



THE CLAYTON GUIDE TO STEAM GENERATION



History

Clayton Steam Systems is a world leader in the design and manufacture of compact, high efficiency, rapid start steam systems that are safe to use and are of advanced designs.



The **Clayton Company** was founded in 1930 and reorganised under the name of the Clayton Manufacturing Company in 1935 to investigate and develop new concepts in thermodynamic and mechanical products. The Clayton Steam Generator was the first such product and was conceived as a packaged, force circulation coil steam generator that could automatically produce steam in five minutes from a completely cold condition.

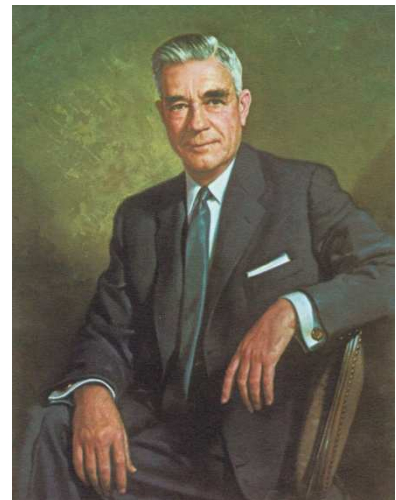
The **Clayton Steam Generator** is of a unique design where high efficiency and rapid start-up are combined with high steam quality and fast response to changes in steam demand. In addition, the low blowdown requirement saves energy, water and treatment chemicals. The operating principle of the Clayton Steam Generator has eliminated the need to contain and heat large quantities of water. Consequently all generator models are small in size and weight and can be accommodated within a limited space.

One of the major safety advantages of the small water content is that there is no possibility of a steam explosion from a Clayton Steam Generator.

The energy saving features of the Clayton Steam Generator was of considerable interest to William Clayton who was concerned with fuel conservation long before the modern day awareness and effects of energy use.

The **Clayton Exhaust Gas Boiler** operates on the same tried and tested principles and has been produced to satisfy a variety of industrial and marine applications to recover heat from waste gas.

Designs are continually being improved and developed as well as being upgraded to incorporate the latest engineering technology and techniques. The range of sizes has been added to over the years and it is now no longer necessary to use the traditional fire tube boiler for outputs in excess to 60 tonnes of steam per hour.



The many advantages of the designs make Clayton Steam Systems ideally suitable for any steam application.

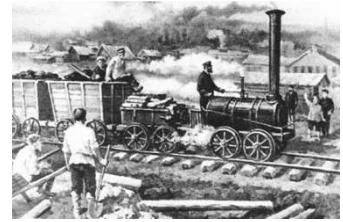


The Old Steam Age

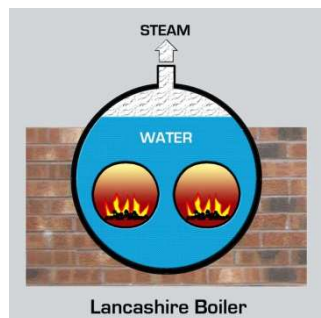
Steam was the driving force during the days of the industrial revolution and was used to power the giant textile mills, steam trains and ocean going ships of the time.



In those days steam boilers were just like the common domestic kettle where a volume of water is heated in a container and steam is ejected through the spout.



One such steam boiler design was the famous Lancashire Boiler that was the most advanced of it's time. In this boiler coal was used as fuel to heat two 'firtubes' which in turn heated the water that surrounded them. As the temperature of the water rose, steam bubbled off the water surface and into the steam pipe.



However one of the many drawbacks of the old firetube design was the explosion hazard that caused death and serious injury with alarming frequency. These tragedies were regarded as acts of god in those days but we now know that they were a consequence of this particular method of steam production. The hot water is stored inside a firetube boiler at the same pressure as the steam and a failure of the outer casing will cause the water to expand to around 1600 times its volume in less than a second - causing a devastating explosion. This is most likely to happen when the water level in the boiler drops to a dangerously low level.

It's not difficult to imagine the second disadvantage which is the time it takes to heat up in the first place. This is measured in hours rather than minutes because the large mass of steel and water must first be heated before the steam pressure can build up. This means that boilers had to be started well in advance of when they were needed - or had to be kept ticking over so that they were available when steam was required. The inherent lag in response also meant that the boiler had to be large enough in size to cater for varying outputs.

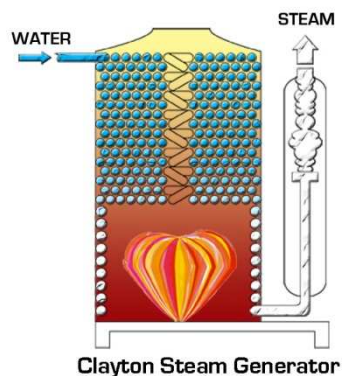
These old boilers are early versions of the firetube boilers that are the horizontal cylindrical shape we still recognise today. Improvements in the firetube design have, of course, been made where possible.

But why didn't someone come up with a different method of producing steam that does not have all of these disadvantages? - Well Someone Did!



The New Steam Age

Instead of heating a large amount of water and steel - heat a small amount of water and steel.



This is possible by pumping water through the inside of a small diameter heated coiled tube so that cold water goes in one end and high pressure steam comes out the other. The Clayton Steam Generator is a unique design that does just that. Instead of the familiar steam train image of a boiler we now have a compact steam making machine with staggering advantages for the world we live in today.

The Clayton Steam Generator uses only three main components. These components are a special pump, a special water tube coil and a special steam separator. Water is heated as it is pumped through the coil and it is then fed to the steam separator to produce very high quality dry steam.

So all of the momentum from the heavy steel and large volume of water has been eliminated which means that the boiler is small in size and will start-up in five minutes from the flick of a switch. The response is more like a racing car than an oil tanker when it's running because the steam flow is synchronised with the speed of the pump and the heat source - so it can ramp up and down in seconds with unrivalled fuel efficiency. And when it is not needed at the end of the working day it can be switched off with the lights to conserve energy.



The basic operating principle produces one advantage that leads to another and another. These are not limited to the quick start-up, rapid response, small size, low weight, low running cost automatic operation, and reliability.

Many people consider that the main advantage of the Clayton Steam Generator compared to a firetube boiler is that safety has taken a great leap forward. This is because there is no possibility of a steam explosion. It is not even necessary to check the water level – because there isn't one. So the peril that was a constant danger once-upon-a-time has now been completely eliminated. In fact the Clayton Steam Generator can run without operator attendance even at very high steam pressures and temperatures.



Most of the world forward looking companies and institutions that use steam in their production or process already operate Clayton Steam Generators.

The traditional horizontal cylindrical boilers image that made history has now made way for high powered vertical Clayton Steam Generator of today.



Principle of Operation

The Reason for the many advantages of the Clayton Steam Generator is the Forced Circulation Monotube Coil Concept. This operates on a simple but ingenious principle.

The boiler feedwater is pumped by means of a specially designed Clayton Pump and is forced through a single heating coil from the top to the bottom. The steam/water mixture from the outlet of the coil is then passed to a high efficiency centrifugal separator. Steam quality from a Clayton Steam Generator is up nearly completely dry saturated and the separated water is re-cycled.

The Clayton Coil is of a unique design that has been developed for optimum heat transfer at all steam output levels.

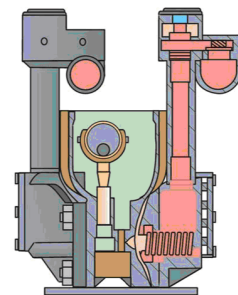
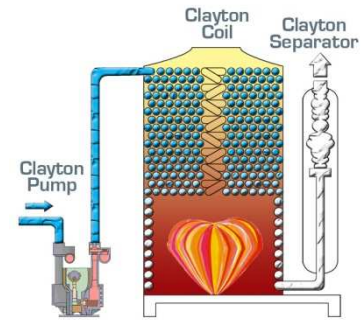
The coil is a single water tube which is stacked in spirally wound layers in the upper section and forms a 'water wall' around the combustion chamber of the lower section. The configuration of the coil as well as the variation in the tube diameter, spacing between layers and spacing between tube turns in different temperature zones of the coil are all carefully designed to maximise efficiency and prevent hot spots.

The spiral construction of the coil is extremely robust and counteracts the effects of expansion during rapid heating and cooling. In the case of oil fired units, sootblowing facilities are provided to remove deposits from the outside of the coil while the unit is in operation to keep it running at maximum efficiency.

The Clayton Pump is of a remarkable design and is manufactured specifically to provide the forced circulation through the coil of a Clayton Steam Generator.

The pump is a positive displacement type that ensures flow stability over a wide range of varying pressure conditions. The Clayton Pump does not rely on mechanical seals, packing rings or glands to separate the water being pumped and the drive mechanism. Operation is completely unaffected by high water temperature and the construction of the Clayton Pump is extremely robust, very reliable and low in maintenance.

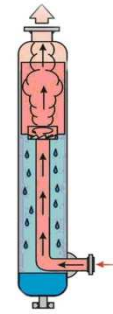
On every Clayton Steam Generator the pumping rate is synchronised to the burner firing rate so that the steam output can be ramped up and down as required.



Principle of Operation

The Clayton Steam Separator is a high efficiency centrifugal design that has no moving parts. The very high steam quality is produced even under variable load conditions and is at least 99.5% dry saturated.

The steam/water mixture from the Clayton Steam Generator is directed to the inlet of the separator where it is directed over a series of vanes and separated by means of centrifugal force. The water is collected and dry steam is discharged through the top outlet. The blowdown from a Clayton Steam Generator is extremely low since this is taken from the water collected by the separator.

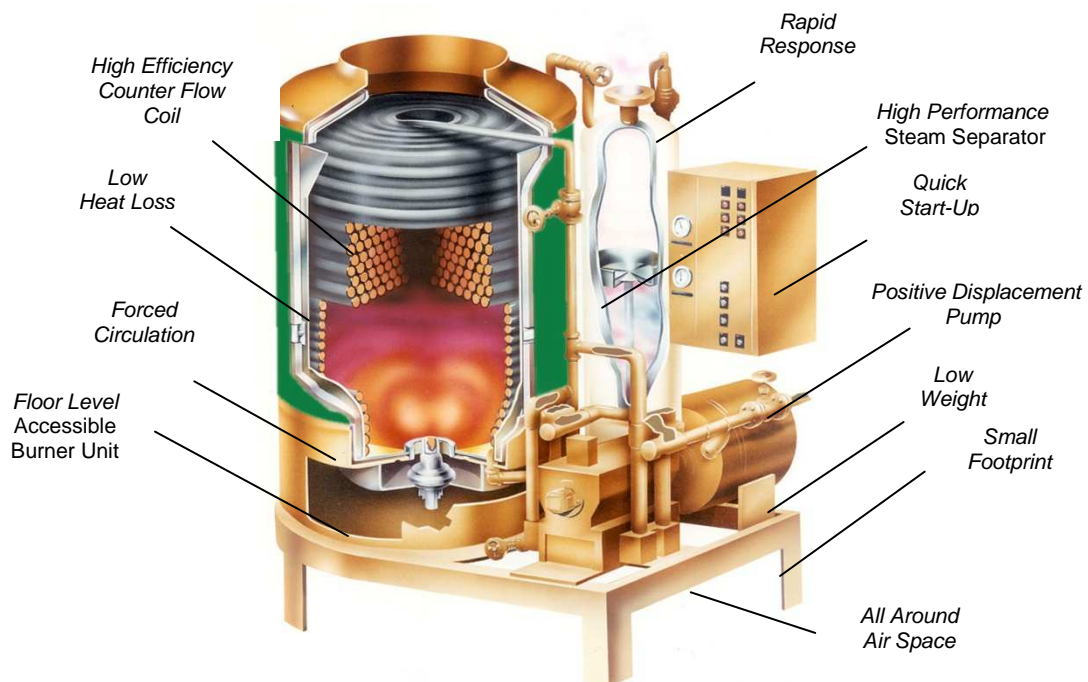


The Clayton Burner is specially designed to ensure that the flame is confined to the combustion chamber and that combustion is complete before the hot gasses are released over the coil.

To achieve this, the air for combustion enters the burner manifold at high velocity where it picks up fuel in a whirlpool action to form a heart shaped flame where the flame tip folds over into the low pressure zone. Fuel and air are blended in precise ratios and the burner fires upwards, which is the natural direction for heat.



The Clayton Advantage



Benefits

High Efficiency

Very high efficiency is the most obvious benefit that comes from small sizes because of the low heat losses. Heat flow is upwards - in the opposite direction to the water flow - and this optimises heat transfer and results in low running costs.

Small Size

The compact size means that minimal space is required for a complete boiler house. Building costs are reduced and a Clayton system can easily be fitted into the available area. The light weight even allows location on an upper floor level.

Rapid Start

Start up from a completely cold condition is five minutes. Warm up fuel is minimised and the unit can be switched off when not required. The Clayton Steam Generator is therefore also ideal when used as an auxiliary or standby boiler

Safety

It is not possible to have a steam explosion. This is a danger associated with low water level in other types of boiler that store a large volume of hot water. The Clayton Steam Generator does not have a water level and does not store a large volume of water.

High Quality Steam

Steam quality is the best available from any type of boiler and is at least 99.5% dry saturated at all steam loads. This reduces the amount of water and impurities going into the steam line and ensures higher energy content of the process steam.

Rapid Response

Extremely rapid response to changes in the demand for steam is inherent in the forced circulation design. A Clayton Steam Generator will speedily ramp up or run at maximum steam output continuously without faltering.

Low Blowdown

Blowdown which is necessary to prevent the build up of impurities in all types of boiler is extremely small with the Clayton design. This saves fuel, saves chemicals and saves water.

Fully Automatic

The rapid start and rapid response can be controlled automatically. All Clayton systems can be started by a single switch locally or remotely just like any modern advanced machinery - if the automatic start option is included.

Unattended Operation

Because of the inherent safety and automatic systems all Clayton Steam Generators can be supplied to run without operator attendance for up to a period of one week if the unattended control option is included.

Low Maintenance

One of the practical benefits of the simple design concept is that maintenance requirements are minimal. The technology has been developed and improved over many years to make the Clayton Steam Generator the most reliable steam boiler available today.



Safety

Unless you have experienced a firetube boiler explosion personally it is hard to imagine the enormous destructive potential of steam. In a firetube boiler (shell boiler) a large mass of water is stored in a cylindrical vessel and heated to form steam. A faulty firetube boiler is just like a time bomb. It can produce a near instantaneous, uncontrolled, release of energy.

Fortunately, due to government legislation and established design codes as well as proper operator training and sophisticated control systems these explosions are now much less frequent than in days gone by. But there can be no cast iron guarantee that a disaster will not occur.

Overheating caused by low water is the most frequent cause of boiler explosions, or other damage. The most important job of the firetube boiler operator is to make sure the water level is correct at all times. In contrast a Clayton Steam Generator does not have a water level and it is not possible to have a steam explosion with the Clayton design.



Clayton famously demonstrated this when they tested a 500 boiler horsepower steam generator to destruction after removing all of the safety devices from the unit. This demonstration took place in front of an invited audience, including inspectors from the Technical Standards and Safety Authority of Ontario, Canada. The test was recorded on video.



The operating principle of the Clayton Steam Generator is very different from that of the firetube boiler. A firetube boiler uses natural convection for heat transfer and subsequently it must store a large amount of energy in the form of high pressure hot water.

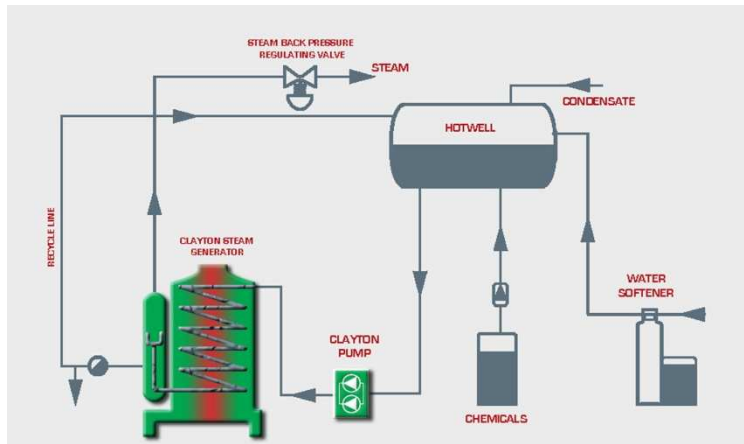
The Clayton Steam Generator, by comparison, uses forced circulation of water through a helical coil which is heated to produce steam. It follows therefore that there is relatively little water in a Clayton Steam Generator contained within the coil.

Even if the coil of a Clayton Steam Generator is damaged in any way this cannot produce a dangerous condition.

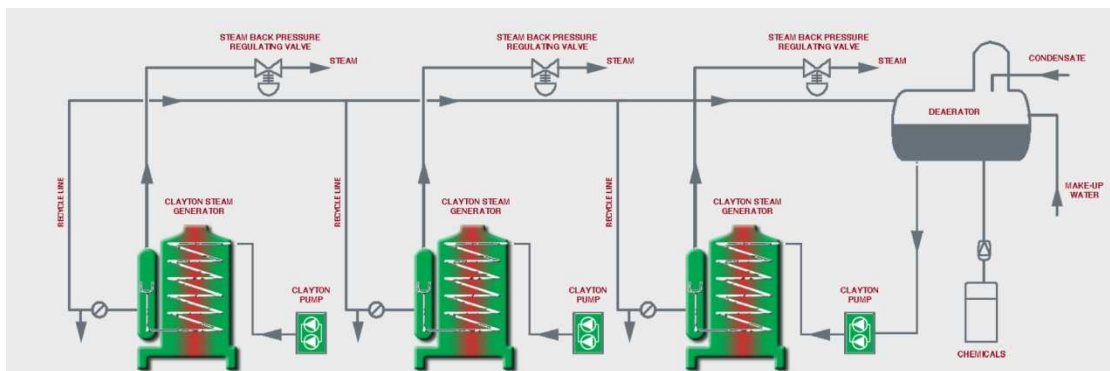


Steam Systems

Systems and equipment that ensure trouble-free operation of the steam generating plant are designed with the same Clayton experience and expertise. Clayton offers a range of ancillaries and packages to match the selected steam generators and manufactured to the same high standards.



The most common system is the Clayton **Open System** in which condensate can be returned at atmospheric pressure. In the Open System, boiler feedwater is directed from an atmospheric Hotwell to the Clayton Pump and is fed to the Clayton Steam Generator. Steam flows from the Clayton Steam Separator outlet nozzle through a backpressure regulating valve and the condensate from the separator is re-circulated back to the hotwell. The small amount of blowdown required on a Clayton Steam Generator is taken from the recirculation line. The make-up water supply can be passed through a water softener and chemicals can be dosed directly into the hotwell.



On multiple Clayton Steam Generator installations the feedwater equipment is common to all. Other tried and tested designs include the Clayton **Closed** and **Semi-Closed Systems** that are used where energy savings from condensate heat recovery is required.



Ancillary Equipment

Clayton Hotwells are designed to perform several essential functions. The Clayton Hotwell provides feedwater for the Steam Generator acts as a reservoir for returned condensate and is an ideal means of blending water treatment chemicals. An important feature of the Clayton hotwell is that it is a partial deaerator capable of removing most of the oxygen - which is the major cause of corrosion in feedwater. The hotwell is steam heated to maintain a controlled temperature of around 90 to 95°C and the residence time is calculated to ensure that the oxygen level is significantly reduced.



Clayton Hotwells are available as either horizontal or vertical vessels. All are supplied complete with special inducer tubes, temperature control, automatic level control and automatic filling. For large steam flows, high pressure steam or superheated steam system the Clayton Thermal Deaerator may be recommended.

Clayton Back Pressure Regulating Valves can be provided with each steam generator to control the minimum pressure of the generator in response to the pressure sensed by an impulse line on the downstream side. The purpose of the valve is to ensure stable operation under fluctuating loads and is used as part of the Clayton Automatic Start System.



Clayton Chemical Dosing Systems will maintain the correct water quality which is a requirement of all types of steam raising plant. The systems incorporate a chemical storage tank which is sized for the Clayton Steam System and micro-processor controlled diaphragm chemical injection pump to accurately meter the amount of chemical used. The chemical dosing system will ensure long life of the equipment.

Clayton Water Softeners are of the automatic ion-exchange type that remove hardness from the raw feedwater. Because water softeners must be periodically regenerated these are available as single (simplex) units on plants where the Clayton Steam Generator will be off during regeneration and as double (twin) units for continuous or long running periods of the Clayton Steam Generator.

Regenerations of simplex water softeners are instigated on an operator-set time basis and twin softeners are fitted with a micro-processor which allows regeneration to take place in proportion to water usage.



Ancillary Equipment

Clayton Water Test Kits provides a simple and practical means of measuring the quality of the feedwater supply to the Clayton Steam Generator. The kit includes the necessary equipment to carry out tests for water hardness, levels of oxygen scavenger, dissolved solids and pH.



Full instructions for use are included with the kit and a Clayton Feedwater Treatment Manual is available which provides information on the water quality required and how this is achieved.



Clayton Booster Pumps will ensure that the minimum net positive suction head is maintained for the main Clayton Pump where the hotwell is mounted at low level. Booster pumps are selected to suit the generators being supplied.

Clayton Blowdown Vessels are designed to safely handle the discharges from the automatic or manual blowdown systems on the Clayton Steam Generator. Blowdown vessels can also be supplied with discharge cooling systems if required.



Clayton Water Treatment Chemicals are specially formulated to maintain the correct water conditions to protect the Clayton Steam Generating System. The use of these chemicals will guarantee trouble free operation and long life of the equipment. Chemicals are available in powder or liquid form and are easily dosed using the Clayton Chemical Dosing Systems.



Skid Mounted Boiler Rooms

Clayton Steam Generator Systems can be supplied as separate modular units for installation on site or supplied as pre-assembled packages - or even as complete Skid Mounted Boiler Rooms which save installation time and on-site costs.

Each package is compact, easily transported and quickly installed. The systems can be supplied from our standard range or specially built to the customers' requirements. Fully automatic control can be included as well as monitoring devices, feedwater conditioning and all the necessary fittings, pipework and electrical wiring.



Feedwater Treatment Skid



Containerised Boiler Rooms

The Clayton Containerised Boiler Room is a completely weatherproof steam supply system that can be quickly connected on site and easily re-located when required. The small size of the Clayton Steam Generator makes it ideal for this type of construction and systems can be supplied as standard or custom built designs.

All containers are of a heavy duty, weatherproof construction and customised with openings, flooring, bracketing and doors as necessary to suit the application. The Clayton Steam Generator, along with other Clayton ancillary equipment such as the hotwell tank, water softener, blowdown tank, chemical dosing system, valves, controls, instrumentation, pipework and electrical wiring is installed by our specialist factory technicians and all equipment used is of the highest quality.

Some of the options that are available include, aluminium flooring, insulated walls, acoustic air intake dampers, automatic combustion air dampers, frost protection, cooling, lighting, fire protection and wall insulation. The outer surface of the container is shot blasted and coated with an epoxy paint system with a final colour of the customer's choice.



Range of Sizes



The Clayton Range of Steam Generators are suitable for all steam application and can run on natural gas, LPG, light oil, heavy fuel oil and are available as dual fuel oil/gas versions.

Very high steam pressures are available on standard models and special models that provide steam pressures up to 200 barg can be supplied in most sizes.

Other options include economiser sections to improve efficiency even further, low NOx models as well as marine and offshore versions.

Rating (BHP)	Steam Flow (kg/hr)*	Max Load (kW)
10	157	98
15	235	147
20	313	196
26	407	255
25	391	245
35	548	343
40	626	392
50	783	490
60	939	589
75	1174	735
80	1253	785
100	1566	981
125	1957	1226
150	2349	1471
185	2897	1815
200	3131	1962
250	3914	2432
300	4697	2943
350	5480	3433
400	6263	3924
500	7829	4905
600	9394	5886
700	10977	6868
1000	15657	9809
1100	17223	10790
1200	18788	11771
1300	20354	12752
*F&A Values		

More details are shown in the data sheets.



Exhaust Gas Boilers

The Clayton Exhaust Gas Boiler was developed following the success of the Clayton Steam Generator and the design is based on the same tried and tested operating principle. This results in an Exhaust Gas Boiler of small size and weight that can produce steam of very high quality.

An added advantage of the Clayton Forced Circulation Monotube Coil Concept is that it is not necessary to rely on any type of fins on the tube surface to assist heat transfer and this reduces the possibility of clogging with exhaust gas deposits. The configuration of the Clayton plain coiled tube is designed to maximise performance and allow free flow of hot gas over the tube in the opposite direction to the water flow in a counterflow pattern for maximum efficiency.

Due to the small size and weight of the Clayton Exhaust Gas Boiler a number of installation options are possible and the boiler can be fitted into the exhaust gas ductwork to suit the client's requirements.



The Clayton Exhaust Gas Boiler can produce steam using the heat in the waste gases from diesel engines, small gas turbines, incinerators, glass furnaces, enamel ovens, stress relieving ovens and other suitable applications.

On marine installations the Clayton Exhaust Gas Boiler has been used extensively for over 40 years to recover heat from the exhaust of main propulsion and power generating diesel engines. On-board ships a separate oil-fired Clayton Steam Generator is often supplied in conjunction with the Clayton Exhaust Gas Boiler for use when the vessel is in port.



Diesel engines on electrical generators of sizes up to 15 MW of electrical power are ideal for heat recovery using the Clayton Exhaust Gas Boiler these include light and heavy oil fired engines, gas fired engines and dual fuel units of 4-stroke and 2-stroke design.

On other applications the Clayton Exhaust Gas Boiler is ideally suitable for gas flows and temperatures within the following ranges:-

Gas Inlet Temperature	Gas Flow Rates
200 - 650 °C	680 - 59,000 kg/h
650 - 1400 °C	400 - 30,000 kg/h



Exhaust Gas Boilers

Construction of the Clayton Exhaust Gas Boiler is modular and a range of standard coil sections have been developed to suit a wide variety of process conditions. The sections are chosen for optimum performance by computer programme, based on the heat available, the steam output required and the allowable pressure drop.

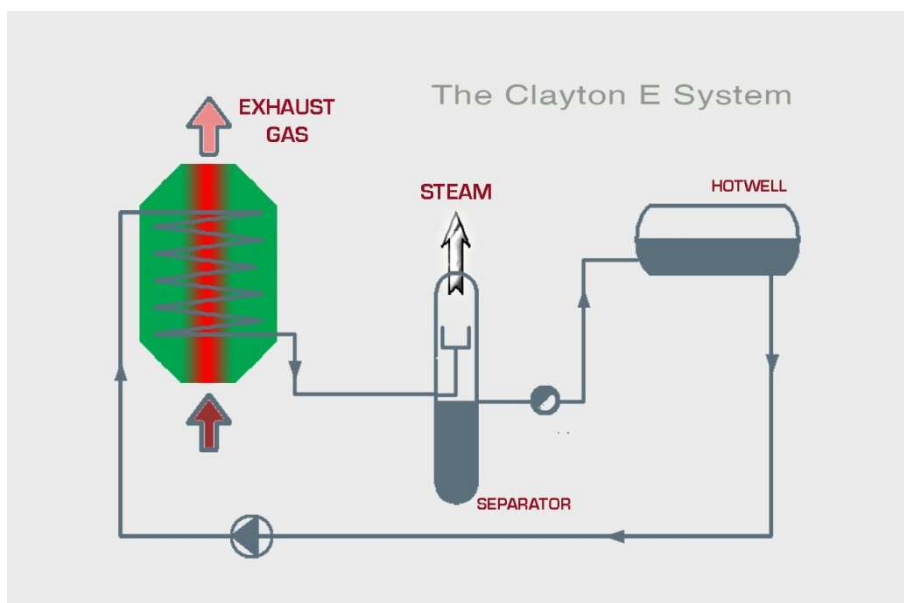


Because of the modular construction of the Clayton Exhaust Gas Boiler the assembly is a straightforward matter since the standard coil sections are bolted together and coned transition pieces are then added onto each end for connecting to the exhaust ducting. The water connections between each section are made on the outside of the boiler shell and an effective sootblowing system is built into every Clayton Exhaust Gas Boiler.



Clayton Exhaust Gas Systems have been devised to suit numerous processes. On all designs the water is pumped through the steam generating coil and the steam/water mixture produced at the outlet of the boiler is directed to a vortex separator which can be housed in a separator or accumulator.

More than one Clayton Exhaust Gas Boiler can be connected to a single accumulator. A feature of every system is that means are provided to avoid dew point corrosion of the tubes to prolong the life of the boiler.



Customer Care

Service for Clayton Steam Generators and Exhaust Gas Boilers is available worldwide in more than 100 countries to provide commissioning, preventative maintenance, and advice to customers. Clayton operate round-the-clock service **24 hours a day, seven days a week and 356 days a year**.

Our after sales service is second to none and all of our engineers are dedicated trained specialists for all Clayton products. In addition all engineers are fully trained and certificated and are familiar with site-safety practices and permit-to-work systems.

Advice on installation requirements is available from Clayton engineers and our comprehensive installation manual gives general guidance to installers. Electrical and mechanical drawings are also provided for every unit.

Preventative Maintenance Contracts are arranged for many of our customers and these are based on regular visits by our engineers to carry out scheduled maintenance tasks to ensure optimum performance and efficiency. Our engineers are also available for strip-down and refit work associated with insurance inspections. Service contracts can be tailored to suit customers requirements and can range from labour only contracts to complete parts and labour maintenance contracts.

Commissioning services are available for equipment on-site and Clayton engineers carry out all necessary safety and operational checks and full commissioning services. Operator training is also available and customised training courses can be arranged if required.

Spare Parts are held in stock in many areas of the world and these are available for immediate despatch. Any spare can be provided based on our comprehensive records of every unit supplied. We can also advise on customer spare stocking policy to minimise downtime if required.

Training on Clayton Steam Systems can be seminar format or site based, hands-on instructions. The main topics include operating principle, water/steam/fuel system, safety precautions, electrical system, routine maintenance, fault diagnosis, water testing and regular checks. The content of the course can be varied to suit the level of competence of the participants. Technical literature is also provided and a certificate is issued to each student.

Clayton reserves the right to make alterations to designs and equipment without notice and the information sketches and photographs contained herein is intended as a general guide only. Clayton Industries make no claim as the accuracy of the steam tables or any other data and independent verification of all data should be sought by any person using this information for any purpose.



Clayton Worldwide

Clayton Steam Systems is a worldwide company with four manufacturing and a vast network of subsidiary companies and distributors throughout the Globe.



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