Case study – Cost Savings from Improved Boiler Water Chemistry

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Introduction

This case study will briefly highlight some cost savings achievable through changes to boiler water chemistry and boiler system operation.

Meat Processor Location: South East Qld

Site Particulars

The operators of this site have taken ownership of the site in recent years and have employed the services of a specialist water chemistry consultant to help improve the operation and life of the existing boiler system.

The current boiler system does not include a separate feed water tank but has a large de-aerator tank that also doubles as the feed water tank. An inspection of the de-aerator tank after acquiring the site showed considerable corrosion pitting on internal surfaces, which is a common sign of corrosion due to high levels of dissolved oxygen in the water.

The dissolved oxygen content was previously being treated using a tannin based oxygen scavenger and there had been issues with the steam injection heating of the de-aerator such that it was not in use.

With the de-aerator also being used as the feed water tank for the boiler, fresh cold make-up water was being added to the tank along with returned condensate from the facility.

Steam Boiler – Water-tube type
Operating Pressure – 850 to 900 kPaG
Steam Generation Rate – 7,875 kg/hr
Condensate Return – 3,750 kg/hr (~50%)
Make-up Water – 3,750 L/hr, softened towns water
De-Aerator (Feed Water Tank) – ~95 °C
Run Time – up to 15 hrs per day, 5 days per week
Boiler Fuel – Black Coal

Background Information

Oxygen Content of Water

Oxygen, like other gases, will dissolve in water to a certain extent and can cause significant corrosion pitting inside boilers, feed tanks and steam lines. The oxygen content in water is very dependent on temperature as can be seen in Figure 1. Therefore one of the easy ways to reduce the oxygen content of water in the system is to increase the temperature of the water.

There are, however, limits to the temperature you can operate the feed water tank (or in this case the de-aerator tank). The main issue being cavitation of the feed water pumps. Cavitation occurs in pumps due to the reduced liquid pressure in the eye of the pump impeller causing the liquid to boil forming small bubbles which then violently collapse. This results in noise, vibration and erosion inside the pump. Cavitation in feed water pumps can be reduced or eliminated by installing feed water tanks high in the air to provide additional liquid head pressure in the pump suction line. At this site the de-aerator tank is installed some 10 m above the feed water tanks enabling the water temperature to be increased to approximately 95 °C.

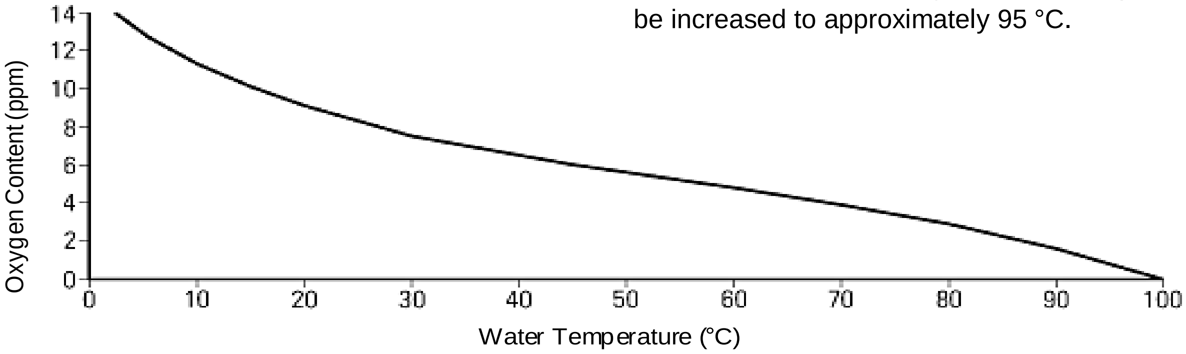

Fig 1 – Water Temperature vs Dissolved Oxygen Content [**3**]

Heating Feed Water Tanks

Heating of feed water tanks or de-aerator tanks can be achieved by injecting a small percentage of the generated steam into the tank or by simply returning condensate from steam usage in the processing facility and mixing that with the fresh cold make-up water. Both methods should be employed to maximize both water recovery and minimize steam usage. Another option of increasing the feed water temperature is to pre-heat the make-up water using the hot exhaust gases from the boiler. This is usually achieved using an economiser installed in the boiler flue gas outlet and is a good way of maximising the efficiency of the boiler fuel.

Condensate Recovery

Condensate recovery is important not only for reducing water usage and saving crucial resources but it also has many additional benefits.

Condensate being hot, has a very low dissolved oxygen content, reducing the amount of oxygen scavenger chemicals required. The heat energy in the water also helps reduce the amount of energy required by the boiler to generate steam.

Condensate is almost pure water and unless there is corrosion in the condensate return pipes, the condensate will be very low in dissolved minerals, reducing the need for phosphates and other precipitation type chemicals. This can also result in reduced blowdown requirements from the boiler.

One potential issue with condensate recovery that has been experienced by the operators of this site, as well as other sites, is the potential for contamination of condensate from the process. This is often seen in tallow heating duties where corrosion or other mechanical damage to the tank heating coils has allowed tallow to enter the condensate lines and return to the boiler. Once fats and oils reach the boiler, they cause big problems with boiler water level control and are very difficult to clean out. For this reason, at this processing facility all condensate from tallow tank heating is not recovered and is directed to drain.

Improvements

The installation of a simple under-flow fat/oil trap tank in the condensate return prior to the de-aerator tank (feed water tank) should mitigate the issues of tallow contamination of the boiler feed water and allow more condensate to be recovered. A simplified diagram of such a tank is shown in Figure 2. This will collect and isolate any fats and oils contaminating the condensate and allow a greater recovery of clean condensate, reducing the volume of water going to the effluent system and required make-up water. This could be trialled in the drain line for several months to prove its effectiveness before being installed permanently and condensate from tallow tank heating recovered.

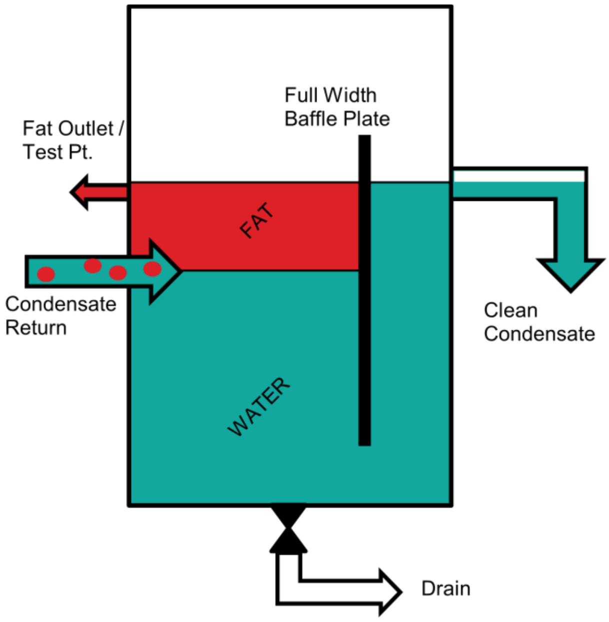

Fig. 2 – Under-flow Oil Trap Tank [**1**]

As discussed, increasing the feed water temperature has the benefit of reducing dissolved oxygen and therefore the amount of oxygen scavenger chemical can also be reduced. A sample calculation of this is provided.

Basis:

Dosing rate of sodium sulfite oxygen scavenger is 8ppm per 1 ppm oxygen + 30 ppm excess
Oxygen scavenger supplied at 53% concentration

Oxygen scavenger chemical $4.11 / L (200 L drum)

Towns water cost $4.2885 / kL

Black coal cost $110 / tonne

Case 50% Condensate Return, no additional heat input to tank
Steam generation rate – 7875 kg/hr
Condensate return rate – 3938 kg/hr

Make-up water rate – 3938 kg/hr

Condensate @ 100 °C will mix with make-up water @ 20 °C resulting in a feed water temperature of 60 °C

Reading from the graph in Fig 1

water @ 60 °C has an O_2 content of 4.8 ppm/kg

sodium sulfite required = 4.8 x 8 + 30 = 68.4 ppm/kg

scavenger chemical req = 68.4 / 53% = 129 ppm/kg

at the steam generation rate, this equates to

129 ppm/kg x 7875 kg/hr = 1.02 kg/hr

and over a year is approximately 3964 kg of oxygen scavenger chemical

This can then be repeated with various other condensate return amounts, the results of which are shown in Table 1. These are then compared in Table 2.

The temperature of the feed water can also be increased by taking some of the generated steam and injecting this into the feed water tank. This will further reduce the amount of dissolved oxygen in the boiler feed water and amount of oxygen scavenger required. A conservative calculation gives the requirements of 0.021 kg of steam at 900 kPaG to heat 1 kg of water by 10 °C. So at the steam generation rate of this boiler, 163.4 kg/hr of steam is needed to the raise the feed water temperature by 10 °C, which is only 2.1% of the total steam being generated. The dissolved oxygen content and scavenger chemical calculations were performed again based on differing temperature increases and the results are also shown in Table 1, with comparison of the results presented in Table 3.

Not only does heating the feed water reduce the dissolved oxygen content and hence the amount and cost of oxygen scavenger chemicals required but the additional heat energy of the water also reduces the amount of fuel energy required by the boiler. This has been shown graphically in Figure 3.

Table 1 – Various Case Study Results

Base Case **No Condensate Return** **No Additional Heating**	**Feed Water Tank** **Make-up Water** **O_2 Scavenger Chemical** **Energy to Generate Steam**	**20 °C** **30.84 ML/yr** **5,911 kg/yr** **103,017 GJ/yr**
Base 1 **25% Condensate Return** **No Additional Heating**	**Feed Water Tank** **Make-up Water** **O_2 Scavenger Chemical** **Energy to Generate Steam**	**40 °C** **23.13 ML/yr** **4,752 kg/yr** **99,807 GJ/yr**
Case 2 **50% Condensate Return** **No Additional Heating**	**Feed Water Tank** **Make-up Water** **O_2 Scavenger Chemical** **Energy to Generate Steam**	**60 °C** **15.42 ML/yr** **3,964 kg/yr** **96,598 GJ/yr**
Case 3 **75% Condensate Return** **No Additional Heating**	**Feed Water Tank** **Make-up Water** **O_2 Scavenger Chemical** **Energy to Generate Steam**	**80 °C** **7.71 ML/yr** **3,083 kg/yr** **93,388 GJ/yr**
Case 4 **60% Condensate Return** **No Additional Heating**	**Feed Water Tank** **Make-up Water** **O_2 Scavenger Chemical** **Energy to Generate Steam**	**68 °C** **12.33 ML/yr** **3,593 kg/yr** **95,314 GJ/yr**

Case 5 50% Condensate Return 10 °C Additional Heating	Feed Water Tank Make-up Water O_2 Scavenger Chemical Energy to Generate Steam	70 °C 15.42 ML/yr 3,546 kg/yr 94,993 GJ/yr
Case 6 50% Condensate Return 20 °C Additional Heating	Feed Water Tank Make-up Water O2 Scavenger Chemical Energy to Generate Steam	80 °C 15.42 ML/yr 3,083 kg/yr 93,388 GJ/yr
Case 7 50% Condensate Return 30 °C Additional Heating	Feed Water Tank Make-up Water O2 Scavenger Chemical Energy to Generate Steam	90 °C 15.42 ML/yr 2,619 kg/yr 91,784 GJ/yr

Table 2 – Condensate Return Rate and Cost Savings

Case Comparison	O_2 Scavenger Savings	Water Savings
Base to Case 1 (0% to 25% return)	1,159 kg/yr or 19.6% Cost saving of $3,477	7.7 ML/yr or 25.0% Cost saving of $33,060
Base to Case 2 (0% to 50% return)	1,947 kg/yr or 32.9% Cost saving of $5,841	15.4 ML/yr or 50.0% Cost saving of $66,120
Base to Case 3 (0% to 75% return)	2,828 kg/yr or 47.8% Cost saving of $8,484	23.1 ML/yr or 75.0% Cost saving of $99,180
Case 1 to Case 2 (25% to 50% return)	788 kg/yr or 16.6% Cost saving of $2,364	7.7 ML/yr or 33.3% Cost saving of $33,060
Case 2 to Case 3 (50% to 75% return)	881 kg/yr or 22.2% Cost saving of $2,642	7.7 ML/yr or 50.0% Cost saving of $33,060
Case 2 to Case 4 (50% to 60% return)	371 kg/yr or 9.4% Cost saving of $1,113	3.1 ML/yr or 20.0% Cost saving of $13,224

Please Note

1 – Boiler blowdown has not been included for simplicity, blowdown rate may change with changed oxygen scavenger chemical usage

2 – Feed water tank is assumed to be insulated and heat losses are minimal

3 – Sufficient residence time in the feed water tank for dissolved oxygen to be released due to temperature increases has been assumed

4 – Water savings exclude expected savings in softened water treatment costs and waste water disposal costs

Table 3 – Feed Water Heating and Cost Savings

Case Comparison	O_2 Scavenger Savings	Energy Savings
Case 2 to Case 5 (10 °C Additional Heating)	**417 kg/yr or 10.5% Cost saving of $1,252**	**1,605 GJ/yr or 1.7% Cost saving of $6,933**
Case 2 to Case 6 (20 °C Additional Heating)	**881 kg/yr or 22.2% Cost saving of $2,642**	**3,209 GJ/yr or 3.3% Cost saving of $13,866**
Case 2 to Case 7 (30 °C Additional Heating)	**1,344 kg/yr or 33.9% Cost saving of $4,033**	**4,814 GJ/yr or 5.0% Cost saving of $20,800**

Please Note

1 – Feed water tank is assumed to be insulated and heat losses are minimal

2 – Boiler energy efficiency assumed to be 80% in all cases

3 – Sufficient residence time in the feed water tank for dissolved oxygen to be released due to temperature increases has been assumed

4 – Energy cost savings based on an 80% boiler efficiency with black coal having a energy value of 25.46 MJ/kg [2] **and excluding supply costs**

In order to generate steam, water must firstly be heated from its initial temperature to the boiling point temperature (which increases with increasing pressure). Then additional heat needs to be added to vaporise the water into steam. So it stands to reason that the hotter the water entering the boiler less heat energy is required to heat the water to the boiling point temperature. The energy required to vaporise the water into steam remains the same.

This is graphically represented in Figure 3, showing the energy in water at 20 °C and 90 °C and the difference in energy required to generate steam at 900 kPaG. In this example there is a reduction of 10.8% in the energy input requirements

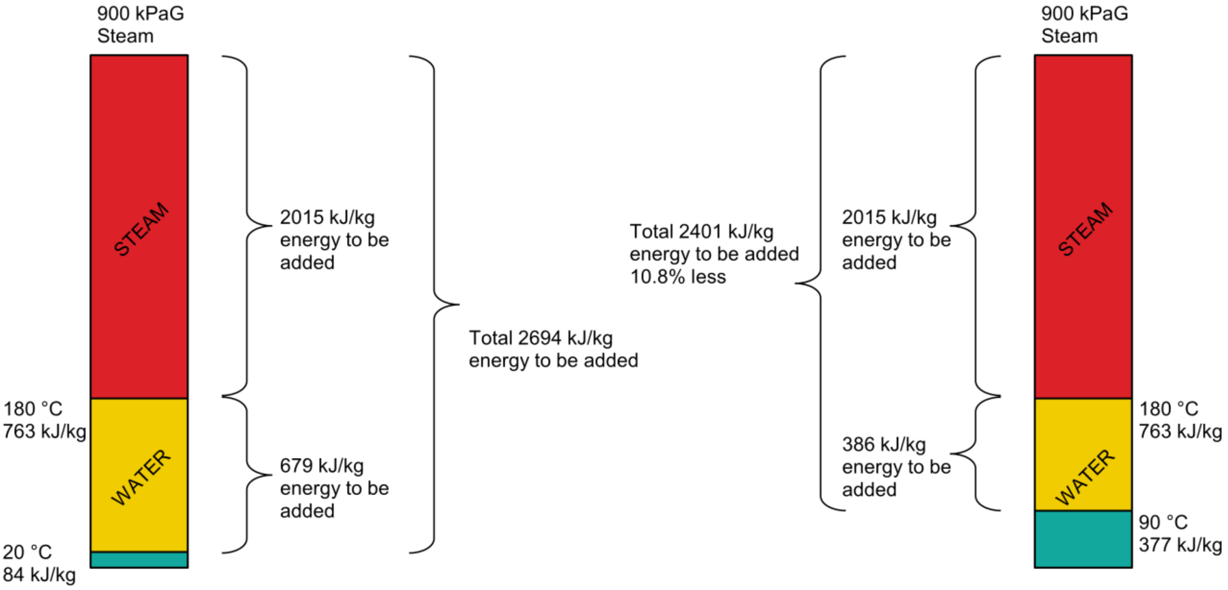

Figure 3 – Energy Comparison, Steam generation at 900 kPaG with different starting temperatures [**3**]

Conclusion

The meat processing site examined in this case study has improved the operating cost efficiency of their boiler system by making a relatively simple change to the de-aerator tank (their feed water tank). By raising the temperature of the feed water by repairing and reinstating the steam heating of the tank, they have reduced both the dissolved oxygen concentration in the water as well as the energy demand in the boiler. Also, based on advice from a specialist water treatment company, they have changed the chemical used for the removal of dissolved oxygen, further reducing the potential for oxygen pitting corrosion. Evidence to date suggests that the existing pitting corrosion in the de-aerator has not worsened and the tank has stabilised, prolonging its operating life. The other benefit of raising the water temperature is that the required dosing rate of the new oxygen scavenger chemical is reduced, saving money.

In addition, if more condensate can be recovered from the facility, this will not only lessen the amount of required steam heating of the de-aerator tank but can greatly reduce the amount of make-up water required. This can deliver significant savings in water supply costs, water treatment costs (pre-treatment softened water unit operating costs as well as other water treatment chemicals) and also waste water disposal costs associated with hot condensate not returned to the boiler. However, to recover condensate from tallow heating duties without the risk of tallow contaminating the boiler system, a reliable fat trap tank (or other means of tallow removal such as sensors and diverter valves) that can guarantee that fat and oil contamination can’t reach the boiler is required.

Bibliography

[1] Meat Research Corporation, Australian Meat Technology, "Steam Generation Systems," 1997.

[2] Coal Marketing International Ltd. Coal Basics. [Online]. http://www.coalmarketinginfo.com/coal-basics/

[3] Spirax Sarco. Spirax Sarco. [Online]. http://www.spiraxsarco.com/resources/steam-engineering-tutorials/the-boiler-house/the-feedtank-and-feedwater-conditioning.asp

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