko (co-author Martin Brown) of GL Noble Denton who presented their paper *Biogas - A Never Ending Source of Natural Gas*. This described a techno-economic study of processing options for improving the quality of bio-gas derived from the Davyhulme waste water treatment plant in Manchester, UK. The objective was to upgrade gas quality to pipeline specification for injection into the UK National Transmission System. Many of the processes Luisa described are already in common use by the Gas Processing Industries. Oxygen and arsine were identified as bio-gas contaminants requiring special attention. Luisa disclosed that pressure swing adsorption was determined to be the most economic option for this specific application.

Bio-gas was also the subject of the second paper of the morning, *BIOgas - Bring it on* presented by Christian Reimann of BASF. Christian posited that there were great opportunities and drivers for bio-gas production in Germany with up to 10 billion cubic meters being produced annually from this source by 2030. Low source pressure, high CO_2 levels and the presence of oxygen in the stream pose the main challenges for quality improvement. BASF's Pura-Treat, an amino-acid based process, offers one solution to this issue, although Christian admitted that the process has yet to be tested for wider application on power plant flue gas streams.

Christian Reimann

Luisa Shelenko

Nathan Vetter

The final paper before a restorative coffee break, *BMW Doubles Output of "Landfill Gas to Energy" Project in South Carolina,* was delivered by Nathan Vetter (co-author Michael Schunk) of Cameron Compression, USA. Nathan described the facilities at BMW Spartanburg, South Carolina. This is the first US project that is generating electric power from remote landfill methane. Landfill gas is piped 9½ miles through a 12" pipeline before compression to 20barg. Installation of two new Solar Taurus 70 turbines and TG2040 compressors has contributed to major efficiency improvements that have doubled power output to 11MW from a constant landfill gas feed rate. Nathan concluded by describing the optimum compressor and seal selections for this currently unique application.

Suitably refreshed by the break, the morning session was rounded off with two papers on Underground Coal Gasification (UCG). Julie Lauder, CEO of the Underground Coal Gasification Association, gave a presentation entitled *Overview of Underground Coal Gasification - A Clean, Safe, Indigenous Energy Supply* and surprised the audience by describing the Angren Plant in Uzbekistan that has been proving this 'new technology' for 48 years! Technology advances developed by the oil and gas industries such as 3-D seismic surveys and directional drilling have overcome many of the perceived technical issues that have hindered wider application of UCG. Julie declared that UCG is entering a new and exciting phase with projects

Julie Lauder

GPA Spring Conference, Vienna

being planned in the USA, Europe, Asia and Africa. While there are still legal and regulatory issues to be discussed and addressed, underground coal gasification has arrived as a viable technology in the clean coal era.

The final paper of the morning, *Underground Coal Gasification in Europe - a road map for success,* continued with the underground coal gasification theme and was presented by Rohan Courtney, Chairman of Clean Coal Ltd. With clever animation, Rohan explained the principles and operation of a UCG development, with specific reference to Clean Coal Ltd's Swansea Bay licence. Swansea Bay will be the first of eleven UK UCG projects and was carefully selected for its offshore coal seam to overcome 'nimbyist' objections. Produced syngas will be directed to a local power station for generation of electricity, thus minimizing the need for surface gas processing facilities.

Lunch arrived in timely fashion to allow the audience to digest not only their meal but also the wealth of information divulged by the morning speakers. *David Weeks*

Rohan Courtney

Hans-Martin Schulz

The afternoon session began with a discussion of *Shale Gas in Europe: the Significance of a new Unconventional Gas Resource* by Hans-Martin Schulz (co-author B Horsfield) of GFZ German Research Centre for Geosciences. Interest in shale gas in Europe has been enhanced by the recent significant development of shale gas in the USA where 1 TCFA of shale gas is produced from over 40,000 wells. The technologies that have opened up shale gas in the USA - horizontal wells and fraccing (the enforced fracturing of the shale to enable the gas to more rapidly flow to the well-head) has suggested that such systems could be exploited in Europe to develop the estimated 510 TCF of gas available from this source. This may be only a small proportion of the estimated global shale gas resources of over 16,000 TCF; however the distribution of shale gas in Europe is different from the USA with greater compartmentalisation which, Hans-Martin suggested, will require creative geological thinking to identify where the best locations to carry out development will be. Indeed, Hans-Martin suggested that the estimate of available and deliverable European shale gas may be an overestimate.

Fortunately a considerable wealth of data does exist on the varying shale forms available in Europe and GFZ have been actively collating this information to develop a database of shale gas formation data which can be used to predict gas-in-place and fracabilty - the GASH ("Gas Shales in Europe") scientific initiative. Information stored in the database includes depth, thickness of the bearing rock, TOC contents, type of organic matter, hydrogen index, maturity, gas shows, well log and seismic information and the database in viewable form via a web-viewer.

Whilst this information is available for analysis, no shale gas is currently commercially developed in Europe

Lunch; Stimulation for the mind and body

A welcome sight, the two Session Chairmen coordinating!

and although a number of exploratory wells are being developed, the European environment will raise a number of challenges not met in the USA such as land access and environmental concerns, with costs being higher and mining regulations tighter. Hans-Martin also noted that the European population are not yet aware of the considerable amount of drilling necessary to develop shale gas plays and the huge amount of water required for the fraccing process. These challenges still have to be overcome, but the data available from the GASH project will be of assistance in the development process.

Dik Paul, Regulatory Affairs Manager for Shell, provided a discussion on *Unconventional Gas in Europe* and the role of shale gas that Shell has been studying. Noting the attractiveness of natural gas as against coal and the time taken to achieve increased power production from nuclear and renewable sources, natural gas faces both a growing demand yet is challenged by declining domestic supplies and thus increasing requirement to import LNG or natural gas from the East. Natural gas produced from Shale, Tight or Coal Bed sources looks like an attractive source of natural gas to augment the future demand. Dik discussed the differences between these sources:

- Tight gas comes from reservoirs where the gas is contained in very low permeability and low porosity rocks,
- Shale gas is trapped in kerogen shales, and
- Coal Bed Methane originates from hydrocarbon adsorbed into coal seams and either released during mining, or by drilling into virgin coal seams.

Each of these sources has considerable challenges but Dik drew attention to the fact that half of US production of natural gas now comes from such unconventional sources with tight gas representing almost 40% of US production.

In Europe, Unconventional Gas is currently only exploited to a small extent, but with EU estimates of perhaps 35 TCM of such gas, the source represents perhaps 60 years of production at consumption rates expected in 2030. Potential areas of such gas include much of Central Europe but also areas of UK, Sweden and France.

Shell has been studying the potential for Shale gas production in Sweden. Seismic investigation has identified seven possible sites for development and well testing is already underway with a second and third well being developed in 2010, but the programme is being carried out in an area of particularly sensitive local communities and Shell has been working hard to ensure these groups are comfortable with their programme. A particular area of issue is the number of wells required to provide a sufficient flow of gas from the field to make development worthwhile.

Development of Unconventional Gas requires a combination of the right regulatory capacity, technology and a contractor base, if future demand is to be satisfied and sustainability increased whilst driving down costs and minimising CO_2 emissions. Examples of the technology approaches are the development of Ultra Slim wells. Standard designs will step down well diameter from 13 3/8" to a bottom hole diameter of 8 3/8", whilst ultra slim holes will step down from 5" casing to 2.9" diameter. This results in a major saving in casing and cementing costs which is of particular attraction when many more wells are required compared with conventional gas fields. The number of wells will also be reduced by drilling multiple directional wells from a single well site which will reduce the impact on the local environment.

Natural Gas is the preferred future fuel of choice which, if a new "Dash for Gas" were to begin, would achieve an almost immediate 24% cumulative reduction in UK CO_2 emissions by 2050 by replacement of coal fired power production. Power

Dik Paul

A bit of light relief during the Q&A

produced from gas sources is much cheaper than conventional power production, both in terms of fuel cost and CAPEX, and is relatively available if unconventional gases are exploited from local sources. Gas therefore becomes the key element of the future energy mix, a destination fuel in Dik's parlance, and thus gas currently referred to as unconventional may become conventional in the future.

The next papers concentrated on the processes and equipment that can be exploited to develop the Unconventional Gases when they arrive at the surface. Doug Harris of Pall Europe discussed *How separations technology can improve the efficiency, economics and environmental impact of the development of unconventional gas sources*. Methane rich gas available from coal, whether from virgin coal beds, particularly those from deep coal seams, or from operating or closed mines, are receiving increasing attention as a viable source of methane. Gas can also be produced from biomass digesters. However impurity content can be significant with high levels of carbon dioxide, air and water having to be removed before the gas can be effectively used, even if this is only in local power generators such as gas engines.

Doug reported on a case study carried out for Origin Energy in Queensland, Australia, into the treatment of coal bed methane water which has to be removed from the coal seam to allow the methane to flow. The water is brackish or saline and large quantities of this must be produced, particularly in the early stages of production. A combination of Pall's Hollow Fibre Membrane Micro Filtration (MF) system in conjunction with a RO system was tested in a specially built pilot facility. The full scale plant was subsequently installed which is now treating 12 million litres per day of brackish water which can now be released to local water courses.

Doug Harris

Time to concentrate

A second case discussed the treatment of mines gas as a local power source. The application was developed in association with Clarke Energy which provide, packaged generators to produce local electricity from waste mines gas. The quality of the feed gas does however need to be controlled, and in particular the presence of liquids or solids in the gas. Initial operation was successful but long term operation was affected by blocking due to iron corrosion compounds and calcium rich material. The solution was found in installing a filter upstream of the cooler and coalescer which then enabled the system to provide consistent gas for operation of the machinery and has now been successfully installed on a number of other sites throughout the UK.

The next paper was presented by Matthew Humphrys (co-uthors Peter Carnell and Vince Atma Row) of Johnson Matthey Catalysts discussing the *Purification Technology for CNG used in Road Transport* or Natural Gas Vehicles (NGVs). Matthew noted the increasing attractiveness of CNG for vehicle fuel providing a much cleaner burn than conventional fuel. Currently there are over 11 million natural gas fuelled vehicles globally with an average annual growth rate of 27 - 29% over the past decade. However, the use of CNG is predicated on its purity being satisfactory for modern vehicles. Contamination by sulphur compounds can damage the catalytic

Matthew Humphrys

converter's ability to convert NOx. While gas specifications are generally focussed on the burn characteristics of the fuel, there can be a surprising range of total sulphur limits from as low as 12 ppm to 450 ppm within the same country. In order to reduce the weight of vehicles, the industry is moving to gas storage tanks made of a composite external material around an aluminium containment vessel. Mercury embrittlement of aluminium is a well-documented phenomenon which would be catastrophic if it occurred to a vehicle's gas storage. In addition there is some evidence to suggest that mercury may impede the reaction of benzene hydrogenation in the catalytic converter and emission of mercury to the atmosphere would be a key environmental concern.

In Abu Dhabi, Johnson Matthey's PURASPEC adsorbent has been installed on a number of NGV filling stations, including one at Yas Island to service demand at the Grand Prix venue. The adsorbent is ideally suited to the adsorption and elimination of both sulphur containing compounds and mercury from the natural gas stream, making the gas much more suitable for NGV use. Associated with the use of PURASPEC adsorbent, Johnson Matthey also offer their PURACARE service to gather and process the spent adsorbent for the recovery of the sulphur and mercury adsorbed during operation.

Co-presenters Nawid Kashani and Peter Wlaschitz

The final paper of the Conference was presented jointly by Nawid Kashani of BASF and Peter Wlaschitz of OMV on the subject of *Meeting sulphur specification regulations in Austria*. The paper was an excellent scene setter for the site visit the following day to the OMV facilities in the Upper Austria region around Vienna.

Nawid commented on the increasing requirement to process natural gas containing higher levels of sulphur species than previously. A key area of concern here is that traditional MDEA systems are not able to deal with the removal of CO_2 and COS formed by the hydrolysis of H_2S and CO_2. BASF have, however, shown that by the use of aMDEA, an activated version of the amine, COS removal can be increased, indeed exceeding removal rates of CO_2.

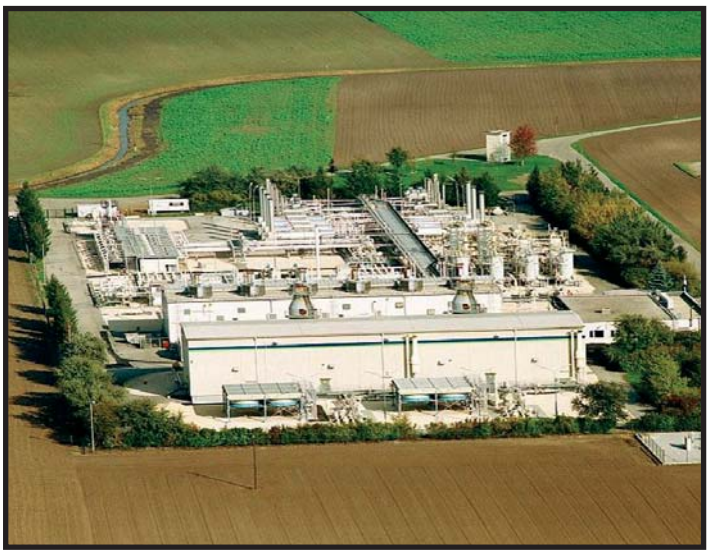
At OMV's gas treatment facility at Anderklaa in Austria, acid gas has been handled by a two stage MDEA absorber followed by both HP and LP flash with recovery of the absorbed species in a stripper. New Austrian gas specifications call for CO_2 content less than 2%, total sulphur less than 10 mg/m^3 and H_2S and COS content each below 5 mg/m^3. At Anderklaa, the feed gas contains up to 12% CO_2, 2% H_2S and 25 - 50 mg/m^3 of COS. Achieving the new specification with the existing absorber system was therefore only achievable by reducing the capacity of the facility or blending the sour gas with a cleaner gas stream. A study was therefore undertaken to upgrade the current absorption system.

Over a six-month period, the subject was studied, new solvent supplied to meet plant shutdown and the facility started up and successfully tested. By using the modified aMDEA material the specification of the gas was more than met with CO_2 concentration being less than 0.6%, H_2S levels below 0.2 mg/m^3, COS below 0.2 mg/m^3 and total sulphur at 12 mg/m^3, less than half the required level. The change also resulted in reduced reboiler energy consumption due to a lower lean solvent flow rate requirement. OMV congratulated BASF on excellent co-operation and exchange of information to achieve the programme. *Sandy Dunlop*

Speakers, Chairs and the Danube

Tour to the OMV Plants in Lower Austria

Compressor Station Auersthal



Gas Storage Facility Schönkirchen - Reyersdorf

Tank Farm Auersthal

Sour Gas Plant Aderklaa I & II

On Friday morning, a group of around 30 gas processors, thirsting both for knowledge and coffee, boarded the coach to OMV's administration and training facility at Gänserndorf.

We were met by Alexander Gerstner, who provided first the coffee, and then the knowledge, in the form of an interesting introduction to OMV's history.

The oil industry in Austria effectively began in 1934 with the first commercial well, Gösting 2. In 1945, after the end of the war, the nascent oil industry was taken into Soviet administration, when it was rapidly developed by the Russians until 1955, when the Austrian State Treaty reestablished Austria as a sovereign state, ending the occupation.

OMV were created in 1956 and were originally called the "Österreichische Mineralölverwaltung" – the "Austrian mineral oil administration" – but today they are simply known as OMV.

OMV signed a gas supply contract with the Soviet Union as early as 1968 and began to store gas underground shortly afterwards. In 1985 they made a strategic move overseas by acquiring a 25% stake in Oxy's Libyan operation. In 2004, OMV bought a 51% share in Petrom SA (Romania).

Today, in addition to its domestic production in Austria, OMV has focused its E&P activities in 6 major areas – UK, Romania, Libya & Tunisia, Yemen & Pakistan, Kazakhstan and New Zealand. Around half the total production, 317,000 barrels of oil equivalent, is produced in Romania.

Following Alexander's introduction, and some further refreshments, we re-boarded the coach and set off on a tour around the nearby facilities with our vastly experienced guide, OMV retiree, Herr Karner, who peppered his talk with numerous experiences from the days when he worked at most of the nearby facilities.

In all, we drove to the tank farm and compressor station at Auersthal, the Gas Storage Facility at Schönkirchen – Reyersdorf, and finally the Sour Gas Plant, Aderklaa I & II, the subject of a technical presentation the previous day.

After returning Herr Karner to the offices at Gänserndorf, we bid our cheerful guide farewell, and the bus took us to the airport. *Justin Hearn*

All photos are reproduced here courtesy of OMV Austria E&P GmbH

Awards

John Sheffield receives his GPA Citation for Services from Bob Dunn, President of the GPA

Adrian Finn and Colin Woodward both receive GPA Exceptional Paper awards for the 2009 San Antonio meeting

Call for Papers

For 2010 / 2011Conferences

November 25th 2010, London UK - CO_2 Capture and Sequestration + AGM
February 23rd - 25th 2011, Amsterdam, Netherlands - Operations, Maintenance, Reliability and Safety
March 23rd 2011, Gastech, Amsterdam - GPAE Theatre Sessions in Exhibition Hall
May 25th - 27th 2011, Copenhagen, Denmark - Impurity Removal Technologies (incl. O_2, Hg, COS, mercaptans)
September 21st - 23rd 2011, Prague Czech Republic 28th Annual Conference
November 2011 - Gas Processing Technologies in a GTL Environment + AGM

GPA Europe is again offering a "Cutting Edge" Conference Programme for 2010 / 2011. If you would like to present a paper at one of our meetings can you please submit a Title and a Brief Abstract (100 - 200 words) as soon as possible.
All submitted papers will be reviewed by the Programme Committee. Paper selections will be advised in good time to enable preparation of the paper. Guidelines for the preparation of your paper and accompanying presentation are given in our Information Document, "Guidelines for Authors".
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Benefits to be gained by speaking include:

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- Positioning of the speaker and organisation alongside the most respected and knowledgeable representatives of the industry;
- Face to face contact with an audience of senior level managers and engineers.

Remember, nothing beats people coming together under one roof to share information, build rapport and motivate each other.
Papers on any relevant aspect, technical or commercial, are requested and contributions from both operating companies and suppliers will be particularly welcome. We also encourage papers from younger engineers that may qualify them for the prestigious Aungier Award.

Abstracts and other information should be sent to the Administration Office

GPA Europe, 10 Shetland Way, Fleet, Hampshire GU51 2UD
email: admin@gpaeurope.com facsimile: 01252 786260

New Corporate Members

Welcome to our new Corporate Members who have recently joined

PREMIER

EON Ruhrgas, Germany - Shaping the Energy Future. In its 80-year history, E.ON Ruhrgas AG has developed from a regional distributor to an international gas company. E.ON Ruhrgas offers a complete range of services and products for the transportation, storage, marketing and use of natural gas.

Gassco AS, Norway - Gassco is the operator for the integrated system for transporting gas from the Norwegian continental shelf to other European countries. This role confers overall responsibility for running the infrastructure on behalf of the owners.

Perenco UK - Perenco operates five compression hubs/gas gathering platforms with their connecting pipelines to Bacton on the Norfolk coast, East Leman, Inde, Trent, Lancelot and Thames. Various satellite fields also flow through these hubs. Perenco also operates the Pickerill field which flows gas through a dedicated pipeline to the Conoco operated gas receiving terminal at Theddlethorpe.

SINTEF, Norway - The SINTEF Group is the largest independent research organisation in Scandinavia. Every year, SINTEF supports the development of 2000 or so Norwegian and overseas companies via their research and development activity.

Vopak LNG Projects, UK - As an independent global LNG terminal company, Vopak LNG develops and operates LNG regasification terminals. Vopak LNG serves a multitude of customers through the LNG regasification terminal infrastructure. Using the existing terminal network of Vopak worldwide, they are able to serve customers at all main ports in the world.

LEVEL 2

Chart Energy and Chemicals, UK - Chart is a leading independent global manufacturer of highly engineered equipment used in the production, storage and end-use of hydrocarbon and industrial gases. The majority of the company's products are used throughout the liquid gas supply chain for purification, liquefaction, distribution, storage and end-use applications, the largest portion of which are energy-related.

Danfoss A/S Oil and Gas, Norway - Danfoss Oil&Gas CLP pumping solutions are designed for metering, injecting and transferring various chemicals, additives and other hard-to-handle fluids into production pipeline systems, gas wells and oil wells.

Optimus Services Ltd, UK - Optimus Services is a company of engineers, consultants and project managers founded by its principals in 2005 to meet the demand for a quality and experienced engineering service in the Gas, Oil and Energy sector. They offer technical services to gas and oil producing companies who have identified business opportunities, but lack either the expertise or the resources to develop the technical solutions required.

PGNiG, Poland - Polskie Górnictwo Naftowe i Gazownictwo is the largest Polish oil and gas exploration and production company. It is a leader in natural gas segments in Poland that are trade, distribution, oil and gas exploration and production as well as gas storage and processing. The company is also the largest importer of natural gas to Poland.

Process Systems Enterprise Ltd, UK - Process Systems Enterprise Limited (PSE) is one of the world's foremost providers of process modelling technology and model-based engineering and innovation services to the process industries and their technology suppliers.

Technodyne Technologies, UAE - Technodyne was established in the heart of the world's largest oil and gas reservoir to serve the energy sector and benefit from the emerging associated sectors - Oil and Gas, Power, Water, Construction and Infrastructure - by supplying innovative engineering products and solutions.

LEVEL 3

O&GBISS BVBA, Belgium - O&GBISS provides technical and commercial support and services to companies in the Oil and Gas Industry.

Never underestimate the value of your service!

Charles Steinmetz was a pioneering genius in harnessing electricity. After he retired, Steinmetz's former employers at General Electric occasionally relied on his brilliance.

Such was the case when an intricate set of machines broke down. In house experts could not find the cause of this malfunction so GE leaders called Steinmetz.

After testing various parts, Steinmetz finally pinpointed the problem and marked the defective part with a piece of chalk. Steinmetz then submitted a bill for $10,000.

Surprised at this unexpected high price (note the era he is from), GE honchos asked Steinmetz to resubmit an itemized statement-- he complied with a new invoice that listed only two items:

Invoice	
Making one chalk mark	$ 1.00
Knowing where to place it	$ 9,999.00
Total amount due	$ 10,000.00

Charles Steinmetz
1865 - 1923

FORTHCOMING EVENTS

2010

22nd - 24th September
Marriott Hotel, Lisbon, Portugal
27th Annual Conference
- Knowledge Session
- Technical Sessions
- Conference Dinner

25th November
Marriott Marble Arch, London, UK
CO_2 Capture and Sequestration
- Knowledge Session
- AGM
- Technical Meeting

2011

23rd - 25th February
Amsterdam, Netherlands
Operations, Maintenance, Reliability and Safety

23rd March
Gastech, Amsterdam
GPAE Theatre Sessions in Exhibition Hall

25th - 27th May
Copenhagen, Denmark
Impurity Removal Technologies (incl. O2, Hg, COS, mercaptans)

21st - 23rd September
Prague, Czech Republic
28th Annual Conference

November
Gas Processing Technologies in a GTL Environment + AGM

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Don and Wendy Cooney

GPA EUROPE

CORPORATE MEMBERS

This listing of current Corporate Members represents the status as at the end of June 2010. In addition there were 175 Individual Members

Corporate Level 1 PREMIER (29)

Atlas Copco Energas GmbH	**Germany**	**Offshore Design Engineering Ltd**	**UK**
BASF SE	**Germany**	**Pall Europe**	**UK**
Bechtel Ltd	**UK**	**Perenco UK**	**UK**
BP	**UK**	**Shell Global Solutions Int BV**	**Netherlands**
Compressor Controls Corporation	**UK**	**Siemens Industrial Turbomachinery Ltd**	**UK**
Costain Oil, Gas & Process Ltd	**UK**		
EON Ruhrgas AG	**Germany**	**Sime**	**Italy**
Exxon Mobil North Sea Production	**UK**	**SINTEF**	**Norway**
Fluor Ltd	**UK**	**Snamprogetti SpA**	**Italy**
Foster Wheeler Energy Ltd	**UK**	**Statoil ASA**	**Norway**
Gassco AS	**Norway**	**Technip**	**France**
GL Noble Denton	**UK**	**Tehran Raymand Consulting Eng's**	**Iran**
Jacobs Engineering	**UK**	**Total**	**France**
Lurgi GmbH	**Germany**	**Vopak LNG Projects**	**Netherlands**
M W Kellogg Ltd	**UK**	**WorleyParsons**	**UK**

Corporate Level 1 (23)

ABB Engineering Services	UK	Johnson Matthey	UK
Air Products Plc	UK	Kellogg Brown & Root	UK
Amec Group Ltd	UK	Koch-Glitsch (UK) Ltd	UK
Amines & Plasticizers Ltd	India	NORIT Nederland BV	Netherlands
AspenTech Ltd	UK	Petrofac Engineering Ltd	UK
BG- Group	UK	SAZEH Consultants	Iran
CB & I Ltd	UK	Siirtec - Nigi S.p.A.	Italy
CB&I Lummus	Netherlands	Sulzer Chemtech Ltd	Switzerland
CECA SA	France	Taminco	Belgium
Chevron	UK	Techint S.p.A.	Italy
ENI Div E&P	Italy	Wintershall Holding AG	Germany
GDF SUEZ	France		

Corporate Level 2 (54)

BASF Catalysts Germany	Germany	Mott MacDonald	UK
Bryan Research And Engineering	USA	Oil & Gas Systems Limited	UK
Cameron Petreco Process Systems	UK	Optimus Services Ltd	UK
Chart Energy and Chemicals	Canada	P S Analytical	UK
Criterion Catalysts & Technologies LP	USA	Peerless Europe Ltd	UK
Danfoss A/S Oil and Gas	Denmark	Penspen Ltd	UK
DtEC Services Limited	UK	PGNiG SA	Poland
E & P Consulting	UK	Pietro Fiorentini	Italy
E.I.C. Cryodynamics Division	UK	Process Systems Enterprise Ltd	UK
Enerflex (UK) Ltd	UK	Prosernat	France
Escher Process Modules BV	Netherlands	Purvin and Gertz Inc	UK
Exterran (UK) Ltd	UK	PX (TGPP)	UK
Fives Cryo	France	Rotor-Tech Inc	USA
FLEX LNG	UK	SBM Offshore Gusto	Netherlands
Frames Process Systems BV	Netherlands	Siemens Nederland NV	Netherlands
GdF Suez E&P Deutschland	Germany	SPT Group	UK
Granherne Ltd	UK	Sterling Thermal Technology	UK
H.A.T. International	UK	Technodyne Technologies	UAE
Hamworthy Gas Systems	Norway	TGE Gas Engineering GmbH UK Branch	UK
Heatric	UK	Twister BV	Netherlands
IMA Limited	UK	UOP NV	Belgium
ISG	Italy	Virtual Materials Group	Netherlands
Iv-Oil & Gas	Netherlands	VTU Engineering GmbH	Austria
John M Campbell & Co	USA	Weir LGE Process	UK
Kanfa Aragon AS	Norway	WinSim Inc	USA
M.S.E. (Consultants) Ltd	UK	Zeochem AG	Switzerland
Maxoil Business Solutions	UK	Zeta-PDM	UK

Corporate Level 3 (11)

Infochem Computer Services Ltd	UK	OAG Energy Consulting Ltd	UK
Kirk Process Solutions	UK	Oilfield Technical Solutions Ltd	UK
Matrix Chemicals BV	Netherlands	Optimized Gas Treating	USA
McMurtrie Limited	UK	Rowan House Ltd	UK
MPR UK Ltd	UK	Softbits Consultants Ltd	UK
O&GBISS	Belgium		

Academic Level (2)

NTNU Trondheim	Norway	University of Surrey	UK

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