GOOD BYE TO GREENHOUSE GASES

Dr. Ory Zik, Qnergy, USA, describes how methane emissions can be reduced from bleeding pneumatic devices.

Millions of pneumatic devices are being used along the LNG supply chain. These devices, when powered using natural gas, constitute one of the largest sources of methane emissions in the natural gas value chain. Thus, the term 'bleeding' pneumatic devices.

Bleeding pneumatic devices use natural gas to activate valves and pumps, mainly for process control and chemical injection. Familiar examples are pneumatically actuated valves, pressure, and level controllers. These devices vent spent gas, i.e. methane, directly into the air.

The International Energy Agency (IEA) estimated that emissions from bleeding pneumatic devices exceed 11 000 kt of methane globally. This represents approximately 15% of the total global emissions of methane from oil and gas operations. It is comparable to approximately 30 million t of CO_2 equivalent, which represents the emissions of nearly six million cars; undoubtedly a substantial number. Therefore, although each pneumatic device is a relatively small emitter, collectively they comprise a major source of methane emissions.

The requirement to eliminate emissions presents a technical challenge: how can we eliminate a large number of very small emitters that collectively accumulate to a substantial contribution to global greenhouse gas (GHG) emissions? The obvious plug and play solution is to replace natural gas as a source of power with compressed air. It is a simple and established construct which was proven to be the lowest cost and easiest to install.

However, nearly half the sites in the US, a larger percentage in Canada, and an additional double-digit percentage globally, are not connected to a stable electrical grid. The reason that bleeding pneumatic devices are so ubiquitous is because most gas fields do not have a stable electrical grid, hence traditionally the choice has been to use pneumatic pressure as a source of power. Taking this into account, it is no surprise that the critical component that is needed to achieve net-zero at any off-grid site is grid-quality electricity.

Unexpected solution

The solution is found in an unexpected place and at an unexpected time. Imagine the year 1816; Robert Stirling, a minister in the Church of Scotland, applied for a patent for a new engine that he built in his spare time. The novel engine operates on a simple principle: the expansion of gas when heated, followed by the compression of the gas when cooled.

The Stirling engine contains a fixed amount of gas that is transferred back and forth between a cold end and a hot end. The displacer piston moves the gas between the two ends and the power piston changes the internal volume as the gas expands and contracts. Once a magnet is attached to the moving piston, one can create electricity. The Stirling engine was modified in the early 1960s with a design that reduced the number of moving parts and nearly eliminated friction and wear altogether. This configuration is called the Free Piston Stirling Engine.

Simplicity has been found to lead to reliability. Once it is properly built and sealed, the Free Piston Stirling Engine can essentially be the first maintenance-free engine: a bold statement backed by decades of testing. Indeed, NASA adopted the Free

Piston Stirling Engine and stated: "There are no gas stations in deep space and there are no mechanics either. So, if you want the power to perform science in the deep, dark frontiers of our solar system, you need an engine that is reliable for the long haul. NASA Glenn Research Centre engineers have set a run-time record for a Free Piston Stirling Engine at full power, with over 110 000 hours of cumulative operation, since 2003. That is over 12 years, and it is still running without issue. This device also set a record as the longest-running heat engine in the history of civilisation, with no maintenance required."[1]

The NASA experiment started in 2002 with a company called Stirling Technology Corporation (STC). The assets including the patents and technology of STC were later acquired by Qnergy who continued to develop the technology. Qnergy was the first to build a commercial power generator using the Free Piston Stirling Engine. The company is dedicated to finding new ways of solving current industrial and environmental challenges. One of the prime challenges addressed by Qnergy is how to abate methane emission from bleeding pneumatic devices.

The Stirling engine is often called an external combustion engine, a descriptive name that implicitly hints to its two key advantages. The first is the no-maintenance aspect – unlike the internal combustion engine, the external combustion engine is sealed from the combustion gases and does not require any oil changes, filter changes, or overhauls. Second, the engine is fuel agnostic, meaning any source of heat at a high enough temperature will generate electricity.

It did not take long for Qnergy to focus on serving the oil and gas industry. The Free Piston Stirling Engine is a natural fit for an industry that requires reliability, prefers unprocessed well gas to tanked fuel or diesel, and largely operates in remote sites off the electrical grid. Leveraging the Free Piston Stirling Engine advantages, Qnergy built a power generator that is optimised for remote locations and oil and gas operations.

In the last few years, the company has installed hundreds of its Stirling-based generators in oil and gas sites around the US and Canada. The product is marketed based on performance; most of the installations are with repeat customers, some are oil majors and others are smaller producers and operators. Figure 1 shows a Stirling-powered automation site in the US.

Circling back to the bleeding pneumatic devices, a prime example of a solution that leverages the advantages of the Stirling engine is to provide clean, dry instrument air. Figure 2 illustrates this concept. It is called CAP3, or compressed air pneumatics. In these systems, the Stirling-based generator uses unprocessed wellhead gas to produce clean instrument air and utility-grade power.

Figure 1. Qnergy PowerGen – a Free Piston Stirling Engine remote power system on a natural gas wellsite.

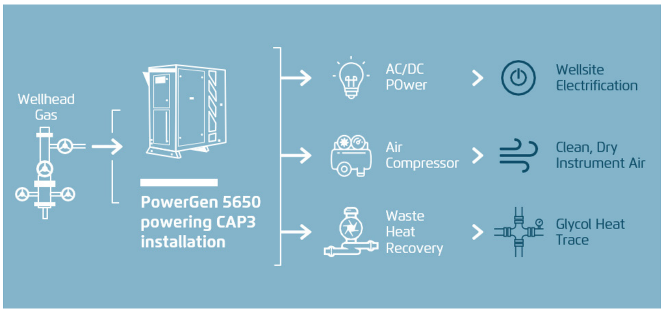

Figure 2. The compressed air pneumatics concept. A Stirling-based generator, using unprocessed wellhead gas, produces clean instrument air and utility-grade power. It can also produce heat.

Multiple alternatives

There are a multitude of ways in which operators can eliminate methane emissions from their well sites. Most operators standardise on the configuration that fits their specific operation. The leading strategies are summarised in Table 1.

In approximately a quarter of cases, companies are switching from high bleed to low bleed. This option is mainly relevant to legacy gas fields referred to as brownfields. One of the disadvantages of the high to low bleed approach is that it does not meet the zero emission criteria, and, secondly, it requires the replacement of many small emitters. Another strategy that gains momentum and applies to approximately a quarter of the cases, especially in new gas fields or greenfields, is electrification. The advantages are that it is a non-venting solution that consumes relatively low power and optimises the amount of chemical used in injection pumps. The downsides of it are the cost and the fact that it is not a plug and play type solution. Safety must also be considered when operating an electrical actuator. If the electrical actuator loses power, the valve in the actuator may default to an open state, which may become a safety hazard. Qnergy often provides generators at sites that need electricity for electric actuators.

Converting to instrument air is arguably the easiest and most cost-effective solution. Today, the GHG abatement cost of methane emissions are lower than US\$4/tCO_2e. From the operator's perspective it is a plug and play, non-venting solution using a familiar technology. One system can retrofit an entire multi-well pad. The two downsides are associated with power reliability (which can be solved using a Stirling engine) and the need for a maintenance regime for the compressor (which is achieved in CAP using a redundant, two-compressor system).

Once the operator settles on instrument air, they still need to choose a power source. Most remote power solutions fall into one of two categories – low power and high power – while the industry actually requires a medium power solution somewhere in the middle.

Table 1. Leading strategies to eliminate methane emissions

Strategy	High to low bleed	Electrification	Instrument air (CAP3)	Collection and destruction
Flow (ft^3/min.)	< 0.3	0.3 - 1	1 - 20	> 20
Pareto[2] (%)	23%	26%	48%	3%
Assets	Brownfield conversions	Single wells; typically, greenfields	Brown and greenfields	Super-pads (>12 wells). Large facilities

Figure 3. Qnergy CAP3 deployment in Louisiana, US. The change from natural gas to compressed air can eliminate 98% of well pad emissions.

On the low power side, operators find that demand for high airflow and excess power deem some of the familiar technologies uneconomical. These technologies include thermoelectric generators (TEG) and fuel cells in combination with a battery bank and off-grid photovoltaics. TEGs are relatively reliable but are low-power and inefficient (leading to high emissions). Fuel cells are efficient but require tanked fuel and have a short operational life. Both become prohibitively expensive when the power requirements cross the 1 kW mark.

On the other end of the spectrum are microturbines, which are both efficient and reliable, but are oversized for most well pad applications. This can lead to high capital costs, high maintenance costs, and high emissions.

Unaware of the possibilities, some operators historically would gravitate towards conventional gas generators that use internal combustion engines (ICE). These configurations lead to extensive maintenance visits for oil changes that contribute to the high total cost of ownership. It also has high NOx and CO emissions that pose environmental challenges.

The Free Piston Stirling configuration has been designed to have the lowest total cost of ownership (TCO) in the industry. From the environmental performance standpoint, Qnergy does not use oil and emits less than 1% of the NOx and CO of ICEs.

CAP3 includes a variety of features that ensure successful deployment. Besides the Stirling engine, the system includes a duplex configuration of low maintenance, robust compressors; an integrated air dryer; an HMI for local data review and control; gas flow measurement for mitigation reporting and carbon credit generation; a gas conditioning unit (GCU) to protect against liquids in the gas inlet, as well as an air receiver tank for air storage.

Deployment leads to abatement

Deployment of the CAP system is straightforward. A fully functional skid is brought to the site and installed in a few hours. The simplicity and ability to abate all methane emissions at once gains immediate support by operators in the field. This is best captured in the words of a GEP Haynesville Sr Production Engineer who, after deploying the system shown in Figure 3, said: "By utilising the Qnergy CAP3 products, we have the opportunity to dramatically reduce our greenhouse gas emissions, and it feels good!"

According to Qnergy's field data, a CAP3 system abates more than 2000 tpy of CO_2 equivalent. For comparison, the cost effectiveness of this approach is approximately two orders of magnitude higher than switching to an electric car. Assuming that an electric car is purely fed by renewable energy (a favourable assumption), the switch to an electric car would remove approximately 4.6 tpyCO_2e (if each electric vehicle fully replaces a conventional passenger vehicle). A factor of more than 400 in GHG abatement between a CAP3 system and a solar-powered Tesla.

Compressed air as a service

A natural next step, after providing utility-like power, is to offer a utility-like business model, where operators can pay for what they consume and do not have to buy the equipment. To address the challenge of limited available capital to manage existing field operations, Qnergy developed a financial programme called compressed air as a service (CAaaS). CAaaS is an accessible, service-based, compressed air solution that is designed to remove the capital barrier to adoption, streamlining the path to emissions reduction and regulatory compliance – which in some markets also translates into sellable carbon credits.

CAaaS helps operators adhere to emission reduction regulations, while maximising the benefits of GHG incentives, without a large upfront capital outlay. This allows operators to play both defence and offense, i.e. to have a flexible strategy that mitigates risks and allows them to meet compliance requirements while making money.

Summary

The Free Piston Stirling Engine has been designed to bring to site unparalleled reliability and an affordable means to eliminate methane emission from pneumatic devices. As the energy industry moves towards decarbonisation and carbon neutrality, reducing the footprint of natural gas extraction and distribution is key to maximising the value of LNG fuel. Stirling-powered compressed air pneumatics and CAaaS are leading methane emissions reduction solutions for these changing times. **LNG**

References

1. *Aerospace Frontiers*, Vol. 20, No. 6 (2018), p.3.
2. Methane Tracker 2020, *IEA*.