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WHITE PAPER

UNDERGROUND GAS STORAGE IN CHESHIRE – THE COSTAIN EXPERIENCE

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Underground Gas Storage in Cheshire the Costain Experience

Costain Oil, Gas and Process have been involved in two large UK underground gas storage projects in Cheshire. The gas is to be stored in salt cavities, which have been leached specifically for the projects. The brine is a commercial product and the leaching process is constrained by the demands of the downstream processes.

Compression will be used at times during both injection and withdrawal. The NTS gas is injected into the cavern dry, however moisture is picked up during storage and this needs to be removed before the gas is delivered into the NTS.

The commercial and strategic reasons for underground gas storage are understood and widely reported. Some of the key design issues such as the choice of compressor, compressor driver and dehydration technology are important decisions and as they are long lead items need early decisions. Another technical area that needs special consideration is the amount of water that will be picked up in the cavern, as this sets the design for the hydrate control and corrosion control strategies.

This paper gives a brief overview of these two projects, the wider planning and environmental issues, and then covers some project specifics; compressor selection, material of construction, venting considerations, dehydration technology and the transfer from leaching to gas operations.

The GDF Gas Storage project at Stublach, currently in construction. View of the Solution Mining Compound

The E.ON Gas Storage project at Holford. Gas pipelines complete and Gas Plant in detailed design.

The need for Gas Storage

By 2010 it is predicted that up to 30% of our gas supply could be imported, by 2015 50% and by 2020 some 80%. This is a direct result of the decline in gas supplied from the North Sea and the low development of alternative supplies of energy, renewables and Nuclear. Since the discovery and development of the North Sea, the UK did not need to consider large amounts of Gas Storage as supply could be ramped up and down from offshore production to meet demand. As a net gas importer this is no longer appropriate and different strategies are needed in order to ensure future security of gas supply, in terms of availability and reliability and diversity of supply sources. A variety of UK entry points and storage options are starting to emerge with new pipelines from Europe and LNG import terminals, as well as underground gas storage facilities.

But why does the UK need to store gas? Strategically it allows security of supply in case there are disruptions to production, transport or supply. These could be due to commercial reasons, somebody else has paid a higher price for the gas, political reasons or an outage. To balance seasonal variations in consumption where the winter demand is greater than the summer usage. To cover peak demands such as weekday evenings. It can also enhance the effectiveness of gas transport and production, where it can be stored locally to where it is being used.

Commercially it is an opportunity for arbitrage and trading.

Gas Storage Types

There are a number of different methods of storing gas; the main methods are in aquifers, depleted gas fields and salt caverns. Each has characteristics that add diversity to the overall UK gas storage picture.

Aquifers

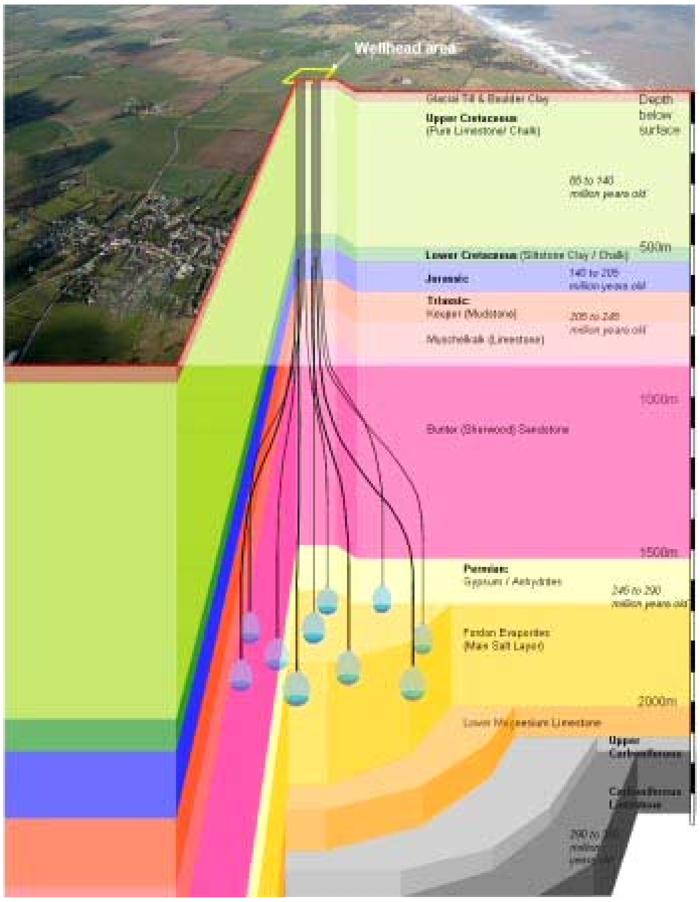
There is no aquifer storage in the UK and none in the public domain in planning, although there are potentially a number of areas where the geology looks promising. In the USA 16% of storage capacity is in aquifers. Aquifers are underground porous, permeable rock formations that act as natural water reservoirs. They tend to be more expensive to develop than depleted reservoirs and are usually used only in areas where there are no depleted reservoirs.

Depleted Reservoirs

The most common form of underground storage is depleted gas reservoirs. They are formations that have already delivered of all their recoverable natural gas. This leaves an underground formation, geologically capable of holding natural gas. It is likely that the original equipment would still be installed such as the wellheads and other production facilities. Of the three types of underground storage, depleted reservoirs are usually the cheapest and quickest to develop, operate, and maintain.

Salt Caverns

Salt caverns are formed out of existing salt bed deposits in the UK, although there are much larger caverns in the USA using salt domes. The cavern is man made by drilling a well down into the formation, and pumping water through the completed well to dissolve the salt which returns to the surface as brine. The walls of the cavern are very resilient against reservoir degradation.



Section showing multiple underground salt caverns. Picture courtesy of E.ON UK showing their planned facility at Whitehill. UK

As the salt cavern is an open vessel it offers very high deliverability. Flow rates can be high and they can be brought on stream and ramped to full flow quickly. They are best for peak loads and short term trading rather than long term seasonal storage.

Base Load storage will be in place to cover seasonal demand, they will be large and will not need to have high deliverability, will fill in the summer and deliver in the winter, turning over once a year and will be provided by depleted reservoirs.

Peak Load will be provided by salt caverns, where the deliverability is higher, turnovers will be higher and facilities are smaller. Salt caverns turnover can be daily or weekly, entirely dictated by commercial trading. Investment needs to be planned as projects take time to get online; for example GDF Stublach has a large number of caverns to leach and will progressively commission the caverns from 2013 to 2018.

Gas Storage in Cheshire

Cheshire produces most of the salt in Great Britain. It has been extracted since Roman times and plays an important role in supporting the industrial structure of the County. The salt deposits of Cheshire form part of the Triassic sediments that dominate the geology of the County. The major beds of salt are found in two well defined formations sandwiched between mudstone beds. The lower salt beds are known as the Northwich Halite and the upper salt beds as the Wylkesley Halite.

It is the thick layer of salt in the Northwich Halite that has lead to a number of projects being planned in the area. The Cheshire County Council minerals development plan has areas around Warmingham, where the EDF Hole House facility is operating and around Holford, where the E.ON and GDF projects are being constructed and the Ineos Enterprises H165 cavern is operating.

There are some other considerations regarding the project economics as in this area the brine can be used as a chemical feedstock rather that the more usual method of disposal at sea. The main users in Cheshire are the two soda ash plants at Northwich operated by Brunner Mond, a vacuum salt plant operated by British Salt at Middlewich and a chlor-alkali plant operated by Ineos Chlor at Runcorn. The alternative disposal route to sea requires a long pipeline through centres of population.

In addition there are planned facilities by British Salt Ltd at Hill Top near Middlewich which has received Hazardous Substances consent to convert 10 existing caverns and to solution mine 11 new caverns and by King Street Energy for a facility north of Stublach, which when complete would have 9 caverns and would be able to store 240 million cubic metres of gas.

View of the Pumping House with the degassing tanks in the foreground under construction at Stublach Brine and Water Facility

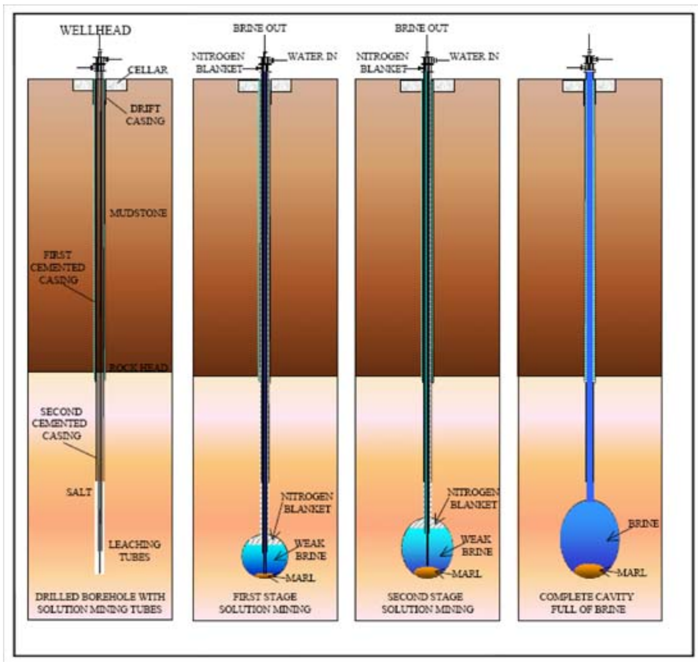
Gas Storage Basics

Normally, solution mining for commercial use of the salt forms a cavern shape that is not suitable for use in gas storage. The formation of a gas storage cavern needs to be carefully controlled to ensure that the depth will contain the pressure and that there is a minimum distance between caverns, such that they can operate independently.

Cavern Formation

There are many references that describe in great detail the technical issues involved in cavern formation and on the internet there are some excellent animations of the process. This article outlines the steps that are needed in the process, that can take as long as 2 years.

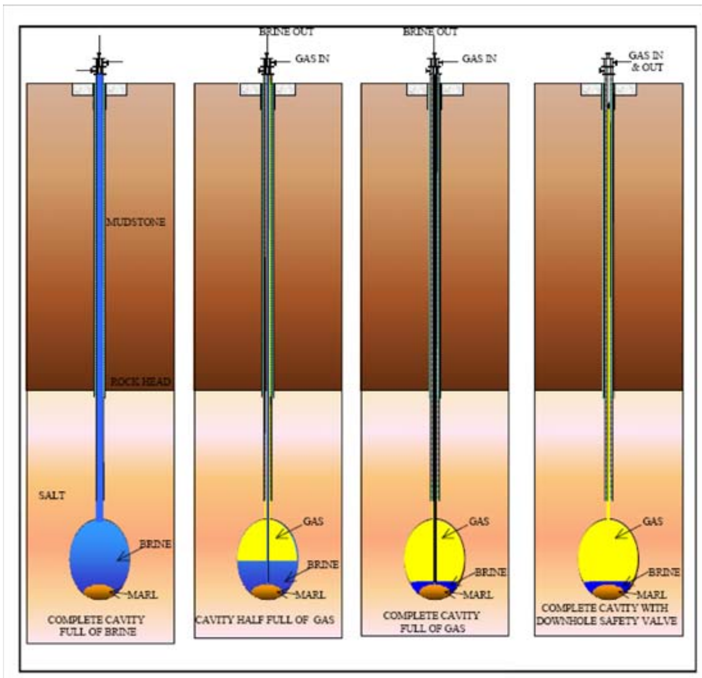
The initial part of the process is to construct the cellar and drill through the mudstone into the salt layer and cement in the casing. There are two strings introduced into the salt for the introduction of water and for the removal of brine. Nitrogen is also introduced above the brine, in the outer annulus, to be used as a blanket gas that controls the cavern shape. Water flow and residence time is carefully monitored where the brine is required as a chemical feedstock. The strings are shortened as the cavern grows taller and the cavern shape is regularly checked by sonar.



Cavern formation by solution mining. Picture courtesy of RPS prepared as part of the Stublach Environmental Statement

Debrining

On completion of the cavern it must be converted to gas. This process is known as debrining and essentially uses gas pressure to remove the brine left in the cavern at the completion of solution mining. Gas in introduced into the cavern and this pushes the brine out. The brine will contain dissolved methane, which will need to be removed before it is sent for disposal. If disposal is to sea, then this is relatively straightforward. If the brine is to be used as feed stock than removal of methane to low levels may be required. The debrining phase is generally in the region of 3 months.



Removal of Brine and replacement with gas. Picture courtesy of RPS prepared as part of the Stublach Environmental Statement

Compression

Compression is required potentially for both injection and for withdrawal, depending on the operating pressure of the cavern. For example, the caverns in the northeast are in deep salt and operate at pressures above the NTS pressure usually greater than 140 bar. The gas from the NTS is compressed into the caverns and then can free flow from the caverns back into the NTS without compression.

The proposed facility near Middlewich, at Warmingham for British Salt operates below the NTS at pressures between 20 and 50 bar and hence the gas could free flow from the NTS into the cavern and would need to be compressed back into the NTS.

Dehydration

The cavern has a heel of brine in the sump, which cannot be removed during the debrining operation and the dry gas injected from the NTS will pick up water in the cavern. The longer the residence time, the higher the water content. This water needs to be removed before it can be exported to the NTS. Various technologies are available as described later in the technology section of this paper.

Metering

The gas must be fiscal metered into the facility and back out of the facility. National Grid have standards that they require for flow accuracy, gas quality and cleanliness and the facility must meet them.

Design Considerations

Hydrates

The caverns, if the storage time is long, will tend to reach the same temperature as the surrounding salt, which gets warmer the deeper the cavern. In Cheshire this temperature will be approximately 25°C. The flow lines are buried 1.2m and will be considerably colder, approximately 5°C. When a cavern comes on line this warm gas will enter a cold pipeline, hydrates will form if the gas has achieved close to saturation. To overcome this hydrate inhibitor will need to be injected.

Once flowing and as the equipment starts to warm up hydrate formation is less likely and inhibitor injection can cease.

There are a number of variables in the operation of the cavern that will affect the likelihood of forming hydrates. If the dry injected gas is in the cavern for a short period then it is unlikely to reach saturation and hydrates will not be formed. If the gas is injected into the cavern hot, then it is less likely to form hydrates as it leaves the cavern.

If the gas leaving the cavern is not throttled by the wellhead valve, it will be less likely to form hydrates. Pressure letdown will be needed if the caverns are operating above the NTS pressure but this will generally be done, after heating, at the gas treatment plant.

Methanol is effective, however losses are high and recovery is expensive. Glycol needs to be injected in greater quantities, but can be recovered more easily and is also effective as a corrosion inhibitor.

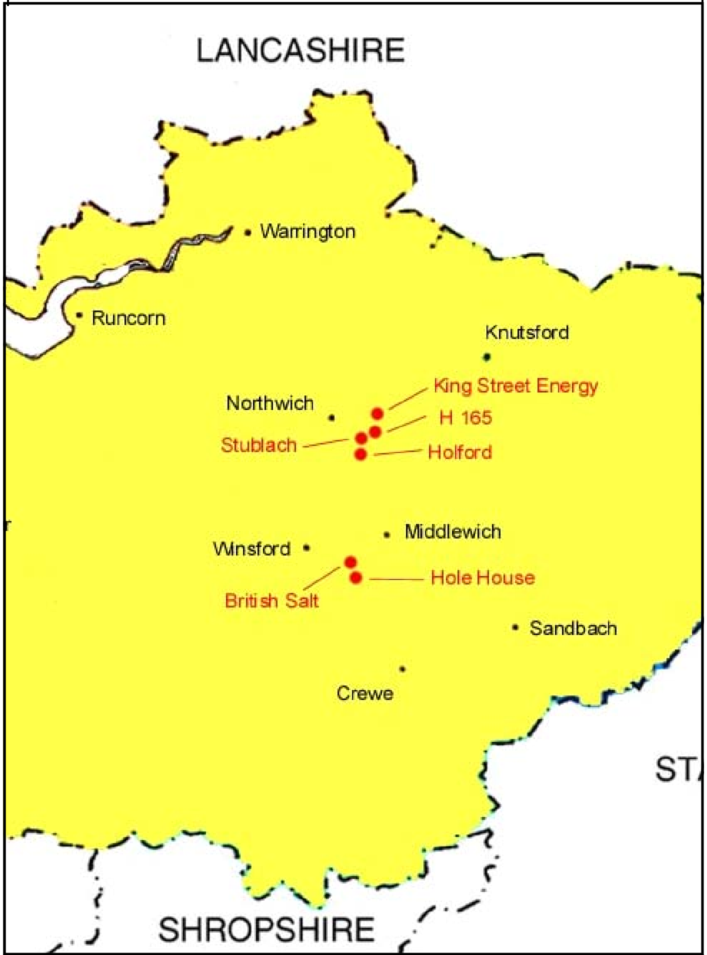
In a survey of European installations hydrates were prevented by measures, in order of popularity, methanol injection, gas heating, glycol injection and trace heating. Kinetic inhibitors were being investigated and regular pigging was thought to be useful.

Corrosion

The National Transmission System in the UK contains CO_2; the exact concentration will vary according to the location in the UK. The network entry agreements indicate a maximum value of 2.5%, but this may rise as the mix of imported gas changes with time. For the Transco pipelines there would not normally be a materials issue, as the gas is dry. In an underground gas storage system the gas while it is being stored in the cavern the gas picks up moisture, the exact amount will depend on how long it has been stored. On withdrawal from the cavern it is possible for free water to be formed in the flowlines between the well head and the gas treatment facility.

As a guide the Norsok standard M-506 can be used to determine the corrosion rates to be expected in the flowlines. With high partial CO_2 pressures and free water present, the M-506 spreadsheet predicts potentially signifi-

Salt Caverns in Cheshire



Holford

Being constructed by E.ON, Eight caverns in the Northwich Halite. Depths of between 630-730 m below ground level with up to 180 m of salt above top of caverns. Maximum cavern height 100 m with a maximum cavern diameter 90 m. Operating pressures of between 40 and 105 bar. Spacing between wellheads – 280 m

Stublach

Being constructed by GDF Suez. Twenty eight caverns in the Northwich Halite. Depths of between 600-650 m below ground level. Maximum cavern height 100 m with a maximum cavern diameter 100 m. Operating pressures will be lower than the Holford caverns. Spacing between wellheads – 300 m

Hole House

Being operated by EDF, in operation since 2001. Located in the Warmingham Brinefield. Four caverns in the Northwich Halite. Two caverns in Phase 1, two in phase 2. Depths of between 300-400 m below ground level.

Holford H165

A single cavern which for 20 years had been used by Transco for diurnal gas storage and is now used for trading by Ineos Enterprises.

A further 2 developments are planned for King Street Energy and British Salt.

cant corrosion rates, more than can be solved by corrosion allowance alone. However these high corrosion rates are not observed in operation as free water is not always present in the flowlines:

If the gas is only in the cavern for a short period of time the amount of water that is picked up is less than saturation and no free water is formed in the flowline.

The same flowlines are used to inject the dry NTS gas into the caverns, hence during this period of operation the flowline will pick up condensed water.

The general corrosion rate will be less than predicted by M-506, however the design must be aware of deadlegs where free water can collect and other areas that will be sensitive to corrosion mechanisms.

In the same survey mentioned earlier on European installations, most facilities employed cathodic protection to protect against external corrosion with wall thickness monitoring for internal corrosion. The next most popular mitigations were choice of material, chemical inhibitors and coating.

Flowline Design

Where the gas plant is serving a small number of caverns it is possible to connect each well head individually to the gas plant. Inspection of the flowlines is via temporary pig launchers and receivers. Where a large number of caverns networks are required care must be taken to ensure that pipelines can be inspected and that liquid can be removed where necessary. If it is expected that liquid will accumulate in the flowline, then this will be exacerbated at low flow and may give rise to large slugs if the flow is ramped up quickly. Drain points along the pipeline are not preferred.

Cavern Performance

The cavern is not infinitely flexible in how it can operate. The maximum pressure that it can operate at is dependent on the depth of the cavern and can be approximated to 0.184 bar per meter of depth. A safety factor is applied on top of this.

The caverns also have a minimum pressure and this is set to minimise salt creep and potential cavern collapse. Convergence is usually less than 1% per year but significantly more can be experienced in deeper caverns

The cavern will also have restrictions on the speed that it can be filled and emptied and there will be limitations on the velocity in the production string.

Compressor Selection

As with most gas processing facilities, the selection of the compressor to best match the process duty is a key factor in the reduction of operating costs. For underground gas storage the selection process can be complex and will rely on a number of factors, not all of which can be completely decided at the point of purchase. It is likely that there will be iterations between compressor capabilities and process requirements until the best overall optimum has been found. The main factors in the UK, where the compressor duty is most likely to best fit a centrifugal machine, are as follows:

<u>Gas Turbine or Electric Motor Drive</u>

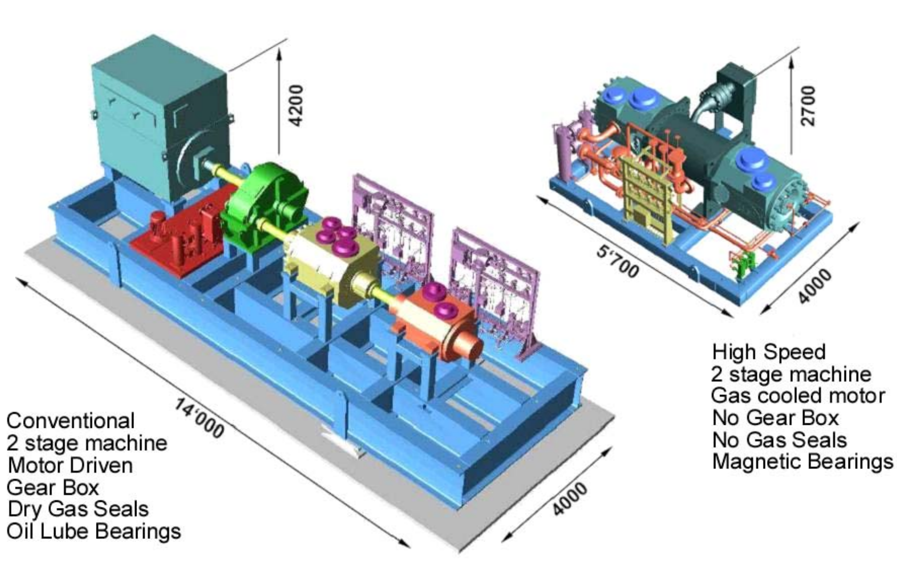
If there is sufficient electrical power in, or close to the location, then the BAT case will dictate that motor drive will be used. For more remote locations where the LEC needs to run overhead cables for significant distances then Gas Turbines can be considered.

<u>Operating Scenarios</u>

The compressor will operate most efficiently at it’s design point which is likely to be at a high flow and head. If all operating scenarios fit this model, then a fixed speed motor driven compressor will suffice. The reality is that the operating scenarios will not be known until the customers are known and the trading model established. The designer will be asked to provide maximum flexibility to allow the Gas Traders to move gas in and out of the cavern to maximise profit. This means that the flows will vary, the head will vary and the compressor is likely to have a variable frequency drive with flexibility to operate across a number of scenarios.

<u>Conventional, magnetic bearings or high speed, oil free</u>

Conventional is a compressor with dry gas seals, oil lube bearings, gear box, potentially and an electric motor. It is possible to replace the oil lube system with magnetic bearings. The high speed, oil free alternative is a compressor, with gas cooled magnetic bearings and a gas



Conventional and high speed compression. Picture courtesy of MAN Turbo cooled motor. The compressors selected for duties in the UK cover all types with the final selection based on life cycle costs. The high speed machines have no emissions, have no need for seal gas and have a good turn-down capability at low pressure ratios.

Debrining Duties

The gas needed for debrining is a small flow compared with the main gas trading flows, however the head required is similar. Use of the Gas Trading compressor for debrining will lead to a loss of trading opportunity and will mean that the machine will need to run in recycle while on the debining duty. In some applications a separate compressor is supplied just for debrining.

Dehydration Selection

The gas entering the caverns is to NTS specification and needs no treatment while being injected. The gas exiting the caverns has picked up moisture from the cavern walls and sump and needs to be dried before entry to the NTS. Technologies with references for gas storage that are applicable to salt cavities include:

Molecular Sieve

Removal of water vapour to very good water dewpoints on a fixed bed adsorbant. The driers operate cyclically with one bed onstream with the second being regenerated using hot gas. Depending on the flowrate more than 2 driers can be used. The regeneration takes place using hot dried feed gas, which is then recombined with wet feed gas. This may require an additional compressor or a reduction in the feed gas pressure to drive the regeneration gas back into the feed gas. The regeneration gas is hotter than for competing technologies and with a number of high pressure vessels molecular sieves tend to be utilised on the smaller facilities.

Silica Gel

Similar to the molecular sieve driers, but the pore size for silica gel is larger, adsorption capacities are larger and they can be regenerated at lower temperatures. They are used on depleted reservoirs as they will also provide a good hydrocarbon dewpoint; this is not a requirement in salt cavern storage as there is no naturally occurring condensate. There are references for the use of silica gel in the UK on salt cavern storage.

Glycol

Standard glycol systems cannot be used as they will not make the dewpoint, are not regarded as BAT (Best Available Technology) for emissions and cannot provide fast online times from a cold start. However with the addition of stripping gas, the use of a thermal oxidizer to burn the emissions and some additional lean and rich glycol storage this technology is competitive for most applications. It is widely used in Europe.

Twister

This is a new technology for gas storage and works on the principle of expansion followed by cyclonic gas/liquid separation followed by re-compression. It can only work where there is free pressure energy between the cavern and the NTS. Hence if the cavern operates between 100 bar and 140 bar, exporting to the NTS at 70 bar, then Twister could be considered. For lower storage pressures, the Twister would have no pressure drop available and could not normally be economically considered. Twister bv have announced that they have been selected for a UK UGS project.

Debrining

This operation is to remove the brine from the cavern once the leaching operation is complete and the cavern is fully formed. The brine is pressurised out of the cavern using feed gas. The volumetric flows of gas are low, but the pressure required is close to the eventual storage pressure, which may lead to the necessity to use a dedicated debrining compressor, rather than the trading compressors during the 3 month debrining operation. The interface between the water and brine leads to gas being dissolved in the brine, increasing as the amount of brine to be removed decreases. The brine that is removed is degassed as it reaches the surface and then is disposed of. If the brine is being put into the sea, then no further treatment is necessary. If the brine is being exported as a chemical feedstock then the methane may need to be reduced further in a stripping column. There are choices on this technology as well as a central facility or dispersed on each wellsite.

Venting

In normal operation there are very low gas emissions. However the Gas Plant contains large volumes of gas, which need to be disposed of in case of an emergency, such as a fire. The practice is to vent directly to atmosphere through a cold vent stack and the design needs to be carefully considered and in accordance with accepted codes, such as API RP 521. The height of the vent can be a planning constraint and the size of the sterile area, assuming the vent ignites, should be sufficient to ensure that plant operators and members of the public outside the site fence are not exposed to excess radiation. If the vent height cannot be raised and there is not sufficient sterile area, then sequential depressurisation could be considered as well as controlled blowdown, if there is sufficient spacing between the depressurisation zones.

Statutory Considerations

Designers are used to working to client standards and national and international codes. Gas storage facilities, especially in salt caverns, tend to be greenfield and this brings in a number of other statutory considerations, such as planning permission, dangerous substances consent and the protection of endangered species. The following is nowhere near a complete list; there are over 100 bodies that need to be consulted when undertaking new Gas Storage projects.

Planning

The case for gas storage in the UK is robust and immediate. The planning process to allow the plants to be built has not been smooth and there are many cases of where there have been delays while companies satisfy the planning regulations. The track record for salt caverns is marginally better than for depleted reservoirs in the UK. Currently planning permission has been granted for Stublach, and Holford, formerly Byley, but has not yet been granted for King Street.

The recent history of projects being developed in the UK has been littered with delays due to the planning process. Local residents, quite rightly, want to be sure that this technology is being properly implemented in projects. Once granted the planning permission is usually prescriptive with restrictions on construction, noise and visual impact. For process engineering the planning issues of noise, construction are reasonably straightforward to design to, but visual impact does need special consideration.

Cheshire is a very flat county with trees, 8m to 18m, being the tallest 'structures' that can provide natural screening. The Environmental Statements produced to support the planning application show the view of the completed plant from centres of population as agreed with the local planning authority. These are proposed in the application a long time before the detailed design has started and constrain the operator, especially with the taller items such as the vent stack, compressor houses, dehydration towers and fired heater stacks. Depending on the deviation from the planning permission a new application, with the potential delays, may be necessary.

The Health and Safety Executive

In the UK the HSE's primary role and regulatory responsibilities are to ensure safety is complied with during the design, construction, operation and decommissioning of these sites; and for ensuring appropriate emergency plans are developed.

COMAH

The main means to achieve safety when the installation starts to operate is primarily achieved through the Control of Major Accident Hazards Regulations 1999 (COMAH). These regulations are enforced by the HSE and the Environment Agency (EA), with the HSE taking the lead.

The first step for the operator is to send information to the HSE in a pre-construction safety report (PCSR) before construction starts. This is followed by a second report, the pre-operational safety report (POSR), which must be submitted before gas is introduced to the caverns. Early activities, such as infrastructure can commence, but ma-

Planning Application Case Studies

Holford (formerly Byley)

Planning consent was not granted when Scottish Power originally applied with 4,000 letters of protest.. Scottish Power made some changes to the application, swopping Gas Turbine Drives for Motor Drives and reducing the visual impact. Scottish Power appealed the 2002 decision, which led to a Public Inquiry in late 2002. Following the Inspector's decision and after an intervention in the national interest by the then Deputy Prime Minister John Prescott, consent was granted in May 2004. There were still some 15,000 letters of protest and final planning was confirmed after a legal challenge against the intervention failed in December 2004.

Stublach

The Stublach gas storage facility is about 2 km from Byley. The planning application to develop the Stublach facility, comprising 28 caverns was submitted by INEOS Enterprises Limited to the Cheshire County Council in December 2005. Planning consent was granted in 2006. The project was subsequently sold to GDF Suez in 2007.

King Street

King Street Energy Ltd, is proposing to develop a salt cavern gas storage facility just north of Stublach. The project consists of nine cavities with the supporting gas processing facility located on the former Associated Octel Site on the northern edge of the Holford brinefield.

King Street Energy Ltd proposes to construct a twin pipeline system between the Mersey Estuary and the King Street site to supply leaching water and to discharge the weak brine.

British Salt

British Salt have obtained Hazardous Substances consent for use of ten existing cavities and to solution mine eleven new cavities for Gas Storage. The brine product will be used in their existing salt manufacturing facility in Middlewich. A planning application has also been applied for.

Ariel view of the Stublach Phase 1 Leaching facility showing the well site, infrastructure on a flat Cheshire landscape jor activities such as drilling cannot. The PCSR should be providing evidence to the HSE that the principles of ALARP (as low as reasonably practicable) have been observed.

The on-site emergency plan must also be issued before gas is allowed to enter the caverns, which will be a comprehensive review of incidents and the controls put in place to minimize risk to operators, assets and the environment. The local authority will need to be aware of the on-site plans such that they can produce their off-site plans.

Hazardous Substances Consent

As all underground gas storage caverns contain more than 15 tonnes of natural gas they fall under the Planning (Hazardous Substances) Regulations 1992 and must apply to the Hazardous Substances Authority (HSA) for consent. In many cases the HSA is the same as the local planning authority. The HSA will consult with the HSE and other organisations on the suitability of the proposed location.

Borehole Sites and Operations Regulations 1995 (BSOR)

These regulations apply from the beginning of the operation and continue until the cavern is abandoned.

Pipeline Safety Regulations 1996

When natural gas is transported in a pipeline at pressure above 8 barA it is classified as a major accident hazard pipeline and the regulations apply. The HSE will want to be notified 6 months before construction of it's route and design and will need to complete their review 14 days before gas is introduced.

The Costain Experience

Costain Oil, Gas and Process have a long track record of front end innovation and experience in the gas industry and have been a prominent player in the development of gas storage projects in the UK. Costain's first project was a FEED utilising a depleted reservoir for Wingas at Saltfleetby. Such have been the delays in gaining approval, this project is still awaiting to progress to retailed design. Currently Costain are working on 2 Cheshire based projects

Leaching Facilities for GDF at Stublach

The project is being constructed at Stublach, Lach Dennis, Cheshire in a green field rural environment where enabling construction activities have been ongoing since August 2007.

The Phase 1 Brine and Water infrastructure includes the preparation and construction of the well sites to accommodate the drilling rig equipment and operation platform. Construction of a Solution Mining Compound including two reinforced concrete degassing tanks, a pumphouse, water/brine pumps, Nitrogen storage and distribution system, a Distributed Control System and power supply equipment including a new 33kV substation incorporated into the local electrical grid network. The Solution Mining Compound is connected to the well sites through the installation of extensive below ground carbon steel pipe work and cable network.

Considerable pre-construction planning and co-ordination activities have proved successful in ensuring the project worked within the constraints of the planning conditions which dictated that only 30 HGV deliveries could be made each day.

Costain are currently working on the FEED for the Gas Plant.

Gas Plant at Holford for E.ON

Costain were employed to conduct a Peer Review on the original FEED and were successful in the EPCm phase of the project, which comprises the Gas Plant, the modifications to the wellsites needed after solution mining to allow debrining and to convert to gas trading and to the AGI and gas marshalling area.

Acknowledgements

All information for this paper has been sourced from the public domain. I would like to thank E.ON and GDF for permission to write about the specifics of the Holford and Stublach projects.

Mike Healy

Costain Oil, Gas and Process

November 2008

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