Steam and high temperature hot water boilers

Introducing energy saving opportunities for business
Preface

Reducing energy use makes perfect business sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change.

The Carbon Trust provides simple, effective advice to help businesses take action to reduce carbon emissions, and the simplest way to do this is to use energy more efficiently.

This technology overview introduces the main energy saving opportunities for steam and high temperature hot water boilers and demonstrates how simple actions save energy, cut costs and increase profit margins.
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Energy consumption

Steam and high temperature hot water (HTHW) boilers are commonly used in industrial sectors and in some applications in public and commercial organisations.

They are found in circumstances where there is a continual demand for steam or hot water, in a wide range of industrial processes, such as cooking large vats of food, corrugating cardboard and chemical production amongst others. Other large users of these utilities are laundries and hospitals.

Operation of these boilers is energy intensive and can therefore represent a significant proportion of an organisation’s energy costs. In the UK, boilers account for some 60% of carbon emissions from industrial operations and buildings. Therefore, it is important for owners and operators of these boilers to ensure that the plant is designed, installed, commissioned and operated with due regard to energy efficiency as well as safety and reliability.

This overview covers both steam boilers and HTHW boilers, ranging in size from 100kW to over 30MW. Steam boilers operate at a higher temperature than hot water boilers. However, the exact operating temperature will depend on the pressure of the system, which varies between individual boilers. The temperature and pressure requirements of a boiler are dictated by process requirements.

For information about hot water boilers which operate at a lower temperature and are used extensively for central heating and hot water, order or download the Carbon Trust’s technology overview, Low temperature hot water boilers (CTV008).

Summary of key areas

Being so energy intensive, steam and high temperature boilers offer many energy savings opportunities to businesses and these actions can make significant cost savings.

The most appropriate solution will depend on the type of boiler and heating system, the requirements of the process or other heating demands and budget.

Opportunities for energy saving in boiler performance

These can range from simple maintenance actions to combustion air preheating. See page 10.
Opportunities for energy saving in steam distribution
These include checking for and repairing leaks, identifying redundant pipework and ensuring that the system is adequately insulated. See page 26.

Who is this publication for?
This technology overview is written for energy managers, project managers and maintenance teams who are involved in the day-to-day operation of industrial steam and HTHW boilers. It provides an introduction to the key issues that users and operators should consider.

This publication deals mainly with shell boilers, as most existing UK boiler plant is of this design, although much of the advice is applicable to other types of boiler.

This overview covers some of the straightforward steps to saving from improving operation and maintenance, and upgrading boilers and distribution systems. It also introduces some simple measures regarding distribution systems associated with steam and high temperature boilers.
Technology overview

Boilers

A boiler is a device that converts the chemical energy of a fuel into a useful heat output, such as steam or hot water. The fuel type most commonly used in the UK is gas, but some older coal and oil-fuelled boilers are still in operation. The main reasons for choosing oil firing are unavailability or unreliability of gas supplies. There are also a small number of biomass-fired boilers in operation, where there is a good availability of fuel.

Inside a boiler, the fuel is combusted by burners. These produce flames, and the hot combustion gases created transfer the heat to water, which has been fed into the boiler from an external source. The feedwater may enter the boiler directly, or via a buffer tank. The temperature that this water is heated to will depend on whether the boiler output is steam or hot water. High temperature hot water boilers produce hot water at temperatures of over 90°C. Hot water boilers producing water at temperatures of 90°C and below are classed as low temperature hot water boilers and are outside the scope of this technology overview. For information about these, refer to Low temperature hot water boilers (CTV008) available from the Carbon Trust.

There are many different types of boiler design and construction, but all boilers are derivatives of two main types:

• The shell type – where the hot combustion gases pass down a tube and into subsequent bundles of tubes immersed below water level. The heat from these gases is then transferred to heat the water. Most steam and hot water boilers in the UK are derivatives of the shell type, which are also referred to as ‘fire tube’.

• The water tube type – where the water is contained in tubes and the hot combustion gases pass around them to heat the water.

In either case, the heat must transfer across the surface of the tubes containing the water or combustion gases. Therefore, these tubes are made of materials with good heat-transfer properties.

After use, the combustion gases exit the boiler via a chimney known as a flue.

The output steam or hot water will be fed out of the boiler into a distribution system. This is a network of insulated pipes that transfer the steam/hot water to the point(s) at which it is used.

Did you know?

A survey of 300 boilers at over 100 UK sites showed that an average saving of 7% can be made by improving the efficiency of steam generation.
Types of fuel used in boilers

There are a wide range of fuels used. Boilers commonly burn standard hydrocarbon fuels, such as natural gas, oil and coal, but some burn tallow or waste materials. Some boilers, known as dual-fuel boilers, can burn gas or oil. This is useful in the rare cases where an interruptible gas supply contract is held. Coal burners can be a variety of designs mainly centring on how the coal is fed to the boiler and burnt. Currently, gas boilers are the most popular type of steam-raising or hot-water-producing equipment.

Biomass boilers are becoming more popular. Biomass is any solid non-fossil-based organic fuel and includes wood (either grown specifically as a fuel or as waste material), straw, types of grass and many other organic by-products.

The mechanisms for handling and burning fuel differ markedly for solid, liquid and gaseous fuels, and the design of a boiler depends on the intended fuel type(s). However, as many of the general principles for saving energy are the same, this guide does not distinguish between fuel types.

Boiler losses and measures of efficiency

The operational efficiency of a boiler is measured by the percentage of the fuel input energy that is eventually delivered as useful heat output. Not all of the heat released when the fuel is combusted can be used and some potential heat is never released due to incomplete combustion. Major sources of heat loss from steam boilers are through the flue gas, blowdown and radiation to the boiler’s surroundings. See Figure 1 for a diagram of major losses; note that losses in the flue gas are the most significant.

Many measures of performance can be used to define efficiency. Two common ones are combustion efficiency and boiler efficiency, the calculations of which are shown in the example.

The box, right, shows how efficiencies can be quoted. Bear in mind that figures may be expressed as either gross efficiency or net efficiency, depending on whether the gross or the net calorific value of the fuel is used when calculating the energy content of the fuel. Gross calorific value includes the energy (heat) that is held in the water vapour formed during combustion of the fuel. This energy is not included in the net calorific value of a fuel.

Calculations of efficiency – at a glance

Calculations of efficiency – at a glance
Combustion efficiency is defined as the percentage of energy in the fuel that is released after combustion within the boiler. Some of the energy contained in the fuel is lost due to incomplete combustion.

Combustion efficiency (%) = (Actual energy released during combustion x 100)/Total energy content of the fuel.

or

Combustion efficiency (%) = 100 – percentage heat lost due to incomplete combustion of fuel.

Combustion efficiency for gas and liquid fuels is usually quite high, at around 99%.

Boiler efficiency (%) = 100 – (percentage of flue-gas losses + radiation and other unaccounted losses).
When operated correctly, all modern boilers are capable of achieving an efficiency of around 80% (based on the gross calorific value of the fuel). If they do not, action should be taken to achieve at least this level of performance. Higher efficiencies (of up to 85%) are possible for condensing gas boilers and for plant fitted with economisers. However, note that the efficiencies that can be achieved by steam boilers are different from those available to hot water boilers. The type of economiser will have significant impact on the efficiency improvement achieved.

**Steam losses**

As well as the energy losses associated with boilers, there will also be losses associated with the distribution of the steam and hot water. These losses will be due to heat loss from pipework, malfunctioning steam traps, and leaks and unnecessary use of the steam and hot water at the point of use. Opportunities for saving in distribution systems are discussed on page 26.
Scope for boiler savings

Depending on the existing boiler, savings of 20% or greater are possible. The following table gives indicative savings for a range of energy saving measures.

Table 1  Indicative savings for a range of energy saving measures

<table>
<thead>
<tr>
<th>Technique/method</th>
<th>Energy saving potential*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation and maintenance of boilers</td>
<td>Up to 5%</td>
</tr>
<tr>
<td>Boiler and burner management systems, digital combustion controls and oxygen trim</td>
<td>Up to 5%</td>
</tr>
<tr>
<td>Economisers</td>
<td>Up to 5%</td>
</tr>
<tr>
<td>Blowdown heat recovery</td>
<td>Up to 4%</td>
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<tr>
<td>Combustion air preheating</td>
<td>Up to 2%</td>
</tr>
<tr>
<td>Water treatment and boiler water conditioning</td>
<td>Up to 2%</td>
</tr>
<tr>
<td>Total dissolved solids (TDS) control and boiler blowdown</td>
<td>Up to 2%</td>
</tr>
<tr>
<td>Flue-gas shut-off dampers</td>
<td>Up to 1%</td>
</tr>
</tbody>
</table>

* Note that the percentages above represent potential saving if only the corresponding action is taken. Implementing several at once will not always result in savings that are a simple addition of both figures.

Top tip:
All modern boilers are capable of achieving an efficiency of at least 80%. If yours does not, take the simple actions in this publication to achieve at least this level of performance.

Did you know?
Many processes just make use of the latent heat of steam for heating, although there are further opportunities available for energy saving by recycling the hot condensate itself. These include the return of the condensate to the boiler (thus reducing its heating requirement) or the use of the condensate to preheat a feedstock elsewhere in the plant.
Opportunities for energy saving in boiler performance

Low-cost savings
Measures that can be taken immediately include:
• Monitor energy use.
• Carry out boiler maintenance.
• Check combustion efficiency.

Monitor energy use
By monitoring the energy used by boiler plant, the effect of improvements can be assessed in financial and environmental terms. In addition, unusually high energy consumption can be spotted quickly, problems identified and remedial action taken. Determination of current boiler energy use patterns creates a benchmark against which future boiler performance can be assessed.

Key measurements required to determine boiler energy use are:
• **Fuel input** – the amount of fuel fed into the boiler. This can be metered, and in the case of multi-boiler systems, fuel input to each boiler can be monitored.
• **Water input** – the volume and temperature of the boiler feedwater. This can be measured using a meter fitted to the water inlet. Feedwater quality is also important as it determines how much blowdown is required.
• **Water/steam output** – the temperature of the water/steam leaving the boiler, as well as the pressure of the steam/volume of water. This can be measured using steam or water meters fitted to the boiler outlet.

A change in the fuel or water inputs required or in the steam/hot water output obtained may indicate a problem, which is reducing the efficiency of the boiler.

Keep a spreadsheet or log book to record details of boiler performance over time.
Set targets and keep a check on progress towards meeting targets. If progress is slow, carry out another review of the system and look for additional measures that can be taken.

Carry out boiler maintenance
Most equipment operates best when it is new and recently commissioned. Effective maintenance is needed to sustain optimum performance and to prevent faults or inefficient operation. Any facility
where steam is generated, distributed and used requires high maintenance standards and good operational practices. For this reason, sophisticated engineering and control systems are increasingly replacing manual control.

Boiler maintenance actions can be divided into two main categories: those actions that ensure continued safe operation; and those that ensure continued optimum efficiency of performance. The former are mandatory and must always be carried out. The latter are often considered less important, but can lead to significant increases in efficiency and, therefore, reductions in operating costs.

Efficiency maintenance addresses the three main areas where the efficiency can reduce over time:

- **Combustion efficiency** – the effectiveness of release of heat from fuel.
- **Heat transfer efficiency** – the effectiveness of transfer of heat from the combustion gases to the heat transfer medium (steam, water or oil in thermal oil boilers).
- **Boiler heat loss (or thermal integrity)** – the effectiveness of the boiler at retaining the heat introduced into it by the burner.

**Maintaining combustion efficiency**

Boiler fuel is combusted by the burners. Over time, the burner controls can deviate from their original settings and mechanical components can become worn, which can affect combustion efficiency. Therefore, burners and their controls need to be checked at regular intervals and adjusted as necessary.

Combustion efficiency may also be affected if deposits of unburnt fuel build up on the burner surfaces as soot. This is most likely to occur in boilers burning fuels such as coal and biomass, but can also occur with heavier oil fuels. Such build-up can interfere with the airflow patterns in the boiler combustion chamber, leading to inefficient combustion. Where ash is present in the fuel (for coal, biomass and heavier fuel oils, see Maintaining heat transfer efficiency section overleaf), damage to burner surfaces through erosion can also occur, again affecting combustion efficiency as a result. The occurrence of these problems can be reduced and efficiency maintained through regular servicing and equipment checks carried out by a specialist boiler contractor.

**Maintaining heat transfer efficiency**

Heat-transfer surfaces in boilers include the surfaces of the tubes, which contain water or combustion gases depending on the type of boiler water-tube or shell. These surfaces are optimised to provide a balance between the physical resilience necessary for such a demanding environment, and the heat-transfer properties of the surfaces.

When these surfaces become fouled by a build-up of material, their heat-transfer characteristics are compromised. All boilers are susceptible to the build-up of material on the side through which the water flows (the water side), as dissolved solids or suspended particles can be deposited on surfaces. This is particularly common in steam boilers. To reduce the level of build-up, specialist treatment must be applied to the boiler feedwater. Regular checks on the function of water treatment systems must also be carried out to ensure that under- or over-treatment is not occurring. It is usually necessary for these checks to be carried out by a specialist contractor. Further details on water treatment can be found on page 19.
Heat-transfer surfaces may also suffer from corrosion. In addition to reducing the strength of boiler tubes, the presence of corrosion scale on these surfaces reduces the efficiency of heat transfer. Regular corrosion checks should be carried out as part of a boiler maintenance plan.

The use of some fuels – such as coal, biomass and heavier oils – creates ash, that is, unburnable material remaining following combustion of the fuel. Ash can build up on the burner or fire side of the heat-transfer surfaces; this is known as the fouling. It may be necessary to check the condition of these surfaces periodically and to clean them if required. Monitoring of boiler conditions (such as the flue-gas temperature) can provide early warning that a problem is developing. If a trend of increasing flue gas temperature is observed, it could mean that deposits on the surfaces are reducing heat transfer rates so that heat is removed from the flue gas.

Cleaning boiler ash deposits does not always require a specialist contractor, but is potentially hazardous. Therefore, appropriate safety measures, including wearing personal protective equipment such as dust masks, must be taken. For water/steam-side cleaning, an acid wash is usually needed for which it is necessary to seek specialist assistance.

Managing boiler heat loss
Heat is lost from boilers by two main routes; through the flue gas and through the outer surface of the boiler.

Heat loss from the flue gas is largely influenced by how well combustion is controlled and how effectively heat is transferred from the combustion gases. Maintenance issues relating to these factors are the same as for those described in ‘Maintaining heat transfer efficiency’ above.

Heat loss through boiler surfaces can increase if the insulation around a boiler shell is removed or damaged. This is a relatively simple problem to address by ensuring that insulation is always replaced after boiler inspections and by repairing any insulation damage.

Boiler servicing should be performed on an annual basis as a minimum and should be carried out by a suitably qualified technician. It may be necessary to undertake certain actions more frequently, depending on the individual boiler, and the technician will be able to advise on this.

Produce a maintenance manual
A maintenance plan details the maintenance tasks to be carried out, the frequency of these tasks and who is responsible.

A maintenance manual should be produced that is updated regularly. This manual should include:

- The maintenance plan.
- Diagrams of the boiler plant showing the location of key components and controls.
- Schematic diagrams of the heating system and the controls.
- Operating instructions and control settings.
- Emergency shutdown procedures.
- Contact details of installation/maintenance technicians and boiler manufacturers.
Keep a maintenance log book detailing records of work done, the person responsible, and when they were completed. The formalisation of maintenance in this manner should help ensure that tasks are carried out at the correct frequency and will highlight ongoing problems.

**Check combustion efficiency**

For combustion to be carried out efficiently, the correct amount of combustion air should be mixed with the fuel in the burner. There is a theoretical air requirement but, in practice, complete combustion requires more than this. Too little air will result in incomplete combustion whereas too much excess air will lead to heat being unnecessarily lost to the flue-gases. The excess air required is typically 15-25% (more for coal), but the exact amount depends on factors such as the fuel, burner make and type, and firing rate. The optimum amount of excess air required should be known for a particular boiler and can usually be found in the boiler’s manual. Under circumstances where this is not the case, it may be necessary to contact the manufacturer to obtain this information.

Incorrect air-to-fuel ratio can lead to excessive fuel consumption, poor combustion and possibly illegal emissions (see box below). Monitoring the furnace flue gas will highlight any problems with the air/fuel ratio.

**The Clean Air Act 1993** contains provisions relating to the control of grit, smoke, fumes and dust. For example, the Act prohibits, subject to conditions, emissions of dark and black smoke from chimneys serving boilers and industrial plant. It also controls the release of dark smoke from chimneys from industrial and trade premises. It can also regulate chimney height, and grit, dust and fumes from non-domestic furnaces.

Analysis of the flue gas will highlight if there is incomplete combustion in a boiler. The analysis checks the amount of oxygen and carbon monoxide in the flue gas to determine whether combustion is being carried out in an optimum manner. In most cases, this will be done routinely by the process operators or may be carried out automatically.

An air/fuel ratio may be wrong because of poor control, a poor set-up or mechanical problems with the burner.
A specific type of combustion control is oxygen trim control. The oxygen content in the flue-gas stream is measured, giving a good indication of combustion efficiency. Following measurement of the oxygen content, a signal from the control unit alters the amount of combustion air (via damper or fan-speed control) to maintain optimum combustion conditions throughout the range of firing rates at which the burner can operate. Oxygen-trim controls can be added to a conventional combustion control system or can form an integral part of a digital control system. They can take account of changes in air density such as when ambient conditions (for example, air temperature) alter or when airflow is restricted through filters. Note that air entering the plant as a result of leakage into ductwork can provide false signals. Trim controls can also incorporate CO measurement so that poor combustion can be avoided when trimming the oxygen level. The equipment requires regular inspection, cleaning and calibration, particularly of the probe as it operates in arduous service conditions.

Case study
What other businesses are doing

A digital combustion control system that included an oxygen detector in the boiler flue was installed at a distillery in Elgin. This detects the oxygen content of the flue gases, and then adjusts the fuel and air mixture accordingly. It is this constant feedback that ensures maximum efficiency throughout the firing range of the boiler. In addition, the combustion-air modulating damper was replaced by variable speed drive control of the fan motor.

These changes resulted in annual savings of about 1,009,800kWh of gas and 44,400kWh of electricity. This equates to a reduction of 6.3% in total site energy consumption against 2001 levels. Annual emissions of CO₂ reduced by an estimated 210 tonnes through reduced gas use and a reduction in imported electricity. An additional technical benefit is that the new controls are able to respond quickly to any changes in steam demand, which has led to improved production rates due to reduced downtime and steadier steam flows and pressures.
**Medium-cost savings**

There are a number of energy saving measures that require some financial outlay. These include:

- Recovering flue-gas heat.
- Installing flue-gas dampers.
- Installing variable speed drives for combustion air fans.
- Minimising radiation heat losses.
- Checking that water treatment is adequate.
- Optimising boiler blowdown.
- Recovering blowdown heat.
- Reheating combustion air.

**Flue-gas heat recovery**

Boiler flue gas contains a great deal of heat that can be recovered and used elsewhere. Flue gas from a boiler is at a higher temperature than that of the steam produced and is typically around 200°C in most modern steam boilers. The potential for heat recovery is often limited when the combustion gases contain acidic elements, such as with coal or oil firing. In these cases, it is usually necessary to maintain the exhaust-gas temperature above a certain level to prevent the condensation of acid.

Still, heat recovery is a viable option for most businesses using gas-fired boilers. The most common action is the installation of economisers.

**Economisers**

A tried-and-tested technology for recovering heat from flue gases for shell and water-tube boilers, an economiser is a gas-to-water heat exchanger located within a purpose-built flue section (see Figure 2 below). The main use of the heat from economisers is to preheat boiler feedwater before it is introduced into the boiler. The relatively cool feedwater is pumped through the heat-exchanger tubes where it absorbs heat from the hot flue gas exhausted from the boiler before being pumped into the boiler. Therefore, during normal boiler operation, the economiser receives a continuous flow of water.

Condensing economisers use the same principle, but further reduce the flue-gas temperature, which improves the boiler system efficiency further.

Simpler economisers are also available that consist of a water-jacket fitted around the stack, but these are less efficient.

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**Figure 2 Schematic of an economiser**
Economiser installation requires careful financial and technical consideration. Attention should be given to the correct sizing of the economiser as, if too much heat is transferred to the feedwater, it may be flashed off to steam or it may exceed the acceptable operating temperature for the system. This temperature can be found in the boiler specification. Alternatively, the manufacturer or an expert consultant should be able to provide advice. Attention should also be given to the additional controls and bypasses required for varying loads and fuels, the risk of potential problems with the flue-gas flow and the possibility of damage to the stack.

Economisers are best suited to gas-fired boiler plant. It is generally considered less economically viable to install an economiser to recover heat from boilers burning other fuels. With dual-fuel (gas and oil) burners, the economiser is normally bypassed when firing oil to avoid corrosion caused when the flue-gas temperature falls below the dew point (the temperature at which condensation will occur and the moisture which will cause corrosion). In steam boilers, where a substantial proportion of the condensate is returned to the boiler feed tank, the boiler feedwater may be at a relatively high temperature already, so the potential increase in temperature available from the economiser will decrease and the increase in efficiency will, therefore, be minimal.

Economiser installation involves:
- Fitting the heat exchange unit in the flue section.
- Diverting the feedwater pipework to and from the unit.
- Wiring to the bypass damper limit switches (if necessary).
- Fitting water and flue-gas thermometers (to establish performance).

Depending on the size of the boiler, economisers can be quite large. Therefore, consideration should be given to the space available within the boiler room at the boiler-flue outlet.

Fact:
Installing a economiser typically gives energy savings of between 2% and 5% although larger savings may be possible depending on the flue gas temperature and type of economiser.

Case study
What other businesses are doing
At an international food processing company, projects to improve boiler house performance involving the fitting of an economiser and advanced boiler control resulted in:
- Annual cost savings of over £55,000.
- Annual energy savings of about 7,000MWh, equivalent to CO₂ savings of around 1,300 tonnes.
- Boiler efficiency increased by 9.8%.
- Payback period of one year.
Install flue-gas dampers

During stand-by, there is a continuous flow of heated air through the boiler to the flue due to natural convection resulting in heat transfer from the water and equipment. This heat is lost from the boiler to the chimney and can be significant where boilers are put on stand-by regularly due to process load changes. The function of a shut-off damper is to restrict airflow through the flue and prevent heat loss from the boiler when on stand-by. Dampers are particularly suited to situations where intermittent capacity is needed, and where it is necessary to operate a boiler in stand-by mode and cycle it to keep the required pressure/temperature conditions.

Automatic, gas-tight, shut-off dampers are widely available for installation in boiler flues. A cheaper alternative for forced-draught burners is to install an automatic, air-sealing damper at the combustion-air fan inlet. This is particularly economic for retrofit projects. An automatic, fully closing damper, fitted either at the flue-gas exit or at the burner combustion-air fan inlet, closes after any post-combustion purge operation. This reduces the ingress of cold air and prevents air being drawn through the boiler when it is not firing. Therefore, this reduces the system standing losses and prevents excessive fuel being consumed. Figure 3 right, shows a typical shut-off damper installation.
### Damper installation

The installation of dampers is relatively simple and may be undertaken by the manufacturer or a suitable contractor.

The work involves cutting the flue ducting (if a hot-gas damper is chosen), inserting the unit, complete with servomotor drive, and making the necessary electrical interlock connections. Safety interlocks are fitted to prevent the burner firing with the damper closed, which avoids the potential build-up of unburnt gas in the boiler or a build-up of carbon monoxide in the boiler room. Electrical connections are then made from the damper to the appropriate control circuit in the burner panel. The installation cost is relatively low compared with the savings obtained. This device is ideal for stand-by boilers and those with cyclic loads.

Air-inlet sealing dampers are also a cost-effective option; these are generally smaller and are not exposed to hot and, occasionally, dirty flue gases.

### Install variable speed drives

For boilers fitted with fixed speed, forced-draught combustion air fans, control of combustion air is typically achieved by throttling with an inlet air damper. Although simple and reliable, these dampers generally have poor control characteristics at the top and bottom of the boiler’s operating range. In addition, variations in fan motor power consumption with boiler load are minimal. This results in a higher-than-necessary electricity consumption. Installation of a variable speed drive (VSD) to combustion air fans can significantly reduce electricity consumption by fans at low loads.

#### How do VSDs save energy?

Controlling the amount of combustion air delivered to the boiler by using a damper reduces the volume of air delivered, but the fan speed remains constant. A small power reduction is achieved as the airflow decreases. However, as the power consumed by a motor is almost proportional to the cube of fan speed, varying the fan speed as a means of controlling volume flow can generate large electrical energy savings.

A VSD system reproduces the operating characteristics of a fixed-speed combustion air fan and adjustable damper arrangement by controlling the speed of the motor to match the required load. Using a VSD system has been shown to be cost-effective while maintaining good combustion conditions and high boiler efficiency. VSDs for combustion air fans (and oxygen trimming) can be fitted as options with new burners or as a retrofit to existing equipment.

#### Energy saving potential of VSDs

The savings potential is greatest where the load on the boiler is less than the maximum continuous rating for long periods and the burner is required to operate at mid or low-fire. Because electrical energy consumption is proportional to the cube of the motor speed, halving the fan speed can reduce the energy consumption to around an eighth. The actual savings will depend on the operational requirements of specific installations, but electrical savings in excess of 60% may be possible in some applications.

### Minimise radiation heat losses

Radiation heat losses are those heat losses from the surface of the boiler through a combination of convection and radiation heat transfer. In a modern, efficient system, the radiation loss from the boiler should be less than 1% of the heat input rating. However, it may be considerably higher on older boilers and could be more than 2% of fuel input on plant with poor or damaged insulation.
Radiation losses depend on boiler temperature and not output, so running the boiler at a high load, rather than a low load, will be proportionally more efficient. Boiler load depends on the demand of the site or process and it may be possible to run one boiler at high load instead of two boilers at low load, especially if steam or hot water use has recently been reduced by other energy efficiency measures.

Radiation losses can be assessed by monitoring the boiler’s fuel consumption under hot stand-by conditions, that is, the state where the boiler is held at operating temperature, but is not actually fulfilling steam or hot water demand.

To minimise radiation losses, boiler insulation should be kept in good condition. All pipework, valves, flanges and fittings in the boilerhouse should be adequately insulated and valve mats/covers should be replaced after maintenance work. Further information on these actions is given on page 26.

Rescheduling process activities may also help to optimise boiler operation and minimise the periods of operation on low load to minimise radiation losses.

Water treatment

Water is an excellent solvent in which many compounds readily dissolve. It is also an excellent medium for transporting suspended and colloidal material. However, the presence of these impurities and contaminants makes appropriate water treatment and conditioning regimes essential to provide water of a suitable quality for the effective operation of steam boiler plant and systems.

The water used in steam boilers can be supplied from many different sources and will contain various contaminants and impurities. If water is used directly in steam boilers without treatment, then these contaminants and impurities can cause fouling of heat-transfer surfaces and corrosion, leading ultimately to plant failure. Hard water contains mainly calcium and magnesium salts and these result in scale formation. Soft water is preferable for use in boiler plant because it has fewer dissolved solids, so it needs less treatment. Foaming, due to high levels of total dissolved solids (TDS) and alkalinity in the boiler water, can also cause operational problems, such as salt deposits and pipework corrosion.

Poor water treatment and boiler-water conditioning can:

- Reduce the steam-generating efficiency of boiler plant through fouling of water-side, heat-transfer surfaces and increased blowdown.
- Increase the cost of routine boiler cleaning operations (chemical and mechanical) and the need to repair/replace corroded parts.
- Result in carryover (see below) and reduced heat delivered to components using the steam system.
- Result in catastrophic plant failure if sustained over a significant period.

In addition, insurance, warranties, guarantees or leasing terms may require the demonstration of appropriate water treatment.

One critical issue to consider is carryover, whereby water entrained in the steam leaving the boiler contains impurities, called total dissolved solids (TDS) from the boiler water and water-treatment chemicals. Carryover can be caused by chemical or mechanical means and should be avoided or reduced to a practical minimum as it can cause potentially dangerous
corrosion, reduced heat transfer, damage to the steam distribution system and water hammer, which is a knocking or hammering noise that occurs due to a sudden increase in water pressure as a result of a change in direction of flow closure or an obstruction in the line.

The chemical causes of carryover can be influenced by:
- Controlling suspended solids levels.
- Avoiding high alkalinity levels.
- Avoiding the introduction of oils and soap-like substances.

These factors can be controlled by water treatment, which is carried out automatically with most installed equipment. The equipment will need period checks by a water treatment specialist.

The mechanical causes of carryover can be influenced by:
- Avoiding operation at lower-than-design pressure.
- Avoiding operation at high water levels to minimise risk of boiler water entering the steam outlet pipes. This is known as ‘priming’.
- Ensuring internal steam baffles or external steam separators operate properly. These devices aid the separation of the steam produced from any entrained water.
- Matching the burner firing rate to the load.
- Controlling the feedwater by means of a modulating control valve rather than an on-off feed pump. For rapid load changes, consider using a two-element water-level control system based on measuring the steam flowrate.

Types of water treatment
Water treatment is generally divided into two forms:
- External treatment – applied before the water enters the boiler to remove or modify problem mineral salts.
- Internal treatment (sometimes referred to as boiler water conditioning) – chemicals are added directly to the feed or boiler water to prevent scale formation and corrosion.

Modern boilers tend to be compact and have a high rating, so they may require closer control of parameters during water treatment than older or moderately rated plant, which can tolerate more extreme water conditions.

Energy saving potential of correct water treatment
The most obvious loss of efficiency (and therefore the greatest energy saving potential) will be through scale. The impact of any scale deposits is determined by the composition and thickness of the scale. Scale will lead to a rise in the flue-gas temperature and, as a rule of thumb, for each 5°C rise in flue-gas temperature, the efficiency will fall by 0.25% of fuel input.

Loss of efficiency will also occur as a result of carryover and corrosion, but this is less quantifiable.

Optimise boiler blowdown
When water is converted to steam in a boiler it leaves behind suspended solids and dissolved salts. This has the effect of increasing the solid and salt concentration in the remaining water and, if left unchecked, will eventually lead to crystallisation of these salts on any surface. This leads to the fouling of heat transfer surfaces and a general build-up of solids in the base of the boiler. The total quantity of mineral salts that can be tolerated in a boiler depends on the boiler design. Controlling the quantity of TDS is an integral part of boiler water treatment. See below for the recommended levels.
Table 2 Recommended TDS levels

<table>
<thead>
<tr>
<th>Boiler type</th>
<th>Maximum TDS (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke and water tube up to 10bar</td>
<td>5,000</td>
</tr>
<tr>
<td>High-pressure water tube</td>
<td>3,000-3,500</td>
</tr>
<tr>
<td>Packaged and economic</td>
<td>3,000</td>
</tr>
</tbody>
</table>

To maintain the TDS concentration below the maximum recommended level, a portion of the boiler water at steam temperature must be removed, or ‘blown down’, from the boiler and then replaced with cooler make-up water, which has been treated and has a lower TDS content than the old boiler water. This process reduces the overall suspended and dissolved solids content in the boiler water and, therefore, reduces the likelihood of scaling inside the boiler. The disadvantage of blowdown is that typically 1-5% of the energy input to the boiler is lost and any treatment of the make-up water imposes an added cost.

Before discharging to drain, it is necessary to cool blowdown water to below 43ºC (to comply with consent conditions and thus avoid detrimental effects at sewage treatment works). This is achieved by diluting it in the blowdown vessel with cold water. If the make-up water is treated, the blowdown process also has associated chemical costs.

The correct level of TDS required for a particular boiler is controlled manually or automatically and the blowdown regime can be intermittent or continuous, or a combination of both.

In manual systems, a representative sample of the boiler water is tested and the correct TDS level is maintained by the operator controlling how often and how long the manual valve at the bottom of the boiler is opened. This form of control is basic and can result in wide fluctuations in measured levels of TDS. Provided the boiler can withstand these variations, this is generally not a problem as long as the severity and duration of the variations are within limits accepted by the boilermaker and approved by the water-treatment specialist.

With manual control, excessively low TDS levels are usually maintained to allow for the higher margins of error due to manual operation. As a result, energy loss tends to be greater than necessary. Therefore, it is preferable to provide automatic control of TDS levels.

Automatic control devices rely on sensors, and monitoring and control equipment to regulate blowdown via an automatically controlled, boiler blowdown valve. This valve is usually provided in addition to a valve arrangement, which is used to provide bottom blowdown for periodic sludge removal or to test water-level controls.

It should be noted that automatic TDS control systems should be inspected, cleaned and calibrated regularly, particularly the probe as it operates in arduous service conditions.

Top tip:
Consult your boiler manufacturer to find out what the recommended TDS level is and compare this with your current operating regime. You may be able to use blowdown less frequently and save energy and water costs.

Recover blowdown heat
Energy and water treatment efficiency can be improved by recovering flash steam and residual heat from blowdown. As explained above, boiler blowdown water has to be cooled in a blowdown vessel or tank to below 43ºC before it can be discharged to an effluent treatment system or drain. Up to 80% of the heat in the boiler blowdown water can be recovered.
Heat recovery can be implemented through the use of flash steam recovery vessels, heat exchangers or both. Such measures save energy by increasing the temperature of the feedwater to the boiler and reducing the amount of fuel consumed in the boiler. Figure 4 right, shows a typical system with recovery of flash steam and residual heat from blowdown water.

**Recovery of flash steam**
Passing the blowdown water through a flash vessel generates low-pressure steam. The flash steam that separates as the pressure is reduced downstream of the boiler blowdown valve can then be collected. Flash steam can be used for feed tank heating or other uses. This system of heat recovery is suitable for plants with continuous blowdown systems.

**Energy saving potential from blowdown heat recovery**
Recovering flash steam from continuous blowdown can reduce the energy loss by up to 50% to give an energy saving of 0.5-2.5% of the boiler heat input. Using heat exchangers to recover heat from the remaining liquid blowdown can provide a further saving of around 25% to give an overall energy saving of 0.75 - 3.75% of heat input.
Preheat combustion air

The air required to combust the fuel is generally taken from within the boiler room, either assisted by a fan in a forced-draught burner or unassisted in the case of a natural-draught burner. This incoming combustion air is at boiler room temperature, which is cooler than boiler operating temperature. Therefore, boiler efficiency can be improved by preheating the incoming combustion air up to boiler operating temperature. This reduces the amount of boiler energy that becomes transferred to the combustion air as it enters the system, and, as a result, provides a higher flame temperature from the burner.

The usual heat sources for heating combustion air are:

- Heat remaining in the flue gases.
- Higher temperature air drawn from the top of the boilerhouse.
- Heat recovered by drawing over or through the boiler casing to reduce shell losses.

Using the heat remaining in the flue gases can be expensive and requires a stainless-steel, plate-type heat exchanger to be fitted in the boiler-flue system. It is also necessary to fit bypass dampers when firing fuel oil instead of natural gas. In addition, the forced-draught fans must be capable of overcoming the additional back pressure.

Most gas and oil burners used on boiler plant were not originally designed for high preheat temperatures and a maximum increase of 50°C is usually the most that can be tolerated (see top tip box below). Modern burners are available that can stand much higher temperatures. Therefore it is possible to consider installing a heat exchanger in the exit flue as an alternative to an economiser, although this is likely to be a less efficient method than preheating boiler feedwater.

**Energy saving potential of preheating combustion air**

Boiler efficiency can be increased by 1% by raising the combustion air temperature by 20°C although the savings achieved will depend on the type of system installed. Ducting hot air down from the top of the boilerhouse will typically provide savings of up to 1%, while drawing combustion air over or through the boiler casing can provide savings of up to 2%.

**Top tip:**

Preheating the combustion air is less effective than preheating water through economisers, but increasing air temperature 20°C gives a 1% improvement in efficiency so as most burners in industrial boilers can only operate with up to 50°C of air pre-heat a maximum saving of 2.5% is possible.

**Did you know?**

Burner manufacturers now supply a range of low-NOₓ burners for cold-air and hot-air firing that incorporate exhaust-gas recirculation. The burners incorporate a number of special features (usually including carefully staged combustion and partial fuel premixing) and have been shown to reduce NOₓ emissions significantly.

Although more commonly used in furnace applications, self-recuperative burners have been developed that are equipped with an ejector pump, known as an eductor, to draw hot waste gases from the flue or chimney through an inbuilt recuperator where they can preheat the incoming cold combustion air. A separate recirculating fan can also be used, but flue-gas recirculation is generally considered a pollution control measure rather than an energy efficiency measure.
Longer-term savings

Boiler replacement

If a boiler is more than 15 years old, or if it is showing signs of inefficient operation it may need replacing. Boiler replacement requires careful consideration of a number of factors to ensure that the replacement meets the needs of the business.

Process requirements

When selecting a new boiler it is important to make sure that it will meet requirements. Quite simply, choose the right size. First review the current requirements of the processes that the boiler is used for, as these may have changed over time. Then match the new boiler to meet demand. Smaller boilers cost less, so it is important that the new boiler meets, but does not excessively exceed, requirements.

However, it may be necessary to consider the future development of the business in terms of any associated increase in the boiler capacity required. Some organisations may choose to install a larger boiler to meet anticipated future demand, while others may simply ensure that the boilerhouse has sufficient space to address new capacity requirements by adding new boilers in the future. Perhaps the most efficient way of addressing future demand issues is to replace the old boiler with a series of smaller boilers. If demand drops, capacity can then be reduced by shutting down or removing boilers from the system, thus enabling the remaining boilers to continue to fire under the most efficient load levels.

Boiler compatibility

When replacing a boiler, it is necessary to ensure that the new boiler is compatible with the existing steam or hot-water distribution system. Incompatibility may mean expensive pipework upgrades must be carried out. There may be opportunities to reduce any existing areas of redundant pipework or to upgrade insulation during the replacement process.

The size of the current boilerhouse must also be taken into consideration. In particular, this will be relevant if a boiler with a larger footprint is being considered, or if a move to several smaller boilers is a possibility. This is also a good time to consider whether the current boiler is located in the most suitable position – is it close to the main points of use? If a new boilerhouse is required, this may provide an ideal opportunity to relocate the boiler to an optimum location.

Replacement of older boilers may also mean a change of fuel supply (for example, from oil to gas). This may require a different system for fuel storage and input to that of the old boiler. The availability of the new fuel type must also be assessed.

Selecting burners

There are many types of burner and it is important to choose the correct one for a particular application to avoid excessive energy consumption and high energy costs. Some companies simply replace like for like, but new types of burner are frequently coming into the market, and they may be more appropriate and efficient for the application.

Financial considerations

When purchasing a new boiler, always analyse the life-cycle cost, which includes capital expenditure, maintenance and fuel. Consider the rate at which the investment will pay for itself as a result of the increased efficiency over the old boiler.

A change of boiler may also mean changes to maintenance costs, which may include extra budget for staff training on how to maintain the new system. It is also possible that maintenance procedures previously carried out in-house will now need to be contracted out or vice-versa.
If a change of boiler fuel is required, investigate the availability and cost of the new fuel supply before selecting a new boiler.

**Environmental considerations**
The environmental policy of a company may be a key influence in boiler selection. A new, higher efficiency boiler may have reduced emissions of harmful gases such as NO_x, SO_x and CO_2. In addition, the fuel type used may influence emission levels. It may also be possible to further reduce these emissions, (for example, by selecting a boiler with a low-NO_x burner).

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**Case study**

**What other businesses are doing**

A quality knitwear manufacturer in Scotland replaced its existing oil-fired boiler, which served production processes and factory space heating, with two smaller gas-fired boilers equipped with digital combustion control. The combination of advanced controls and correct boiler sizing allowed better boiler utilisation and afforded substantial fuel and cost savings. The annual savings for the company totalled nearly 400,000kWh or the equivalent of 35,000 litres of fuel oil and the substitution of natural gas for oil also resulted in a cleaner operation with reduced CO_2 emissions. The whole project realised total annual savings of £13,200 (2003 costs).
Opportunities for energy saving in steam distribution

Check for leaks

Steam is an expensive utility that is difficult to contain. Any processes that use steam or any steam distribution systems are likely to have steam leaks, which cost money and also present a safety hazard. The wastage caused by even a small leak can be significant.

A regular programme of leak checking and repair should be undertaken, tackling the largest leaks first. Steam leaks most frequently occur at faulty valves or traps, pipework flanges and joints. The ‘wisps’ of steam are often visible or audible and can frequently be detected through these means. However, in noisy or darkened environments more sophisticated methods of detection may be required. This may include metering the steam as it leaves the boilerhouse and when it arrives at its destination. Any sudden increase in the difference between the steam metered at the two locations may indicate a leak somewhere in between. There is also a range of steam-leak detection systems available commercially that employ techniques such as ultrasonic detection and alert operators to the problem. Any company dealing with steam distribution systems will be able to provide advice on appropriate leak-detection equipment.

The method of repair will depend on the location and cause of the leak. Leaks at valves and traps may sometimes be caused by the ingress of dirt. If this is detected at an early stage, cleaning these parts can fix the leak. However, leaks caused by faulty equipment may require replacement of the valves, traps, flanges or joints. In some cases, leaking pipework may require welding. In all cases these repairs should be carried out by a specialist.

Ensure adequate insulation

Insulate all steam pipework, including valves and flanges, to prevent heat losses. The current lagging may not be the correct thickness, some lagging may be missing and other parts of the lagging may be damaged or waterlogged. By checking insulation regularly and taking corrective action, energy and cost savings of up to 5% can be made. Regular checks on insulation should also be made on hot-water and hot-oil systems.

Thermal surveys can detect excessive heat loss from pipework. These surveys can be carried out by specialist lagging companies who can then recommend a lagging thickness to correspond to the pipe size and temperature as appropriate.

For more information about thermographic surveys of pipework, see the Carbon Trust’s publication, Identifying energy savings with thermal imaging (CTG003).
Identify redundant pipework

On older sites, some of the original steam distribution system may have become redundant, for example, if parts of the plant have since been removed or relocated. If this is the case, it is important that the redundant part of the system is sealed off as near to the boiler as possible. Otherwise, the resulting ‘dead leg’ can become a source of unnecessary heat loss. This action is equally valid for hot-water and hot-oil systems. All work in sealing dead legs requires the input of a specialist.

For new installation or refurbishment, unnecessary heat loss can be prevented at the design stage by locating the plant as close to the boiler as possible. This action will minimise the use of unnecessary lengths of pipework and will, therefore, result in a more efficient system with lower heat loss.

Ensure that steam traps are working effectively

It is inevitable that some steam will condense in the distribution network. Steam traps, if they work correctly, remove this condensate from the system without significant losses of steam. However, a major source of steam loss is through sticking steam traps. These will result in a continuous escape of steam that will be visible and audible. Steam traps should be checked as part of a regular distribution network survey and corrective action taken if any are found to be defective. Replacement of steam traps can be carried out by a site maintenance team, if available, or by specialist contractors.

Consider condensate recovery

Steam condensate from the plant is a valuable source of heat and, where possible, insulate the pipework that returns this to the boiler, thereby reducing the energy load on the boiler and conserving water.

Decentralise and rationalise steam supply

In the manufacturing and process industries, energy for process and space heating has traditionally been provided from one central boilerhouse (or on large sites several) through site-wide steam distribution systems. Over time, it is not unusual to find that the steam demand on sites has grown, moved or diminished because of changes to processes and operations. These often occur incrementally with time and this is particularly the case on long-established sites. Such changes can result in boilers operating at low loads and the distribution losses accounting for a disproportionate amount of the boiler output.

Decentralisation has the potential to provide significant savings. It involves replacement of a site’s centralised steam supply system with individual point-of-use energy sources tailored to their specific requirements. This approach has been adopted by some companies, particularly since natural gas has become the dominant fuel used in industry. Decentralisation can help reduce overall steam production across a system, give control over the quality of the steam supplied for each application, and reduce energy losses associated with distribution systems.

Top tip:

Repairing leaks
When repairing leaks, make sure you tackle the largest steam leaks first to maximise your savings.
When considering decentralising the system, think about:

**What is the steam for?**
Consider everything that steam is used for, and think about whether steam is even the best utility. One example is space heating. This might not need a steam boiler at all, but could be tackled with a low temperature hot water boiler, or gas-fired radiant heaters.

**What steam pressure is needed?**
Some applications will need a much higher pressure than others – and running them from the same boiler may not be the most efficient way of serving this need. Analyse the quality of the steam required and consider if point-of-use boilers will make savings.

**Are there any redundant applications, or dead legs?**
If these are closed off, what does that mean for the distribution system? This can also have an effect on where new boiler plant is housed or the way pipework runs.

**What level of steam supply security is needed?**
Some businesses cannot afford any loss of steam supply, for example, if it would halt production and/or spoil product. In this case a back-up supply would be essential and its provision would need to be considered in any potential de-centralised system.

**Are there alternatives?**
In addition to replacing large centralised steam generation with smaller local supplies, it may be possible to deliver energy for some uses by alternative means. For example, a site may have scope (typically a stable heat requirement and a readily available supply of fuel) to use a biomass boiler.

The diagram on page 29, shows an example of how a company could make savings by decentralising its system.
In this example (Figure 5), a site has several applications all run from a central set of boilers. These include operational processes around the site, space heating and even a redundant process. The processes have different levels of steam requirement, with one requiring a higher pressure.

The second diagram (Figure 6) suggests how the example system might be decentralised to enable energy savings:

- The applications with a lower pressure demand are served by a central boiler – less energy is required to raise steam to lower pressures.
- The process requiring higher pressure steam is supplied from a separate point-of-use boiler – pipework lengths and the associated heat losses and potential for leaks have been reduced significantly.
- The redundant process and associated pipework is removed, removing the associated heat losses and potential for leaks completely.
- The space heating requirement is supplied directly by a hot water boiler rather than using the steam to heat the water.
It should be remembered that this is just an example and each site will need to analyse their requirements and the options carefully, perhaps with the help of an expert.

Case study
What other businesses are doing

A major Scottish distillery moved from provision of space heating by 30 year old low efficiency (55%) steam boilers in a central boiler house to a decentralised system that involved replacing/downsizing the central boiler capacity and addition of local heat provision from boilers and radiant gas heaters.

- Annual energy saving of around 10,553 MWh.
- Total energy cost savings of £219,000 per annum.
- CO₂ savings of 3,337 tonnes per annum.

Figure 6 Decentralised system
In summary, for companies using steam and high temperature hot water boilers there are a significant number of actions that can be carried out at no or low cost. The following table gives an overview of the opportunities presented in this publication.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Action</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>No/low</td>
<td>Monitor energy use</td>
<td></td>
</tr>
<tr>
<td>No/low</td>
<td>Carry out boiler maintenance</td>
<td></td>
</tr>
<tr>
<td>No/low</td>
<td>Check combustion efficiency</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Consider flue-gas heat recovery</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Install flue-gas dampers</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Install VSDs for combustion air fans</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Minimise radiation heat losses</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Check water treatment is adequate</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Optimise boiler blowdown</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Consider blowdown heat recovery</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Consider combustion air preheating</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Consider boiler replacement</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Action</td>
<td>Progress</td>
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<tr>
<td>-------</td>
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</tr>
<tr>
<td></td>
<td>Steam distribution</td>
<td></td>
</tr>
<tr>
<td>No/low</td>
<td>Check for leaks</td>
<td></td>
</tr>
<tr>
<td>No/low</td>
<td>Ensure adequate insulation</td>
<td></td>
</tr>
<tr>
<td>No/low</td>
<td>Identify and seal redundant pipework</td>
<td></td>
</tr>
<tr>
<td>No/low</td>
<td>Ensure steam traps are working correctly</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Consider condensate recovery</td>
<td></td>
</tr>
</tbody>
</table>
# Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>Unburnable material produced in boilers which use fuels such as coal, biomass and heavier oils.</td>
</tr>
<tr>
<td>Blowdown</td>
<td>High-pressure water at the steam saturation temperature that is released from a steam boiler to control water quality and therefore prevent scaling of the boiler.</td>
</tr>
<tr>
<td>Burner</td>
<td>Devices which combust the boiler fuel through mixing it with air.</td>
</tr>
<tr>
<td>Carryover</td>
<td>The water entrained in the steam leaving the boiler.</td>
</tr>
<tr>
<td>Combined heat and power (CHP)</td>
<td>A plant designed to produce both heat and electricity from a single heat source.</td>
</tr>
<tr>
<td>Combustion air</td>
<td>Air that contains the oxygen needed to burn the fuel. Identified as either primary air (introduced at the point of combustion) or secondary or tertiary air (introduced to the flame).</td>
</tr>
<tr>
<td>Combustion efficiency</td>
<td>The percentage of heat released that is put to use compared with the total heat energy in the fuel.</td>
</tr>
<tr>
<td>Condensate</td>
<td>The pure water formed as steam condenses.</td>
</tr>
<tr>
<td>Damper</td>
<td>A device which restricts the airflow through the flue, preventing heat loss from the boiler when it is on stand-by.</td>
</tr>
<tr>
<td>Dew point</td>
<td>The temperature to which air must be cooled to reach saturation, where condensation can occur.</td>
</tr>
<tr>
<td>Dry steam</td>
<td>Steam containing no water droplets.</td>
</tr>
<tr>
<td>Economiser</td>
<td>An economiser is a heat exchanger which transfers heat from the hot flue gas of a boiler to the water being fed into the boiler.</td>
</tr>
<tr>
<td>Eductor</td>
<td>An ejector pump.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>-----------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Feed tank</td>
<td>A tank which contains the feedwater prior to its entry into the boiler.</td>
</tr>
<tr>
<td>Feedwater</td>
<td>The water that is piped into the boiler from an external source.</td>
</tr>
<tr>
<td>Fire side</td>
<td>The side of the boiler heat-transfer surfaces that the burner is located.</td>
</tr>
<tr>
<td>Flash steam</td>
<td>The steam produced when the pressure of hot condensate is reduced.</td>
</tr>
<tr>
<td>Flue</td>
<td>The boiler’s chimney – used to transport exhaust gases to the atmosphere.</td>
</tr>
<tr>
<td>Gross calorific value</td>
<td>A theoretical measurement of the total energy of the fuel for the boiler. See Net calorific value.</td>
</tr>
<tr>
<td>Heat exchanger</td>
<td>A network of pipes within a boiler whereby the heat from the burner is transferred to the circulating water.</td>
</tr>
<tr>
<td>Higher efficiency motors</td>
<td>Motors which, because of their manufacture from advanced materials, are more efficient than standard motors.</td>
</tr>
<tr>
<td>Heat transfer surfaces</td>
<td>Those surfaces within the boiler across which heat can pass, for example, tubes carrying water or combustion gases.</td>
</tr>
<tr>
<td>Make-up water</td>
<td>Additional water added to the boiler to replace losses through steam and leaks.</td>
</tr>
<tr>
<td>Net calorific value</td>
<td>A measurement of the energy of the fuel, excluding the energy lost in the combustion process. See Gross calorific value.</td>
</tr>
<tr>
<td>Oxygen trim control</td>
<td>A device which measures the oxygen content in the flue-gas stream and which alters the amount of combustion air to maintain optimum conditions.</td>
</tr>
<tr>
<td>Priming</td>
<td>The entry of boiler water into the steam outlet pipes.</td>
</tr>
<tr>
<td>Recuperator</td>
<td>A device which uses the heat normally lost through the flue to preheat the boiler feedwater.</td>
</tr>
<tr>
<td>Servomotor drive</td>
<td>A type of motor frequently used for opening and closing components such as valves and dampers that do not require 360 degree rotation.</td>
</tr>
<tr>
<td>Stand-by</td>
<td>The situation where the boiler is under operating conditions, but is not firing.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Steam baffle</td>
<td>A device which helps to separate the steam produced from any entrained water.</td>
</tr>
<tr>
<td>Steam separators</td>
<td>A device which helps to separate the steam produced from any entrained water.</td>
</tr>
<tr>
<td>Steam trap</td>
<td>An automatic valve that releases condensed steam (condensate) from a steam space while preventing the loss of live steam. It also removes air and non-condensables from the steam space.</td>
</tr>
<tr>
<td>Shutdown</td>
<td>When all boiler systems have been turned off.</td>
</tr>
<tr>
<td>Total dissolved solids (TDS)</td>
<td>The quantity of solids dissolved in a known volume of water.</td>
</tr>
<tr>
<td>Variable Speed Drive (VSD)</td>
<td>A drive which can respond to the variable requirements of the fan or pump to which it is fitted and as a result operates more efficiently than a standard motor.</td>
</tr>
<tr>
<td>Water hammer</td>
<td>A knocking or hammering noise which occurs due to an increase in water pressure due to a change in direction of flow, closure of a valve or an obstruction in the line.</td>
</tr>
<tr>
<td>Water side</td>
<td>The part of the boiler through which the water flows.</td>
</tr>
</tbody>
</table>
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The Carbon Trust provides a range of tools, services and information to help you implement energy and carbon saving measures.

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