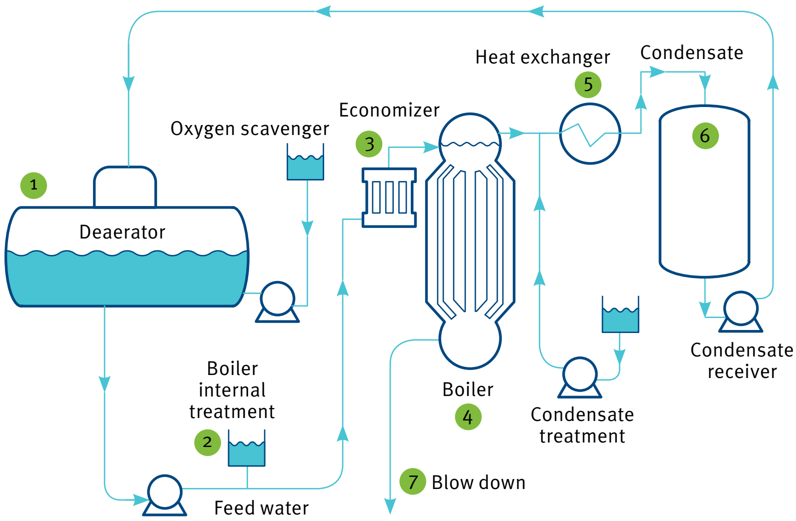
BOILER EFFICIENCY – F7

Energy eco-efficiency opportunities in Queensland Foundries

Don't boil your money away

Boilers are used by some foundries to provide steam and hot water. Boilers use large amounts of water and energy so efficient operation can provide significant savings. Often the efficient use of water in boilers leads to a reduction in energy and vice versa. This fact sheet provides a list of opportunities to assist foundries in the more efficient operation of boilers.



Feed water is held in the **deaerator (1)** tank to help remove dissolved oxygen and is then **treated (2)** prior to entering the **boiler (4)**. There are two types of boilers - water tube and fire tube. **Water tube boilers** heat water in tubes and the hot combustion gases are contained in the space around the tubes. **Fire tube boilers** on the other hand have hot combustion gases contained inside tubes and the water is circulated around these. An **economiser (3)** pre-heats feedwater using the flue gases from the boiler's chimney. The water is heated in the **boiler (4)** to produce hot water and/or steam that can be used directly in the process or sent to a **heat-exchanger (5)**. The **heat-exchanger** transfers the heat from the circulating boiler water to another media such as the product, as indirect process use. Any **condensate (6)** (steam that has condensed) is captured and returned to the deaerator for reuse. Because the build up of contaminants in the circulating water can cause biological growth, corrosion and scale, a portion of the circulating water is **blown down (7)**.

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Reduce blowdown losses

Reduce blowdown

As water evaporates in the boiler, salts and minerals accumulate that can cause corrosion and scale. To reduce the build up of these dissolved solids, a portion of the water (usually around 4-10 per cent) is bled off (released) periodically.

To reduce excessive bleed, a conductivity probe can be used to measure the salt level within the water and only blowdown when that level exceeds a set value. The payback period is usually around one to three years and can reduce boiler energy, required to heat up feed water, by 2-5 per cent, plus saves on water and water treatment costs.[1]

Recycle or reuse blowdown

It may be possible to reuse the boiler blowdown water for other activities such as cleaning, provided it is of appropriate quality and any chemicals used are compatible.

Blowdown heat recovery and flash steam recovery

A blowdown heat recovery system consists of a heat exchanger and flash tank.

The flash tank drops the pressure of the blowdown, converting some of the blowdown into low-pressure steam which is sent to the deaerator and can be used again in the boiler. The remaining water is sent to a heat exchanger and used to preheat the incoming feed water. The system also may assist businesses to comply with local authority requirements limiting the discharge of hot liquids to sewer.

Reduce makeup usage

Alternative water sources such as rainwater, condensate, recycled water, process water and bore water can be substituted for mains water where appropriate.

Reduce flue (combustion) losses

Combustion efficiency is a measure of the boiler's ability to convert fuel into heat.

Inefficient combustion results in:

- wasted energy and emission of unnecessary combustion gases
- unburnt fuel deposits (soot) on boiler tubes which act as an insulator, reducing heat transfer efficiency and allowing heat to escape up the flue.

Soot has an insulating value five times greater than asbestos and significantly reduces heat transfer.[2]

Measuring flue temperature and analysis of flue gas composition allows boiler operators to monitor, record and track combustion efficiency and identify decreases in performance, assisting prompt corrective action.

Many boilers lose 15-20 per cent of their fuel energy input up the stack.[3]

Monitoring flue temperatures

Flue temperature can be monitored and used as an indication of efficient boiler operation. A $5^{\circ}C$ rise in flue temperature indicates a one per cent efficiency loss.[4] The optimum temperature can be obtained by reading the flue temperature immediately after the boiler has been serviced and cleaned. Preventative maintenance should include flue temperature readings at least three times a day, at the same firing rate and comparing this temperature with the optimum.

1 Pacific Northwest Pollution Prevention Resource Center, February 2005, Pollution Prevention Technology Profile Conductivity Controls in Water Rinsing, Cooling Towers, and Boilers **www.pprc.org/pubs/technologies/conductivity.pdf**
2 Spielmann, S., 2007 Goodway Technologies Corp, Are You Keeping Customers' Boiler Tubes Clean? Contracting Business.com. **www.contractingbusiness.com/25/Issue/Article/False/5623/**
3 Sustainable Energy Authority Victoria, 2002, Energy and Greenhouse Management Toolkit.
4 Muller, MR, Simek, M, Mak, J & Mitrovic, G., 2001, Modern industrial assessments: a training manual, version 2.0, Rutgers University, New Jersey.

A temperature variation may indicate the need for boiler cleaning. The fuel source used by the boiler will affect the degree of fouling. For example, low grade fuels such as coal and wood will cause more fouling than natural gas.

Soot is usually removed with a brush and vacuum. Fire side tubes can build up scale on the water side which can be difficult to remove, requiring mechanical or acid cleaning, so prevention by good water treatment is essential.

Electronic combustion efficiency testers with data loggers can be used for increased monitoring. Inline temperature sensors must be regularly calibrated and checked for fouling.

Water treatment

Effective water treatment and water analysis can minimise scale build up on boiler tubes and heat exchangers that reduces heat transfer efficiency (see Table 1).

Table 1: Energy loss due to scale deposits[5]

Scale thickness (mm)	Fuel loss (per cent total loss)
0.4	1
0.8	1
1.2	3
1.6	3.9

Engineering solutions, such as pre-heating the boiler feed tank, can help remove dissolved oxygen (that may cause corrosion), reducing the need for oxygen scavenging chemicals.

Monitoring flue gases

Boilers operating with excess air consume more fuel. It is quite common, however, for boilers to use 50-100 per cent excess air, reducing the efficiency of the boiler by up to five per cent.[6] If the boiler does not have a flue gas analyser, an inexpensive carbon dioxide and oxygen gas absorbing system can be used. Computer-based hand held analysers may be more suitable for boilers with high operating costs.

Oxygen trim systems

Oxygen trim systems can be used to optimise the mix of flue gases by adjusting the ratio of air to fuel. The optimum percentages of oxygen (O_2), carbon dioxide (CO_2) and excess air in exhaust gases are shown in Table 2.

Table2: Optimum flue gas composition[7]

Fuel	O_2	CO_2	Excess Air
Natural Gas	2.2 %	10.5 %	10 %
Coal	4.5 %	14.5 %	25 %
Liquid petroleum	4.0 %	12.5 %	20 %

Reduce excess air in the system by routine checks for leaks, as air from leaks will decrease optimisation.

Utilise flue heat

Economisers or heat exchange systems

These systems can recover heat from the flue for preheating boiler feedwater. This option is especially effective if not all condensate is returned to the boiler. Direct-contact economisers spray water directly into the flue gas, which also remove particles and acid gases such as sulphur dioxide (SO_2).

5 US Department of Energy (US DOE), 2001, Green Federal Facilities An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers - 5.2.1 Boilers, **www1.eere.energy.gov/femp/pdfs/29267-0.pdf**

6 US DOE, 2001, Green Federal Facilities An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers - 5.2.1 Boilers, **www1.eere.energy.gov/femp/pdfs/29267-0.pdf**.

7 Muller et al., 2001.

Air preheaters

Air preheaters are used to heat the inlet air to increase combustion efficiency and can use recovered heat from the flue gases as well as warm air from the boiler room ceiling or even solar panels.

Reduce distribution losses

Some losses of steam/heat energy will occur during the distribution of steam. These can be minimised by investigating the following actions.

Correctly size and install pipework

Steam and heat losses can be minimised in pipework by:

- removing redundant pipework
- not over-sizing as the larger surface area will increase heat losses as well as increase insulation and maintenance costs
- not under-sizing as the pipes will require higher pressure (and therefore additional pumping energy) and consequently often have high leakage rates
- ensuring correct layout, for example, valve outlets from the distribution headers allows unused sections of the plant to be turned off
- sloping down pipework in the direction of flow
- using steam traps at any low points where condensate collects.

Rectifying steam leaks

Steam leaks are hot water lost from the system and require colder feedwater to be added back into the system. Chemicals and fuels are also required to treat and heat that water. These leaks should be identified and repaired as soon as possible.

Repair steam leaks promptly to reduce energy loss.

A 1 mm diameter hole on a steam line at 700 kPa will lead to an annual loss of 300 L of fuel oil or $4300 m^3$ of natural gas.

Bellows seal valves, in place of conventional gland seal valves, use flexible metal bellows that do not leak and require little maintenance. The initial capital cost can be recouped through fewer leaks and reduced maintenance time.

Use of tabulators

Tabulators are twisted pieces of metal inserted into the tubes of fire tube boilers to reduce the speed of the hot gases and create more turbulence, resulting in better heat transfer to the water. Tabulators can be retrofitted to older boilers.

Use of Insulation

Insulation of boiler and steam lines and condensate return piping and fittings reduce heat loss by as much as 90 per cent, as shown in the Table 3. Surfaces over 50°C should be insulated.

Deteriorated insulation allows heat loss so repair promptly

A 1 m^2 of uninsulated surface with steam at 700 kPa will lose 225 MJ in a 24 hour period or 2 tonnes of fuel oil per year.

Ensure leaks and damaged insulation are repaired promptly.

Table 3: Heat loss from steam lines[8]

Level of insulation	Heat loss (MJ/m/h)	Steam loss (kg steam/m/h)	Equivalent fuel cost (gas per 50 m of pipe/year)
Uninsulated	2.83	1.0	$3396
Insulated with mineral fibre	0.138	0.05	$165
Insulated with polystyrene	0.096	0.03	$115

Assumptions: 125 mm steel pipe at 150°C; natural gas cost of $0.012/MJ of boiler operating 8 hours/day, 250 days/year.

8 US DOE, 2001, Green Federal Facilities An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers - 5.2.1 Boilers, **www1.eere.energy.gov/femp/pdfs/29267-0.pdf**

Maintaining steam traps

Maintaining steam traps reduces energy loss from traps that fail to effectively close or open. A trap that fails to close allows steam to escape while a trap that fails to open allows the system to become water-logged thereby reducing the heat output.

The cost of a leaking trap can add up over a year as shown in Table 4 below.

Table 4: The cost of a leaking trap[9]

For an operation of 10 hours per day, 5 days per week and 40 weeks per year.

Steam loss from a trap per hour (kg/hr)	20
Hours of operation per year	2000
Total loss of steam and water per year (kg)	40,000
Cost of steam per tonne	$32
Total cost of leaking steam trap per year	$1,280

A steam leakage sensor on steam traps can be a cost effective option for plants with a large number of traps.

Condensate return lines

Condensate is effectively distilled water free from contaminants such as calcium and magnesium. As it is already hot, capturing this condensate and returning it to the boiler reduces the amount of energy required to heat the boiler feed water. It also reduces the amount of water and chemicals required as softeners added to mains water are not needed.

Condensate and associated flash steam (steam formed when high pressure/temperature condensate is suddenly decreased in pressure) contains 26 per cent of the energy used to raise the steam in the boiler.

Other efficiency opportunities

Match steam supply with demand

Downsize or use multiple boiler systems to match demand and reduce energy use. The boiler may be oversized and producing more steam than required if it continually cycles (turning off and on a number of times in a relatively short period). Two or more boilers, sized correctly and carefully located, can meet a variable load of different steam pressures at different locations and times during production, provided they can be fired appropriately.

Pressure reducing valves

Boilers should be operated at their maximum possible design working pressure. Operating them at lower pressures will result in lower quality steam and reduced overall efficiencies. If the system requires lower pressures, use pressure reducing valves, ideally at the point of end use.

Accumulators

Accumulators can help meet peaks in a variable demand. A large vessel is filled with water and heated by the steam to temperature. Steam that is not needed to heat water simply flows through it and out to the plant, but when a sudden peak is imposed the pressure is reduced and a proportion of the water immediately becomes flash steam, thus protecting the boiler from instantaneous loads.

Start up boilers as late as possible and shut them down as early as possible.

Rationalise boiler use

Investigate the economics of a smaller steam boiler or hot water system for times of low load. Operating boilers outside production hours for cleaning or amenity hot water can be inefficient.

9 Spirax Sarco – Queensland, 2009, Pers. Coms with Glenn Schultz **www.spiraxsarco.com**

Reduce the temperature

Replace hot and warm water with warm or cooler water respectively where feasible. Limit hot water temperatures to the minimum required while still meeting hygiene and operational standards.

Boiler alternatives

Solar-assisted and biomass-fired (e.g. wood pellets) boilers can serve as alternatives to conventional boiler systems.

Heat pumps use low-level heat energy in the ground, water, air or process and transfer the heat by circulating a refrigerant. The refrigerant in an evaporator coil absorbs the heat before passing through a compressor to increase the heat (pressure). Finally the hot gas passes through a condenser where the heat exchange occurs.

Cogeneration

Cogeneration or combined heat and power systems use a single source of fuel to produce both electrical and thermal energy. For example, a gas turbine used to produce electricity can supply a heat source suitable for applications requiring high pressure steam. Similarly heat recovered from a reciprocating or piston engine (from the exhaust and jacket coolant) can be used to heat water to around 100°C or low pressure steam.

Manufacturers can investigate energy performance contracts where a third party funds and manages the cogeneration project and is refinanced through energy savings.

ADVANTAGES OF CO-GENERATION[10]

Techni-Cast Corp. in California, USA produces 82% of its electricity requirements onsite using a natural gas fuelled cogeneration plant. Even with today's high natural gas prices the site still saves 33% on electricity. Exhaust from the cogeneration plant is also used to preheat metals before going to a dust collection system and filter. The air released from the site is cleaner than the air it takes in from its surrounds. The site is also able to recover heat from engine jacket oil used to cool the generator of the cogeneration plant by sending it to an absorption chiller system that provides heating, cooling and humidity for the company's offices.

For more information see the fact sheets at Sustainability Victoria, Sustainable Manufacturing, Resource Smart Business:

www.seav.vic.gov.au/manufacturing/sustainable_manufacturing/ and

The Carbon Trust: www.carbontrust.co.uk/energy/startsaving/tech_chp_introduction.htm

This series of fact sheets provides examples and suggestions to the modern foundry operator on how to achieve both economic and environmental benefits from eco-efficiency. Visit the project website www.ecoefficiency.com.au for more ideas and case studies.

10 Miratech, 2005, Overcoming the Hurdle of Emissions Control, Creative Co-Generation Cuts Calif. Foundry's Costs miratechcorp.com/images/data/attachments/0000/0015/MIR_26618_Technicast.pdf

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