Alternatives to Venting of Natural Gas – ANG gas capture to reduce emissions

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Introduction

With growing concerns over greenhouse gas emissions associated with natural gas industry operations, there is a requirement to develop technology and processes to reduce emissions, as methane is one of the most significant greenhouse gases.

For gas transmission pipeline networks, a major emission source is from in-line compressors as a consequence of routine depressurisation that can result in substantial gas emission to the atmosphere. Clearly there is a need to reduce or even eliminate the need for large volume, repeated venting from compressors.

This paper reports on a project which focused on the development of technology to understand options for venting reduction and undertake field trials of selected technologies to characterise the emissions saving benefits from both a financial and environmental view-point.

Gas Emissions Reduction Approaches

The first stage of the project assessed different types of venting operations through development of scenarios based on real network information and at the same time collating technology information based both on accepted international best practice and on innovation.

The second stage sets out to match technology options to the venting scenarios through a combination of technical and cost-benefit analysis.

To improve environmental performance the following options were considered:

- Capture of gas using ANG (Adsorbed Natural Gas), and possible reinjection of the gas to the pipeline network or acting as a temporary gas storage system with the gas used on site.
- Recompression and injection of the gas back to the pipeline network.
- Flaring of the gas – conversion of the gas to CO_2 to reduce the environmental impact
- Use the gas directly at the site for powering compressors / gensets or other combustion equipment if the gas load matches the vented gas quantities.

Several factors impacted on technology selection, including amount of gas vented, frequency of venting, gas load at the sites to use the vented gas, network operation and system availability.

The initial analysis highlighted that the lowest carbon footprint and best fit to compressor site operations is through ANG technology.

Background on ANG Technology

In ANG technology, a capture/storage vessel is filled with a suitable adsorbent material (Activated carbon) to enhance the storage capability. Activated carbon's large micro-pore volume and its ability to form dense packed beds make it highly suitable as an adsorbent. . As the gas molecules physically enter the pores of the carbon particles and form weak bonds through Van der Waals forces (i.e. physisorption), they occupy a much smaller volume than in their free state. The energy density of the storage medium will be greater than that of the same vessel without the adsorbent, when filled to the same pressure. For example, in laboratory-scale tests at 35 bar, ANG can store larger amounts of gas than compressed natural gas (CNG) at 100 bar ie. a significant storage capacity improvement at a significantly lower pressure.

Figure 1 shows the methane storage capacity of ANG technology using two different types of activated carbon compared to a simple pressurised system. The vertical axis represents the volume of methane stored per volume of vessel.

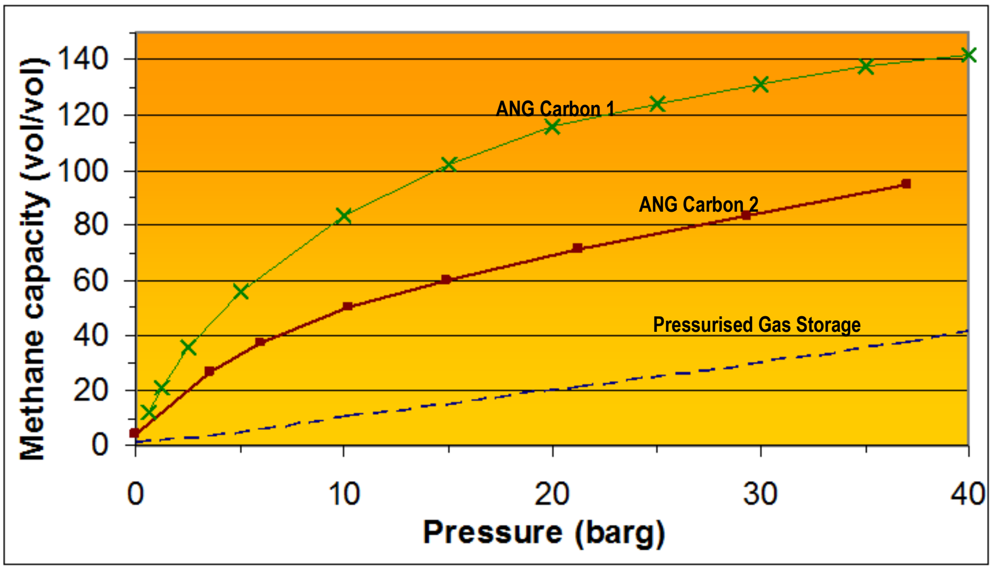

Figure 1: Example of ANG performance relative to CNG for two different adsorbents

ANG Gas Capture Concept

The operation of gas transmission network compressor sites means that they vent gas in an unpredictable manner, responding to overall system demands and network flows.

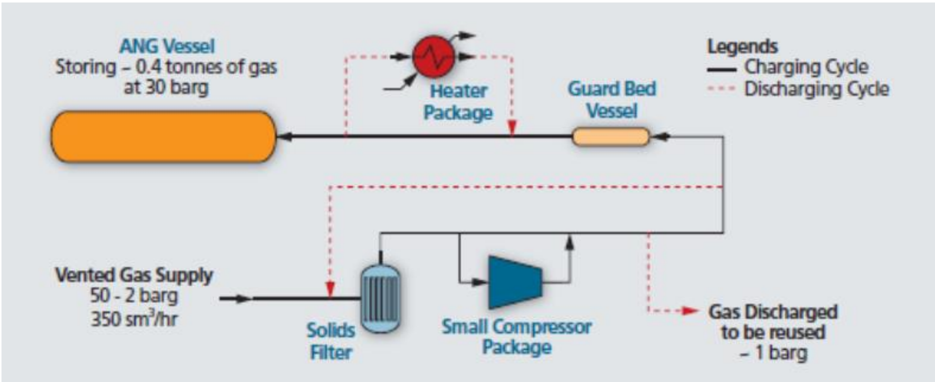

Figure 2: Outline of the ANG gas capture concept

Table 1 shows the key system components and a description of the function:

Components	Description
ANG storage vessel	Packed with adsorbent (normally a selected activated carbon) and stores gas up to about 30 barg.
Guard bed vessel	A pre-adsorption vessel designed to remove higher hydrocarbon components (C5+) from the gas stream which will cause long term adsorbent degradation in the main vessel.
Activated carbon	The components to be adsorbed in the main bed and the guard bed determine which type of activated carbon is selected for each vessel.
Solids filter	Removes any carbon dust that is entrained from the ANG vessel and/or guard bed vessel during the discharge cycle.
Heater package	This is installed as part of the guard bed system to achieve a controlled desorption of higher hydrocarbon from the carbon in the guard bed back into the gas during discharge cycle for gas quality requirements.
Compressor package	Helps capture the maximum amount of vented gas and at the same time enhance the storage capacity.

Table 1: Overview of ANG system components

At the start of the charging phase when high pressure is available, the gas bypasses the compressor and flows directly into the ANG vessel. When the pressure at the source of vented gas and the ANG vessel equalises, the compressor is then utilised to compress and transfer the remaining gas into the ANG vessel to up to 30 barg.

During the discharge phase, the gas desorbs from the ANG main vessel and entrains the higher hydrocarbon components from the guard bed vessel. The heater is used to help desorb the hydrocarbon components on the guard bed carbon. Depending on the downstream application, the use of the compressor during the discharge cycle is optional. To optimise the delivery of gas, final use of the gas at a pressure close to atmospheric pressure is recommended.

ANG Technology Field Trial

For the ANG technology field trial, the key aim is to evaluate the performance and capabilities of the ANG storage technology as well as the carbon footprint (environmental benefit) at a scale similar to a real application. The system has been designed to capture and store approximately 400 kg of natural gas, based on results from laboratory-scale measurements and process modelling.

The field trial aimed:

- To replicate compressor venting scenarios
- To evaluate and verify the storage capacity based on the type of activated carbon chosen for this installation.
- To demonstrate cyclic operation and flexibility of ANG storage and optimise the control strategy to provide constant gas quality.
- To determine the overall process time required to capture and store the gas, and also the time for the optimum discharge process
- To verify carbon footprint reduction (environmental benefit) of the technology during the field trial.

ANG Main Vessel Design

An existing high pressure vessel was used. To avoid permanent modification of this vessel, a metal frame was constructed to mount the thermocouples on and enable insertion into the vessel. These were used to monitor the temperature at various locations inside the ANG main vessel as shown in Figure 3.

A gas distributor was placed along the bottom of the ANG vessel. The location and design of the distributor allows uniform gas distribution along the vessel during charge and discharge phases.

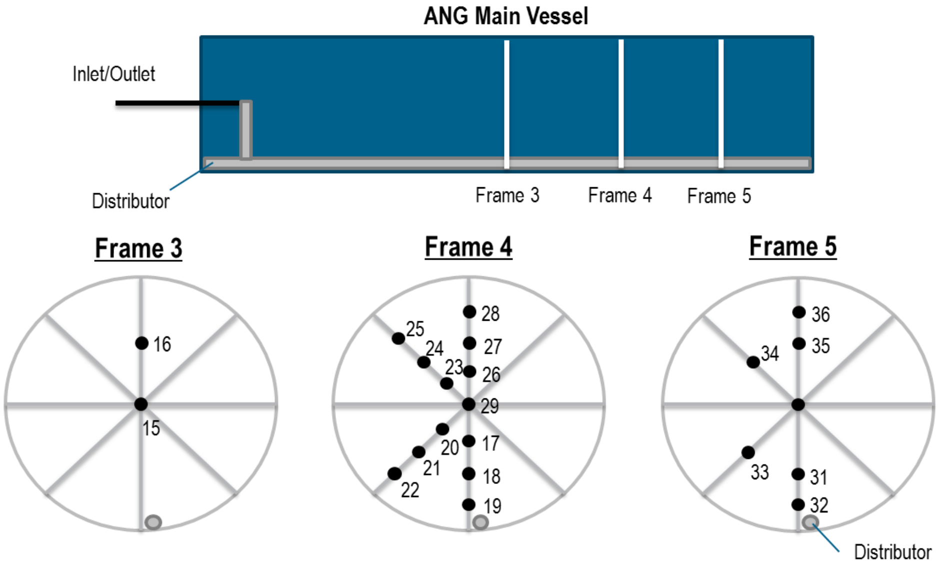

Figure 3: Location of thermocouples inside the ANG main vessel.

Figure 4 shows a photograph of the metal frame with the thermocouples attached and the gas distributor.

Figure 4: Photograph of the metal frame showing the thermocouples and distributor.

The thermocouples were used to measure the temperature inside the main ANG vessel across the bed of packed activated carbon to understand the variation in temperature caused by the adsorption and desorption processes.

Figure 5 shows the ANG test facility, including the control valves and instrumentation installed to enable system parameters to be measured and logged, and used to evaluate overall gas capture performance.

Figure 5: Photograph of the ANG field trial test facility

Field Trial Results

Stored and Delivered Capacities

The mass of gas adsorbed and desorbed varies for each cycle as the performance of the adsorbent depends on the operating conditions during previous cycles, the starting conditions of the bed (i.e. pressure inside vessel and bed temperature) and ambient temperature. Figure 6 shows the amount of natural gas stored and recovered for each cycle at various operating conditions.

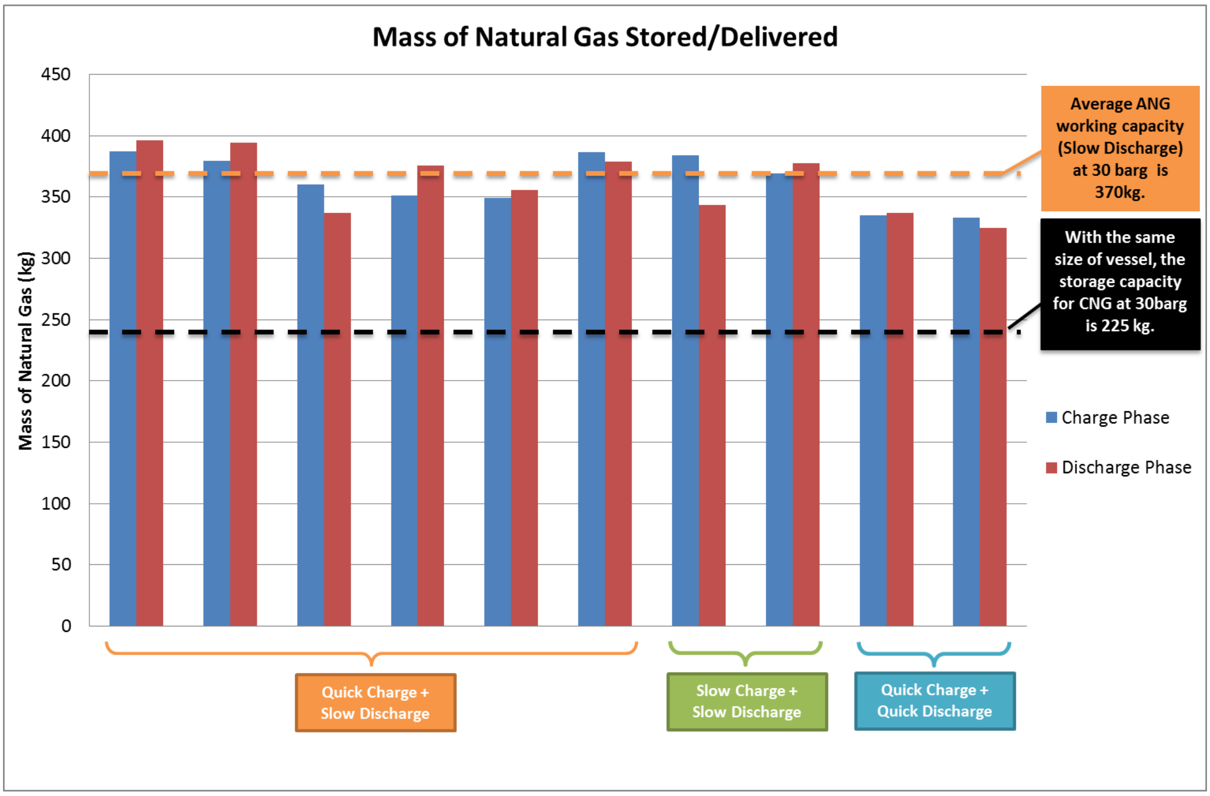

Figure 6: Mass of natural gas stored/delivered for charge and discharge phases.

The average working capacity of ANG technology, with "slow" discharge rates, was found to be approximately 370 kg with a vessel volume of 9.8 m^3 at 30 barg. For "quick" charge and discharge rates, the average working capacity is 340 kg at 30 barg. The results show that at full scale and a pressure of 30 barg, ANG provides a 70% increase in working capacity compared to CNG. The achievement of 370 kg stored at 30 barg is close to the design value of 400 kg.

The thermodynamics of the adsorption process means that the adsorbent in the ANG main bed and guard bed heat up during the charge phase and cools down during the discharge phase. A change in bed temperature alters the amount of gas that the activated carbon can adsorb at a particular pressure. This accounts for some of the variation in the results shown in Figure 6.

Gas Quality

In line sensors combined with detailed gas chromatographic analysis was used to determine the gas quality of the incoming gas during the charge phase, and the outgoing gas during the discharge phase. In addition, gas quality measurements between the guard bed and main bed were made to determine if any higher hydrocarbon components "broke through" the guard bed, as these could impact on the longer term performance of the main ANG bed.

The gas quality of the discharged gas was extremely important as it had to comply with the UK Gas Safety Management Regulations GS(M)R which stipulate strict limits on the Wobbe Number (WN) of gas transported within high pressure gas pipeline networks. According to the GS(M)R, the WN of gas in the gas transmission system should be between 47.20 and 51.41 MJ/m³, at the reference conditions of 15°C and 1.01325 bar The average WN of the charge and discharge phases were within the range of the GS(M)R as shown in Figure 7.

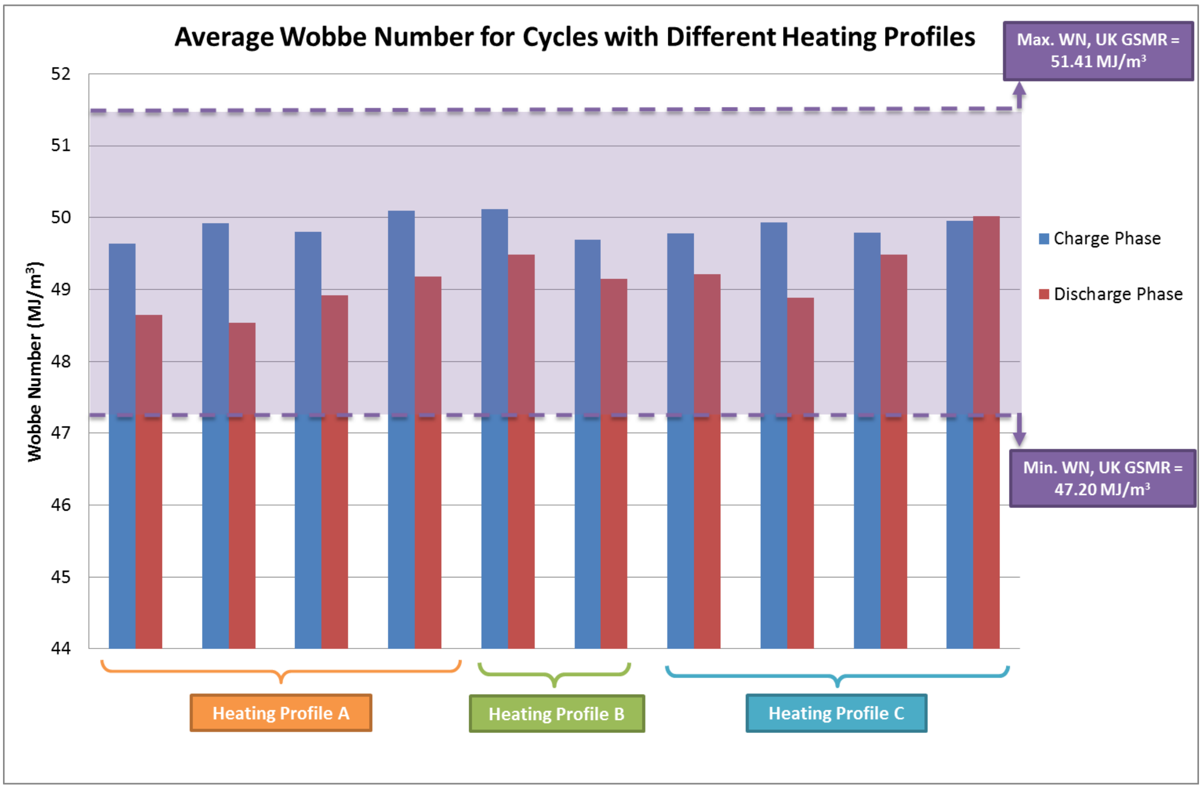

Figure7: Average WN of gas during the charge and discharge phases.

The guard bed vessel was used to protect the main ANG vessel by removing the higher hydrocarbon components (i.e. C5+) from the natural gas before it enters the ANG main bed. This results in a change of gas composition during the charge phase, which must be reversed during the discharge phase.

Heat is required to control the desorption of higher hydrocarbon species in the guard bed vessel. Initially a heating profile A was used that had been determined from previous pilot scale experiments. This approach was used for the first four cycles and the results shown in Figure 7. The average WN for the charge phase is higher than for the discharge phase. To increase the recovery of higher hydrocarbon species during the discharge phase, the heating duration was extended and the temperature was increased. After the heating profile was changed (i.e. to heating profile B and then finally to profile C), the average WN of the gas in the discharge phase was higher and closer to that during the charge phase.

Conclusion

Overall the project was successful in meeting its key objectives. The results demonstrated that ANG gas capture technology was suitable for installation at gas compressor sites as they trial has shown that it can mimic the expected venting and capture process. The amount of gas stored was close to the design value of 400kg and ANG provides a 70% increase in working capacity compared to CNG; ie. a significant uplift in storage capacity.

As expected, the adsorbent in ANG main bed and guard bed heats up during the charge phase and cools down during the discharge phase. The bed temperature affects the amount of gas the activated carbon adsorbs or desorbs, but does not appear to give inherent reduction in gas capture performance through repeated cycles. The gas quality could be managed through the use of an in-line heater between the guard bed and the ANG main bed.

The main power consumption of the ANG technology was associated with the process compressor and heater packages. These required relatively small amounts of power and the technology has a significant emissions saving in avoiding the gas emission. Overall, there is a reduction in emissions over venting in excess of 95% in terms of tonnes of CO_2 equivalent.

There was no noticeable decrease in performance throughout the lifetime of the tests – following repeated charge and discharge cycles.

The time taken for the charge and discharge processes met the requirements of the compressor operators.

The positive results from the ANG Field Trial highlight that this technology could be used to reduce greenhouse gas emissions associated with gas transmission compressor venting.

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