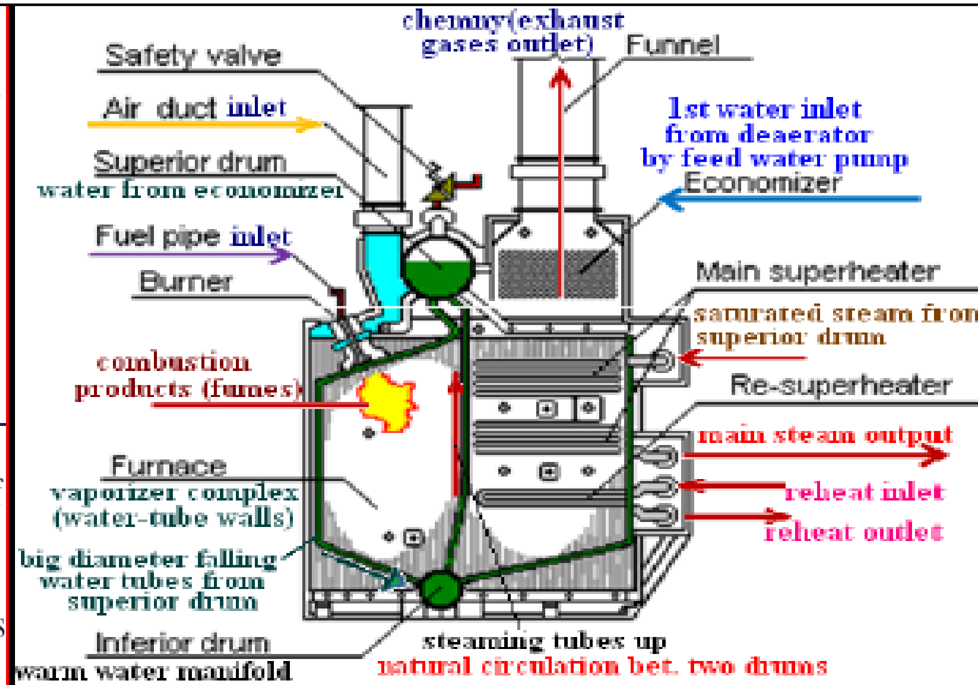
Boiler Control Objective

For proper control application, it is necessary to understand the objective of the control system. In the case of steam boilers, there are three basic objectives:

- **Accuracy** 1. To cause the boiler to provide a continuous supply of steam at the desired condition of pressure and temperature.
- **Efficiency** 2. To continuously operate the boiler at the lowest cost for fuel and other boiler inputs. Consistent with high levels of safety and full boiler design life
- **Safety** / **Stability** 3. To safely start up, shut down, monitor on-line operation, detect unsafe condition, and take appropriate actions for safe operation at all time.

Input / Output

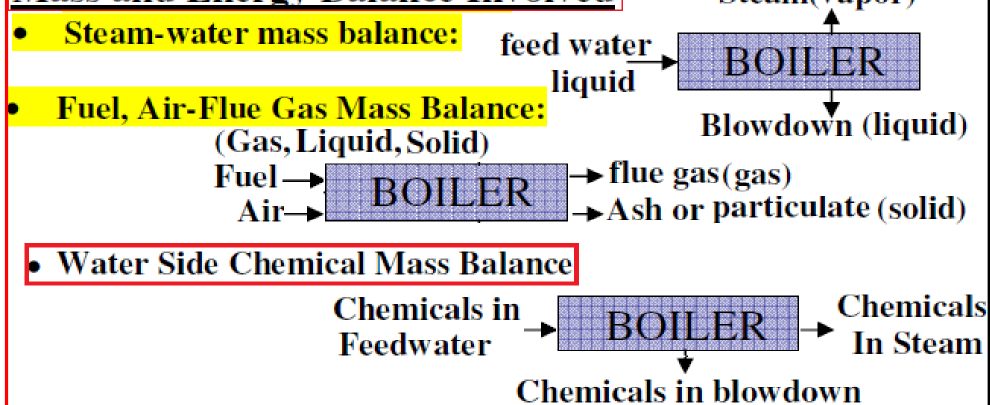
Before we begin the design of a boiler control system, we need to specify the input and outputs of the system, this is done after performing mass and energy balance, obviously this has to be done for any process control to be able to determine the manipulated variables, an interesting point is what one considers to be input / output of a plant can be the output / input of the control system as in our case.



Boiler Control-The Process of Managing the Energy and Mass Balances

The boiler control system is the vehicle through which the boiler energy and mass balances are managed. All the boiler energy and mass inputs must be regulated in order to achieve the desired output conditions. The measurements of the output process variables furnish the information to the control system intelligence unit figure below is a block diagram showing how the parts of the overall control system are coordinate into the overall boiler control system. For the energy input requirement, a firing rate demand signal must be developed. This firing rate demand creates the separate demand for the mass of fuel and combustion air the mass of the water-steam energy carrier must also be regulated, and the feedwater control regulates the mass of the water in the boiler. The final steam temperature condition must also be regulated. The effects of the input control actions interact, since firing rate also affects steam temp and feedwater flow affects the steam pressure, which is the final arbiter of the firing rate demand.

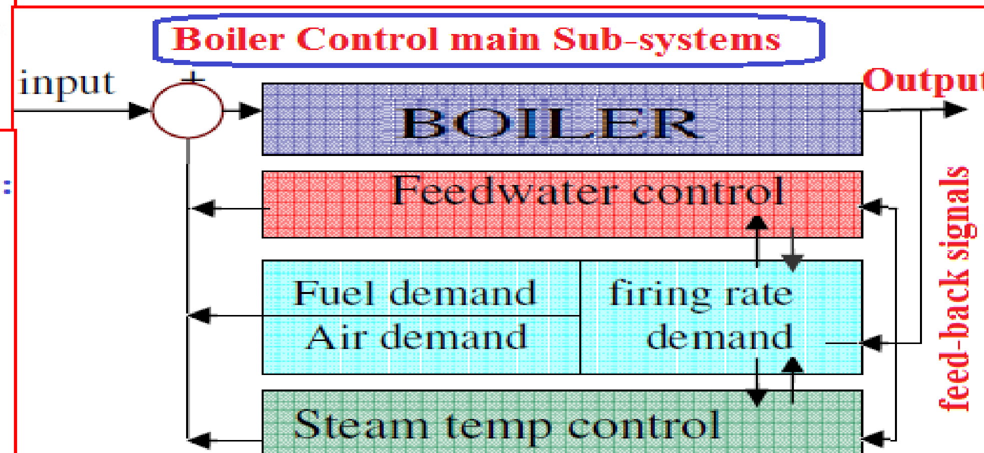
Mass and Energy Balance Involved

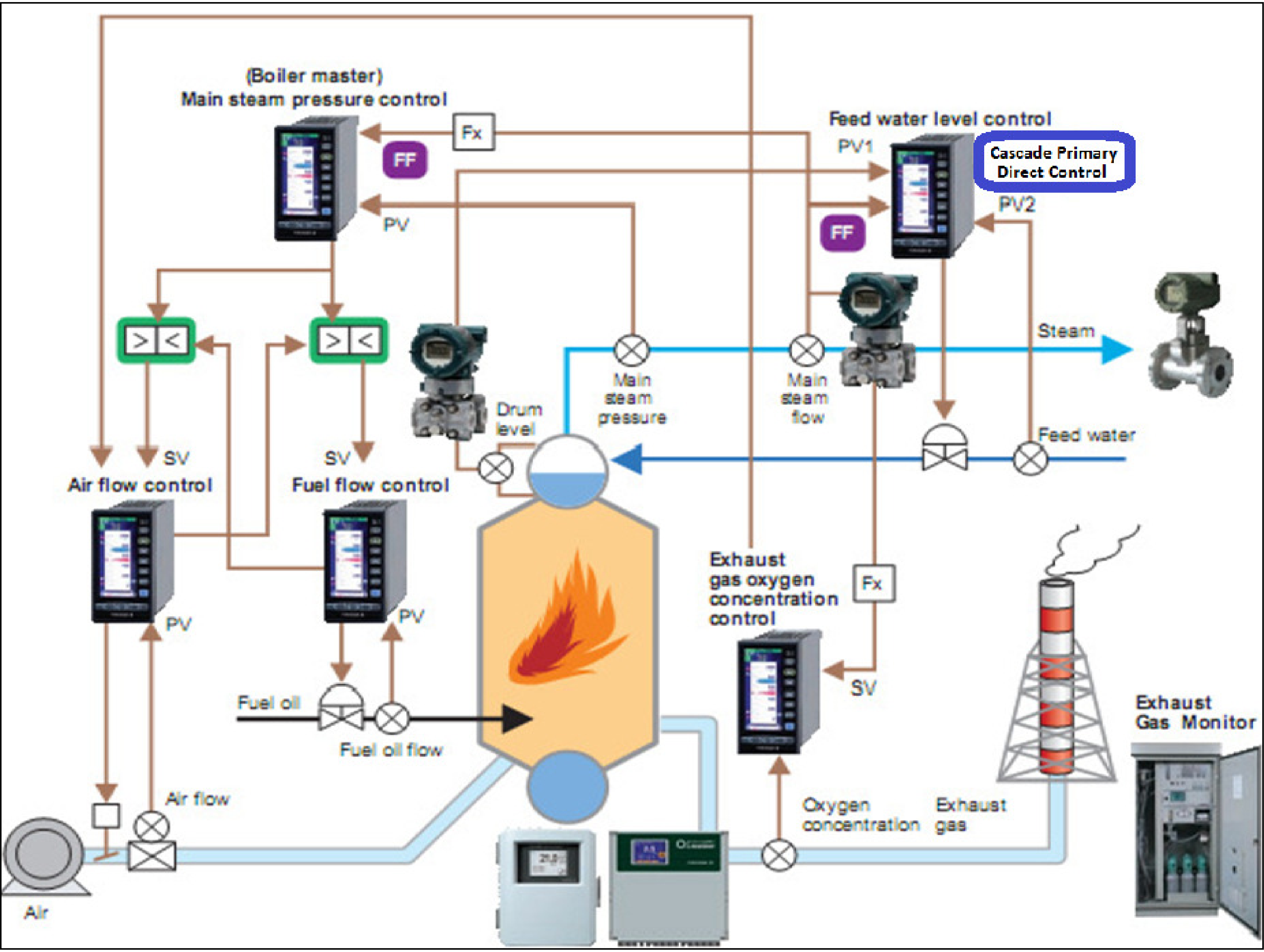


HIGHLIGHTS

Boiler control systems generally include subsystems:

- Plant Master
- Boiler master control
- Combustion control (air to fuel ratio control)
- Furnace pressure control
- Drum level (feedwater) control
- Steam temperature control




(Boiler master)
Main steam pressure control
Fx
FF
PV
Feed water level control
PV1
Cascade Primary
Direct Control
PV2
FF
Steam
Main
steam
pressure
Main
steam
flow
Drum
level
Feed water
SV
SV
Air flow control
Fuel flow control
PV
PV
Exhaust
gas oxygen
concentration
control
Fx
SV
Fuel oil
Fuel oil flow
Air flow
Air
Oxygen
concentration
Exhaust
gas
Exhaust
Gas Monitor

Steam Generators: What are Boilers? What is Water Tube Boiler? What are the Control & Alarm Systems used in Boilers?

Steam has come a long way from its traditional associations with locomotives and the Industrial Revolution. Steam today is integral and essential part of modern technology. Without it, food, textile, chemical, medical, power, heating and transport industries could not exist or perform as they do.

Steam provides mean of transporting controllable amount of energy from a central, automated boiler house, where it can be efficiently and economically generated, to the point of use. Therefore as steam moves it can be considered the transport and provision of energy.

For many reasons, steam is one of most widely used commodities for conveying heat energy. Its use is popular throughout industry for a broad range of tasks from mechanical power production to space heating and process applications.

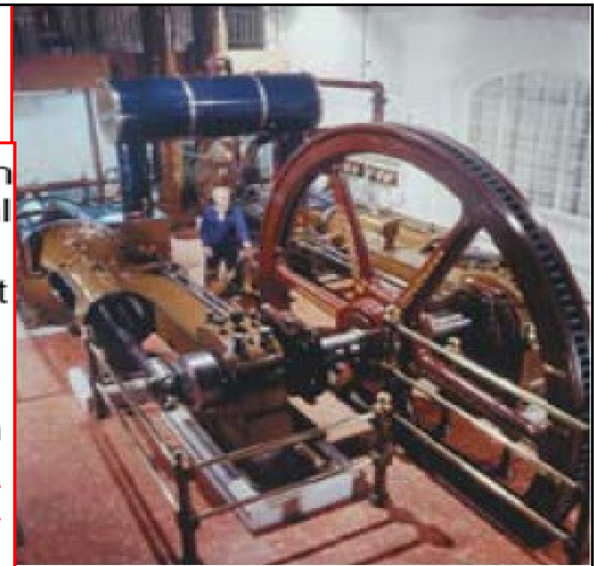


Fig. 1. 18th century steam engine

Steam is efficient and economic to generate

Water is plentiful and inexpensive. It is non-hazardous to health and environmentally sound. In its gaseous form, it is a safe and efficient energy carrier. Steam can hold five or six times as much potential energy as an equivalent mass of water.

When water is heated in a boiler, it begins to absorb energy. Depending on the pressure in the boiler, the water will evaporate at a certain temperature to form steam. The steam contains a large quantity of stored energy which will eventually be transferred to the process or the space to be heated.

It can be generated at high pressures to give high steam temperatures. The higher the pressure, the higher the temperature. More heat energy is contained within high temperature steam so its potential to do work is greater.

- Modern shell boilers are compact and efficient in their design, using multiple passes and efficient burner technology to transfer a very high proportion of the energy contained in the fuel to the water, with minimum emissions.
- The boiler fuel may be chosen from a variety of options, including combustible waste, which makes the steam boiler an environmentally sound option amongst the choices available for providing heat. Centralised boiler plant can take advantage of low interruptible gas tariffs, because any suitable standby fuel can be stored for use when the gas supply is interrupted.
- Highly effective heat recovery systems can virtually eliminate blowdown costs, return valuable condensate to the boiler house and add to the overall efficiency of the steam and condensate loop.

The increasing popularity of Combined Heat and Power (CHP) systems demonstrates high regard for steam systems in today's environment and energy-conscious industries.

Steam easily and cost effectively distributed to point of use

Steam is one of the most widely used media to convey heat over distances. Because steam flows in response to the pressure drop along the line, expensive circulating pumps are not needed. Due to the high heat content of steam, only relatively small bore pipework is required to distribute the steam at high pressure. The pressure is then reduced at the point of use, if necessary. This arrangement makes installation easier and less expensive than for some other heat transfer fluids.

Overall, the lower capital and running costs of steam generation, distribution and condensate return systems mean that many users choose to install new steam systems in preference to other energy media, such as gas fired, hot water, electric and thermal oil systems.

Fig..2 A modern packaged steam heat exchange system used for producing hot water

Steam is easy to control

Because of the direct relationship between the pressure and temperature of saturated steam, amount of energy input to the process is easy to control, simply by controlling saturated steam pressure. Modern steam controls are designed to respond very rapidly to process changes.

The item shown in Figure 1.1.4 is typical two-port control valve and pneumatic actuator assembly, designed for use on steam. Its accuracy is enhanced by the use of pneumatic valve positioner. The use of two-port valves, rather than the three-port valves often necessary in liquid systems, simplifies control and installation, and may reduce equipment costs.

Fig. 1.1.4 Typical two-port control valve with pneumatic actuator and positioner

Energy is easily transferred to the process

Steam provides excellent heat transfer. When steam reaches the plant, condensation process efficiently transfers the heat to the product being heated.

Steam can surround or be injected into the product being heated. It can fill any space at a uniform temperature and will supply heat by condensing at constant temperature; this eliminates temperature gradients which may be found along heat transfer surface - problem which is so often a feature of high temperature oils or hot water heating, and may result in quality problems, such as distortion of materials being dried.

Because the heat transfer properties of steam are so high, the required heat transfer area is relatively small. This enables the use of more compact plant, which is easier to install and takes up less space in the plant. A modern packaged unit for steam heated hot water, rated to 1200 kW and incorporating a steam plate heat exchanger and all the controls, requires only 0.7 m² floor space. In comparison, a packaged unit incorporating a shell and tube heat exchanger would typically cover an area of two to three times that size.

The modern steam plant is easy to manage

Increasingly, industrial energy users are looking to maximise energy efficiency and minimise production costs and overheads. The Kyoto Agreement for climate protection is a major external influence driving the energy efficiency trend, and has led to various measures around the globe, such as the Climate Change Levy in the UK. Also, in today's competitive markets, the organisation with the lowest costs can often achieve an important advantage over rivals. Production costs can mean difference between survival and failure in marketplace.

Ways of increasing energy efficiency include monitoring and charging energy consumption to relevant departments. This builds an awareness of costs and focuses management on meeting targets. Variable overhead costs can also be minimised by ensuring planned, systematic maintenance; this will maximise process efficiency, improve quality and cut downtime.

Most steam controls are able to interface with modern networked instrumentation and control systems to allow centralised control, such as in the case of a SCADA system or a Building/Energy Management System. If the user wishes, the components of the steam system can also operate independently (standalone).

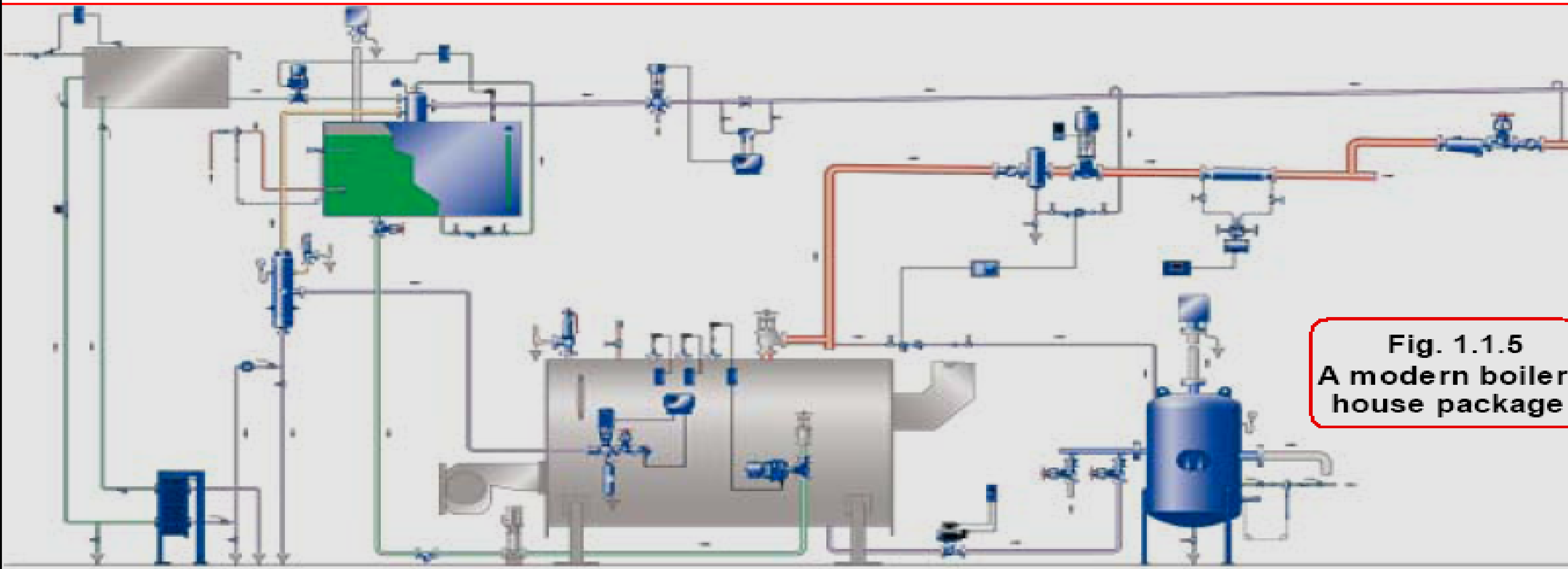


Fig. 1.1.5
A modern boiler house package

With proper maintenance a steam plant will last for many years, and the condition of many aspects of the system is easy to monitor on an automatic basis. When compared with other systems, the planned management and monitoring of steam traps is easy to achieve with a trap monitoring system, where any leaks or blockages are automatically pinpointed and immediately brought to the attention of the engineer.

This can be contrasted with the costly equipment required for gas leak monitoring, or the time-consuming manual monitoring associated with oil or water systems.

In addition to this, when steam system requires maintenance, the relevant part of system is easy to isolate and can drain rapidly, meaning that repairs may be carried out quickly. In numerous instances, it has been shown that it is far less expensive to bring long established steam plant up to date with sophisticated control and monitoring systems, than to replace it with alternative method of energy provision, such as a decentralised gas system.

Todays state-of-the-art technology is far from traditional perception of steam as of steam engines and Industrial Revolution. Indeed, steam is the preferred choice for industry today. Name any well known consumer brand, and in nine cases out of ten, steam will have played an important part in production.

Steam is flexible

Not only is steam an excellent carrier of heat, it is also sterile, and thus popular for process use in the food, pharmaceutical and health industries. It is also widely used in hospitals for sterilisation purposes.

The industries within which steam is used range from huge oil and petrochemical plants to small local laundries. Further uses include the production of paper, textiles, brewing, food production, curing rubber, and heating and humidification of buildings. Many users find it convenient to use steam as same working fluid for both space heating and for process applications. For example, in sugar industry, steam is used in variety of ways during different stages of process, from direct injection to coil heating.

Steam is also intrinsically safe - it cannot cause sparks and presents no fire risk. Many petrochemical plants utilise steam fire-extinguishing systems. It is therefore ideal for hazardous areas or explosive atmospheres.

Clean steam pipeline equipment in pharmaceutical process

Other methods of distributing energy

The alternatives to steam include water and thermal fluids such as high temperature oil. Each method has its advantages and disadvantages, and will be best suited to certain applications or temperature bands.

Compared to steam, water has a lower potential to carry heat, consequently large amounts of water must be pumped around the system to satisfy process or space heating requirements. However, water is popular for general space heating applications and for low temperature processes (up to 120°C) where some temperature variation can be tolerated.

Thermal fluids, such as mineral oils, may be used where high temperatures (up to 400°C) are required, but where steam cannot be used. An example would include the heating of certain chemicals in batch processes. However thermal fluids are expensive, and need replacing every few years - they are not suited to large systems. They are also very 'searching' and high quality connections and joints are essential to avoid leakage.

Different media are compared in Table 1.1.1, which follows. The final choice of heating medium depends on achieving a balance between technical, practical and financial factors, which will be different for each user.

Broadly speaking, for commercial heating and ventilation, and industrial systems, steam remains the most practical and economic choice.

Steam	Hot water	High temperature oils
Steam traps required	No steam traps required	No steam traps required
Condensate to be handled	No condensate handling	No condensate handling
Flash steam available	No flash steam	No flash steam
Boiler blowdown necessary	No blowdown necessary	No blowdown necessary
Water treatment required to prevent corrosion	Less corrosion	Negligible corrosion
Reasonable pipework required	Searching medium, welded or flanged joints usual	Very searching medium, welded or flanged joints usual
No fire risk	No fire risk	Fire risk
System very flexible	System less flexible	System inflexible

Steam	Hot water	High temperature oils
High heat content Latent heat approximately 2 100 kJ/kg	Moderate heat content Specific heat 4.19 kJ/kg°C	Poor heat content Specific heat often 1.69-2.93 kJ/kg°C
Inexpensive Some water treatment costs	Inexpensive Only occasional dosing	Expensive
Good heat transfer coefficients	Moderate coefficients	Relatively poor coefficients
High pressure required for high temperatures	High pressure needed for high temperatures	Low pressures only to get high temperatures
No circulating pumps required Small pipes	Circulating pumps required Large pipes	Circulating pumps required Even larger pipes
Easy to control with two way valves	More complex to control - three way valves or differential pressure valves may be required	More complex to control - three way valves or differential pressure valves may be required.
Temperature breakdown is easy through a reducing valve	Temperature breakdown more difficult	Temperature breakdown more difficult

Table 1.1.1 Comparison of heating media with steam

The benefits of steam - a summary:

Table 1.1.2 Steam benefits

Inherent benefits	System benefits	
Water is readily available Water is inexpensive Steam is clean and pure Steam is inherently safe Steam has a high heat content Steam is easy to control due to the pressure/temperature relationship Steam gives up its heat at a constant temperature	Small bore pipework, compact size and less weight No pumps, no balancing Two-port valves - cheaper Maintenance costs lower than for dispersed plant Capital cost is lower than for dispersed plant SCADA compatible products	Automation; fully automated boiler houses fulfil requirements such as PM5 and PM60 in the UK Low noise Reduced plant size (as opposed to water) Longevity of equipment Boilers enjoy flexible fuel choice and tariff Systems are flexible and easy to add to
Environmental factors	**Uses**	
Fuel efficiency of boilers Condensate management and heat recovery Steam can be metered and managed Links with CHP/waste heat Steam makes environmental and	Steam has many uses - chillers, pumps, fans, humidification Sterilisation Space heating	

How do we get Steam? The boiler house (has many types of Control Systems&Alarms)

The boiler is the heart of the steam system. The typical modern packaged boiler is powered by a burner which sends heat into the boiler tubes.

The hot gases from the burner pass backwards and forwards up to 3 times through a series of tubes to gain the maximum transfer of heat through the tube surfaces to the surrounding boiler water. Once the water reaches saturation temperature (the temperature at which it will boil at that pressure) bubbles of steam are produced, which rise to the water surface and burst. The steam is released into the space above, ready to enter the steam system. The stop or crown valve isolates the boiler and its steam pressure from the process or plant.

If steam is pressurised, it will occupy less space. Steam boilers are usually operated under pressure, so that more steam can be produced by a smaller boiler and transferred to the point of use using small bore pipework. When required, the steam pressure is reduced at the point of use.

As long as the amount of steam being produced in the boiler is as great as that leaving the boiler, the boiler will remain pressurised. The burner will operate to maintain the correct pressure. This also maintains the correct steam temperature, because the pressure and temperature of saturated steam are directly related.

The boiler has a number of fittings and controls to ensure that it operates safely, economically, efficiently and at a consistent pressure.

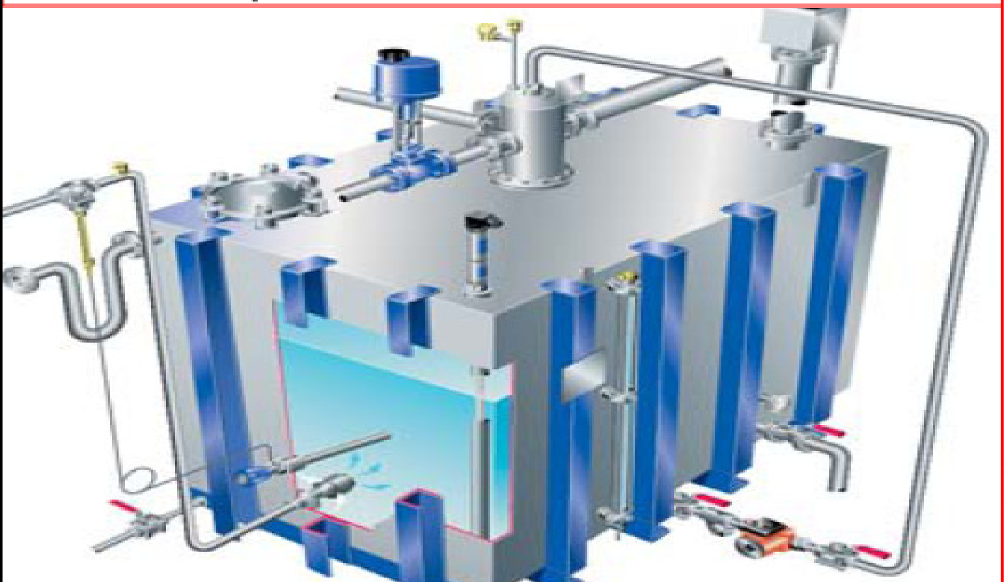
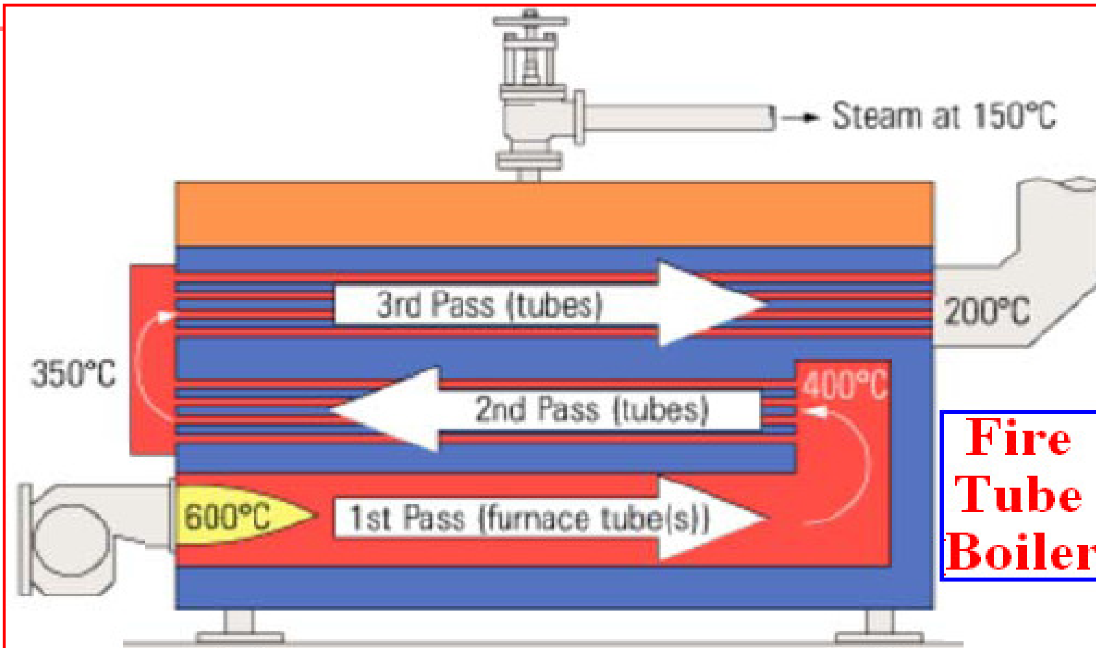


Fig. 1.3.2 A sophisticated feedtank system where the water is being heated by steam injection



Fire Tube Boiler

Fig. 1.3.1 Typical heat path through a smoke tube shell boiler

Feedwater (must have Control & Alarm System)

The quality of water which is supplied into the boiler is important. It must be at the correct temperature, usually around 80°C, to avoid thermal shock to the boiler, and to keep it operating efficiently. It must also be of the correct quality to avoid damage to the boiler.

Ordinary untreated potable water is not entirely suitable for boilers and can quickly cause them to foam and scale up. The boiler would become less efficient and the steam would become dirty and wet. The life of the boiler would also be reduced. The water must therefore be treated with chemicals to reduce impurities it contains.

Both feedwater treatment and heating take place in the feedtank, which is usually situated high above the boiler. The feedpump will add water to the boiler when required. Heating the water in the feedtank also reduces the amount of dissolved oxygen in it. This is important, as oxygenated water is corrosive.

Blowdown (must have a Control System)

Chemical dosing of the boiler feedwater will lead to the presence of suspended solids in the boiler. These will inevitably collect in the bottom of the boiler in the form of sludge, and are removed by a process known as bottom blowdown. This can be done manually - the boiler attendant will use a key to open a blowdown valve for a set period of time, usually twice a day.

Other impurities remain in the boiler water after treatment in the form of dissolved solids. Their concentration will increase as the boiler produces steam and consequently the boiler needs to be regularly purged of some of its contents to reduce the concentration. This is called control of total dissolved solids (TDS control). This process can be carried out by an automatic system which uses either a probe inside the boiler, or a small sensor chamber containing a sample of boiler water, to measure the TDS level in the boiler. Once the TDS level reaches a set point, a controller signals the blowdown valve to open for a set period of time. The lost water is replaced by feedwater with lower TDS concentration, consequently the overall boiler TDS is reduced.

Level control (very important Control & Alarm system)

If the water level inside the boiler were not carefully controlled, the consequences could be catastrophic. If the water level drops too low and the boiler tubes are exposed, the boiler tubes could overheat and fail, causing an explosion. If the water level becomes too high, water could enter the steam system and upset the process.

For this reason, automatic level controls are used. To comply with legislation, level control systems also incorporate alarm functions which will operate to shut down the boiler and alert attention if there is a problem with the water level. A common method of level control is to use probes which sense the level of water in the boiler. At a certain level, a controller will send a signal to the feedpump which will operate to restore the water level, switching off when a predetermined level is reached. The probe will incorporate levels at which the pump is switched on and off, and at which low or high level alarms are activated. Alternative systems use floats.

The flow of steam to the plant

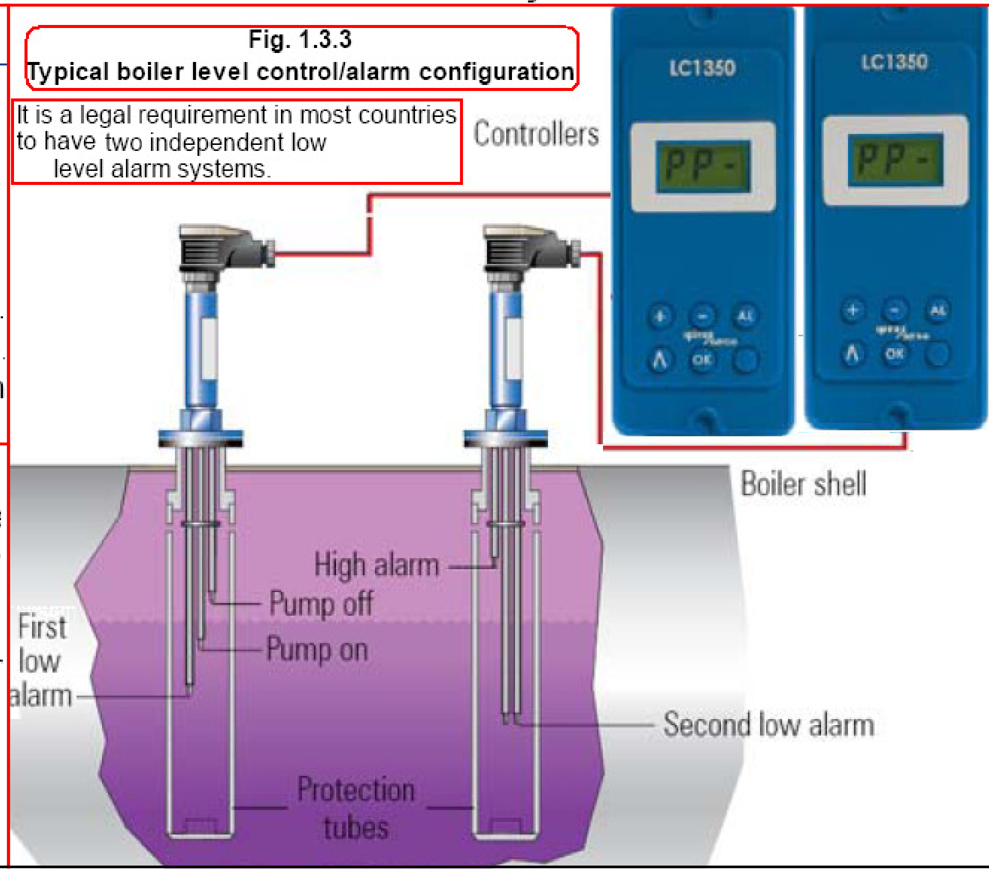
When steam condenses, its volume is dramatically reduced, which results in a localised reduction in pressure.This pressure drop through the system creates flow of steam through pipes.The steam generated in the boiler must be conveyed through pipework to the point where its heat energy is required. Initially there will be one or more main pipes or steam mains which carry steam from the boiler in general direction of the steam using plant. Smaller branch pipes can then distribute the steam to individual pieces of equipment. Steam at high pressure occupies lower volume than at atmospheric pressure. The higher the pressure, the smaller bore of pipework required for distribution of a given mass of steam.

Steam quality

It is important to ensure that the steam leaving the boiler is delivered to the process in the right condition. To achieve this the pipework which carries the steam around the plant incorporates strainers, separators and steam traps. A strainer is a form of sieve in the pipeline. It contains a mesh through which steam must pass. Any passing debris will be retained by the mesh. A strainer should regularly be cleaned to avoid blockage. Debris should be removed from the steam flow because it can be very damaging to plant, and may also contaminate the final product. The steam should be as dry as possible to ensure it is carrying heat effectively. A separator is body in the pipeline which contains series of plates or baffles which interrupt the path of steam.

Fig. 1.3.3
Typical boiler level control/alarm configuration

It is a legal requirement in most countries to have two independent low level alarm systems.



A separator is a body in pipeline which contains series of plates or baffles which interrupt the path of the steam. The steam hits the plates, and any drops of moisture in the steam collect on them, before draining from the bottom of the separator. Steam passes from the boiler into the steam mains. Initially the pipework is cold and heat is transferred to it from the steam. The air surrounding the pipes is also cooler than the steam, so pipework will begin to lose heat to the air. Insulation fitted around the pipe will reduce this heat loss considerably. When steam from the distribution system enters steam using equipment steam will again give up energy by: a) warming up equipment and b) continuing to transfer heat to process. As steam loses heat, it turns back into water. Inevitably the steam begins to do this as soon as it leaves the boiler. The water which forms is known as condensate, which tends to run to the bottom of pipe and is carried along with the steam flow. This must be removed from the lowest points in the distribution pipework for several reasons:

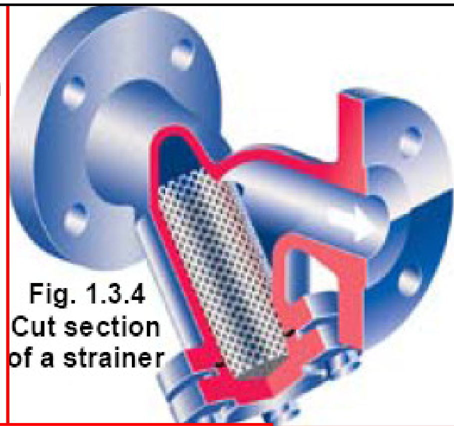


Fig. 1.3.4 Cut section of a strainer

- Condensate does not transmit heat effectively. A film of condensate inside plant will reduce the efficiency with which heat is transferred.
- When air dissolves into condensate, it becomes corrosive.
- Accumulated condensate can cause noisy and damaging waterhammer.
- Inadequate drainage leads to leaking joints.

A device known as steam trap is used to release condensate from pipework whilst preventing steam from escaping from the system. It can do this in several ways:

- A float trap uses difference in density between steam and condensate to operate a valve. As condensate enters trap, a float is raised and float lever mechanism opens main valve to allow condensate to drain. When condensate flow reduces float falls and closes main valve, thus preventing the escape of steam.
- Thermodynamic traps contain a disc which opens to condensate and closes to steam.
- In bimetallic thermostatic traps, bimetallic element uses difference in temperature between steam and condensate to operate the main valve.
- In balanced pressure thermostatic traps, a small liquid filled capsule which is sensitive to heat operates the valve.

Once the steam has been employed in the process, the resulting condensate needs to be drained from the plant and returned to the boiler house.

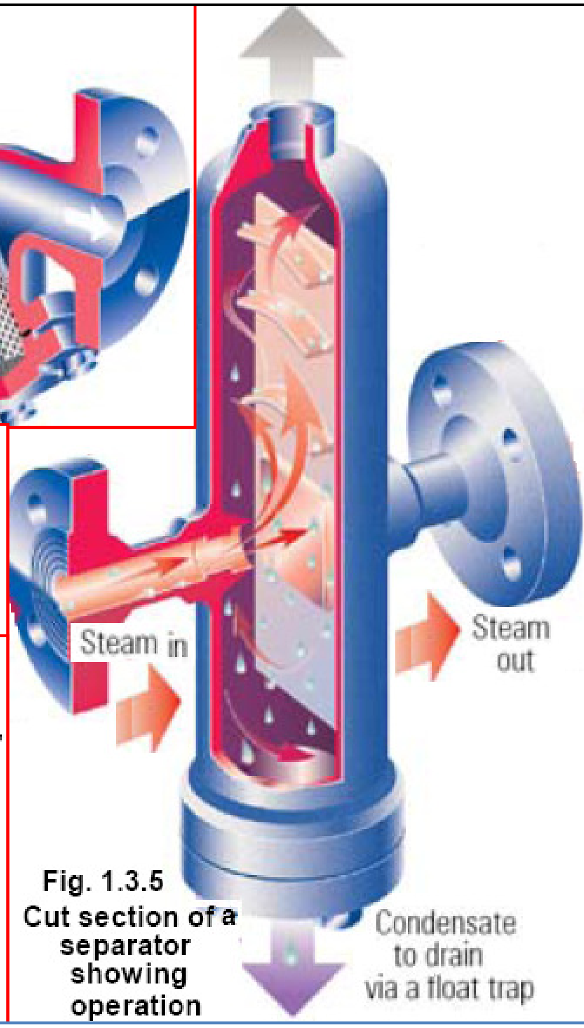


Fig. 1.3.5 Cut section of a separator showing operation

Pressure reduction (Steam Pressure&Temperature must have Control & Alarm system)

As mentioned before, steam is usually generated at high pressure, and the pressure may have to be reduced at the point of use, either because of the pressure limitations of the plant, or the temperature limitations of the process. This is achieved using a pressure reducing valve.

Steam at the point of use

large variety of steam using plant exists. A few examples are described below:

- **Jacketed pan** - Large steel or copper pans used in food and other industries to boil substances anything from prawns to jam. These large pans are surrounded by a jacket filled with steam, which acts to heat up the contents.
- **Autoclave** - A steam-filled chamber used for sterilisation purposes, for example medical equipment, or to carry out chemical reactions at high temperatures and pressures, for example the curing of rubber.
- **Heater battery** -For space heating, steam is supplied to coils in heater battery. The air to be heated passes over coils.
- **Process tank heating** - A steam filled coil in a tank of liquid used to heat the contents to the desired temperature.
- **Vulcaniser** - A large receptacle filled with steam and used to cure rubber.
- **Corrugator** - A series of steam heated rollers used in the corrugation process in the production of cardboard.
- **Heat exchanger** - For heating liquids for domestic/industrial use.

Control of the process

Any steam using plant will require some method to control the flow of steam. A constant flow of steam at the same pressure and temperature is often not what is required - a gradually increasing flow will be needed at start-up to gently warm plant, and once the process reaches the desired temperature, flow must be reduced. Control valves are used to control the flow of steam. The actuator, see Figure 1.3.6, is the device that applies the force to open or close the valve. A sensor monitors conditions in the process, and transmits information to the controller. The controller compares the process condition with the set value and sends a corrective signal to the actuator, which adjusts the valve setting.

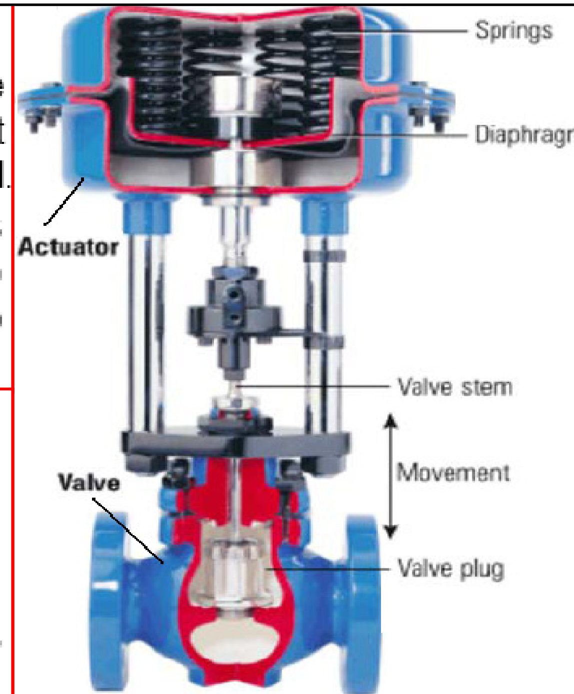


Fig. 1.3.6 A pneumatically operated two-port control valve

A variety of control types exist:

- **Pneumatically actuated valves** - Compressed air is applied to a diaphragm in the actuator to open or close the valve.
- **Electrically actuated valves** - An electric motor actuates the valve.
- **Self-acting -** There is no controller as such - the sensor has a liquid fill which expands and contracts in response to a change in process temperature. This action applies force to open or close the valve.

Condensate removal from plant

Often, the condensate which forms will drain easily out of the plant through steam trap. The condensate enters the condensate drainage system. If it is contaminated, it will probably be sent to drain. If not, the valuable heat energy it contains can be retained by returning it to boiler feedtank. This saves on water and water treatment costs. Sometimes vacuum may form in steam using plant. This hinders condensate drainage, but proper drainage from steam space maintains effectiveness of plant. The condensate may then have to be pumped out. Mechanical (steam powered) pumps are used for this purpose. These, or electric powered pumps, are used to lift condensate back to the boiler feedtank. A mechanical pump, see Figure 1.3.7, is shown draining an item of plant. As can be seen, the steam and condensate system represents a continuous loop. Once condensate reaches feedtank, it becomes available to boiler for recycling.

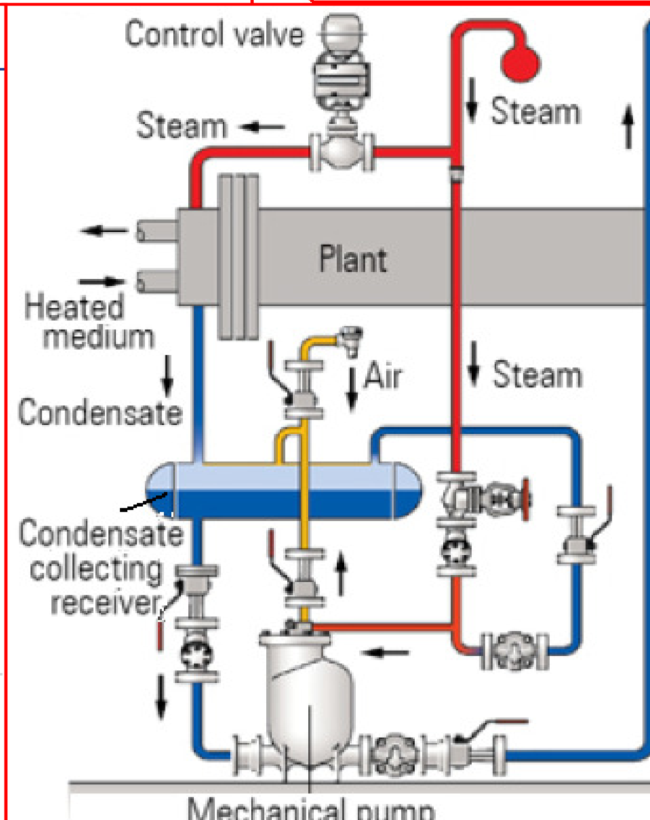


Fig. 1.3.7 Condensate recovery and return

Energy monitoring (Steam flow+Combustion & A/F ratio Control)

In today's energy conscious environment, it is common for customers to monitor the energy consumption of their plant. Steam flowmeters are used to monitor the consumption of steam, and used to allocate costs to individual departments or items of plant.

Fuels used in Boilers (must control combustion + A/F ratio + exhaust gases)

The three most common types of fuel used in steam boilers, are coal, oil, and gas. However, industrial or commercial waste is also used in certain boilers, along with electricity for electrode boilers.

We shall discuss only oil and gas fuels as they are the two most common types used in Egypt.

Using Liquid Oils in Boilers:

Oil for boiler fuel is created from the residue produced from crude petroleum after it has been distilled to produce lighter oils like gasoline, paraffin, kerosene, diesel or gas oil. Various grades are available, each being suitable for different boiler ratings; the grades are as follows:

- **Class D** - Diesel or gas oil.
- **Class E** - Light fuel oil.
- **Class F** - Medium fuel oil.
- **Class G** - Heavy fuel oil.

Oil began to challenge coal as the preferred boiler fuel in the UK during the 1950s. This came about in part from the then Ministry of Fuel and Power's sponsorship of research into improving boiler plant.

The advantages of oil over coal include:

- A shorter response time between demand and the required amount of steam being generated.
- This meant that less energy had to be stored in the boiler water. The boiler could therefore be smaller, radiating less heat to the environment, with a consequent improvement in efficiency.
- The smaller size also meant that the boiler occupied less production space.
- Mechanical stokers were eliminated, reducing maintenance workload.
- Oil contains only traces of ash, virtually eliminating the problem of ash handling and disposal.
- The difficulties encountered with receiving, storing and handling coal were eliminated.

Approximately 15 kg of steam can be produced from 1 kg of oil, or 14 kg of steam from 1 litre of oil.

Using Gas fuels in Boilers:

Gas is a form of boiler fuel that is easy to burn, with very little excess air. Fuel gases are available in two different forms:

- **Natural gas** - This is gas that has been produced (naturally) underground. It is used in its natural state, (except for the removal of impurities), and contains a high proportion of methane.
- **Liquefied petroleum gases (LPG)** - These are gases produced from petroleum refining and are then stored under pressure in a liquid state until used. The most common forms of LPG are propane and butane.

In the late 1960s the availability of natural gas (such as from the North Sea) led to further developments in boilers.

The advantages of gas firing over oil firing include:

- Storage of fuel is not an issue; gas is piped right into the boiler house.
- Only trace of sulphur is present in natural gas, meaning that sulphuric acid in the flue gas is virtually zero.

Approximately 42 kg of steam can be produced from 1 Therm of gas (equivalent to 105.5 MJ) for a 10 bar g boiler, with an overall operating efficiency of 80%.

Using waste materials or waste heat to generate Steam:

There are two aspects to this:

- **Waste material** - Here, waste is burned to produce heat, which is used to generate steam. The motives may include the safe and proper disposal of hazardous material. A hospital would be a good example:
  - In these circumstances, it may be that proper and complete combustion of the waste material is difficult, requiring sophisticated burners, control of air ratios and monitoring of emissions, especially particulate matter. The cost of this disposal may be high, and only some of the cost is recovered by using the heat generated to produce steam. However, the overall economics of the scheme, taking into consideration the cost of disposing of the waste by other means, may be attractive.
  - Using waste as a fuel may involve the economic utilisation of the combustible waste from a process. Examples include the bark stripped from wood in paper plants, stalks (bagasse) in sugar cane plants and sometimes even litter from a chicken farm.

The combustion process will again be fairly sophisticated, but the overall economics of the cost of waste disposal and generation of steam for other applications on site, can make such schemes attractive.

- **Waste heat** - Here, hot gases from a process, such as a smelting furnace, may be directed through a boiler with the objective of improving plant efficiency. Systems of this type vary in their level of sophistication depending upon the demand for steam within the plant. If there is no process demand for steam, the steam may be superheated and then used for electrical generation.

  This type of technology is becoming popular in Combined Heat and Power (CHP) plants:
  - A gas turbine drives an alternator to produce electricity.
  - The hot (typically 500°C) turbine exhaust gases are directed to a boiler, which produces saturated steam for use on the plant.

Very high efficiencies are available with this type of plant. Other benefits may include either security of electrical supply on site, or the ability to sell the electricity at a premium to the national electricity supplier.

Which fuel to use?

The choice of fuel(s) is obviously very important, as it will have a significant impact on the costs and flexibility of the boiler plant. Factors that need consideration include:

- **Cost of fuel** - For comparison purposes cost of fuel is most conveniently expressed in £/kg of steam generated.
- **Cost of firing equipment** - The cost of the burner(s) and associated equipment to suit the fuel(s) selected, and the emission standards which must be observed.

Security of supply

What are the consequences of having no steam available for the plant? Gas, for example, may be available at advantageous rates, provided an interruptible supply can be accepted. This means that the gas company will supply fuel while they have a surplus. However, should demand for fuel approach the limits of supply, perhaps due to seasonal variation, then supply may be cut, maybe at very short notice.

As an alternative, boiler users may elect to specify dual fuel burners which may be fired on gas when it is available at the lower tariff, but have the facility to switch to oil firing when gas is not available. The dual fuel facility is obviously a more expensive capital option, and likelihood of gas not being available may be small. However, cost of plant downtime due to non-availability of steam is usually significantly greater than additional cost.

Fuel storage

This is not an issue when using a mains gas supply, except where a dual fuel system is used. However it becomes progressively more of issue if bottled gas, light oils, heavy oils and solid fuels are used. The issues include:

- How much is to be stored, and where.
- How to safely store highly combustible materials.
- How much it costs to maintain temperature of heavy oils so that they are at suitable viscosity for the equipment.
- How to measure the fuel usage rate accurately.
- Allowance for storage losses.

Boiler design

The boiler manufacturer must be aware of the fuel to be used when designing a boiler. This is because different fuels produce different flame temperatures and combustion characteristics. For example:

- Oil produces a luminous flame, and a large proportion of the heat is transferred by radiation within the furnace.
- Gas produces a transparent blue flame, and a lower proportion of heat is transferred by radiation within the furnace.

On a boiler designed only for use with oil, a change of fuel to gas may result in higher temperature gases entering the first pass of fire-tubes, causing additional thermal stresses, and leading to early boiler failure.

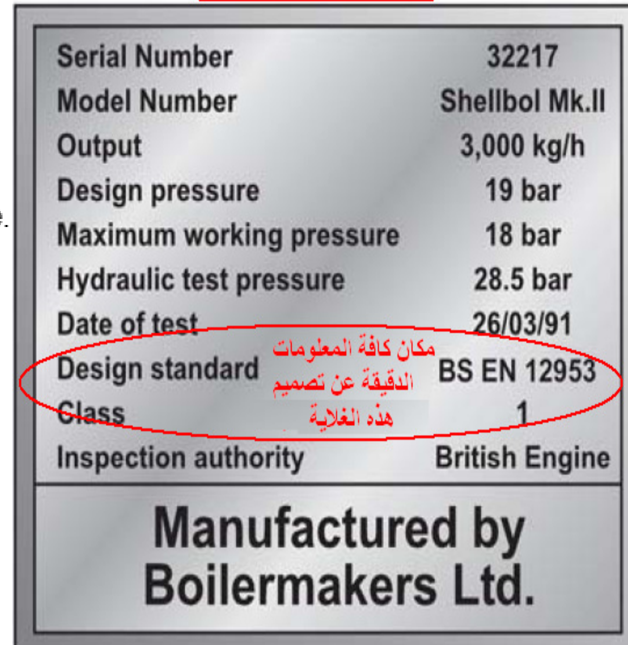
Boiler types

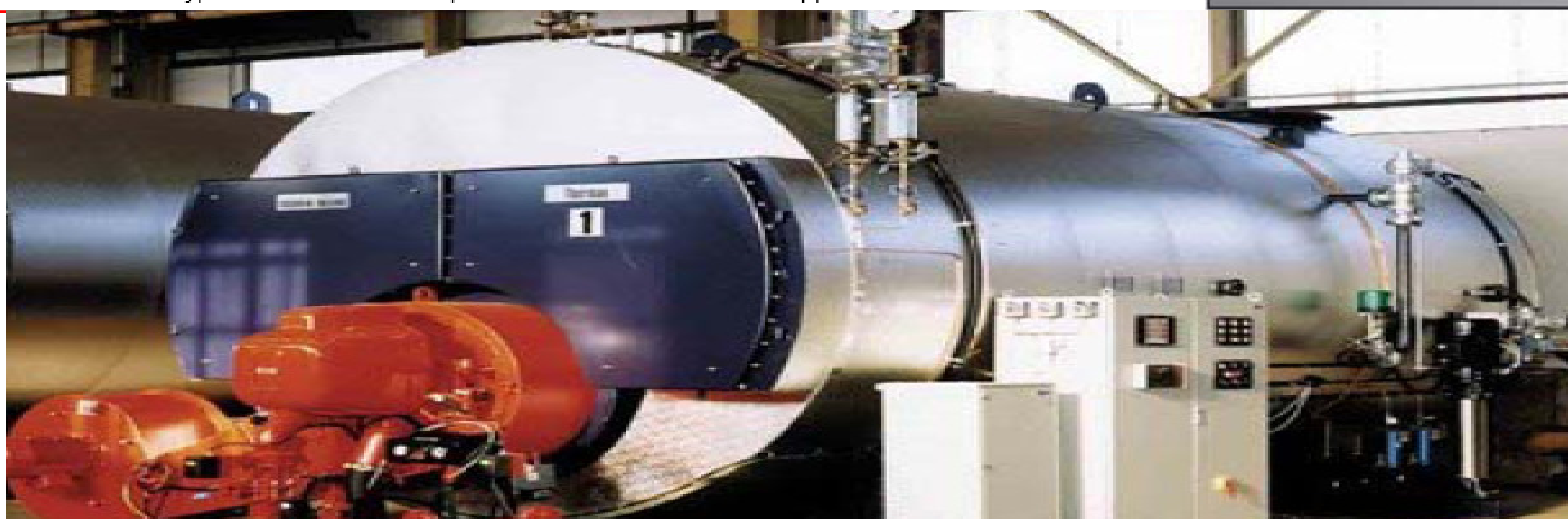
The objectives of a boiler are:

- To release the energy in the fuel as efficiently as possible.
- To transfer the released energy to the water, and to generate steam as efficiently as possible.
- To separate the steam from the water ready for export to the plant, where the energy can be transferred to the process as efficiently as possible.

A number of different boiler types have been developed to suit the various steam applications.

Boiler name-plate





Typical packaged steam boiler