Guide to Furnace Sootblowing

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A basic guide to sootblowing of large p.f. coal tangentially fired furnaces to ensure maximum boiler efficiency is achieved and design superheat/reheat temperatures are maintained. This document is meant as a training guide and should be accompanied by hands on training. Originally written back in 2022, I have recently given it a small update.

Contents

1 Introduction

The following information was originally written to explain sootblowing techniques for Paiton Private Power Project Phase II in Indonesia. back in the year 2002. This plant consisted of 2 x 612MW Siemens steam turbines and CE Canada tangentially fired boilers.

The first thing all people must realize when reading this document is that all boilers are slightly different from one another. When a boiler is designed the engineer will be after some performance value and other items will be secondary. As such each design will be a compromise.

Depending on what was the engineer's performance aim the boiler can be constructed or configured very differently from another similarly sized boiler at another plant.

For example whilst Paiton unit 5&6 and MaptaPhut unit 1&2 (Thailand) are both similar in steam flow output, each having 6 pulverisers, overfire air and many other similarities, there are also many differences.

- The distance between the lower pulveriser (A mill) and the furnace bottom is a lot smaller at MapTaPhut – thus the burner tilts hardly ever go negative.
- The coal supplied is different as Paiton had a full flow FGD plant so tended to burn higher sulphur coal. Each type of coal has differing ratio's of radiant to convective heat release, and slagging and fouling properties.
- Locations of sootblowers also differs, as this is usually determined by the slagging and fouling properties of the design coal to be fired.

Each boiler is designed to burn specific coal – however during the life of the unit, it is becoming very rare to actually burn the design coal. Instead the trend is towards cheaper coal and in fact any coal that you can get.

2 Simplified Model of the Furnace

Below is a simplified drawing of the boiler at Paiton. It is not meant to be an accurate representation and its only use is for demonstrating the theory of furnace slagging and soot blowing.

The main features of this drawing are;

- It indicates the position of the fireball within the furnace. This can be adjusted with the burner tilt mechanism.
- Shows the amount of slag accumulation on the water walls, superheater, reheater and economizer heat transfer sections.
- Shows the superheater, reheater, and air heater outlet temperatures relative to design.
- Indicates the amounts of superheater and reheater spray water flow.

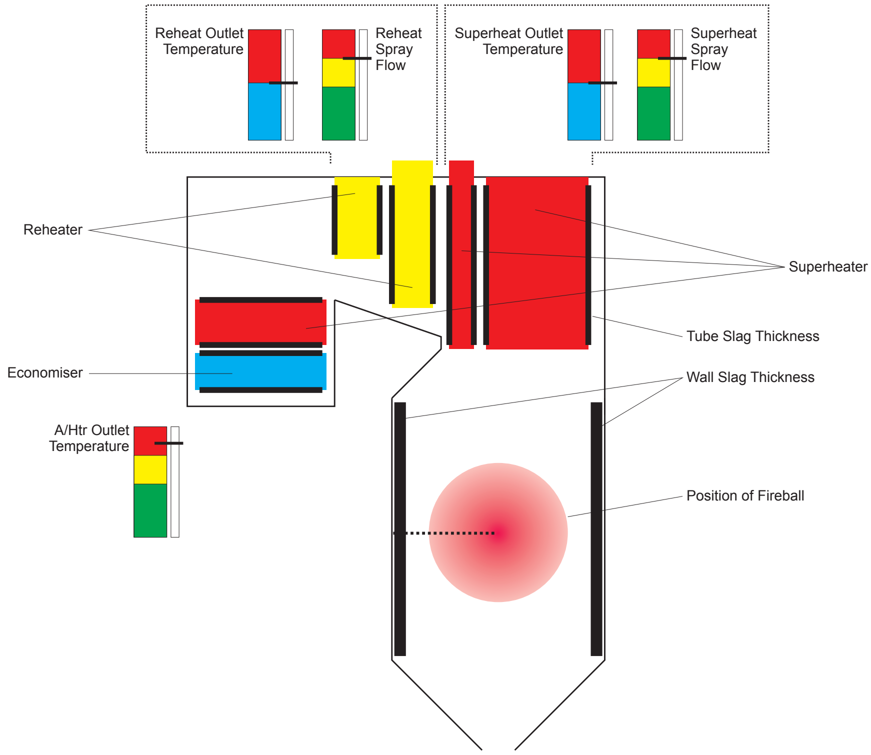
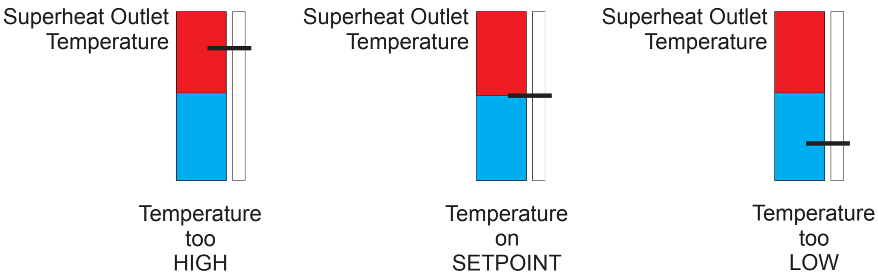


Figure 1: Simplified model of furnace

Both the superheater and reheater outlet steam temperatures are indicated by a bar chart the shows temperatures as either;

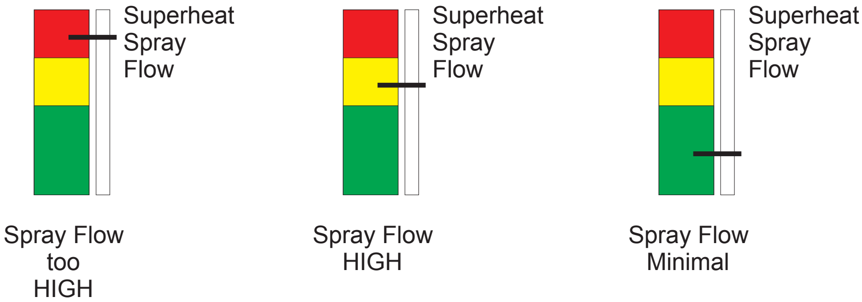
- Too High
- On Setpoint
- Too Low

The superheater and reheater outlet steam temperature will only show high under transient conditions as the spray water flow to both will just increase to correct the temperature to its set point value. So too much heat being directed into the superheat or reheat sections will be indicated by high spray water flows.



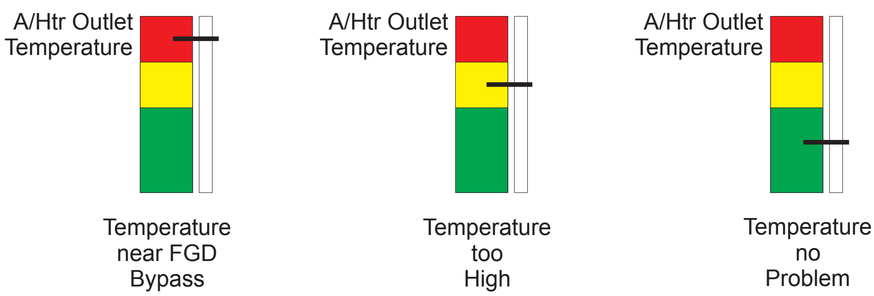
The superheater and reheater spray water flows are also displayed in bar chart form, with spray flow shown as;

- Too High
- High
- Minimal



The Air Heater Outlet flue gas temperature is displayed on a single bar chart with flue gas temperature shown as;

- Near FGD Bypass temperature
- Too High
- No Problem



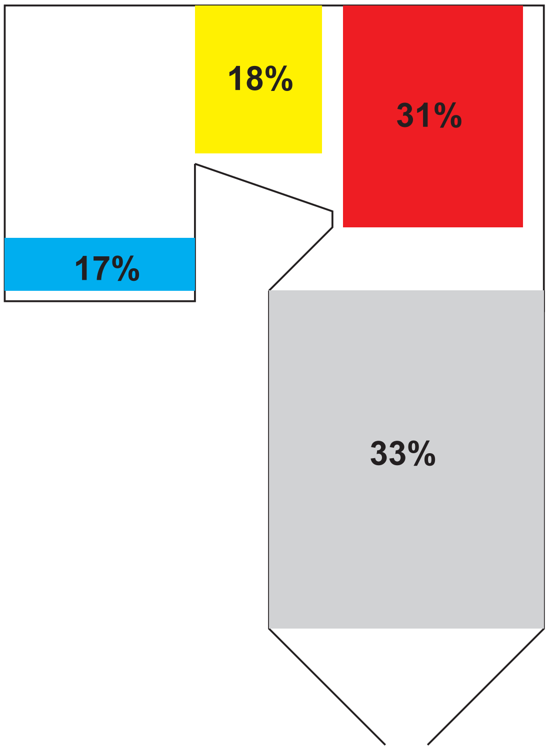
In addition the slagging factor of the water walls, superheater, reheater, and economizer heat transfer surfaces are shown by black lines of varying thickness's with a scale of;

- Slight
- Medium
- Heavy

3 Where does all the heat go

If the unit is stable at any given load (with the HP turbine steam bypass valve closed), then the boiler is making the exact amount of steam that is required by the turbine. The way that this steam is produced is by feeding in the correct amount of fuel to produce enough heat to generate this steam.

So if we take an example at 610 MW, the fuel being fed into the pulverizes is the correct amount to produce the heat, which will in turn generate the required amount of steam to drive the turbine at 610 MW. We can say that the heat produced for this load is 100% of the heat required for this load.



Note: At 167 bar boiler pressure (full load boiler pressure in this case) approximately 33% of heat is absorbed into the water-walls, an additional 31% into the superheater, approximately 18% into the reheat section, and 17% for the economizer. This drawing shows the primary/secondary superheater as a single block to simplify the example. At a boiler pressure below 167 bar a larger percentage of the heat is required to be directed to the water-walls (i.e. the lower the pressure – the greater the enthalpy needed to change water into steam).

The way that heat is absorbed into all the heat transfer surfaces depends on the amount of fouling present on them. If for instance the water-walls are very clean the amount of steam produced for 100% fuel flow, will be greater than if the water-walls are very dirty. We however do not want this steam flow to change, and that is the reason our boilers are equipped with tilting burners.

However the process of the water-walls becoming fouled is an on-going process. If you start with a clean furnace you will see over time that the fouling on the water-walls becomes progressively thicker. The amount of time that this requires depends on the unit load, characteristic of the coal fired, excess O_2, etc. If the burner tilts can be operated on automatic then as the water-wall fouling gets progressively thicker the controller should operate to gently lower the burner tilts.

3.1 Load and Heat in the furnace

As stated above, the lower the boiler pressure below 167 bar the larger the percentage of heat is required to be directed to the water-wall to achieve the desired steam flow (i.e. the lower the pressure – the greater the enthalpy needed to change water into steam).

We can see below that at 75% load the heat needed to turn water into wet saturated steam at a boiler pressure of 128 bar has increased from the 33% at 167 bar to about 41%. This means that as the boiler pressure is lowered on the sliding pressure curve, the fireball must also be lowered to give a larger percentage of the heat into the water walls.

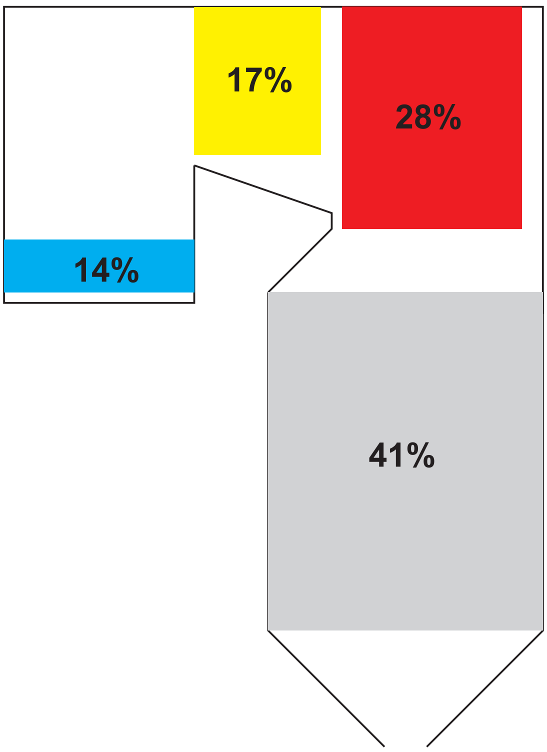


Figure 2: Boiler at 75% steam flow – boiler pressure of 128 bar

If we continue to lower the boiler pressure on the sliding pressure curve until we reach 50% steam flow, we will be at 110 bar and the needed heat distribution will be as follows.

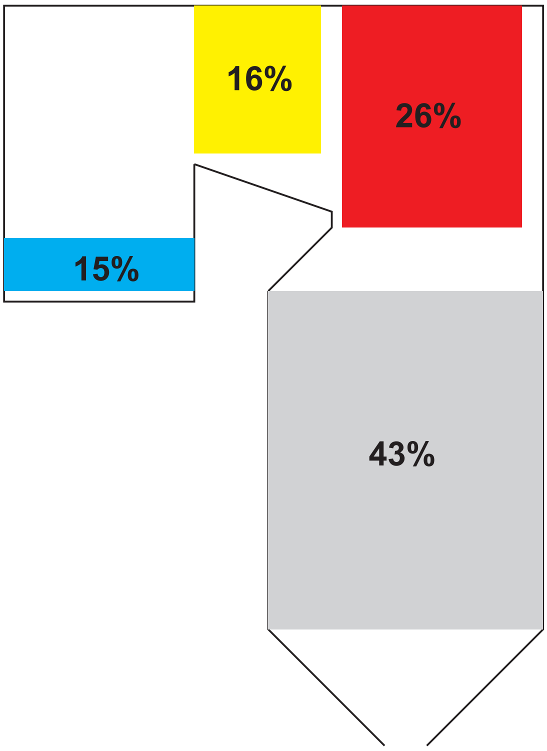
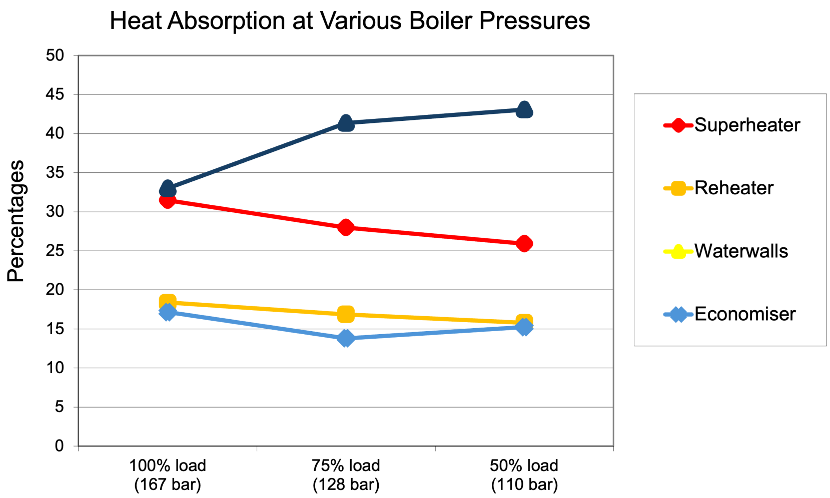


Figure 3: Boiler at 50% steam flow – boiler pressure of 110 bar

These three separate heat distribution diagrams can be combined into a single chart, which shows the heat absorption values for water walls, superheater, reheater, and economizer at 50%, 75% and 100% steam flows.



This explains why as we decrease load the burner tilts will be driven downwards to limit the amount of spray water flow, and push more of the heat into the water walls where it is needed. Whilst as we increase load, the tilts should eventually be driven upwards as we now need less heat in the water walls.

Important: The differing heat transfer requirements for differing boiler pressures as described in the above section will now be ignored in the interests of clarity. All future examples in this document will be for a boiler pressure of 167 bar and a steam flow of 100% (546 kg/s).

Remember:

- The heat needed to change water into steam varies with the pressure. The less pressure the more energy required to convert 1 kg of water to 1 kg of steam. We have a sliding pressure system in place and this is why our burner tilts move on changing load.

4 Controlling furnace heat distribution

Depending on the configuration of the boiler there are a number of ways to change and therefore control the heat distribution in the furnace. Generally to increase superheat and reheat temperatures we can;

- Raising the burner tilts.
- Place the top most burners in service (i.e. instead of mills A,B,C,D,E we could use mills B,C,D,E,F). This will move the fire ball closer to the reheat and superheat tubes.[1]
- Increase the coal flow on the upper mills at the expense of the lower mills. This will mean more coal burning in the upper furnace and less in the lower.
- Increase boiler excess O_2 by increasing air flow. This will transport the hot flue gases through the furnace quicker and carry the heat up into the superheat, reheat and back pass. This method is not recommended as an action the operator may take.
- Change the fuel selection. Burning a high CV and high volatile coal will result in a higher flame temperature and more radiant energy being released.
- Sootblowing selected areas of the furnace to get just the right amount of heat flow for that area. This can be more difficult than it sounds.

A lot depends on the design calculations done for the furnace before construction on which of the above methods will have the most effect. Some plants such as Paiton units 5&6 could achieve superheat temperature at full load but was a little low on reheat temperature. This situation can be fixed by allowing the furnace walls and superheater to slag up a little bit, but keeping the reheat tubes clean.

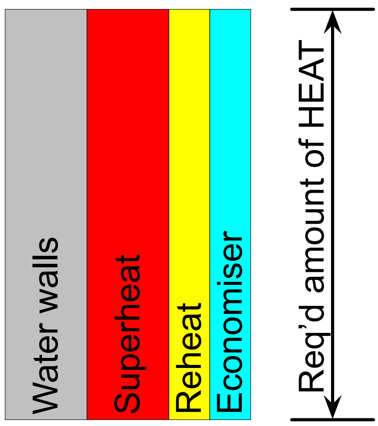
Paiton units 7&8 had an even lower reheat temperature at full load and eventually the decision was made to add additional reheat tube area as it was just not possible to reach the design value of $540°C$. Before the modification the plant was lucky to reach $500°C$.

Other plants such as MapTaPhut can easily achieve reheat steam temperatures when the entire furnace is clean, but at the expense of high superheat spray water flow. This is a case of the control system only looking at reheat outlet temperature and not even considering superheat temperature or spray water flow.

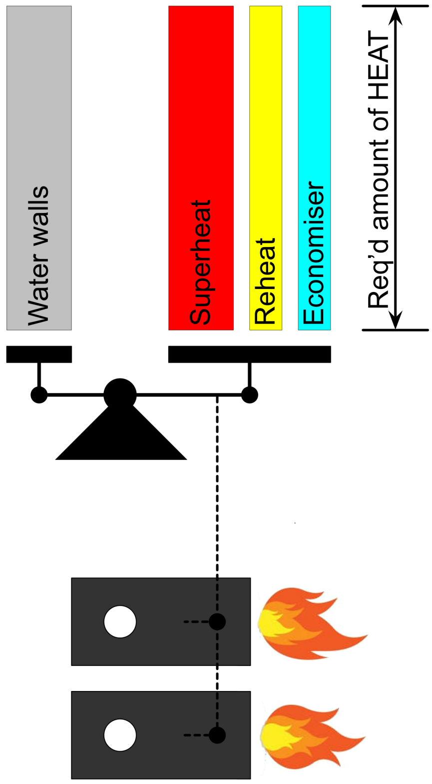
[1]assuming the coal burners are numbered from bottom to top.

4.1 Visualising heat distribution in the furnace

The graph below represents the total heat being released in the furnace by the combustion of the fuel, split into the component required for the water walls (approx 33% in this example) to make steam and the component that is needed for the superheat, reheat and economizer sections (total approx 66%), we get a graph as below.

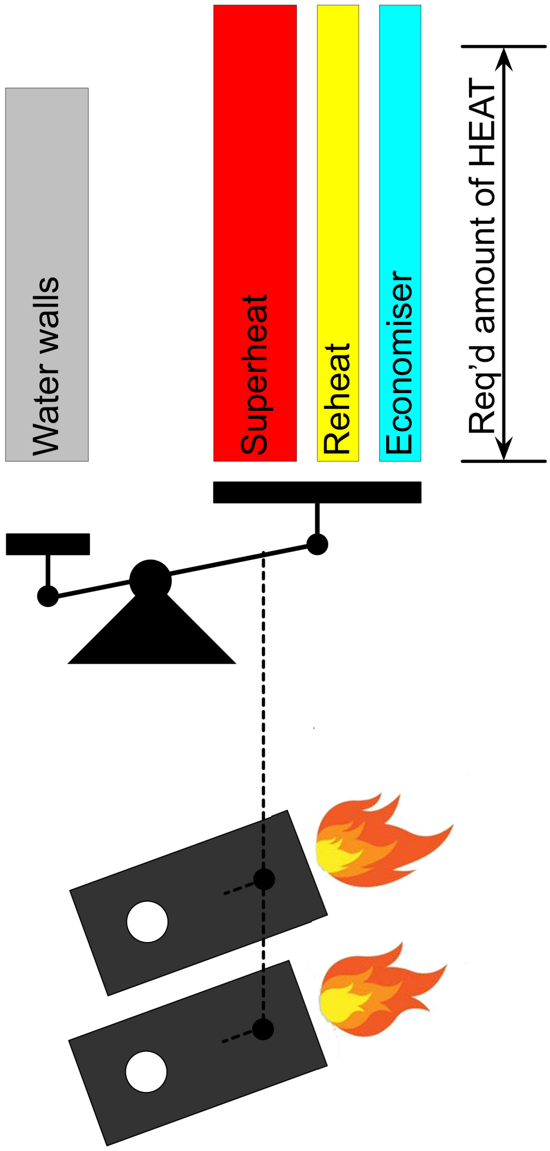


Let us now represent the action of the burner tilts on this graph by drawing a set of scales linked to a representation of the burner tilts.

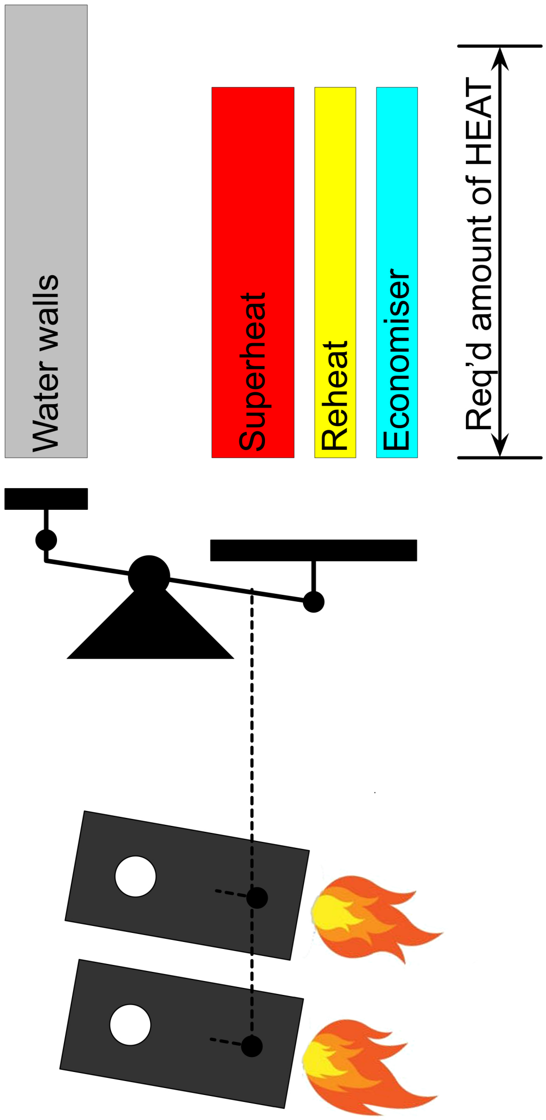


We can see that as the tilts go up then less heat is directed to the water walls and more to the superheat, reheat and economizer sections. This means that the 33% of heat needed to make steam is not supplied; therefore the boiler master will sense this and increase the fuel flow to compensate.

Note: superheat and reheat spray flows will increase to control these temperatures.

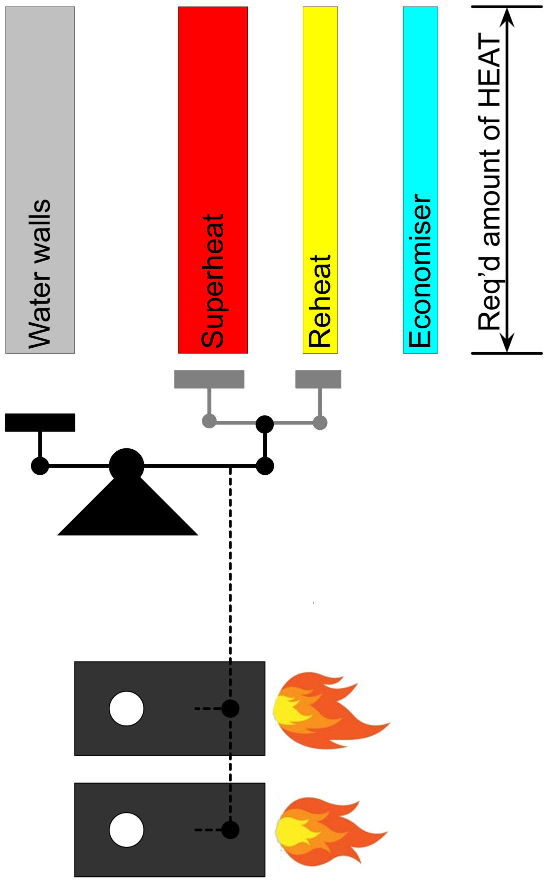


Conversely we can see that as the tilts are directed downwards that more heat is directed into the water walls and less to the superheat, reheat and economizer sections. This means that more than the required 33% of heat is being supplied to the water walls; therefore the boiler master will sense this and reduce the fuel flow to compensate. Superheat and reheat temperatures will drop and be below design values.



We can see above that adjusting the burner tilts affects the superheat, reheat and economizer sections as one (i.e. either adding more heat than required to all, or not supplying enough heat to all).

Let us now split the right hand side of the drawing into its individual components. We get a graph for superheat, reheat and economizer sections. We can also modify our drawing of the set of scales and add a sub-scale for the superheat and reheat sections.



4.2 Automatic operation of burner tilts

From the first time the boiler is fired slag will start to accumulate on the water walls and fouling of the superheat and reheat section will commence.

The ash content, ash fusion temperature and coal flow will determine the rate at which this occurs, but over time it will just continue to build up. A lot depends on the design of the boiler and the coal being burnt which boiler surfaces will slag or foul up first and when sootblowing is necessary.

On most tilting burner boilers it is the reheat outlet steam temperature that is controlling the burner tilt mechanism. If the reheat temperature is high then the tilts will be commanded to lower. Conversely if the reheat temperature is low the tilts will tend to drive up.

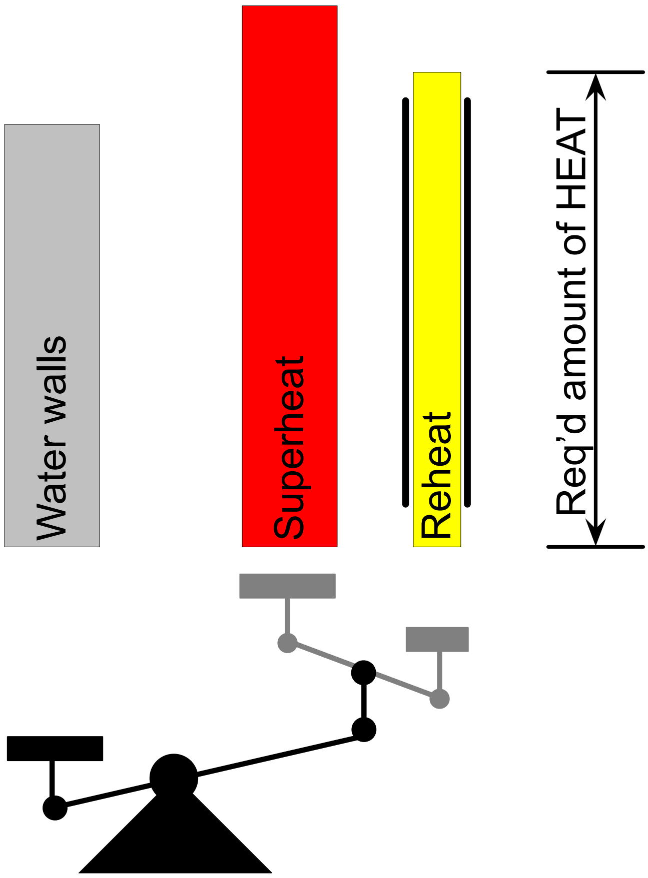
In the example that the reheat steam temperature is low and the tilts get the command to drive up. This will increase your reheat temperature up to its design value, but at the same time will also increase your superheat outlet steam temperature. If your superheat temperature was also initially low then this is not a problem, but if it was already high then the extra heat being forced at it will raise it even more. The superheat temperature will not actually increase above its design value as the superheat spray valves should open to de-superheat the steam and keep the outlet temperature at the correct value.

From an efficiency point of view, increasing the spray water into the superheat section is undesirable as it will lower the unit efficiency by a small amount.

Note: whilst superheat spray water will lower the unit efficiency by a small amount, reheat spray water will cause a much bigger reduction in unit efficiency and should be avoided if possible.

So why would the superheat outlet temperature already be high with the reheat outlet temperature low (i.e. and causing the tilts to drive up). There are two possible answers to this question; one is a design problem with mismatched superheat and reheat area, the other is fouling of the reheat section.

Fouling build-up on a heat transfer surface will act very much like an insulation blanket and limit the amount of heat being transferred from the fire side of the tube through to the water/steam side of the tube. If not as much heat is getting through to the reheat steam section then the outlet temperature will be lower. Also something which we will discuss latter is that if the heat isn't being absorbed into the reheat steam then the flue gases leaving the reheat section will contain more heat and this will be passed on to the back pass of the furnace and the economizer.



The thick black lines on either side of the graph that represents the reheat section are an indication that heavy fouling is present on this heat transfer surface.

We can see that to get the required outlet steam temperature from the reheat section (It is this that usually drives the burner tilts), we need to have the tilts pointing upwards. This has the effect of depriving the water wall section of the heat required to make steam (this will be made up my the boiler master controller increasing the firing rate), and providing the superheat section with too much heat which will have the effect of increasing superheat spray water to control its outlet temperature at design value.

So to recap; we can control the distribution of heat to the water walls and the superheat, reheat, and economizer as a block using the burner tilts. However the only way to control the heat distribution between the superheat and reheat section is by either sootblowing or not sootblowing.

In the above diagram if we choose to not sootblow the superheat section it will slowly foul up over time and eventually the heat absorbed by the superheat and reheat section will be more in balance and superheat spray flow will be reduced.

Note: This is not the preferred option in this case as the superheat section and the reheat section both now have a thick layer of slag on them limiting heat transfer which means the flue gases leaving these section will be at a higher temperature (not as much heat has been removed from them), which will be passed to the economizer and eventually to the airheater, precipitator, ID fan and the chimney as waste heat.

A better option in this case is to sootblow the reheat section which will increase the heat transfer from the flue gases to the reheat steam causing the reheat outlet steam temperature to increase, which will in turn command the burner tilts to lower and this will lead to a decrease in superheater temperature and more heat being directed into the water walls and a reduction in fuel demand by the boiler master.

However keeping all the heat transfer surfaces clean by sootblowing continuously is not the answer. Depending on how the boiler was designed and even on the coal you are currently burning it may be necessary to allow some heat transfer surfaces to slag or foul up to get the design temperatures from the superheat and reheat section.

4.3 Seasoning the furnace

Most boilers (Paiton units 5&6 is a good example) require a number of days to allow slag to accumulate on the water walls (i.e. to season the furnace) before superheat or reheat temperature finally rise up to the design points. In this case the boiler, even with the burner tilts all the way up is absorbing too much heat into the water walls and not allowing enough to pass over to the superheat or reheat sections. However once the walls have a thin layer of slag then the temperatures in the superheat and reheat section will rise up to design values.

As the walls get thicker and thicker with slag more heat is being carried over to the superheat and reheat sections and as such the burner tilts will start to lower to try and control the reheat temperature.

As the tilts come slightly into the negative then the wall de-slaggers should be used to clean some areas of the wall tubes to allow more heat absorption into the walls and allow the tilts to rise up slightly. It would be a mistake on this boiler to blow all the wall de-slaggers at once as this will allow too much heat absorption into the walls and superheat and reheat temperatures will then be below design value.

However at the same time fouling of the superheat and reheat areas is also occurring and this is limiting the heat pickup by these items. This has the effect of raising the burner tilts to try and maintain these temperatures and also of allowing more heat to travel over to the economizer and air heaters.

So the two main drivers of the burner tilts are working in opposition to each other;

- Wall slagging up causes the tilts to drive down
- Superheat and reheat fouling causes the tilts to drive up

At Paiton it was relatively easy to keep the burner tilts inside the control range (i.e. $\pm 15^\circ$) and as a general rule if the tilts are $> 5^\circ$ up and no spraywater on superheat and reheat section then need to sootblow superheat and reheat. If tilts are $< 10^\circ$ down and reheat spray flow increasing then it is time to blow the wall de-slaggers.

Note: At Paiton units 5&6 the burner tilts looked at both superheat and reheat steam temperatures and would drive up the burner tilts until 541°C was achieved on either of them. Usually it was the superheat that achieved 541°C first and therefore the reheat temperature would be a little less than that. This means the plant was losing efficiency from not reaching design reheat temperatures (unless the operator used the sootblowers just right to get a little bit of fouling on the superheat section to balance the heat pickup), but was also not over spraying the superheat section – another loss of efficiency.

At MapTaPhut it is a different story. It appears that the boiler on start up from a clean condition can immediately get superheat and reheat temperatures. Also due to the short distance between the A pulveriser burner nozzles and the bottom of the furnace it is very rare to see the burners tilting downwards. Because of this the MapTaPhut boilers have a very limited control using burner tilts on where the heat will be directed in the furnace compared to Paiton units 5&6.

In addition as the burner tilts predominately look at reheat outlet steam temperature the tilts tend to drive up to achieve this and in the process direct too much heat to the superheater (remember that burner tilts affect both superheat and reheat temperature) causing the spray flow on the superheat section to be excessive.

Note: Given the way the burner tilts operate at MapTaPhut on automatic it would be advantageous to add area to the reheat section (i.e. make the reheater bigger), as this would raise the outlet temperature of the reheat section, causing the tilts to lower and thus also reduce the superheat section spray flow. However it would also have the effect of lowering the heat supplied to the economizer section and air heaters so the boiler would need to increase firing to make this up.

4.4 Back end temperatures

In the drawings above we included the heat required for the economizer, but did not discuss how the operator can change this. The economizer and air heaters take the heat that is not absorbed by the water walls, superheat and reheat section – so it takes what is left over from making the steam and superheating/reheating it.

Whilst the economizer has sootblowers, they should be operated on a scheduled basis to keep the economizer tubes clean. The most effective way the operator has of controlling the flue gas temperature of the economizer section is by sootblowing up stream in the water wall, superheat and reheat section. i.e. if you have clean walls, a lot of the heat will be absorbed into them and so less will be available for the economizer section.

The air heaters also usually have sootblowers, but their main function is to keep them clean so they don't block up with ash and restrict air flow.

4.5 Left-right temperature splits

Larger boiler with over firer air for NOX control can have a problem with large temperature differences between left and right sides of the boiler. It depends on the design of the boiler if this is a problem or not, but is usually most evident in the reheat section.

At Huntly (New Zealand) with a single reheat outlet header with the take off in the middle and afterwards splitting into 2 pipes for the IP turbine steam inlet it is not a big problem. As the steam has a common temperature before it splits up the temperature variation will be non existent. In addition Huntly does not have over fire air.

At MapTaPhut with a left and right side reheat outlet header a large difference in temperature can exist. This is also not a problem for the turbine as both pipes join together in a mixing section of pipework before splitting apart again for entry to the IP turbine. So the 2 legs of steam entering the IP turbine are of the same temperature.

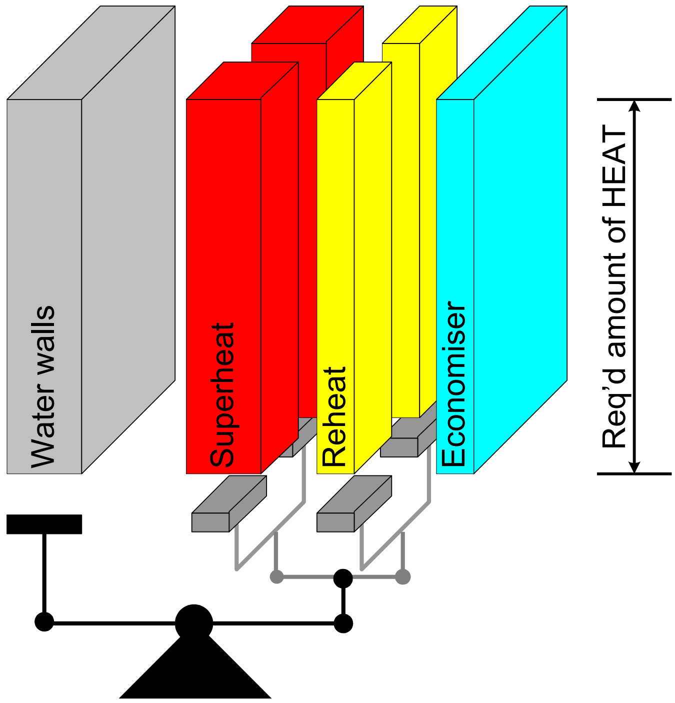
However as the burner tilt set point is derived from the average of the left and right side reheat outlet temperatures, a large difference in these temperatures can lead to operation of the burner tilts that is not ideal. One side of the reheat outlet steam will have a low temperature (below set point), whilst the other side will be high (above setpoint) and hence will require reheat spray water to bring it back to setpoint. Reheat spray water is a big loss of efficiency.

Stations like Paiton units 5&6 had no mixing or cross over pipe between the left and right steam legs from the reheat outlet so any temperature differences had the effect of making one steam leg a little bit longer than the other (linear expansion is proportional to temperature). This extra length was transmitted to the IP turbine and had the effect of pushing it out of alignment and when greater than $50°C$ would lead to increased vibration of the IP turbine, and the risk of metal to metal contact inside the turbine.

Other than making adjustments to the over fire air yaw dampers, which should be done during commissioning only by the engineer, and checking windbox to furnace differential pressures are the same on both sides of the furnace (Paiton unit 6 ran for a few years with one windbox dp transmitter calibrated differentially than the other leading to the fireball not being central in the furnace) the operator has only the sootblowing system available to him to correct this problem.

If you as the operator are getting prepared to sootblow the reheat section of the boiler and have a temperature split (a temperature split $< 5°C$ is not really a problem, $> 25°C$ is getting a big problem) it can be useful to sootblow more on the lower temperature side of the reheat section. E.g. if the furnace has 6 sootblowers for the left and 6 sootblowers for the right side of the reheat section and the left side is showing a lower steam outlet temperature then attempt to blow all 6 blowers on the left, but only 5 on the right. This will have the effect of correcting the temperature imbalance. Only experience and trial and error will enable the operator to get this right every time.

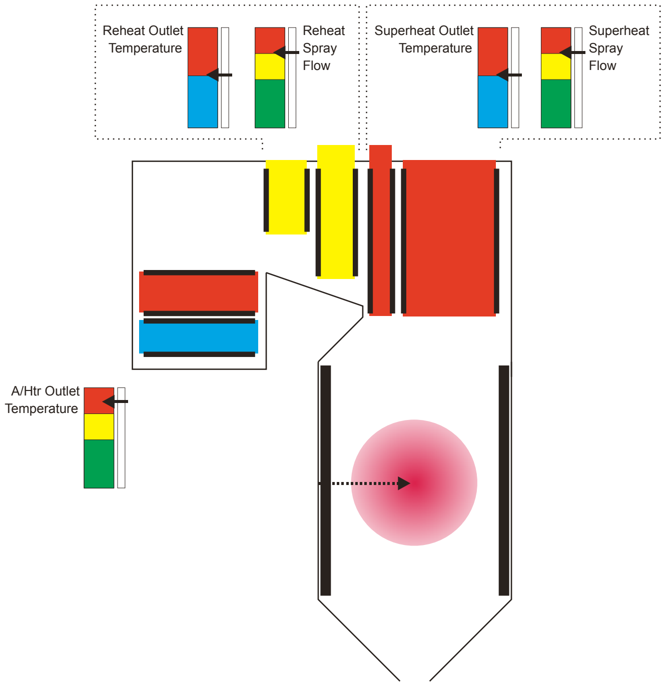
Note: the next time the reheat section needs sootblowing and a similar temperature difference exists you can do the same technique of blowing 6 on the left and 5 on the right, but it is a good idea to omit a different sootblower on the right (i.e. do not leave out the same sootblower all the time – mix it up)



Using the diagram above we can see that the superheater and reheater are usually split into left and right side streams which feed the steam turbine whilst the economizer which also can be split left and right feeds the common steam drum so differences in heat distribution do not have any effect on the economizer (from a temperature point of view). However flue gas temperature differences left to right can have some effect on the economizer section as a split may lead to differing amounts or even different size of grits (or even grits with differing properties such as stickiness) accumulating in the economizer hoppers and this may cause one side hoppers to become blocked more easily than the other.

4.6 Scenario #1 – High Air Heater Outlet Temperature

Many times at Paiton units 5&6I we can find the furnace in this condition. The tilts are still about or above the horizontal position; the air heater outlet temperature is high (near the trip mark); and the superheat and reheat sprays are spraying excessively. In this instance the fouling on the heat transfer surfaces is not allowing enough heat to be removed from the flue gas before it reaches the back-pass, thus causing the high temperature there. In addition the tilt position is too high (and should be lowered), causing the excessive amounts of spraying in the superheater and reheater.



By sootblowing any of the heat transfer surfaces in the furnace, you will have the effect of reducing the air heater outlet temperature. However sootblowing of some surfaces will have a greater effect than the sootblowing of others.

1. If we choose to sootblow the back-pass section we will see a slight drop in the air heater outlet temperature due to the increased heat transfer into the economizer and primary superheater sections. Whilst the increased heat transfer to the economizer will improve boiler efficiency, the increased heat transfer into the primary superheater will only mean that we must spray still harder to maintain the superheater outlet temperature at its setpoint value (more sprays means less efficiency).

2. If we choose to sootblow the reheater and/or secondary superheater we would also see a slight drop in the air heater outlet temperature due to increased heat transfer into these sections (and therefore less heat available to be carried over to the backpass). Again it will also increase the amount of spray water we are using on the reheat and superheat section leading to a big drop in boiler efficiency.

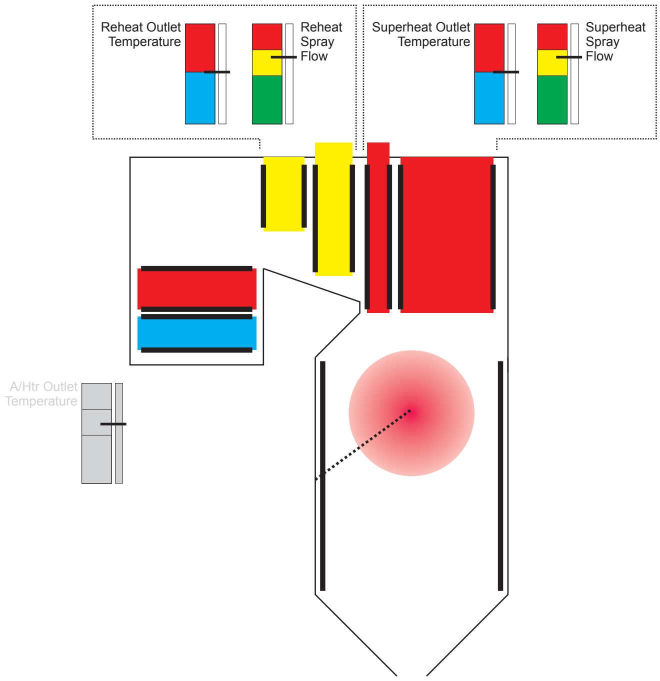
3. The third option is to sootblow the furnace walls. This has the effect of allowing greater heat transfer into the water-walls, leaving less heat in the flue gases to pass over into the

secondary superheater/reheater section; the backpass; and eventually the air heater. With less heat being carried over to the air heater the outlet temperature will fall. Another benefit of this method is that due to less heat being carried over into the superheater/reheater, the amount of spray water will be reduced – leading to improved boiler efficiency.

The third method is the best.

4.7 Scenario #2 – Superheater and/or Reheater Spray amount HIGH

If the boiler is making its design outlet temperatures, but the spray water flow is either HIGH or TOO HIGH then the fireball is positioned too near the top of the furnace. Usually this will occur when the furnace water-walls have slight to medium fouling and therefore heat absorption into the water-walls is reduced thus causing more heat to be carried over into the superheater and reheater sections. In this instance the burner tilts should be lowered until the superheat and/or reheat spray flow has reduced to a minimal level. Remember spray water flow is lost efficiency and therefore money.

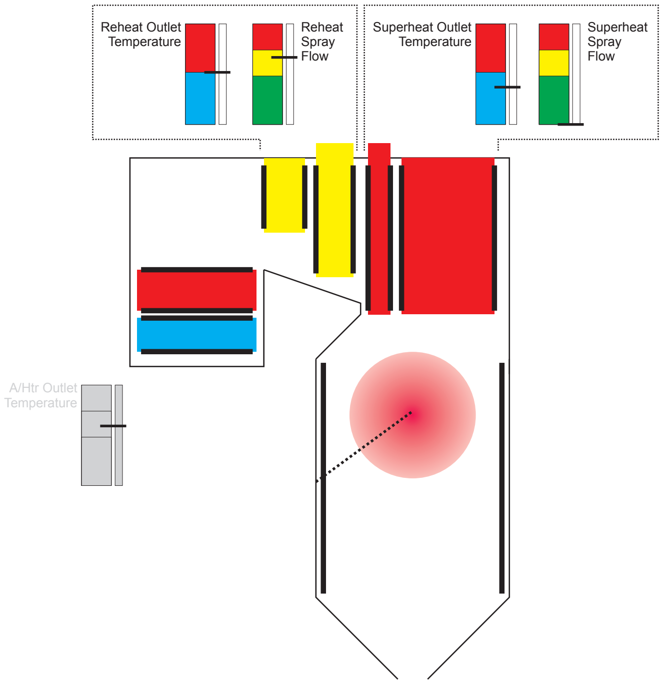


Note: this scenario is easy to fix if both the superheat and reheat sprays are operating approximately equally, but less easy if it is only the superheat or only the reheat sprays that are spraying. Sometimes a compromise is necessary as we may find that lowering the burner tilt position will reduce the spray flow on the reheater to an acceptable level, but in the process reduces the M.S temperature below the design value. In the short term this situation we can live with (both too high a spray water flow on the reheater and too low a M.S temperature have a negative effect on efficiency), but in the long term we can try to balance the ratio of heat absorption (i.e to about the 31% heat needed by the superheater and the about 18% heat needed by the reheater). As the burner tilts have an approximately equal effect on both the superheater and reheater heat supply we cannot use them to control the ratio of heat going to the superheater or reheater. Our only option is to allow slag to accumulate on heat transfer surfaces that we wish to reduce heat absorption into, and to sootblow surfaces that we wish to increase heat absorption into.

Therefore to reduce the heat absorbed into the reheater we need to allow slag to build up on it. This will therefore lower its share of the 49% of heat available that it is taking (and also increase the superheater share of the 49% of available heat), reducing the reheat spraying and at the same time increasing the M.S temperature.

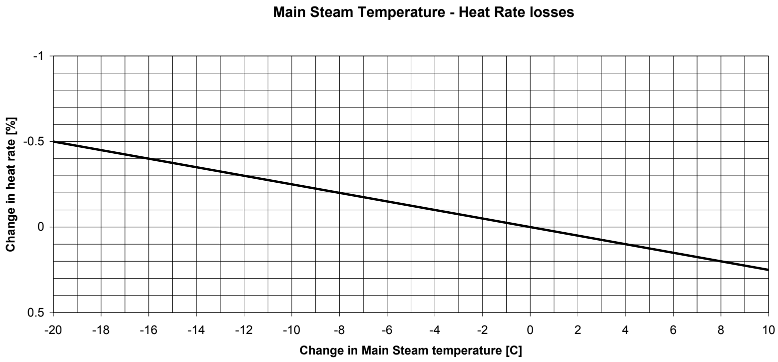
4.8 Scenario #2.5 – Superheater temperature LOW and Reheater Spray amount HIGH

In the following situation a decision must be made by the operator to either raise the burner tilts to achieve main steam temperature at the expense of excessive reheater spray water flow, or to lower the tilts to get a reasonable amount of reheater spray water flow and put up with the reduced main steam temperatures. This situation as discussed above can be fixed in the long term by selective sootblowing of the superheater and allowing a build up of slag to accumulate on the reheater.

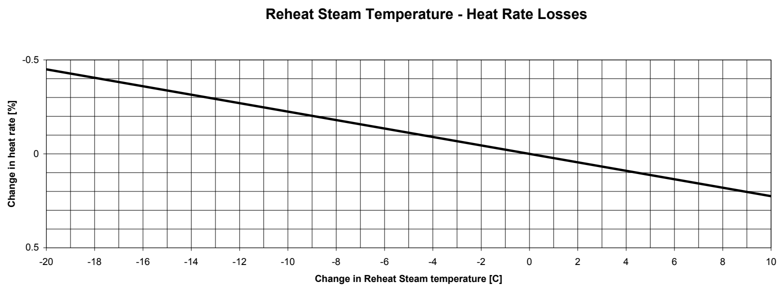


4.9 Performance charts

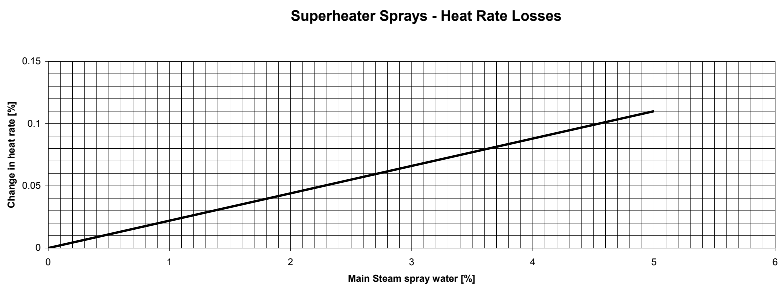
The charts below are for Paiton units 5&6, all other plants should have similar documents provided by the boiler manufacturer. These charts will allow the operator to make a decision based on efficiency (therefore cost) of either raising or lowering the burner tilts.



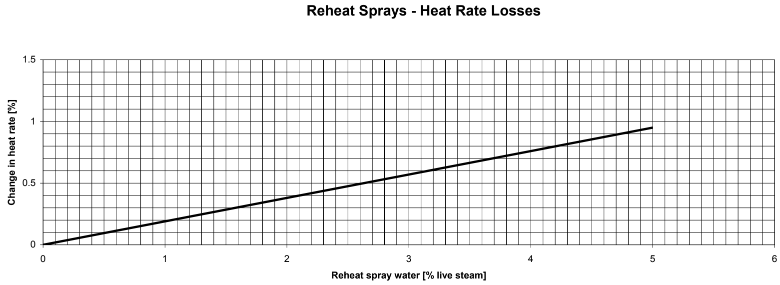
The above chart shows the percentage loss of heat rate (unit efficiency) for a given change in main steam temperatures. Therefore if actual main steam temperature is only $528°C$, then this will have an effect of reducing the units heat rate by 0.25%. Conversely if the main steam temperature is only $518°C$, then this will cause a 0.5% reduction in heat rate.



The above chart for reheat steam temperature heat rate losses shows values very near that of the main steam chart.



This chart for heat rate losses for a given amount of superheater spray water flow, shows that for each percentage point of live steam spray water flow (1% spray water flow of 546kg/s main steam flow is equal to 5.46kg/s of spray water), a heat rate loss of 0.022% is achieved.



This chart shows that for each percentage point of reheat spray water flow (again 1% reheat spray water flow of 546kg/s main steam flow is equal to 5.46kg/s of spray water), a heat rate loss of 0.2% is achieved.

It can be seen that excessive spraying on the reheater, or low steam temperatures on the superheater and reheater are the biggest losses of heat rate. Superheater sprays have a much smaller impact on the units efficiency.

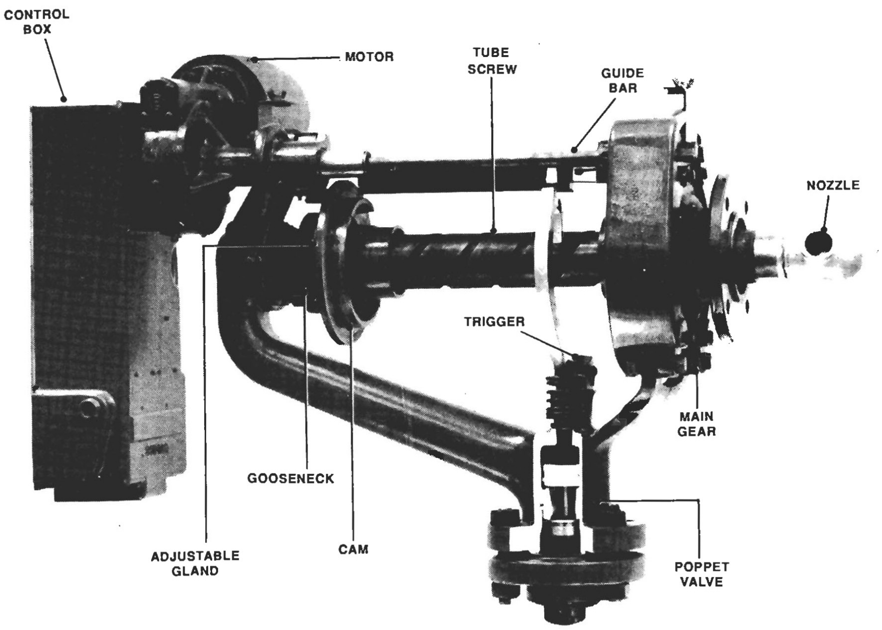
Note: The above charts are for full load (546kg/s steam flow) only. Whilst the charts for main steam and reheat steam temperature will be correct at all loads, the superheater and reheater spray water losses will be inaccurate at anything but full load.

5 Types of Sootblowers

All of the main heat exchange surfaces within the boiler are provided with a particular type of sootblower that is most suited to and is most effective in the removal of an accumulation of deposits. These areas include the lower and upper regions of the boiler furnace walls, the high temperature superheater zone, the reheater zone, the low temperature superheater zone, the economiser and the air pre-heater.

5.1 Furnace wall sootblowers/ wall de-slaggers

They are comprised of a short single-nozzle retractable blower, referred to as a wall blower, and removes the ash that is deposited on the walls of the furnace chamber. Supported by wall boxes welded to the furnace tubes it takes the form of a short stroke lance which penetrates the furnace wall by one or two inches. Its mounting allows it to move down and up with the furnace tubes as they heat and cool. The single nozzle at the tip directs a supersonic high-energy jet of superheated steam or air tangent to the furnace face of the water-wall tubes, dislodging the slag deposits.



The lance rotates through 360 degrees and cleans approximately a five - foot radius; the effective radius depends on how tenacious the deposit is.

Some coals with difficult to remove slag will require wall blower spacing to be closer; the maximum cleaning radius may only be 3 to 4 feet.

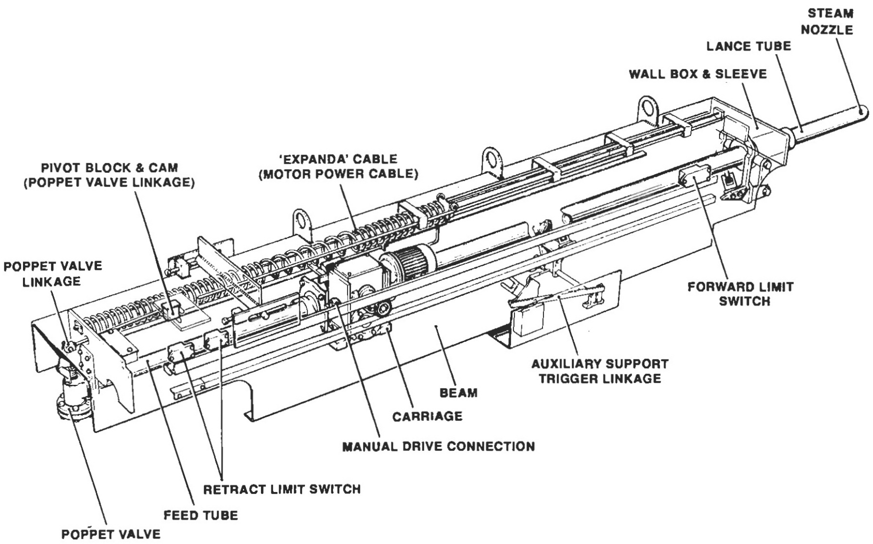
Blowing frequency depends on the rate of slag build – up, but frequencies within the 3 to 4 hour range can be quite common.

5.2 Convection surface sootblowers

Superheater/reheater, and economiser sections are cleaned with long, fully retractable lances which penetrate the cavities between the major heat – absorbing sections.

The long retractable type sootblower is the most effective way to clean radiant and convection heating surfaces. It normally uses two 180 degree opposed cleaning nozzles which at the tip emit a high – energy jet of superheated steam or compressed air perpendicular to the lance. While the lance traverses the boiler, it rotates, forming a helical blowing pattern which effectively cleans the tubes and the spaces between the tubes in the superheater, reheater, or economizer banks. In widely spaced platenized sections, these nozzles are angled slightly, leading and lagging the perpendicular so as to gain more dwell time on the tube surface. The effective range of the long lance blower depends on the gas temperature in the zone to be cleaned and the ash characteristics of the coal being fired. Therefore, the maximum effective cleaning radius varies from 4 to 9 feet. It is difficult to relate cleaning radius to blowing pressures because of various nozzle combinations. Blowing pressures depend not only on supplying an adequate steam flow for cleaning, but in high temperature zones, supplying an even greater flow for the cooling of the lance itself. To this end, it is customary to include steam flow monitoring as a form of protection in the steam supply system for long lance blowers that are located in the high temperature gas zones.

A long lance retractable blower on one side of a large utility boiler can penetrate half the width of a 90ft wide boiler. The blower typically uses a two point support which allows for boiler expansion. A wall box welded to the tubes supports the front of the lance, with a platform structure supporting the rear.



5.3 Air Heater sootblowers

Cold end deposits occur when the boiler flue gases reach the condensation temperature. The fly ash in the flue gas can combine with moisture and sulphur derivatives to form a fine grained deposit or scale on the cold end heating surface. Sootblowing can remove and control regenerative air heater cold end deposits provided those deposits are not subjected to moisture.

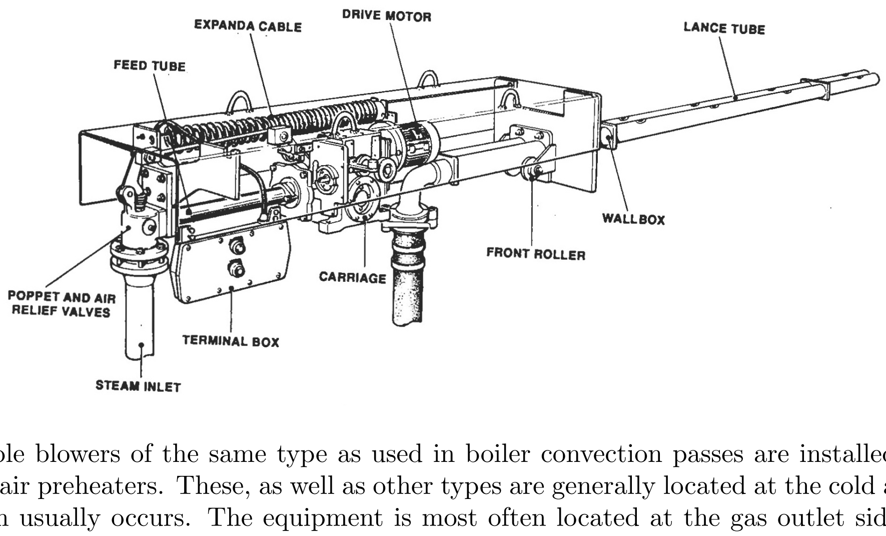
Moisture can be introduced as drainage from water cooled gas analysis probes, economiser tube leaks, and unprotected FD and PA fan inlets through which rain water can enter the air heater. Leaking steam sootblower and water washing shut-off valves can add to this problem. However, the most frequent causes of external moisture is the sootblowing steam. Moisture in this blowing medium can be eliminated by selecting a steam source with controlled pressure and temperature to provide dry steam to the sootblowers at all times. Air heater element fouling can also result from the carryover of material from the economiser and the subsequent lodging of the larger particles in the heating surface, particularly at the air heater hot end.

Regenerative air preheater fouling can be limited by controlling the cold end temperature level and by the use of proper maintenance procedures and cleaning equipment. The primary requisites for this purpose are sootblowing and washing equipment, a dry blowing medium, an adequate water supply, and a good drainage system.

Three types of sootblowing equipment are available and can be installed on rotary type air preheaters.

1. Power–driven sootblowers which have nozzles mounted on a swinging arm arrangement are used extensively.
2. while a stationary multi – nozzle type can also be adopted.
3. On air preheaters of a diameter of greater that 32 ft, retractable sootblowers are installed as standard equipment.

A typical large power-driven device, is supplied as either as a single or twin nozzle sootblower. The nozzle arm, which moves slowly over the heating surface, is controlled by a gear driven mechanism powered by an electric motor through a speed reducer. The blowing cycle consists of one pass across the heating surface, either from the rotor periphery to the rotor post or from the post to the periphery.



Retractable blowers of the same type as used in boiler convection passes are installed on large diameter air preheaters. These, as well as other types are generally located at the cold and where deposition usually occurs. The equipment is most often located at the gas outlet side so as to to eliminate fly ash from being carried into the windboxes. They are installed either as an integral part of the air preheater duct, or in the gas outlet ducting immediately adjacent to the unit.

Superheated steam containing approximately 150 degrees celsius of superheat, or dry compressed air is recommended as a cleaning medium. Although saturated steam, which contains some moisture, has been used occasionally, superheated steam has been found to be more effective for sootblowing.

Although compressed air is considered to be the premium cleaning medium, its merits do not stem from an inherent cleaning ability, but from the moisture deficiency when compared with steam. In fact, under dry discharge conditions, the kinetic energy of a steam jet at 13 bar, is approximately twice that of air at the same blowing pressure. So a steam source must be selected to have pressure / temperature conditions which, by proper control measures, may be used to provide dry steam to the air preheater sootblower. If a steam source is of an undesirable quality, unwanted moisture will be introduced to the air heater surface.

The steam blowing pressure should be within the range of 12 to 15 bar.

When using air, care should be taken to install a proper line of traps and separators to remove moisture from the blowing medium. Air pressure at around 12 bar is recommended.

A steam sootblowing piping system should include an automatic drain feature, thermocouples and an automatic admission valve to the blowers. The automatic drain valves should open to free drain discharge until the temperature sensing thermocouple indicates steam of adequate quality.

In cases where sootblowing cannot readily remove residual deposits, it sometimes becomes necessary to water wash the heating surface so as to maintain acceptable draft losses through the air preheater. In some instances this may be required more frequently than during the scheduled boiler outages.

Most deposits forming on the air preheater heat transfer surface are highly soluble in water and, therefore, are easily removed by washing with a sufficient quantity of water. A high penetration, stationary multi-nozzle device is the standard washing apparatus and is available for all air preheater types and sizes.

Adequate drainage is necessary before planning to wash an air heater. Washing can be on either the air or gas side, depending upon which has the best drainage.

Out of service washing is simply washing the preheater in a cold state during periods when the boiler has been shut down. During shutdown is the best time to control the washing operation and to make a thorough inspection of the heating surfaces, both during and after washing. The rotor can be turned at normal speeds. If it is necessary to restrict the discharge of water to one side of the air heater, some form of auxiliary drive will be required to reduce the rotor speed. Surfaces should be examined frequently during the washing process. After the deposits are removed, the unit should be allowed to dry completely before being returned to service. In order to check the effectiveness of the washing process, a powerful light source can be used to carry out a sighting process through the heating elements to ensure that they are completely clear.

Other cleaning methods available include an in service isolated washing system that comprises of dampers located in the air and gas pass that effectively isolate the air preheater allowing it to be water washed whilst the other air heater remains in service with the boiler output restricted to some 66%. This method is very effective, but the air preheater must be thoroughly dried before returning to service.

An on stream in service type washing system is also available whereby the air preheater is rotated at a reduced speed and additional drainage points are installed to eliminate the possibility of the moisture entering the dust collectors, precipitators, windboxes and the boiler. The latter two mentioned systems would probably only merit consideration when burning coals of a high ash content whereby air preheater cleaning by water washing may become a more frequent requirement. The increased capital cost of the additional equipment required would also have to be taken into account.

To keep the airheater in a clean condition essential close monitoring of the primary air and secondary air draft loss across this heat exchanger is of the uppermost importance. As a general rule, sootblow at least once per shift and be guided by draft losses.

The air heater sootblowers are the only sootblowers on the boiler that are provided with permanent steam pressure guages, hence the importance of their correct performance in keeping the air heater clean. It is advisable to monitor and record the steam blowing pressure at certain time intervals so as to ensure the best possible cleaning effect is maintained.

It should be remembered that the air heater sootblowers are designed to keep a clean air heater clean. They will not necessarily restore a dirty air heater to a clean condition. When an air heater is really dirty it invariably results in off load washing to restore it to a clean condition.

Sootblowing the air heater to reduce gas exit and back end temperatures can also be helpful, but is not so effective as blowing other areas of the boiler.

5.4 Sootblower control systems

Modern sootblowers systems have programming techniques so proper sequential operation of the blowers, on an automatic basis, can be established after ash deposition patterns are verified during pre-operational tests. Through programming, ash deposits on the furnace walls generally can be held to a minimum, and combustion gases cooled sufficiently before they enter the convection pass.

The mode of sootblower operation depends upon the size and capacity of the boiler unit and the number of blowers installed. Smaller boilers using fewer sootblowers cannot economically justify the use of automatic control systems, therefore manually operated sootblowers are often fitted. On the other hand, large industrial and power utility boilers can justify various degrees of automatic control.

The sootblower control systems in the early 1960's basically required the blowing of each sootblower, one at a time, in some predetermined operating sequence. Each blowing cycle was started manually by the operator or by a pre-set timer. Therefore, only a simple sequencing device was required to start each blower.

In the early 1970's, transistorised logic elements, hardwired into unique control circuits, replaced these electromechanical sequencing systems. Essentially, the control was still a sequencing system, but additional functions were added as necessitated by the increased boiler cleaning requirements.

The control systems were limited only by the ability of their logic to perform the more complex operations and still retain an economic, relatively small package designed for high reliability. In any typical system, the number of sootblowers increased with the size of the unit and it became necessary to operate several types of sootblowers simultaneously. Common systems operated the furnace wall blowers together with the superheater and reheater blowers. In addition to operating the wall blowers and the retractables simultaneously, multiple blowing of each type of sootblower was also incorporated into the control system. It would be impossible otherwise to operate the sootblowers often enough, to maintain essential degree of boiler cleanliness.

In some large coal fired boiler installations, it is not unusual to find in excess of 200 sootblowers and programmable controllers are frequently installed so that proper automatic sequential operation of the system can be accomplished after ash deposition patterns are established under actual operating conditions. With a properly programmed blowing sequence, ash deposits on the furnace walls are minimal and the combustion gases are cooled to the required temperature before entering the convection pass.

Sootblower control panels are now designed for easy modification of the automatic sequential operation. This gives the operator maximum flexibility to maintaining the cleanliness of the unit. Essential parameters for such a sootblower control installation would include:

- Equipment to automatically start each sootblower in the system.
- A method to cancel the operation of any sootblower in the system.
- A way to determine easily which sootblowers have been selected to operate, and their programmed operating sequence.
- The complete capability to monitor and display the operation of each sootblower.
- The capability to monitor all the essentials of the sootblowing system and prevent continued sootblower operation if the system is not functioning properly and abort the operation of any sootblower if a malfunction occurs.
- A method to select and alter various blowing routines as required by the boiler cleaning requirements.
- The ability to sootblow more than one section of the boiler gas pass simultaneously.
- A means of manually overriding the automatic routines.

Ideally, a sootblower control system would respond automatically to conditions of load, temperature, pressure and fuel to provide for the most efficient boiler operation.

However, because of the number of input variables and the questionable validity of input signals and the complexity of process manipulation, this has curtailed the technical feasibility to date. Some fully automatic control sootblower schemes have been in operation since the mid 90's, but always included the option of manually initiated sootblower selection and sequence. Sequential control with the boiler operator acting as the decision maker remains the choice for the majority of sootblower installations. With the advent of more complex sootblowing operations, the hard-wired solid state logic systems have taken over some of the decision making.

It is extremely beneficial to minimise operator attention and still operate the sootblowers efficiently. Effective performance of any sootblowing control system depends upon its ability to make complex decisions with a minimum of operator input.

6 Changing Plant Conditions

6.1 Changes in coal CV

It is usual for a boiler to be designed for a specific type of coal (or sometimes 2, 3 or more types) that is usually constrained on CV value and percentage of volatiles. It is also normal that after the plant has been running a few years the owner will look at saving money and one of the easier items is to burn lower quality coal (maybe lower CV and higher moisture and ash content or higher sulphur). If the new coal varies too much in CV then it may be necessary to have more coal mills in service for a given load and at full load if all mills are required it can restrict normal mill maintenance. If volatile matter increases significantly then it may be required to check pf pipe velocities as the higher volatile will cause the flame to propagate at a higher speed leading to burning back into the nozzle. It may therefore be necessary to adjust the mill air flow curve accordingly.

The increase in volatile matter also has an effect of the burner tilt operation with the flame burning brighter and more quickly a lot more heat is released in the furnace and less therefore is available to be carried over to the backpass. Therefore the tilts will operate at a higher positive angle relative to the normal coal to maintain the superheater/reheater temperatures and you may find that not all of the tilt range is now usable. The smaller the usable tilt range then the less time is available for sootblowing to keep the tilts within the correct range to maintain outlet temperatures and you may find that enough time is not available to complete a full sootblower cycle. In this case some blowers need to be omitted.

Changing the classifier settings on the pulverisers can have a similar effect to changes in volatile matter with an increase of pf fineness having a similar response to an increase in volatile matter (i.e. flame will burner hotter and quicker the finer the pf sample). The usual criteria is $> 70\%$ and $< 80\%$ through a 200 micron mesh. If $> 80\%$ then the coal is being over ground with an increase in mill power, mill wear and more heat being released in the furnace. When $< 70\%$ the coal is being under ground which results in more heat being carried over to the backpass and higher carbon in ash losses.

6.2 Excess Air

At higher oxidation conditions, iron compounds in the ash melt at a higher temperature than lower oxidation conditions. Therefore, for bituminous coals, which are frequently high in iron content, there is a significant difference in fusion temperatures measured in reducing (oxygen starved) and oxidizing (oxygen rich) atmospheres. Sub-bituminous coals normally contain less iron and exhibit a smaller difference in melting temperatures produced in an oxidizing and reducing environments.

This means that, if slagging is a problem with coals of high iron content, furnace deposits can be reduced dramatically by increasing the amount of excess air. As a general rule, the higher the fusion temperature, the drier the slag in the furnace, and the easier it is to remove.

Adjustment of excess O_2 also affects heat distribution in the furnace as it affects the amount of secondary air that must be provided (i.e. to get an increase in O_2 at the economizer outlet requires a greater increase in air going into the furnace). If the O_2 setpoint is increased then more secondary air is being supplied which leads to higher gas flow velocities in the furnace and backpass. These increased velocities lowers the time available for the pf coal to release its heat in the furnace so less heat in the furnace means more heat in the superheater/reheater. As the velocities in the superheater/reheater are also increased more heat transfer occurs there as increased velocities in this area leads to better heat transfer, however the net result will still be slightly higher economizer exit temperatures. So the lower the excess O_2 values the better so long as a safety margin still exists on economizer outlet O_2 levels (usually about 3.5 – 5%).

7 Take your time

The long view should be taken when considering the condition of the furnace and what if any corrective action should be taken. Just taking a snap shot in time look at the boiler conditions may cause you to assume you have a problem where in reality it is just a slight excursion that will soon be corrected by the boiler master controller.

To gain a more accurate picture of what is happening in the furnace the use of trend screens cannot be over emphasized, as they show in what directions steam temperatures, sprays flow, etc are heading over time.

Note: An increasing trend of boiler steam pressure cycling is a clear indication of a dirty furnace since it creates an inherent time delay response in the heat transfer across the furnace wall tubes that are covered with slag.

However all boiler tend to have some swing in pressure and temperature as a result of the working of the control system so even the trends will show many up and downs and may be difficult to interpret. A solution to this is the use of a program such as PI processbook to show a trend averaged over a set time that will show more clearly where values are heading.

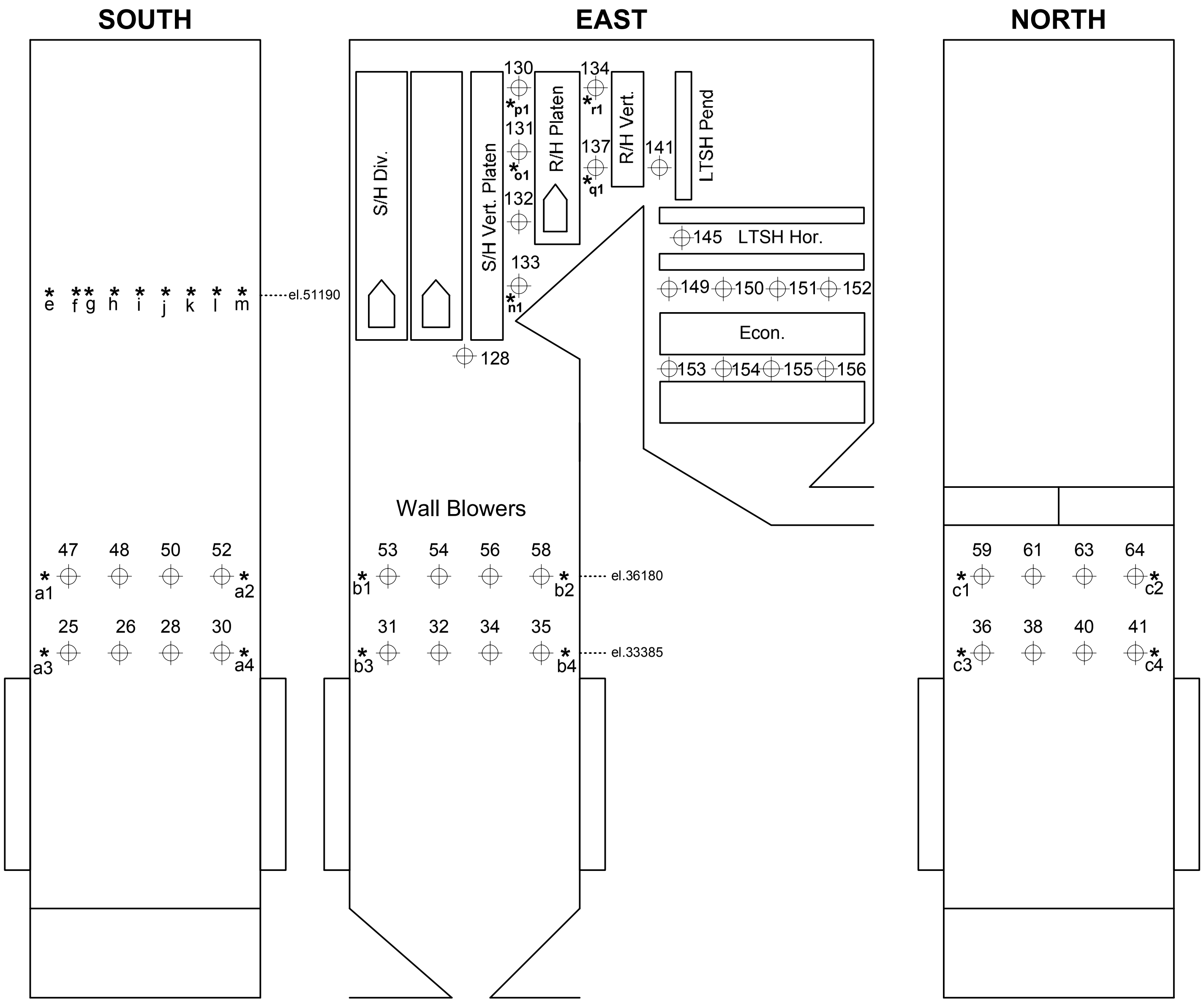
In addition to what the unit operator can see on the control screens the plant operator can also provide information in the form of a furnace internal visual inspection on the amount of water wall and superheat/reheat fouling and slagging. Given enough inspection doors it is possible to get a good picture of the areas and amounts of slagging. At sites like Paiton a pre-prepared boiler map was used and coloured in by the plant operator to give feedback to the unit operator and allow him to make a more informed decision (see next page for an example). However sites similar to MapTaPhut have few inspection doors and viewing conditions are very difficult.

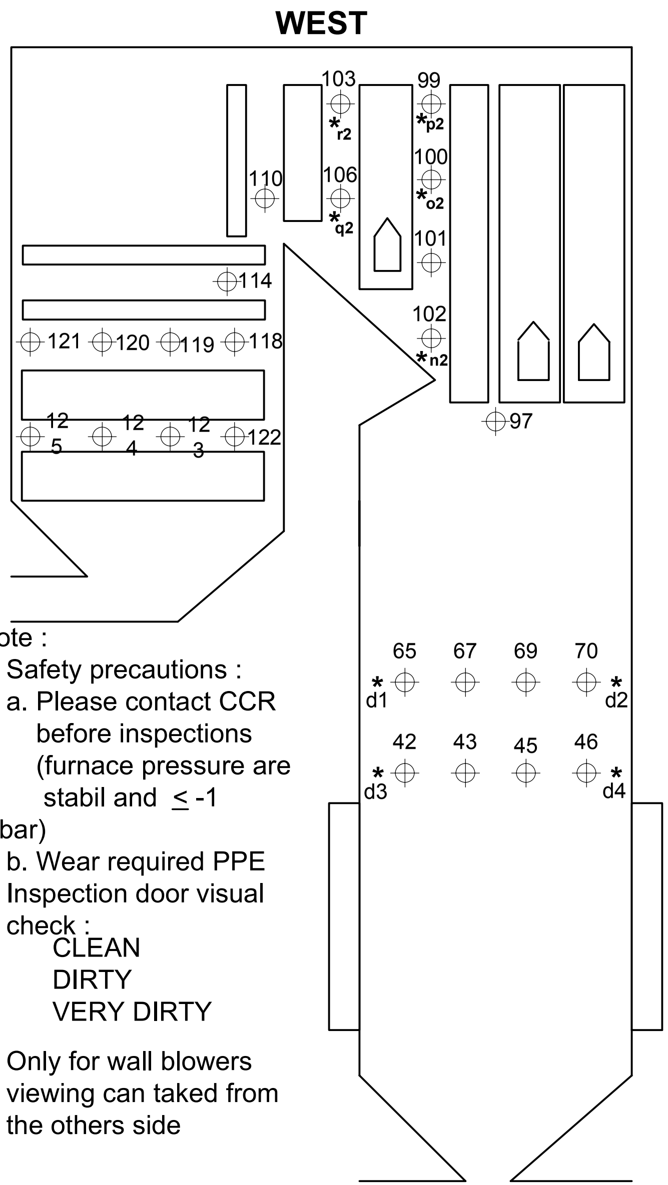
Also the operator must think ahead to what the plant will be doing in a few hours before making a decision. It would not be ideal to blow all water wall de-slaggers at MapTapHut just before changing mills from F to A, as this would allow greater heat transfer to the furnace walls and superheat and reheat temperatures would suffer as a result.

In addition if the operator is new to this sort of thing then blowing a complete pattern such as all wall de-slaggers or both the superheat and reheats section together is not advised. It is better to select individual blowers and start small and monitor the effect. If the effect is what is desired then continue. If it is not then you have not done too much damage to outlet temperatures or spray flow and can now try something different.

BOILER SOOT BLOWERS MAPPING

UNIT 50 / 60

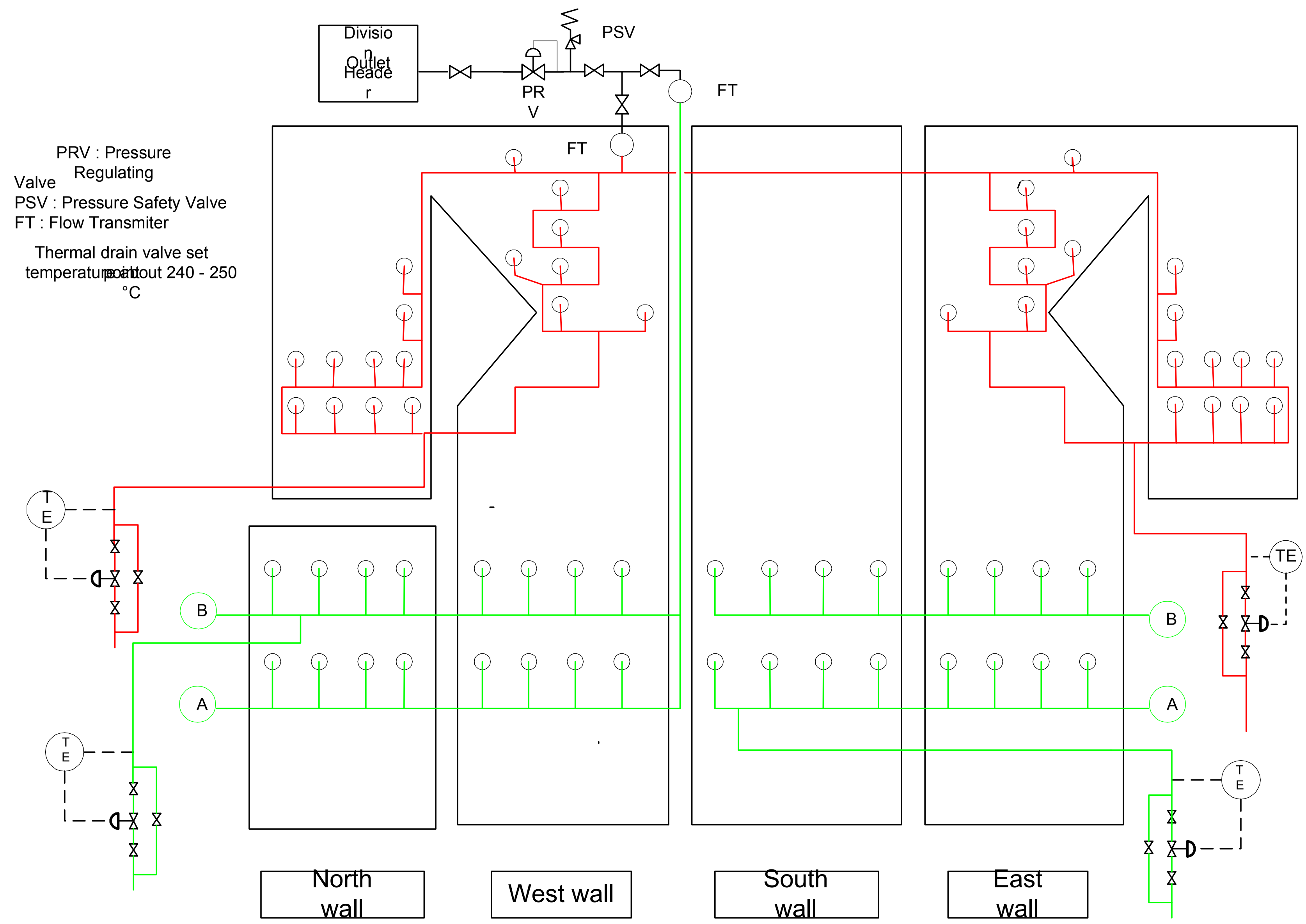




Note :

1. Safety precautions :
   a. Please contact CCR before inspections (furnace pressure are stabil and $\leq$ -1 mbar)
   b. Wear required PPE
2. Inspection door visual check :
   - CLEAN
   - DIRTY
   - VERY DIRTY
3. Only for wall blowers viewing can taked from the others side

DATE :	AIR HEATER GAS INLET TEMP :	NOTE :
	AIR HEATER GAS OUTLET TEMP :	
LOAD :	MAIN STEAM TEMP :	
	REHEATER TEMP :	



	Drawing No.: SD1042	**SOOTBLOWER**	Revision No.: 00
	Related document: PIP.OPS.1042		Drawn by: .
	Drawing Source:		Pages: 1 of 1