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Microturbine technology

Reduce steam pressure and generate electricity

White Paper

First for Steam Solutions

EXPERTISE | SOLUTIONS | SUSTAINABILITY

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1.0 Executive Summary

Industrial steam boilers are typically designed to operate at higher pressures than required by the end use application. The steam produced is then distributed before being reduced in pressure for use by a process or building services application.

Reducing this higher pressure steam for use by the application is conventionally performed by a pressure reducing station comprising a pressure reducing valve and various items of ancillary equipment.

An alternative way to reduce pressure has come to the fore in recent years in the shape of microturbine technology. Passing steam through a microturbine enables operators to use the energy released by the resulting pressure drop to supplement their existing electricity supply. A steam microturbine producing 100 kW of electrical power can generate typical cost savings of more than £75,000 per year (based on 2014 figures).

The electricity produced in this way reduces the need for power from the grid, cutting utility bills and overall carbon footprint. The greater the difference between the price of electricity and the price of gas or oil to fuel the steam boiler, the greater the savings.

Although microturbine-based steam reducing technology has not been deployed as widely as in other countries, the potential is good for UK industrial steam users. That's because (at December 2013, see section 3) UK Industrial gas prices are about one-third of industrial electricity prices, a bigger differential than in most EU countries.

Spirax Sarco has introduced a range of microturbines suitable for saturated or superheated steam. Their compact design makes the turbines suitable for retrofitting into many existing steam systems and they're supplied fully assembled and tested to minimise on-site disruption.

2.0 The need for steam pressure reduction

Typically, process or building services applications' systems raise higher pressure steam in the boiler then reduce the pressure before the steam is actually used. Generating and distributing steam at higher pressure offers two advantages. Firstly, the boiler's thermal storage capacity is increased, helping it to cope more efficiently with fluctuating loads and minimising the risk of producing wet and dirty steam. Secondly, smaller bore steam pipes can be used for distribution, resulting in lower capital cost for materials such as the pipes themselves and their flanges, supports and insulation, as well as labour for installation.

Having distributed the steam from the boiler, its elevated pressure needs to be reduced for each point-of-use to correspond with the pressure required by the application. More importantly, a higher enthalpy of evaporation at lower pressures means more useful energy is available via the condensing process. Lower condensing pressures at the point-of-use tend to save energy. Reduced pressure will lower the temperature of the downstream pipework and reduce standing losses.

Conventionally, the distributed steam supply is lowered to a working pressure by a pressure reducing station comprising a valve and associated controls and ancillaries (see Figure 1).

Figure 1

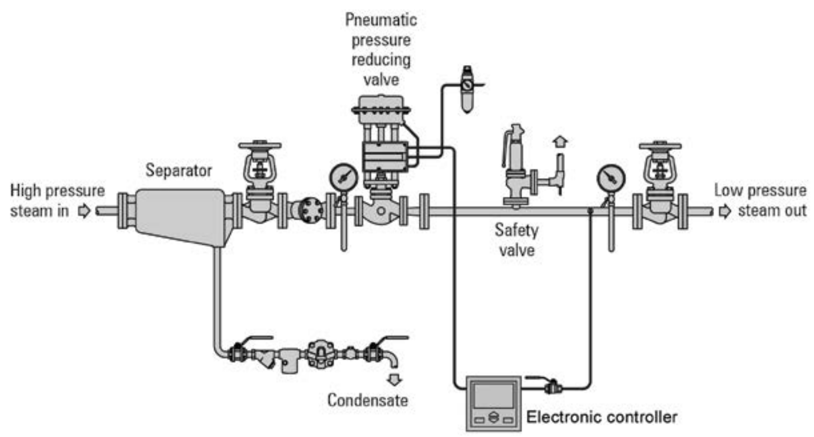
Conventional pressure reducing systems

A conventional pressure reducing station comprises a pressure reducing valve (PRV) and ancillary equipment. The PRV can be pilot operated, direct acting or pneumatically operated depending on the site's requirements and the accuracy of the downstream steam pressure required by the application.

Pressure reducing stations typically include a set of ancillary equipment:

- Separators, trap sets and strainers to keep the steam dry and clean, protecting the pressure reducing valve from wear
- Isolating valves and pressure gauges for easy commissioning and maintenance
- Safety valves are essential for installations where the upstream pressure is higher than the maximum allowable working pressure of any downstream plant

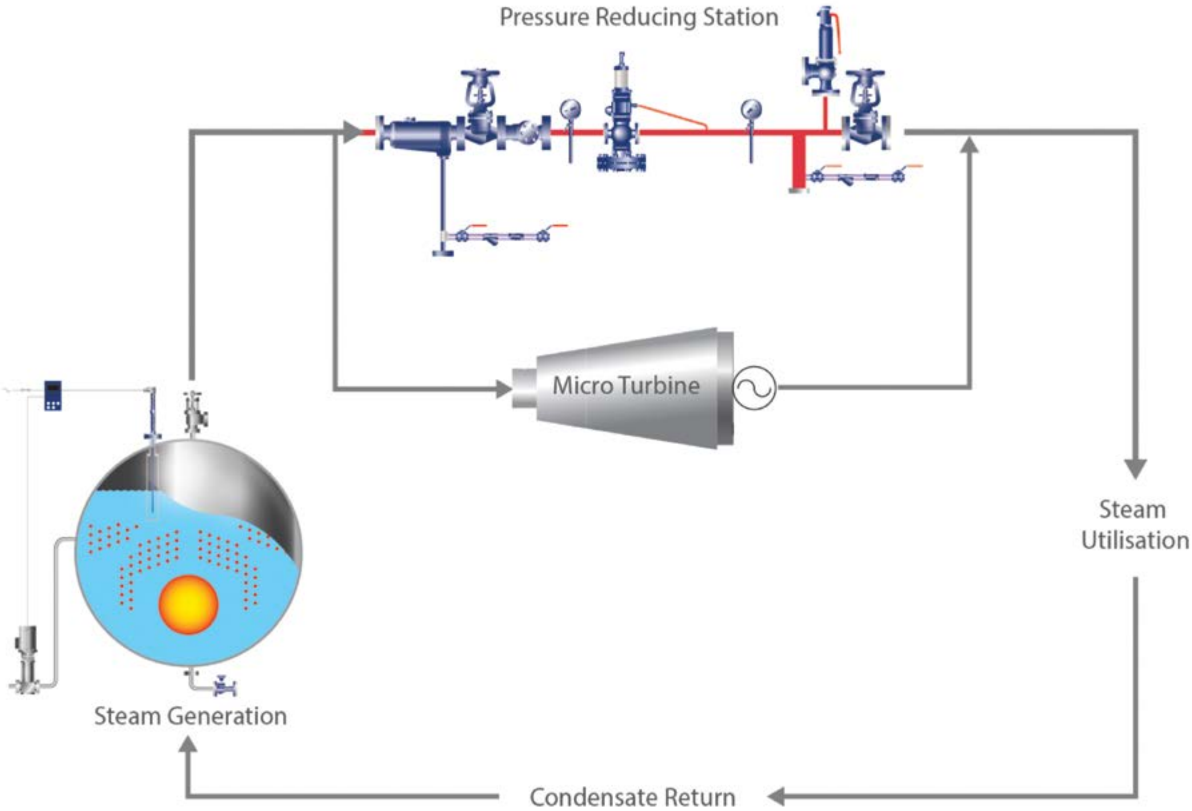
General arrangement of a pneumatically-operated pressure reducing station



However, in recent years a new way to reduce pressure has become available to many steam-using organisations in the form of single-stage microturbines. The technology is similar to that deployed by the power generation industry with multi-stage turbines being fed by very high pressure, often superheated, steam to drive large electricity generators.

Passing plant steam through a microturbine, typically installed in parallel to a conventional pressure reducing station, enables operators to use the energy released by the resulting pressure drop to supplement their electricity supply. Meanwhile, the outlet steam is used by the downstream application as in a conventional system.

Figure 2: Using a microturbine in parallel with a conventional pressure reducing station to supplement a steam system operator's electricity supply



3.0 The need to address rising fuel costs

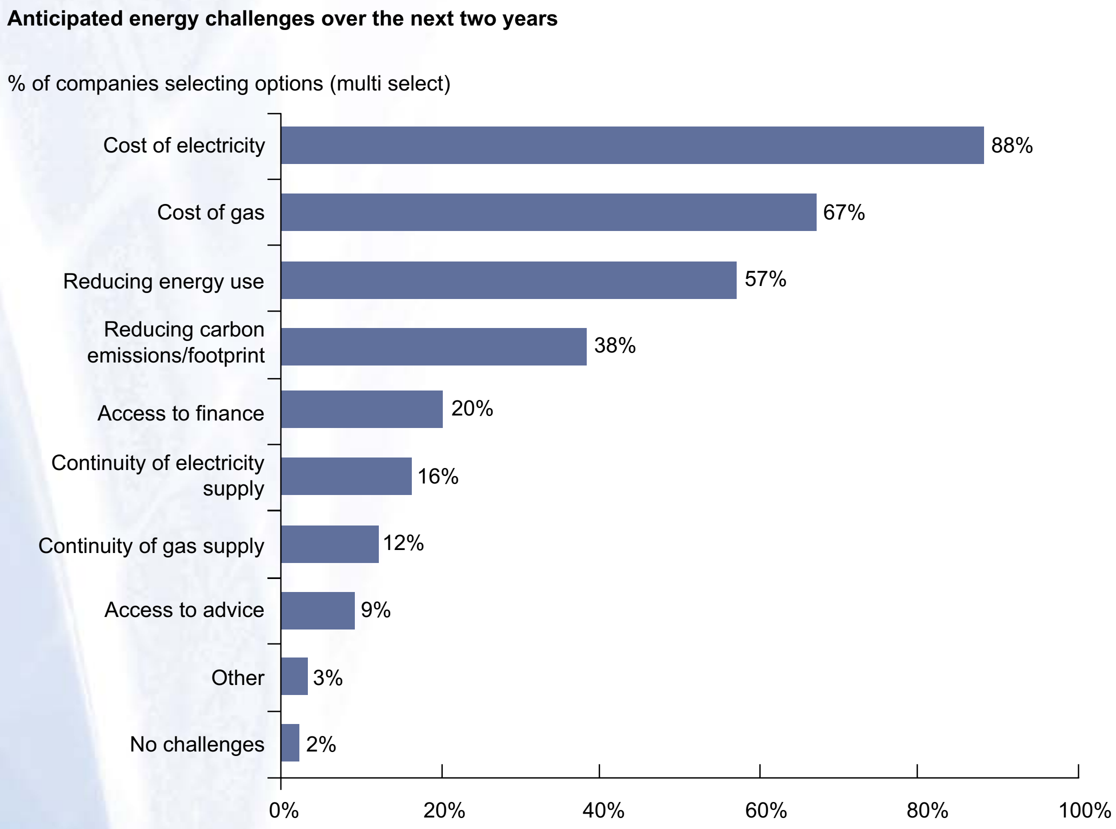
According to the Department of Energy and Climate Change's (DECC's) Quarterly Energy Prices December 2013 report, the UK average price of electricity, including the Climate Change Levy (CCL), has risen by 93% in real terms since 2002.

Average UK industrial electricity prices, including CCL, increased every quarter from the second quarter of 2004 until the first quarter of 2009, then trended down until Q3 2011 when prices started to trend upwards once more. Between Q3 2012 and Q3 2013, average industrial prices in real terms including CCL increased by 3.2% for electricity. Meanwhile, industrial gas prices including CCL rose by 10.4% in real terms.

In Q3 2013, the DECC says UK industrial users paid between 7.08 and 9.73p per kWh of electricity, depending on the amount they used. The price of gas ranged from 2.41 to 3.74p per kWh, roughly a third less.

According to the UK manufacturers' organisation, EEF (formely Engineering Employer's Federation), Executive Survey 2014, gas is the dominant energy source for manufacturing and accounts for 60% of use. Yet electricity prices are of particular concern because they represent the larger cost, with 66% of utility spend on electricity. In its survey, EEF found that the cost of electricity was the most cited energy challenge for UK companies over the next two years.

Figure 3: In its survey, EEF found that the cost of electricity was the most cited energy challenge for UK companies over the next two years



Source: EEF Energy Efficiency and Challenges Survey, 2013

> **"Energy affordability is one of the most critical issues facing manufacturing today. EEF's 2014 Executive Survey confirmed that rising input costs are perceived as the biggest threat to growth."**
>
> EEF Executive Survey 2014: "Business Productivity and Energy Efficiency"

So, while it is notoriously difficult to predict accurately how energy prices will move, the trend is clearly upwards. Indeed, the DECC said in March 2013 that the growing cost of its green policies alone could add 49% to the electricity costs of medium-sized businesses by 2020 and 68% by 2030.

4.0 Implementing energy saving measures

According to the EEF a large proportion of UK manufacturers are already implementing the easier, more cost-effective actions to improve management of energy. Just under two-thirds have undertaken energy audits and over half have already adopted lighting efficiency strategies.

It is therefore likely that more innovative ways to reduce energy bills will become increasingly important to steam-using organisations. Spirax Sarco believes the use of modern microturbine technology to generate electricity from steam pressure reduction is one such innovation.

With the price of electricity for UK industrial users being roughly three times that of gas, producing electrical power via pressure reduction also delivers, in effect, 'free electricity' that can be used locally or sold back into the power grid.

Interestingly, the potential of the technology for UK industrial consumers could be greater than in the rest of the EU. That's because there is a large price differential between electricity and gas in the UK compared to the rest of the EU. According to the DECC, from January to June 2013, UK industrial electricity prices, including tax, were the fifth highest in the EU, while industrial gas prices for medium-sized consumers (defined as using 2,778 - 27,777 MWh of gas annually) including tax were the lowest.

5.0 Types of microturbine technology

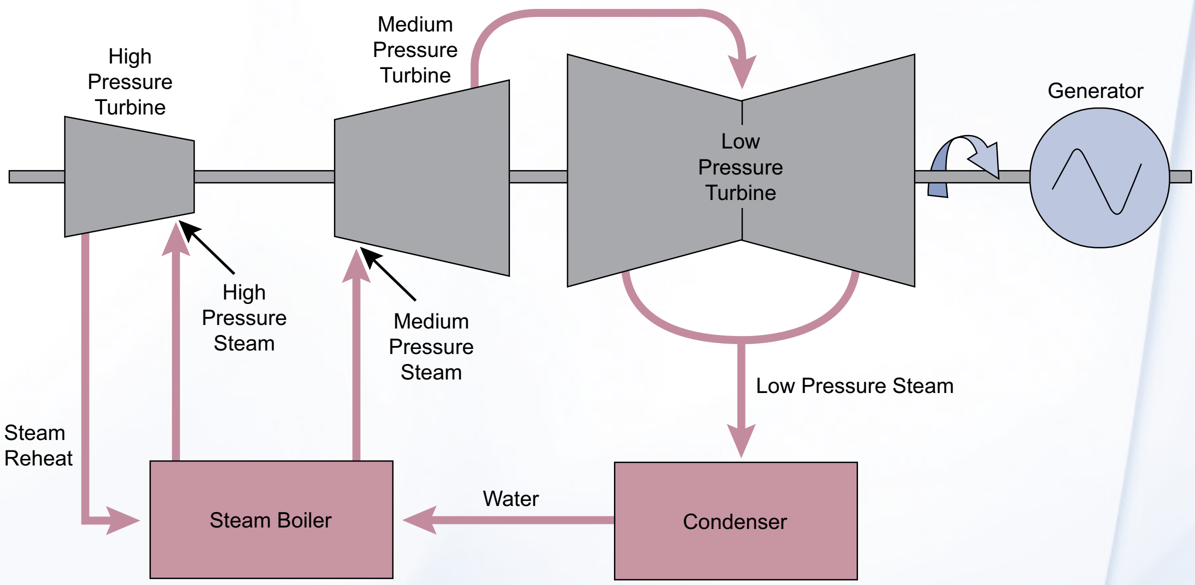
Most of the world's electricity today is generated by steam turbines driving rotary generators. The technology of these large turbines, often sized to hundreds of megawatts, is well established. Steam is reduced in pressure in multiple stages (sets of turbine blades) to achieve the highest pressure drop possible to extract maximum energy to drive electricity generators that feed power into the grid.

However, in the UK the use of much smaller microturbines of a few hundreds of kilowatts by industrial steam users is relatively rare.

Broadly there are two main types of steam turbine – condensing and non-condensing.

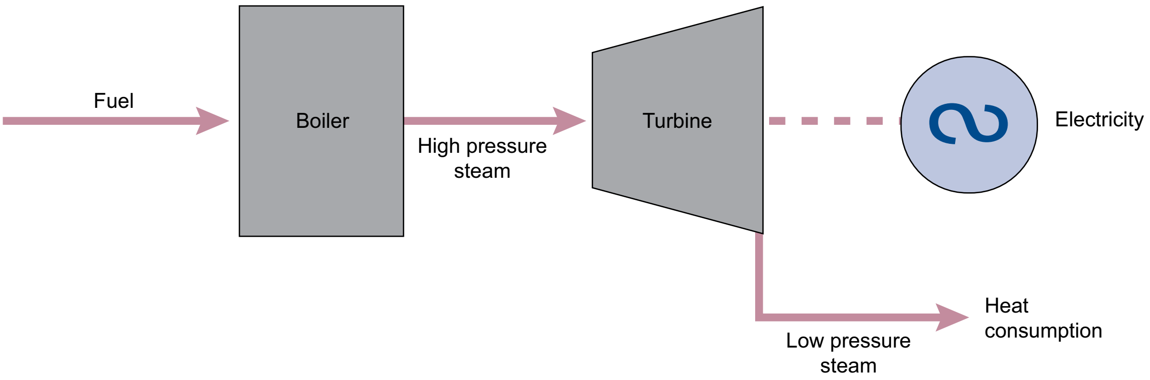
Steam condensing turbines exhaust steam into a condenser, which maximizes the pressure drop across the turbine blades. The condensing steam turbine generates the most electricity from a given quantity of steam, but because it produces only power and has no useful steam output, it is unsuitable for pressure reducing applications. However, condensing turbines can be used to generate electricity in situations where excess steam is produced and would otherwise be vented and therefore wasted.

Figure 4: Schematic of a multi-stage condensing steam turbine used for power generation



Steam back pressure turbines are non-condensing turbines that expand higher pressure steam through a turbine. Shaft power is produced when a nozzle or stator directs jets of high-pressure steam against the blades of the turbine's rotor. The rotor is attached to a shaft that is coupled to an electrical generator. The steam turbine reduces the pressure of the steam that is subsequently exhausted.

Figure 5: Schematic of the principle of back pressure steam turbines



6.0 Microturbines for steam pressure reduction

Most steam systems currently use pressure reducing stations, so many steam users can benefit from installing microturbine-based energy-saving pressure reduction technology. While a pressure let-down ratio of 4:1 is typically required, lower pressure let-down ratios can still offer attractive returns in some instances. However, the greatest benefits will be achieved by applications running at constant load and with a large pressure reduction. The greater the steam demand, the more electricity the turbine will generate and the faster the payback.

To put this into perspective, a steam microturbine producing 100 kW of electrical power can generate typical cost savings in excess of £75,000 per year based on a running time of 8,000 hours per year.

Industries with potential for using the technology include healthcare, food and drink, chemicals processing, pharmaceuticals and any facility with a steam baseload and pressure reduction. The electricity produced can be used locally, for example to run pumps or other equipment, or exported to the power grid. Generating plant connected to one of the UK's electricity distribution networks must meet the requirements set out in Engineering Recommendation (ER) G59/2 (see Figure 6: G59/2 and the connection process).

Microturbine technology itself is well-proven and highly reliable with a service life of 15-25 years. Generally, a system will be installed in parallel to a conventional pressure reducing station. A microturbine will often be sized for a baseline load (for example, in the summer), so a pressure reducing station is still utilised to handle peak loads or seasonal demands.

Figure 6

G59/2 and the connection process

The UK Engineering Recommendation (ER) G59/2, "Recommendations for the Connection of Generating Plant to the Distribution Systems of Licensed Distribution Network Operators (DNOs)" sets out the requirements that must be met before the local DNO will allow generating plant to be connected to the network.

The key stages for meeting G59/2 include (source: Distributed Generation Connection Guide, Energy Networks Association (ENA)):

- Project planning in which the generation scheme's plans are formulated
- Information phase in which information about the proposed plant is submitted to the DNO
- Design in which a formal application is submitted to the DNO which then produces detailed connection design and costs
- Construction during which a contract with the DNO is entered into and the DNO or an independent connections provider builds the connection infrastructure
- Testing and commissioning in which the generating plant is tested and energised

7.0 Spirax Sarco Steam MicroTurbines for pressure reduction

Spirax Sarco have a range of Steam MicroTurbines that are suitable for saturated or superheated steam and are based on the back pressure principle, using well-proven technology that has been deployed in more than 100 units installed globally (see Figure 8: Proven savings across the globe). Their compact design makes the turbines suitable for retrofitting into many existing steam systems and they are supplied fully assembled and tested.

Each installation is supported by a full set of Spirax Sarco expert services starting with an analysis of the site and calculations of the projected savings from a microturbine installation.

Spirax Sarco have a range of MicroTurbines capable of generating from 50 kW of electricity.

The benefits of Spirax Sarco Steam MicroTurbines include:

- **Reduced electricity bills**. Generate from 50 kW of electricity from existing process steam pressure reduction requirements
- **Reduced carbon footprint**. Eliminate energy waste to reduce total carbon emissions
- **Plant optimisation**. Fully utilise steam system capacity to maximise overall plant efficiency
- **Integrity of power supply**. Generating own power supply means less reliance on external suppliers

Figure 7: Spirax Sarco Steam MicroTurbines can generate from 50 kW of electricity

Figure 8

Proven savings across the globe

Spirax Sarco MicroTurbines are delivering multiple benefits for many different organisations around the world in Belarus, Brazil, Czech Republic, Cuba, Egypt, Germany, India, Indonesia, Poland, Russia, Singapore, Slovakia and the UK.

- A district heating installation in the Czech Republic installed a Spirax Sarco Steam MicroTurbine to replace its conventional pressure reducing station (which remains in place as a back-up). Steam at 6 bar g is reduced to 2 bar g, generating 129 kW of power, which is used for running equipment at the district heating plant, with excess electricity fed into the distribution grid.

- A sugar factory in Egypt is generating 145 kW of electrical power from a Spirax Sarco Steam MicroTurbine.

- A food manufacturer in Scotland have installed a Spirax Sarco Steam MicroTurbine to reduce steam pressure from 7.5 bar g to 2.2 bar g to supply a bank of dryers. The company was keen to reduce its electricity costs in the face of an expected 15% rise the following year. The Steam MicroTurbine is designed to produce an electrical power output of 182 kWh for a three-year payback.

8.0 Conclusion

Efficient industrial steam systems are based on generating steam at an elevated pressure in a boiler. This allows the steam to be distributed efficiently using cost effective smaller bore pipework resulting in lower capital costs.

The steam then needs to be reduced to a lower working pressure before it is used by a process or building services application.

A new way to perform this pressure reduction is to use a microturbine. This brings the advantage of using the energy released by the required steam pressure drop to supplement an existing electricity supply or to feed back into the power grid. The energy produced by microturbines reduces the need for electricity from the grid, cutting electricity bills and overall carbon footprint.

Spirax Sarco offers a range of microturbines backed by its expertise to help organisations in many industries to take advantage of this technique to reduce their costs and foster environmentally-friendly operations.

Spirax Sarco is the world leader in steam and energy solutions and can support and help steam users to optimise their systems to achieve the best possible energy and process efficiencies.

Find out more

To find out more about Spirax Sarco energy transfer solutions:

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9.0 Notes

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