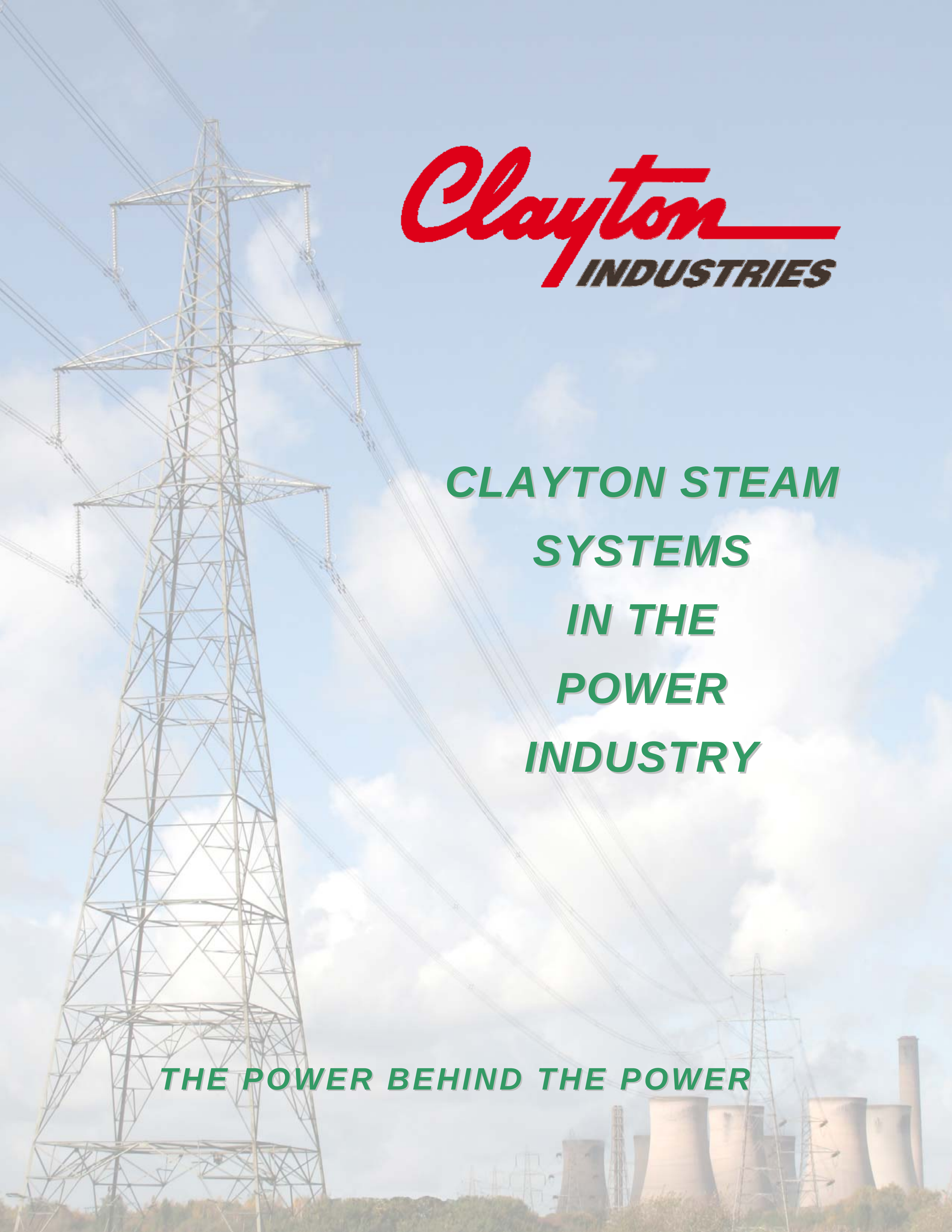
Clayton INDUSTRIES

CLAYTON STEAM SYSTEMS IN THE POWER INDUSTRY



THE POWER BEHIND THE POWER

HISTORY OF CLAYTON

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

The Clayton Manufacturing Company was founded 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.

1935
Clayton Manufacturing Company

In 1935 the company was reorganized under the name of Clayton Manufacturing Company. The Company officers were William Clayton, President; L. F. Working, Vice-President; and J. E. St. Clair as Secretary-Treasurer. A move was in order... Lemon Street in Alhambra, shared with the Edison Company.

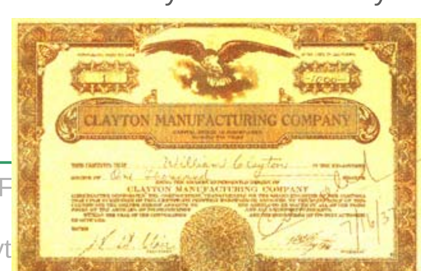
The Clayton Steam Generator represents one of the most significant development in steam production since the advent of boiler technology. The revolutionary design eliminates the need to contain large volumes of water and this principle has proved itself over the years since there has never been a steam explosion with any 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.

Clayton Exhaust Gas Boilers operate on the same tried and tested principles and have 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 appropriate engineering technology and techniques. The range of sizes have been add to over the years and it is now no longer necessary to use the traditional fire tube boiler for outputs up to 30 tonnes of steam per hour.

The many advantages of the design make it ideally suitable for any steam application



CLAYTON WORLDWIDE

Clayton Steam Systems is now a worldwide company with manufacturing facilities, subsidiary companies and distributors throughout the Globe.

The company's world headquarters is in City of Industry, California with other principle manufacturing facilities in Mexico and Europe. The European Headquarters are in Bornem, Belgium and our other European subsidiary companies are located in the UK, France, Germany and Holland.

Manufacturing Plants




LIFETIME CUSTOMER CARE

Service for Clayton Steam Generators and Exhaust Gas Boilers is available worldwide in more than 100 countries. Our dedicated trained specialist engineers can provide advice, commissioning, and operator training and customised training courses can be arranged if required.

The Clayton after sales service is second to none. Preventative Maintenance Contracts are carried out for many of our customers and these are based on regular visits by our engineers to undertake scheduled maintenance tasks to ensure optimum performance and efficiency.

The Clayton Corporate Mission & Commitment

Clayton Industries will continue to meet the needs of our markets by providing the highest quality products and services. Our goal is to exceed the expectations of our customers in all aspects of our businesses. Our products will lead our industry in safety, reliability, efficiency, and the reduction of air pollution.

Clayton will strive to deliver flawless products engineered, manufactured, sold and serviced by the industry's most responsive, professional, talented and diligent team, using state of the art technology and equipment and each Clayton person's commitment to excellence.

In support of its customers, Clayton will continue to invest in its sales and service organization worldwide to increase market share, move into new territories and develop new market segments. We will invest in technology to grow, expand our products, improve our productivity and enhance our customer service. These investments must provide a reasonable level of profitability to serve our shareholders.

Clayton will create an atmosphere of challenge, enrichment and opportunity for its employees which will nourish teamwork, encourage personal growth and foster a commitment to excellence in customer service.

Drogenbos Power Station

Clayton Steam Generator

Model : EOG-304 SH

Quantity : Two

Year : 1993

Project Information

Power Station Name	:	Drogenbos 2 Power Station
Power Company	:	Electrabel Suez
Contractor	:	Suez Tractebel SA
Location	:	Brussels
Year	:	1993
Station Size	:	460 MW
Generator Model	:	EOG-304-SH
Number of Generators	:	2
Number of Pumps	:	1
Use	:	Steam Turbine Gland Sealing
Net Heat Output Per Unit	:	2943 KW
Steam Flow Per Unit	:	3400 kg/h
Modulation	:	Yes
Operating Pressure	:	14 barg
Steam Temperature	:	311^{O}C (Superheated)
Fuel	:	Natural Gas / Oil
Dimensions	:	2745 x 1950 x 3490 mm

The two Clayton Steam Generators at Drogenbos Power Station are capable of providing superheated steam for steam turbine gland sealing and are also able to supply saturated steam at other times.

Sterlington Power Station

Clayton Steam Generator

Model : EG-604

Quantity : One

Year : 2002

Project Information

Power Station Name	:	Sterlington Power Plant
Power Company	:	Cogentrix Energy Inc
Contractor	:	SNC - Lavalin
Location	:	Louisiana
Year	:	2002
Station Size	:	825 MW
Generator Model	:	EG-604 Low Nox
Number of Generators	:	One
Number of Pumps	:	Two
Use	:	Steam Turbine Gland Sealing
Net Heat Output	:	5881 kW
Steam Flow	:	9409 kg/h
Modulation	:	Yes
Operating Pressure	:	17 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Natural Gas
Dimensions	:	3251 x 3225 x 5251 mm

The Clayton Steam Generator is used as an auxiliary boiler for gland sealing on the steam turbines to advance start up time for the power plant. This is a Combined Cycle Cogeneration Power Plant with three GE Condensing Steam Turbine Generators.

Castleford Power Station

Clayton Steam Generator

Model : EG-354

Quantity : One

Year : 2006

Project Information

Power Station Name	:	Castleford Cogeneration
Power Company	:	E.ON UK
Contractor	:	E.ON UK
Location	:	Yorkshire
Year	:	2006
Station Size	:	56 MW
Generator Model	:	EG-354
Number of Generators	:	One
Number of Pumps	:	One
Use	:	Turbine Gland Sealing
Net Heat Output	:	3433 kW
Steam Flow	:	5480 kg/h
Modulation	:	Yes
Operating Pressure	:	25 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Natural Gas
Dimensions	:	2745 x 1950 x 3490 mm

The E.ON Power Station at Castleford is a Cogeneration system at the chemical plant of C6 Solutions and can supply the sites entire electrical and steam requirements. The Clayton Steam Generator is used for start-up.

Medway Power Station

Clayton Steam Generator

Model : SEG-504 SH

Quantity : One

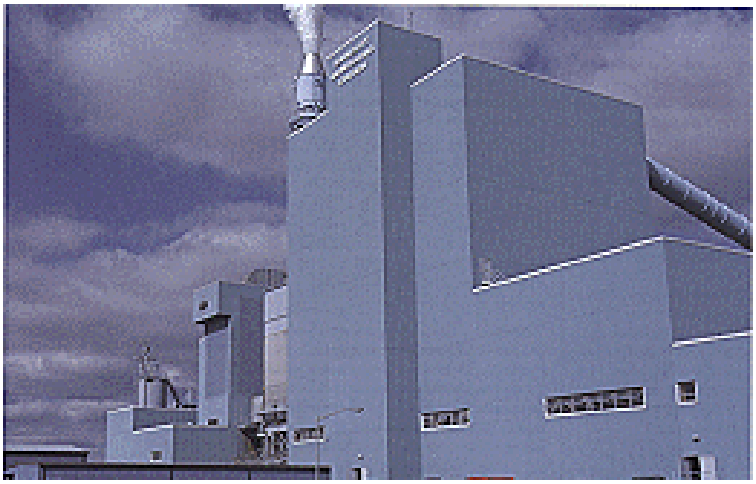
Year : 1999

Project Information

Power Station Name	:	Medway Power Station
Power Company	:	Scottish & Southern Energy plc
Contractor	:	Mitsui Babcock Energy Services Ltd
Location	:	Kent
Year	:	1999
Station Size	:	688 MW
Generator Model	:	SEG-504 SH Low Nox
Number of Generators	:	One
Number of Pumps	:	Two
Use	:	Turbine Gland Sealing and Pre-Warming
Net Heat Output	:	5052 kW
Steam Flow	:	9390 kg/h
Modulation	:	Yes
Operating Pressure	:	17 barg
Steam Temperature	:	269^{O}C (Superheated)
Fuel	:	Natural Gas
Dimensions	:	3200 x 2200 x 6500 mm

The Clayton Steam Generator is used as an auxiliary boiler to reduce starting time of the power plant. The time saved per start is approximately 1.5 hours. Based on electricity generation alone this produce a saving equivalent to £25,000 on every start (based on 1999 electricity prices).

The Endicott Plant



Clayton Steam Generator

Model : EO-300

Quantity : One

Year : 1982

Project Information

Power Station Name	:	The Endicott Plant
Power Company	:	Michigan South Central Power Agency
Contractor	:	MSCPA
Location	:	Michigan
Year	:	1982
Station Size	:	60 MW
Generator Model	:	EO-300
Number of Generators	:	One
Number of Pumps	:	One
Use	:	Start-Up of Coal Boiler
Net Heat Output	:	4564 kW
Steam Flow	:	2940 kg/h
Modulation	:	Yes
Operating Pressure	:	10 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Medium Fuel Oil
Dimensions	:	2500 x 2060 x 4570 mm

The Clayton Steam Generator has been in operation for 25 years and is use frequently to start-up the 24 tonne B&W coal fired boiler. The plant personnel consider the main advantages of the Clayton design is reliability and rapid start-up from cold.

STAG Power Station

Clayton Steam Generator

Model : EOG-304 SH

Quantity : Two

Year : 1994

Project Information

Power Station Name	:	STAG (Steam and Gas)
Power Company	:	SPE
Contractor	:	Suez Tractebel SA
Location	:	Seraing
Year	:	1994
Station Size	:	460 MW
Generator Model	:	EOG-304 SH
Number of Generators	:	Two
Number of Pumps	:	Two
Use	:	Steam Turbine Gland Sealing
Net Heat Output	:	2943 kW
Steam Flow	:	3400 kg/h
Modulation	:	Yes
Operating Pressure	:	14 barg
Steam Temperature	:	311^{O}C (Superheated)
Fuel	:	Natural Gas / Oil
Dimensions	:	2745 x 1950 x 3490

The Clayton Steam Generators at the Société de Production d'Electricité Seraing Power Station are for turbine gland sealing on start-up.

Campeche Power Station

Clayton Steam Generator

Model : SEG-404 SH

Quantity : One

Year : 2002

Project Information

Power Station Name	:	Campeche Power Plant
Power Company	:	Transalta Campeche SA de CV
Contractor	:	ICA Fluor Daniel
Location	:	Campeche, Mexico
Year	:	2002
Station Size	:	252 MW
Generator Model	:	SEG-404 SH
Number of Generators	:	One
Number of Pumps	:	Two
Use	:	Steam Turbine Gland Sealing
Net Heat Output	:	3434 kW
Steam Flow	:	4389 kg/h
Modulation	:	Yes
Operating Pressure	:	15 barg
Steam Temperature	:	322^{O}C (Superheated)
Fuel	:	Natural Gas
Dimensions	:	2921 x 1930 x 4622 mm

The Clayton Steam Generator is used as an auxiliary boiler for gland sealing during start-up. Campeche Power Plant is TransAlta's first plant in Mexico and the Clayton Steam Generator design was selected by ICA Fluor Daniel.

Jenks Power Station

Clayton Steam Generator

Model : EG-604

Quantity : One

Year : 2001

Project Information

Power Station Name	:	Jenks Power Plant
Power Company	:	Cogentrix Energy Inc
Contractor	:	SNC - Lavalin
Location	:	Oklahoma
Year	:	2001
Station Size	:	825 MW
Generator Model	:	EG-604 Low Nox
Number of Generators	:	One
Number of Pumps	:	Two
Use	:	Steam Turbine Gland Sealing
Net Heat Output	:	5881 kW
Steam Flow	:	9409 kg/h
Modulation	:	Yes
Operating Pressure	:	17 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Natural Gas
Dimensions	:	3251 x 3225 x 5251 mm

The Clayton Steam Generator is used as an auxiliary boiler for gland sealing on the steam turbines to advance start up time for the power plant. This is a Combined Cycle Cogeneration Power Plant with three GE Condensing Steam Turbine Generators said to be one of the cleanest sources of electricity in the world.

Bressoux Power Station

Electrabel

Clayton Steam Generator

Model : SEG-304

Quantity : Two

Year : 1991

Project Information

Power Station Name	:	Bressoux Power Plant
Power Company	:	Electrabel Suez
Contractor	:	Electrabel Suez
Location	:	Liege
Year	:	1991
Station Size	:	
Generator Model	:	SEG-304
Number of Generators	:	Two
Number of Pumps	:	One
Use	:	Peak Shaving
Net Heat Output	:	2943 kW
Steam Flow	:	4697 kg/h
Modulation	:	Yes
Operating Pressure	:	16 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Natural Gas
Dimensions	:	2745 x 1950 x 3490

The Clayton Steam Generators at the Electrabel Power Plant at Bressoux are used as peak shavers since they can respond rapidly to alterations in steam demand.

Clayton INDUSTRIES

Peterborough Power Station

Clayton Steam Generator

Model : EO-150

Quantity : One

Year : 1991

Project Information

Power Station Name	:	Peterborough Power Station
Power Company	:	Centrica PG Ltd
Contractor	:	Hawker Siddeley Power Engineering
Location	:	Peterborough
Year	:	1991
Station Size	:	360 MW
Generator Model	:	EO-150
Number of Generators	:	One
Number of Pumps	:	One
Use	:	Standby Steam
Net Heat Output	:	1471 kW
Steam Flow	:	2349 kg/h
Modulation	:	Yes
Operating Pressure	:	10 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Oil
Dimensions	:	2550 x 1950 x 3165 mm

Peterborough Power Station has two gas turbines and one steam turbine. The facility is used to help meet peak demand and typically starts up and shuts down on a daily basis.

Heysham Power Station

British Energy

Clayton Steam Generator

Model : EO-150

Quantity : Three

Year : 1981

Project Information

Power Station Name	:	Heysham 1 Power Station
Power Company	:	British Energy
Contractor	:	CEGB
Location	:	Heysham
Year	:	1981
Station Size	:	1150 MW
Generator Model	:	EO-150
Number of Generators	:	Three
Number of Pumps	:	One
Use	:	Standby Steam
Net Heat Output	:	1471 kW
Steam Flow	:	2349 kg/h
Modulation	:	Yes
Operating Pressure	:	7 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Oil
Dimensions	:	2550 x 1950 x 3165 mm

Heysham 1 Power Station is an AGR station with two reactors.

Hartlepool Power Station

Clayton Steam Generator

Model : EO-150

Quantity : Two

Year : 1981

Project Information

Power Station Name	:	Hartlepool Power Station
Power Company	:	British Energy
Contractor	:	CEGB
Location	:	Hartlepool
Year	:	1981
Station Size	:	1210 MW
Generator Model	:	EO-150
Number of Generators	:	Two
Number of Pumps	:	One
Use	:	Standby Steam
Net Heat Output	:	1471 kW
Steam Flow	:	2349 kg/h
Modulation	:	Yes
Operating Pressure	:	7 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Oil
Dimensions	:	2550 x 1950 x 3165 mm

Hartlepool Power Station is an AGR reactor plant. The two Clayton Steam Generators at the station have been in operation since 1981. They are a vital part of the operation since they are used as standby units to provide steam for vaporising carbon dioxide that is used as primary cooling for the

Corby Power Station

Clayton Steam Generator

Model : EO-154

Quantity : One

Year : 1991

Project Information

Power Station Name	:	Corby Power Station
Power Company	:	E.ON / ESB
Contractor	:	Hawker Siddeley Power Engineering
Location	:	Corby
Year	:	1991
Station Size	:	350 MW
Generator Model	:	EO-154
Number of Generators	:	One
Number of Pumps	:	One
Use	:	Standby Steam
Net Heat Output	:	1471 kW
Steam Flow	:	2349 kg/h
Modulation	:	Yes
Operating Pressure	:	10 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Oil
Dimensions	:	2550 x 1950 x 3165 mm

Corby Power Station is a combined cycle station designed for maximum operating flexibility. Shutdown of one turbine heat recovery is unit possible while the other remains at full power. The plant has two Frame 9F gas turbines and an additional turbine driven by steam from two HRSGs.

Sellafiel Nuclear Site

Clayton Steam Generator

Model : EO-125

Quantity : One

Year : 2003

Project Information

Power Station Name	:	Sellafield Nuclear Site
Power Company	:	British Nuclear Fuels plc
Contractor	:	BNFL
Location	:	Sellafield
Year	:	2003
Station Size	:	Fuel Re-Processing Facility
Generator Model	:	EO-125
Number of Generators	:	One
Number of Pumps	:	One
Use	:	Emergency Standby
Net Heat Output	:	1226 kW
Steam Flow	:	1957 kg/h
Modulation	:	Yes
Operating Pressure	:	7 barg
Steam Temperature	:	99.5% Dry Saturated
Fuel	:	Oil
Dimensions	:	1755 x 1300 x 2405 mm

The Clayton Steam Generator at the Sellafield site is used as an emergency back-up steam supply and is designed to withstand a seismic event. Steam is used in emergency for eductors to transfer liquid.

CLAYTON IN THE POWER INDUSTRY

In the power industry Clayton Steam Systems has gained and enviable reputation where superheated steam, high pressure steam and rapid start capability combined with the inherent safety of the design have significant benefits.

Clayton Power Station Steam Generators allow the plant to be brought on-line and achieve baseload significantly sooner after a shutdown by providing steam to seal the glands on the steam turbine long before the HRSG becomes available. The seal permits vacuum conditions to be established on the steam condenser and reduces the time for synchronisation of the gas and steam turbines. The advantages to the power plant can include:-

- Lower Emissions
- Less Fuel Consumption
- Less Water Consumption
- Lower Chemical Consumption
- Lower Electricity Consumption
- Increased Revenue
- Commercial Advantages of Faster Start

The other ideal applications for Clayton Steam Generatora are for **peak shaving**, **back-up steam** and any **saturated**, **superheated** or **high pressure** duty.

Advantages

The advantages of **The Clayton Steam Generator** is due to the unique and advanced design which has many operational and process benefits. High efficiency and rapid start-up capability are combined with high steam quality and fast response to load changes. In addition, the low blowdown requirement saves energy, water and treatment chemicals.

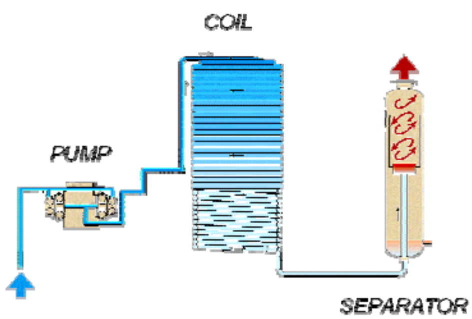
The operating principle of the Clayton Steam Generator has eliminated the need to contain and heat large quantities of water. Consequently all generator models are small in size and weight and can be accommodated within a limited space which is a significant advantage when considering either a new installation or additions to an existing plant.

The major safety advantage of the low water storage requirement is that there is no possibility of a steam explosion from a Clayton Steam Generator.

The Clayton Steam Generator can be provided for unattended operation and a separate boiler house is not required. In addition, operation is completely automatic and the Clayton Steam Generator has a reputation for reliability and low maintenance.

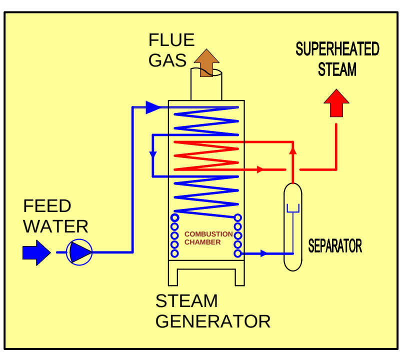
Principle of Operation

The reason for the many advantages of the Clayton Steam Generator is, what we call, 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. 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 to 99.5% dry saturated.

Superheated Steam



On Superheated Clayton Steam Generators dry steam produced in the primary stage is fed into an additional superheat coil section. As with all Clayton Steam Generators, feed water is directed to the topmost layer of coil from where it spirals downwards through each level to the lower part of the boiler. In this lower section, the tube forms a cylindrical shield around the combustion chamber. As the water passes through the steam generator it picks up heat and steam is produced at the outlet from where the flow is directed to a pressurised centrifugal separator vessel. The required superheat is then obtained by feeding this dry steam back to the steam generator where it is passed through the integral superheat coil.

High Pressure

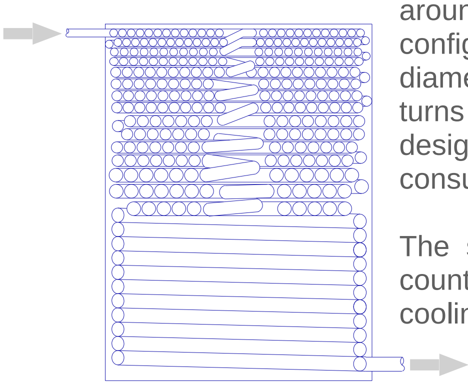
Because of the unique water tube coil design the Clayton Steam Generator can operate at high pressure without substantial increase in size or weight. Standard units are tested at a pressure of 60 barg and higher pressure systems are available up to 200 barg.

THE MAIN COMPONENTS

The Clayton Coil

The coil of a Clayton Steam Generator is of a unique design which 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 of the Clayton Steam Generator 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 thereby minimising fuel consumption.

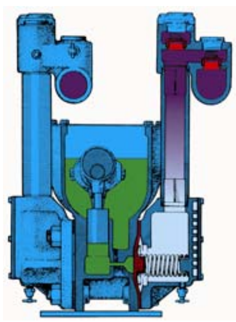


The spiral construction of the coil is extremely robust and counteracts the effects of expansion during rapid heating and cooling cycles. The coil also undergoes in-house heat treatment to eliminate stresses and each coil is tested at high pressure.

An added advantage of the single coil design is that the internal condition can be monitored by observing the pressure of the feedwater at the coil inlet. In the case of oil fired units, sootblowing facilities are provided to remove deposits from the outside of the coil.

The Clayton Pump

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 which ensures flow stability over a wide range of varying pressure conditions and it has a number of mechanical advantages. In particular The Clayton Pump does not rely on mechanical seals, packing rings or glands to separate the water being pumped from the drive mechanism. Operation is completely unaffected by relatively high water temperature and the construction of the Clayton Pump is extremely robust. The Clayton Pump is also very reliable and low in maintenance.

Pumping action is produced by the movement of a diaphragm which acts against a column of water on one side of the diaphragm. The rise and fall of the water column causes spring loaded inlet and outlet check valves at the top of the column to open and close and this produces flow through the pump.

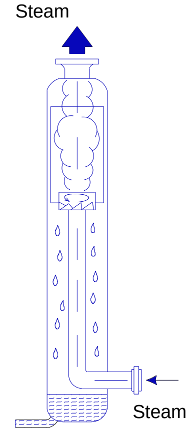
The diaphragm is driven on the other side by the movement of a piston which is semi-submersed in an oil bath. The piston crankshaft is driven by a motor and v-belt drive. On the smaller model Clayton Steam Generators (E10, E15 and E26) the diaphragm is direct driven.

On every Clayton Steam Generator the water supply is related to the steam output. On step fired Clayton Steam Generator the output of the pump is also stepped and on fully modulating units the pump is fitted with a variable speed drive and pump output, burner firing rate as well as air flow can be simultaneously modulated to provide greater efficiency, accurate control and maximum response.

The Clayton Separator

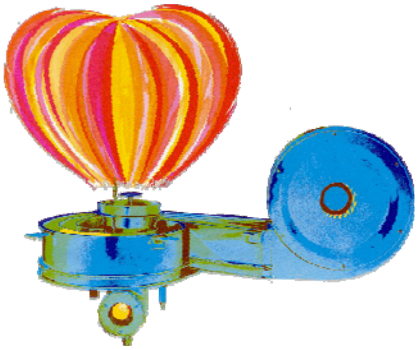
The Clayton Steam Separator is a High Efficiency centrifugal design which has no moving parts. The very high steam quality is produced even under variable load conditions.

The steam/water mixture from the Clayton Steam Generator is directed to the inlet of the separator where is separated by centrifugal force. The water is collected and dry steam is discharged through the top outlet.



The Clayton Burner

The burner of the Clayton Steam Generator 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.

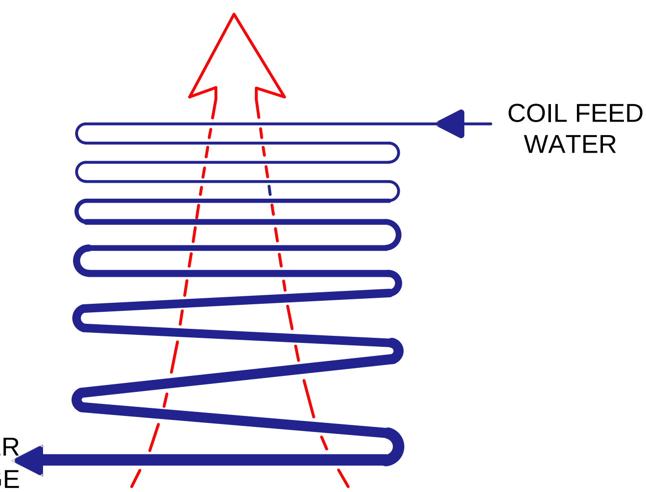


To achieve this the air for combustion enters the burner manifold at high velocity where it picks up fuel in a whirlpool action to form a heart shaped flame where the flame tip folds over into the low pressure zone. Fuel and air are blended in precise ratios and the burner fires upwards, which is the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

EFFICIENCY AND FUEL SAVING

High operating efficiency and fuel savings are inherent in the design of the Clayton Steam Generator and control of the heating gasses, water circulation and combustion of fuel ensure optimum heat transfer. Start-up within five minutes from cold saves energy and also means that a Clayton Steam Generator in standby mode is off and completely cold yet can be operational at the flick of a switch or from a remote signal.

The counterflow coil principle means that the water flows in the opposite direction from the hot gasses and this ensures a low stack temperature which is an indication of efficiency. In fact the stack temperature can actually be lower than the steam temperature on a Clayton Steam Generator and the efficiency can increase as the output is reduced. This is an



COUNTERFLOW PRINCIPLE

important advantage since boilers rarely operate at their maximum rated output for most of the time.

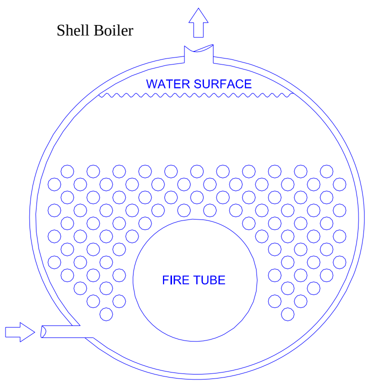
The very low blowdown loss is due to the ability of the Clayton Steam Generator to operate unaffected by high dissolved solids. In addition, because of the high concentration of solids in the collected water, this is the ideal point to evacuate a large amount of concentrated solids in a small amount of liquid.

The many advantages of the Clayton Steam Generator are explained in

'The Clayton Report', is available on request. An independent university report is also available which gives a summary of efficiency tests.

SAFETY

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



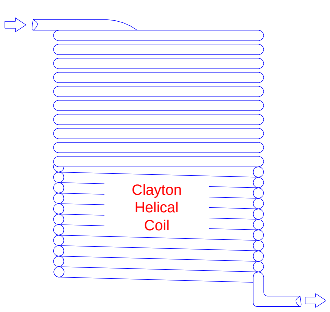
Every year explosions of shell boilers happen all over the world and some of these result in loss of life. Fortunately, due to government legislation and established design codes as well as proper operator training and modern control systems these explosions are now much less frequent than in days gone 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. Statistics from the US National Board of Boiler and Pressure Vessel Inspectors reveal that in 1999 there were 397 accidents which were attributed to low water conditions in steam boilers.

The most important rule for the safe operation of a shell boiler is to maintain the correct water level 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 procedure was recorded on video which can be viewed at www.claytonindustries.co.uk



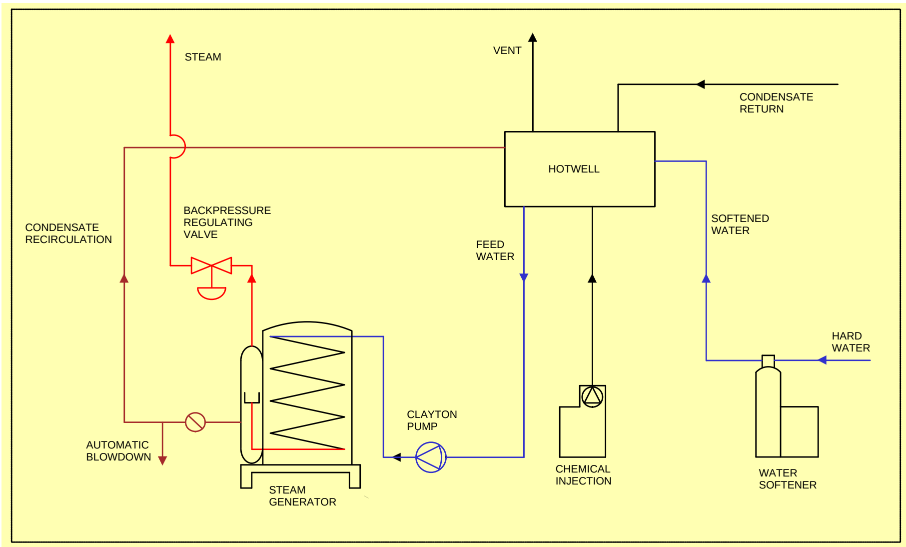
The operating principle of the Clayton Steam Generator is very different from that of the common shell boiler. A shell boiler uses natural convection and subsequently a large amount of energy in the form of hot water must be stored within the shell. The Clayton Steam Generator, by comparison, uses forced circulation of water though 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 itself is damaged in any way this cannot *produce a dangerous condition.*

STEAM GENERATING SYSTEM

The Clayton Open System

The Clayton experience and expertise has also been applied to the design and selection of systems and ancillary equipment which ensures trouble-free operation of the steam generating plant. Clayton offer a range of accessories which match the selected steam generators and which are designed 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 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 since the concentration of dissolved solids is highest at this point.

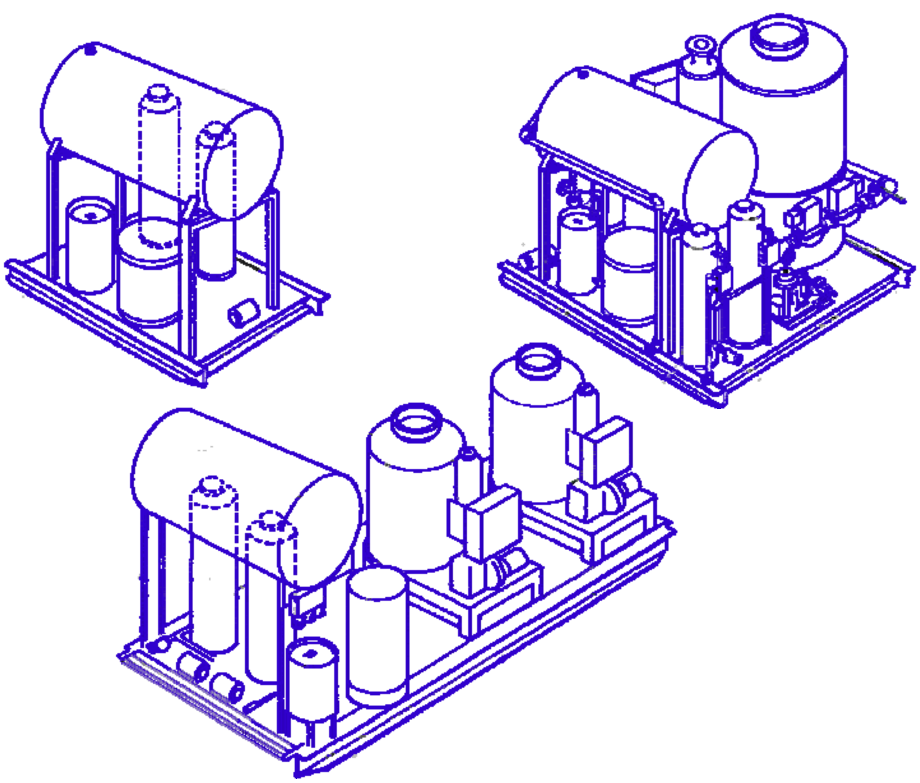
The make-up water supply can be passed through a water softener and chemicals can be dosed directly into the hotwell. Other tried and tested designs include the Clayton Closed and Semi-Closed Systems which are used where energy savings from condensate heat recovery is required.

SKID MOUNTED PACKAGES

The Clayton Steam Generator System can be supplied as separate modular items for installation on site or the equipment can be supplied as pre-assembled packages which save installation time and on-site costs. The Clayton packaged steam plants are supplied as standard units or custom built designed to suit client's individual requirements.

Typical skid mounted packages include the Clayton Steam Generator as well as the hotwell, water softener and chemical dosing system complete with all necessary on-skid interconnecting pipework, on-skid wiring, valves and fittings supplied as a pre-fabricated and factory tested unit. More than one Clayton Steam Generator can be packaged in this way and it is possible to ship a complete boiler plant in one consignment.

These packages are extensively used on offshore oil platforms where space and time are at a premium. On larger systems, or for convenience it is also possible to package the feedwater equipment separately.



THE CLAYTON EXHAUST GAS BOILER FOR CHP PLANT

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 which can produce steam of very high quality.

An added advantage of the Clayton Forced Circulation Monotube Coil Concept is that 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.

Applications

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.

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 ^{O}C	680 - 59,000 kg/h
650 -1400 ^{O}C	400 - 30,000 kg/h

Construction

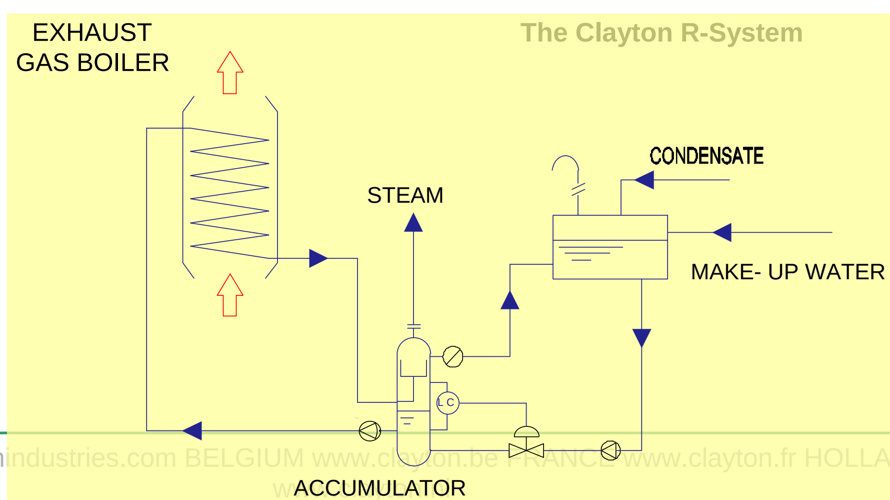
The Clayton Exhaust Gas Boiler is of a modular design and a range of standard coil sections have been developed to suit a wide range of process conditions. The sections are chosen for optimum performance by computer programme, based on the heat available, the steam output required and the allowable pressure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

Because of the modular construction of the Clayton Exhaust Gas Boiler 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 coil are made on the outside of the boiler shell and an effective sootblowing system is built into every Clayton Exhaust Gas Boiler.

Exhaust Gas Boiler Systems

Clayton have developed systems 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 steam drum (or accumulator).

More than one Clayton Exhaust Gas Boiler can be connected to a single steam drum. 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.



STEAM BASICS

Enthalpy, Sensible Heat and Latent Heat

Rapid steam production in a Clayton Steam Generator begins when heat energy from combustion of fuel is transferred to the feedwater being pumped through the specially designed coil. Energy content of water and steam is termed *Enthalpy* and is taken as zero at atmospheric pressure and a temperature of 0^{O} Centigrade.

The total amount of heat that must be added to the feedwater to produce steam is made up of two parts. *Sensible Heat* which is the heat supplied to raise the temperature of water to it's boiling point and *Latent Heat* which is heat required to evaporate the water into steam.

Enthalpy per unit mass (h) is the specific enthalpy and is measured in kJ/kg K. To determine the total enthalpy (h_g) in the steam it is necessary to add together the two types of enthalpy which are required to produce the steam

The heat supplied to raise the temperature of water to its boiling point is called sensible heat because the change of temperature is sensible to the touch and can be measured on a thermometer. This sensible heat is known as the enthalpy of saturated water (h_f).

The heat, which is then added to turn the water into steam, does not raise the temperature and is called latent heat for this reason. Latent heat loosens the forces between molecules to produce the change of state from liquid to gas. This latent heat is known as the enthalpy of evaporation (h_{fg}).

Note: In calculations, the specific enthalpy (h) is used since this is the enthalpy per unit mass (ie per kg) rather than the total enthalpy (H).

Calculating the Enthalpy of Saturated Steam

The specific enthalpy of saturated steam is the sum of:-

(Total Heat)	=	(Sensible Heat)	+	(Latent Heat)
h_g		h_f		h_{fg}

Steam Tables

Steam tables usually show specific enthalpy in kJ/kg ^{o}C for different pressures with pressure shown as absolute pressure. Gauge pressure (barg) is absolute pressure minus 1.013 bar. For convenience, however, the Clayton Steam Tables attached are given for gauge pressure (barg) and the enthalpy is shown as kcal/kg.

Enthalpy of Wet Steam

If insufficient heat has been added to convert all of the water into steam then small water droplets will be present in suspension in the steam space. In this case a dryness fraction must be taken into account. The dryness fraction of steam (x) is calculated by:

$$x = \frac{\text{Mass of Dry Steam}}{\text{Total Mass of Steam \& Water}}$$

and $h_g = h_f - (xh_{fg})$

The Clayton Steam Generator produces steam quality that is a minimum of 99.5% dry saturated at all loads.

Superheated Steam

If heat is added to saturated steam which is maintained at a *constant pressure,* the temperature of the steam will rise. The steam is then said to be superheated. The degree of superheat is the difference between the steam temperature and the saturation temperature at the same pressure.

So for steam with a saturation temperature of 133.5^{o}C which is heated to 180^{o}C the degree of superheat is 46.5^{o}C

The specific heat capacity of superheated steam (c) varies with temperature and pressure and ranges from 1.98 to 2.7 kJ/kgK. The specific enthalpy of superheated steam is enthalpy of dry saturated steam plus $c(s_{up} - t_f)$.

STEAM TABLES

P Barg	T ^0C	Enthalpy (kcal/kg)			Specific volume m^3/kg	Specific weight Kg/m^3
		water	evapora-tion heat	steam		
0.0	100.0	99.7	539.4	639.1	1.6940	0.590
0.1	102.3	102.4	537.7	640.1	1.5490	0.646
0.2	104.8	105.0	536.1	641.1	1.4280	0.700
0.3	107.1	107.3	534.6	641.9	1.3250	0.755
0.4	109.3	109.5	533.2	642.7	1.2360	0.809
0.5	111.4	111.6	531.8	643.4	1.1590	0.863
0.6	113.3	113.6	530.6	644.1	1.0910	0.917
0.8	116.9	117.2	528.1	645.4	0.9772	1.023
1	120.2	120.6	525.9	646.5	0.8854	1.129
1.2	123.3	123.7	523.9	647.5	0.8098	1.235
1.4	126.1	126.5	522.0	648.5	0.7465	1.340
1.5	127.4	127.9	521.0	648.9	0.7184	1.392
1.6	128.7	129.2	520.1	649.3	0.6925	1.444
1.8	131.2	131.7	518.4	650.2	0.6460	1.548
2	133.5	134.1	516.8	650.9	0.6056	1.651
2.2	135.8	136.4	515.2	651.6	0.5700	1.754
2.4	137.9	138.5	513.7	652.3	0.5385	1.857
2.6	139.9	140.6	512.3	652.9	0.5103	1.960
2.8	141.8	142.6	510.9	653.5	0.4851	2.061
3	143.6	144.5	509.6	654.0	0.4622	2.164
3.5	147.9	148.9	506.4	655.2	0.4132	2.420
4	151.8	152.9	503.4	656.4	0.3747	2.669
4.5	155.5	156.7	500.7	657.4	0.3425	2.920
5	158.1	160.2	498.1	658.2	0.3155	3.170
5.5	162.0	163.4	495.6	659.1	0.2925	3.419
6	165.0	166.5	493.3	659.8	0.2727	3.667
6.5	167.8	169.4	491.0	660.5	0.2552	3.918
7	170.4	172.2	488.9	661.1	0.2403	4.161
7.5	172.9	174.9	486.8	661.7	0.2268	4.409
8	175.4	177.4	484.8	662.2	0.2148	4.655
8.5	177.7	179.8	482.8	662.6	0.2040	4.902
9	179.9	182.2	481.0	663.2	0.1943	5.147
10	184.1	186.6	477.4	664.0	0.1774	5.637
11	188.0	190.7	474.0	664.8	0.1632	6.127
12	191.6	194.6	470.8	665.4	0.1511	6.618
13	195.0	198.3	467.7	666.0	0.1407	7.107
14	198.3	201.8	464.7	666.5	0.1317	7.593
15	201.4	205.1	461.8	666.9	0.1237	8.048
16	204.3	208.3	459.0	667.3	0.1166	8.576
17	207.1	211.3	456.4	667.7	0.1103	9.066
18	209.8	214.2	453.7	668.0	0.1047	9.551
19	212.4	217.1	451.2	668.2	0.0995	10.050
20	214.9	219.8	448.7	668.5	0.0949	10.539
21	217.2	222.4	446.3	668.7	0.0907	11.031
22	219.6	224.9	443.9	668.8	0.0868	11.525
23	221.8	227.4	441.6	669.0	0.0832	12.019
24	223.9	229.8	439.3	669.1	0.0799	12.514
25	226.0	232.1	437.1	669.2	0.0769	13.011
26	228.1	234.4	434.9	669.3	0.0740	13.510
27	230.1	236.6	432.8	669.4	0.0714	14.008
28	232.0	238.8	430.6	669.4	0.0689	14.507
29	233.8	240.9	428.5	669.4	0.0666	15.008
31	237.5	245.0	424.5	669.4	0.0624	16.015
33	240.9	248.9	420.5	669.4	0.0587	17.027
35	244.2	252.7	416.7	669.3	0.0554	18.051
37	247.3	256.3	412.9	669.2	0.0524	19.084
39	250.3	259.8	409.2	669.0	0.0497	20.121
41	253.2	263.2	405.6	668.8	0.0473	21.142
43	256.1	266.5	402.0	668.5	0.0451	22.183
45	258.8	269.7	398.5	668.2	0.0430	23.234

THE CLAYTON STEAM GENERATOR RANGE

The nominal specifications for the standard range of Clayton 'E' model Steam Generators are shown on our data sheets.

These are available as: -

- **EG - Gas Fired**
- **EO - Light Oil**
- **EHO - Heavy Fuel Oil**
- **EOG - Dual Fuel (Light Oil and Gas)**
- **EHOG - Dual Fuel (Heavy Oil and Gas)**

The range of Super Efficient Clayton Steam Generators are fitted with economiser sections, to improve efficiency even further. These are designated by the prefix **SE**. Low NOx models are have the suffix **LN**. The Clayton data sheets show details of the full range of sizes.

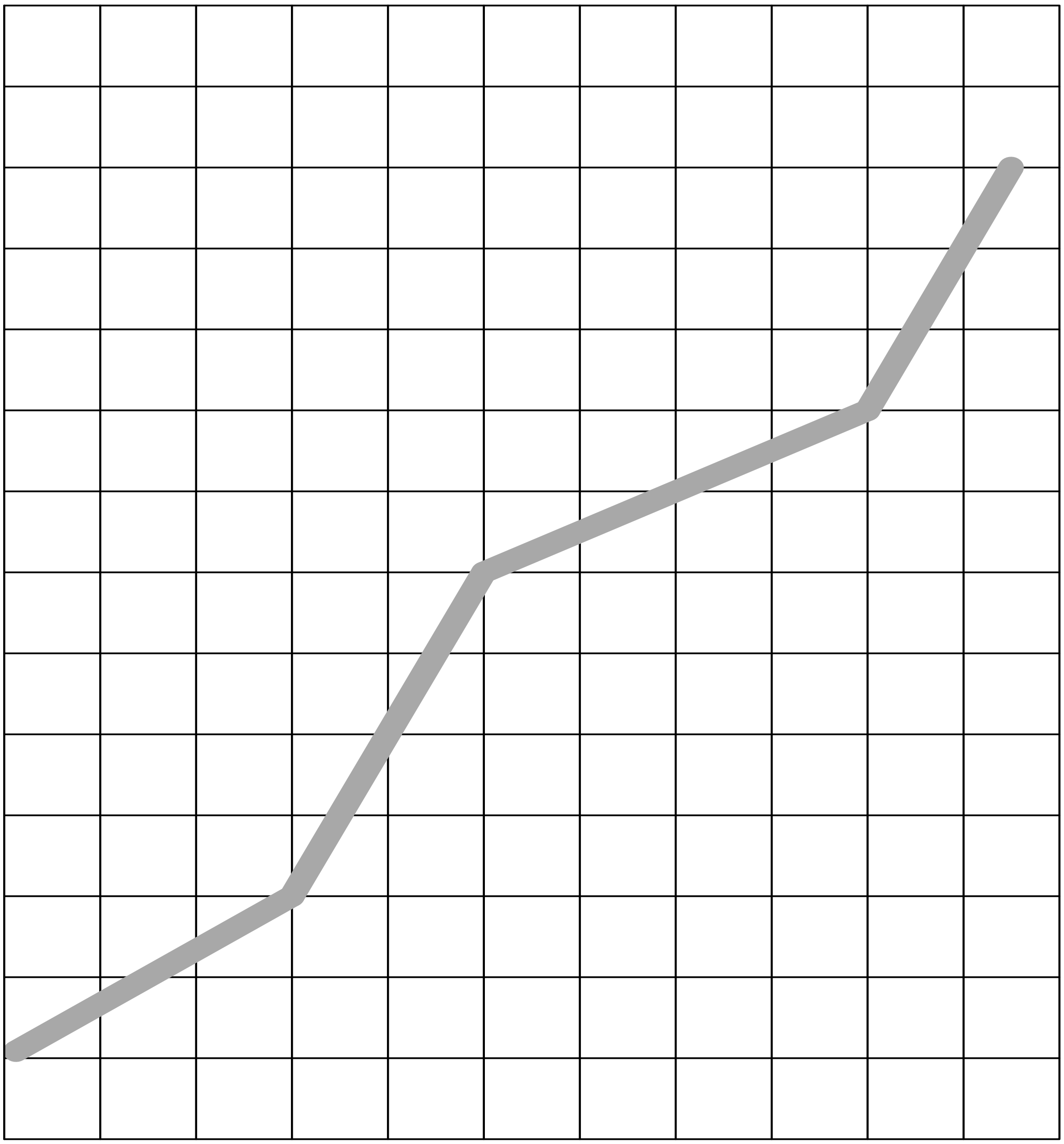
The maximum available steam outlet pressure varies depending on generator model. Standard pressure ranges are shown on the data sheets and special models providing steam pressures up to 200 barg can be supplied on most sizes. Superheated steam models are designated with the suffix **SH**

The smallest Clayton Steam Generator Model **E-10** has a net heat output of 98kW and equivalent output of saturated steam of 157 kg/h.

The largest Clayton Steam Generator Model **E-704** has a net heat output of 6867kW and an equivalent output of saturated steam of 10,948 kg/h.

Clayton Steam Generators provide significant benefits when operated in multiple unit installations since this provides added flexibility where higher steam flows are required.

The Clayton Report…



A GUIDE TO EFFICIENT STEAM PRODUCTION

SECTION ONE

Introduction

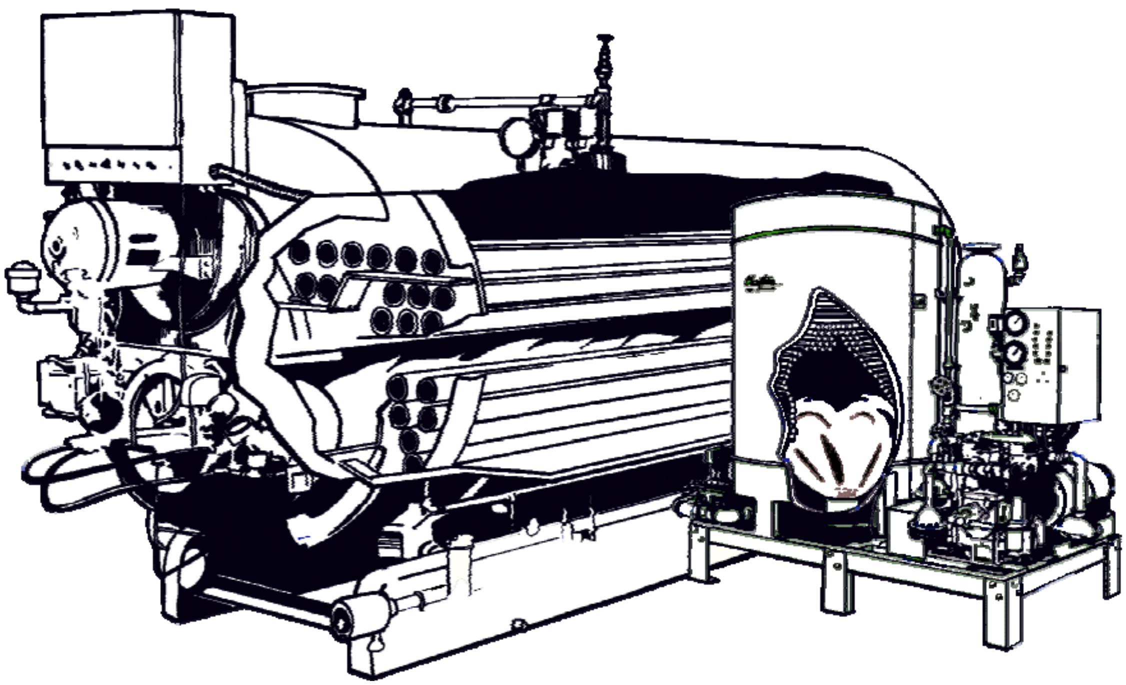


FIGURE 1A

Principle of Operation of Clayton Steam Generators vs. Fire-Tube Boiler Designs. To fully understand the many advantages of the Clayton design over other boiler designs, we must first recognize the differences in the operating principles of both units. The Clayton advantage is a direct result of the control of three fundamental aspects of steam production, control of water circulation, control of combustion gases and control of combustion

First and foremost, a boiler or steam generator is an energy exchange device. Through combustion the energy units in fuels are released and transferred into the water or fluids within the boiler.

The amount of heat that can be captured and transferred is a direct result of the design and operating principles of the particular unit.

Introduction Cont.

Control of Water Circulation. Clayton Steam Generators use a positive displacement pump to force water through a single tube and control circulation at all times. In contrast, fire-tube boilers make use of thermal circulation a less efficient principle. Consider the automobile in which the heat of the engine must be dissipated. If they still relied on thermal circulation, the radiator would have to be very large indeed to accomplish the heat dissipation from today's engines.

Control of Combustion Gases. Absorbing heat units out of the combustion gases is a function of the heating surface and control and direction of these gases. The Clayton design not only directs the combustion gases, but also controls the velocity of these gases for maximum heat absorption. Fire-tube boilers use a variety of passes or flue patterns directed by baffles to attempt to absorb as much heat as possible.

Control of Combustion. Clayton's specially designed burner ensures complete combustion because gaseous or liquid fuels are blended with combustion air at controlled ratios.

Heat transfer is in direct relation to the temperature differentials between the combustion gases and the boiler water

The Clayton counterflow design introduces the feedwater at the coldest point of the flue gases to provide the greatest overall temperature differential to assure maximum exchange of heat from the gases to the boiler water.

Clayton operating principles eliminate the need for large water volumes because only that water required for delivery of steam to the headers is heated.

The following chart presents a comparison of the physical characteristics of Clayton Steam Generators with those of several leading fire-tube boilers. Note that the Clayton unit is more compact, and lighter than any of these fire-tube boilers.

As a result of these design differences, the Clayton Steam Generator has many fuel-saving advantages over the larger fire-tube boiler. These advantages fall into several categories, including overall operating efficiency, rapid start-up and shut-down, nearly zero blowdown losses, better control of scale build-up, high pressure condensate heat recovery and maintenance efficiencies.

Each of these specific areas is covered in a separate section of this document

Comparison of the Characteristics of
Clayton Steam Generators with Conventional Boilers
(4500 kg steam/h units are used for comparison)

	Clayton	**Conventional Boilers**		
		1	2	3
Height (mm)	2890	3385	3010	3000
Length (mm)	2600	5615	5400	5450
Width (mm)	1640	2655	2770	2600
Floor space Required (m^2)	4.3	14.9	14.95	14.1
Operating Weight (kg)	4375	24600	24950	23500

FIGURE 1B

SECTION TWO
Controlled Forced Circulation

The Clayton Steam Generator design features controlled forced circulation, which provides the advantage of maintaining controlled fluid velocity in the heat coil tube. This is done using a specially designed water pump and coil tube pattern.

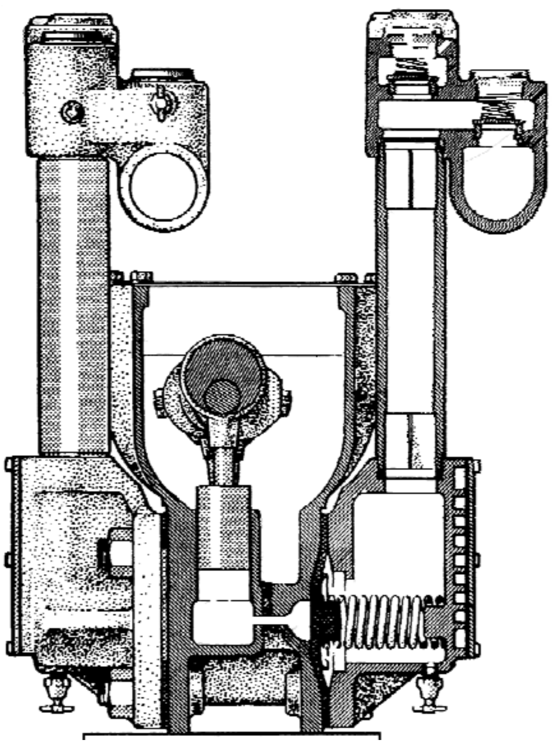


FIGURE 2A CLAYTON PUMP

The Pump. To achieve positive forced circulation, Clayton designed and manufactured pumps are used. They are positive displacement, diaphragm, packless types, so that water is prevented from coming into contact with vulnerable moving parts. This unique design will accommodate high temperature water (to 240^{0}C) and will even tolerate feedwater sludge with minimal maintenance. There are no packings to leak or piston liners to wear.

Pumps are sized for each model to deliver an excess of water at all times to maintain a wet coil. This ensures tube temperature control to prevent hot spots and scale precipitation. All Clayton Generators match water rates to firing rates.

These pumps are capable of maintaining a given water flow rate (within design limits) to assure the desired water-to-steam output ratio. Mechanical reliability, as well as the flow capacity stability of these pumps over varying pressure conditions, is one of the many reasons for the success of the Clayton monotube, forced-circulation design.

Coil Design. The Clayton coil design uses a single tube of graduated diameters to accommodate to the changing density of the fluid as it is heated while moving through the coil. The coil tube is wound into a spiral pattern with a controlled spacing between turns. This provides combustion gas velocity control. Attention to fluid and gas velocities results in the efficient heating coil section of the Clayton Steam Generator.

Steam Separator. Clayton's fixed vane (no moving parts) steam separator yields the dries steam available in industry today, typically less than 0.5 percent moisture at all loads (about 0.2 percent at full load). Superior steam separator action results from maintaining adequate steam and water velocity through the separator at all steam production rates. This assures energy-efficient dry steam even under highly variable load conditions.

The system of positive circulation permits quick start, rapid load changes and quick shut-down without overheating or overstressing the tubes. This added protection provides longer heating coil life with less down time for maintenance.

The Clayton coil design allows the use of standard boiler tubing with a minimum internal volume, better heating surface arrangements and high furnace loading (heat release rate per unit of gas passage volume). This design eliminates explosive possibility and reduces space and weight requirements.

The combustion chamber is water-wall lined for further weight and energy savings by reducing the refractory requirement and the heat that is normally lost during startup.

The controlled fluid velocity maintained in the heating coil allows for operation with a higher level of dissolved solids content in the steam generator and a reduced blowdown rate for added energy savings.

SECTION TWO
Controlled Forced Circulation Cont.

NATURAL CIRCULATION

Fire-tube or Scotch-Marine type boilers depend entirely on natural thermal circulation of water within the boiler shell. Water is convected upward between the tubes, usually faster in the rear of the boiler than in the front. Colder water flows downward along the shell, then upward around the furnace tubes to complete the pattern.

NATURAL CIRCULATION

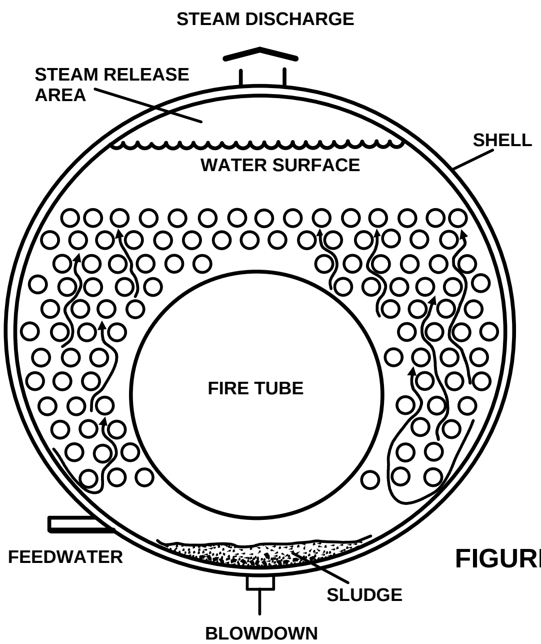


FIGURE 2B

The circulation is caused by the difference in density between the water and steam/water mixture. As the steam bubbles form, they rise to the water surface and release in the steam disengaging area.

There is an inherent lag characteristic with this system which limits operational flexibility such as quick start-up, rapid load change, and quick shut-down. For example, the circulation rate is different at minimum and maximum firing rates. It requires a few moments after a firing rate change to establish the equilibrium which involves circulation, tube wall temperature and other factors.

Steam and water storage capacity is large. Water surface area is also large to permit steam release with limited agitation to control moisture carry-over. Moisture carryover is maximum at full load (2 to 3 percent) and higher during sudden steam demand. In some instances, an external steam/moisture separator is required to maintain desirable steam quality.

Large water storage, at saturation temperature, presents an explosion hazard. For this reason, shell and tube maintenance is critical and inspection of their condition must be regularly scheduled. The necessary strong shell construction and required large water volume results in great weight and physical size.

The uneven tube temperatures which occur in rapid startups and sudden load changes cause high stresses in the fire-tubes, resulting in warped tube sheets, rear door leakage, shortened life and increased down-time for the unit.

Depending on design, the fire box, furnace or front and back sections (whichever is applicable) are lined with refractory cement which results in added weight and lost heat during start-up.

FORCED CIRCULATION

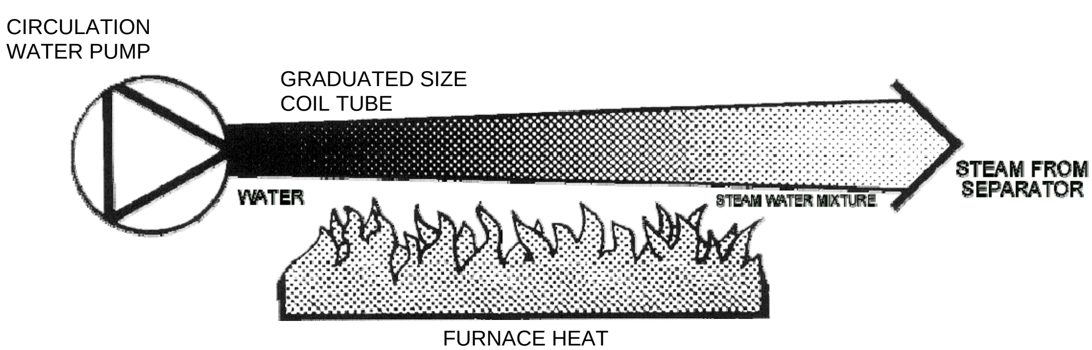


FIGURE 2C

SECTION THREE

Combustion Gas Control

The Clayton Steam Generator design provides a high degree of heat transfer capability because of the spirally wound pancakes of boiler tubing.

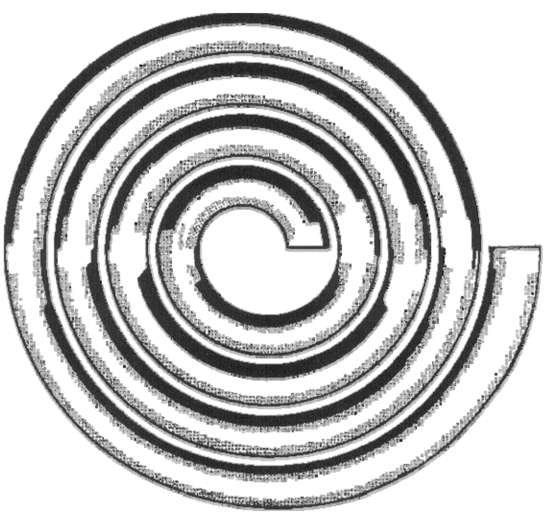
Combustion gases are passed upward from the combustion chamber assisted by the forced draft blower. The tube itself serves as a baffle by virtue of the turns of tubing staggered with respect to the adjacent pancakes. Gas velocities are controlled by changing the tube spacing of adjacent pancakes.

As the hot combustion gases release their heat to the circulating feedwater the gas volume decreases. The spacing between the tubes is decreased as the gas volume declines, maintaining the constant high velocity throughout the upward path of the flue gases, yielding maximized, controlled heat transfer.

Initial combustion gas temperatures are in the range of 1300 to 1650^{O}C. At the flue outlet the gas temperature will have dropped to approximately 180^{O}C, and to about one-third of its original volume.

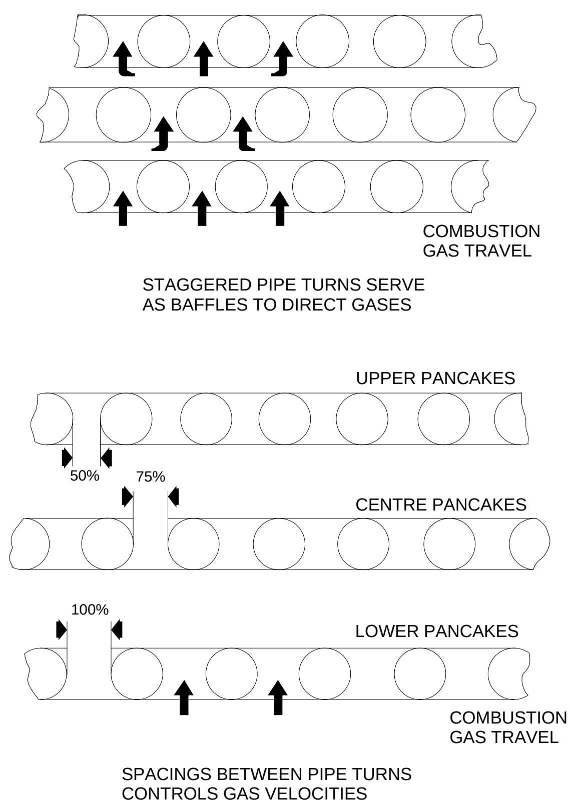
Because of the carefully calculated spacing between the tubing turns, the heat transfer rate is greatly increased. This design allows the Clayton Steam Generator to maintain a ratio of heating surface per boiler horsepower that is less than one half that of a conventional fire-tube boiler.

Flue gas economizing is accomplished with the tube spacing, thus eliminating the need for bulky, expensive stack economizers.



SPIRAL SPRING CONSTRUCTION
ELIMINATES EXPANSION EFFECT

FIGURE 3A



SPACING BETWEEN PIPE TURNS
CONTROLS GAS VELOCITIES

FIGURE 3B

SECTION FOUR

Counterflow Versus Parallel Flow

The superior efficiency of Clayton Steam Generators, compared to conventional fire-tube boilers, is a result of the counterflow coil design, which is made possible by forced water circulation.

The following illustration shows how the monotube counterflow design functions. Note that the exhaust gas leaves the portion of the heating coil that has the lowest temperature fluid -- the feedwater. For this reason, the exhaust temperature at low fire rates is actually lower than the steam temperature. It should be pointed out that the stack temperature of the Clayton Steam Generator is limited by the feedwater temperature. Stack temperature in the conventional boiler is limited to steam temperature.

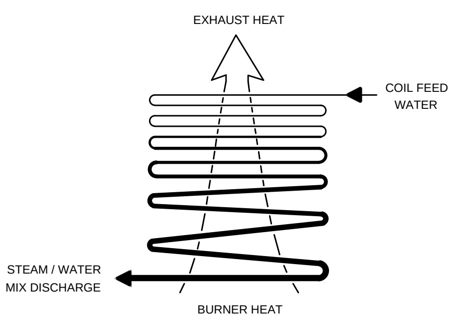
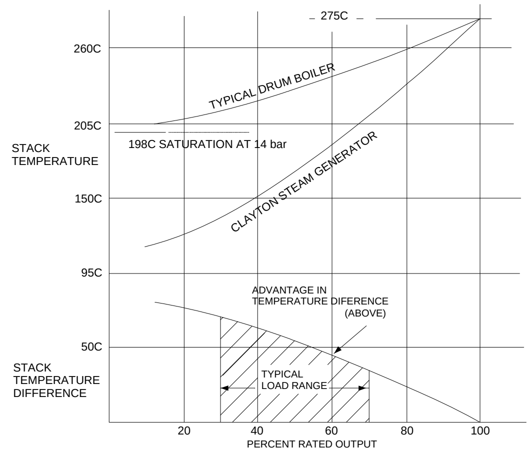


FIGURE 2A

In operation stack temperature is an indication of relative efficiency. The lower the stack temperature, the higher the efficiency -- assuming that other conditions such as CO_2, O_2 and radiation losses remain equal. At partial loading the stack temperature is lower because of the proportionally greater heat transfer surface, e.g. at 50 percent load, the heating surface per BTU transferred is twice that at 100 percent load. The stack temperature can only approach the temperature of the heating surface at the point of exit of the flue gases: steam temperature for the fire-tube, feedwater temperature for the Clayton Steam Generator. Because boilers operate at less than full rated load most of the time, partial load efficiency is more important than full load performance.

Figure 4B shows a graph of the typical stack temperatures for a conventional boiler and a Clayton Steam Generator, each at 14 bar steam pressure.

The graph shows the dramatic difference between the two temperatures at the lower firing ranges.



COMPARATIVE STACK TEMPERATURES
FEEDWATER 90C STEAM PRESSURE 14 bar

FIGURE 4B

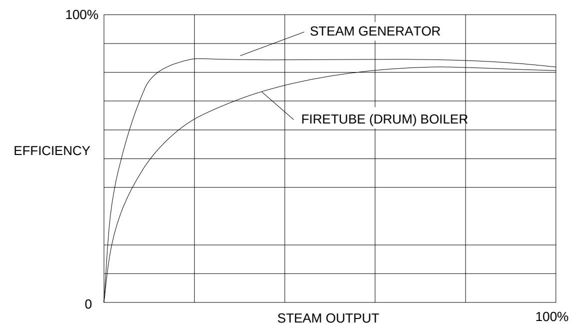


FIGURE 4C

Both types have essentially equal temperatures at 100 percent rating. At 50 percent rating the Clayton unit is 60^{O}C lower. At 20 percent rating the temperature is 85^{O}C lower. The lower portion of the graph shows the difference in temperatures and emphasizes the difference in the typical load range of 30 to 70 percent.

Figure 4C illustrates typical efficiencies for Clayton Steam Generators and fire-tube boilers at all loads from 0 to 100 percent rating. Note that for the Clayton unit the curve is higher at the lower firing rate than it is at 100 percent. This is partly due to the increasing ratio of heating surface to fuel input, partly due to relatively small heat radiation loss, but most importantly because of the counterflow coil that is unique to the Clayton design.At full load the efficiencies are virtually identical, for competitive reasons. With the fire-tube boiler, efficiency falls off at the lower rates because radiation loss is constant and therefore becomes an increasing detriment at low firing rates.

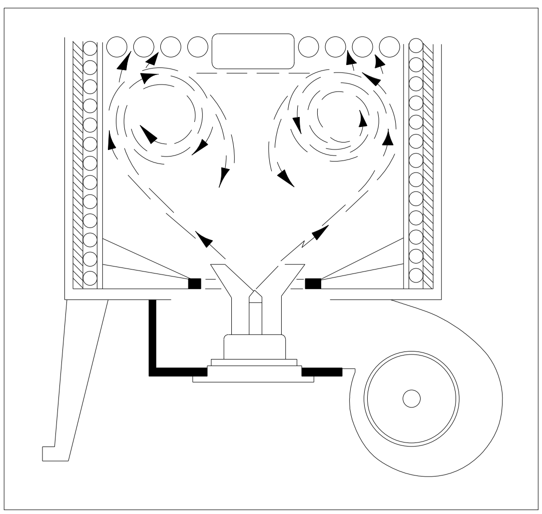
SECTION FIVE

Control of Combustion

The precise mixture of the components of combustion is one of the most critical steps in modern steam production.

In the Clayton Steam Generator gaseous or liquid fuels are blended with combustion air under mechanical control and electronic supervision at fixed ratios. Air, fuel and feedwater are modulated simultaneously to follow demands for steam.

The flame is confined to the combustion chamber by burner design. Combustion is completed before releasing the products of combustion across the tubes for heat transfer. The burner manifold is bottom mounted through the refractory base of the combustion chamber. High velocity combustion air enters around the burner manifold from below in a whirlpool vortex pattern, picking up the fuel from the burner and forming a heat shaped flame pattern. A portion of the flame folds back on itself in the center of the circular combustion chamber assuring complete combustion to provide maximum heat from the fuel to the boiler water.



FLAME PATTERN
FIGURE 5A

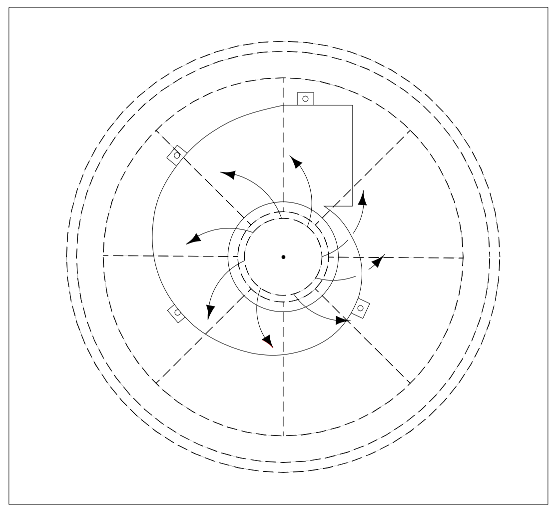
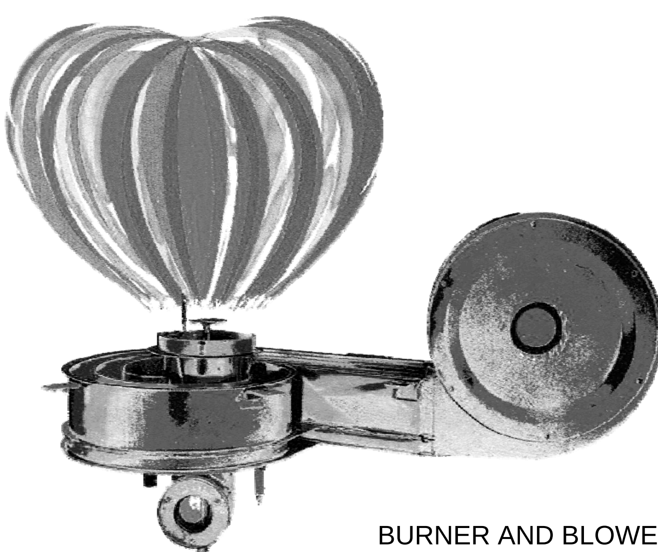


DIAGRAM SHOWING AIR PATTERN FROM BURNER VOLUTE
FIGURE 5B



BURNER AND BLOWER ASSEMBLY
FIGURE 5C

SECTION SIX

Operating Efficiency

What is efficiency? Terms like combustion efficiency, thermal efficiency, boiler efficiency, fuel-to-steam efficiency, input-output efficiency, are widely used. Combustion efficiency is generally understood to relate to burner performance and stack losses only. The other terms all imply the same, namely, the ratio of steam heat output to fuel heat input and more specifically, treat radiated heat from the boiler as a loss along with the stack heat loss. Unfortunately, in the press of competition the terms have been clouded by ambiguous statements. Even the expression fuel-to-steam efficiency - as clear as it appears, has been misused by one manufacturer by including the innocuous phrase "including radiation loss to the boiler room". This leaves the reader with the impression the published values are one thing but in fact are another higher value - not attainable in practice and not directly comparable with other manufacturers "fuel to steam" efficiency ratings.

Efficiency, from a consumer's point of view, is intended to show the relative cost of fuel per unit of steam delivered. The American Society of Mechanical Engineers (ASME) is a recognized authority and has established guidelines for boiler performance evaluation. The guidelines include consideration of all energy inputs and losses in the steam generation operation. Large power boilers are checked by these or similar procedures. In practice, smaller packaged boilers performance ratings do not include energy expenditure (losses) to auxiliary equipment, such as pump and blower motors, compressors, etc., because they total a small proportion of the fuel energy input, and thus are not significant in the economics of the choice of steam source.

Typically a simple steam heat output vs fuel heat input relationship (efficiency) is required. This ratio is desirable over the expected operating load range as well as at full load. Since boilers operate most of the time at less than 100 percent load rating, fuel costs cannot readily be compared unless this information is available and in comparable terms. Comparison between different makes of fire-tube boilers will not show greatly different characteristics, but different forms of steam generation such as fire-tube, water-tube and forced-flow coil-tube will differ appreciably. Ask the boiler vendor how the values quoted were measured and how the various losses etc. were treated. Ask for specific examples and at various loads, i.e. 25, 50, 75 and 100 percent.

It is important to remember when comparing efficiency claims that the percent increase in fuel costs will be greater than the nominal difference in efficiency. For example, 80 percent versus 75 percent efficiency at partial load, a 5 percent difference in efficiency, translates to a 6.25 percent savings in fuel usage.

$$1 - \frac{75}{80} \times 100 = 6.25\% \text{ savings in fuel usage.}$$

Thermal Efficiency

Direct Method. Clayton Manufacturing Company uses the "direct" method for determining thermal efficiency, i.e. the fuel rate and heat value input is measured and feedwater input rate and temperature and steam temperature (pressure) and quality are measured. (The accurate measurement of steam quality is possible usually only in laboratory conditions.) This method is ideal from the customer's standpoint because it indicates exactly what he gets - the heat delivered in DRY steam.

Indirect Method. Most manufacturers use the indirect method. That is, measure fuel rate and heat value input, and measure stack temperature and $C0_2$ output. The steam output is acquired by calculating the heat loss to the stack, adding to that the calculated heat loss by radiation and subtracting the sum from the heat input. This method is acceptable if certain conditions are complied with, i.e. methods of measurements and calculations.

If the boiler manufacturer uses combustion efficiency for his rating (a fairly common practice in Europe and particularly in cases where the boiler manufacturer uses a commercial burner, i.e. not of his own manufacture) then it would be fair to subtract 2 to 3 percent from his published value for radiation loss at high fire. A loss of 2 percent at 100 percent output would amount to 4 percent at 50 percent output.

Also, it is common practice in industry to ignore loss of heat to moisture in steam. Clayton guarantees less than 1 percent moisture. Laboratory tests show Clayton steam to contain about 0.2 percent to 0.5 percent moisture over the full range of loads and operating pressures. It is noteworthy that moisture claims are conspicuous by their absence in all other manufacturer's publications.

SECTION SEVEN

Rapid Start-Up

Less than five minutes to a full head of steam. Due to their small mass of steel and water, Clayton Steam Generators are designed to be fired from a cold start to a full head of steam in less than five minutes. In contrast, fire-tube boilers generally require at least an hour before they are fully productive.

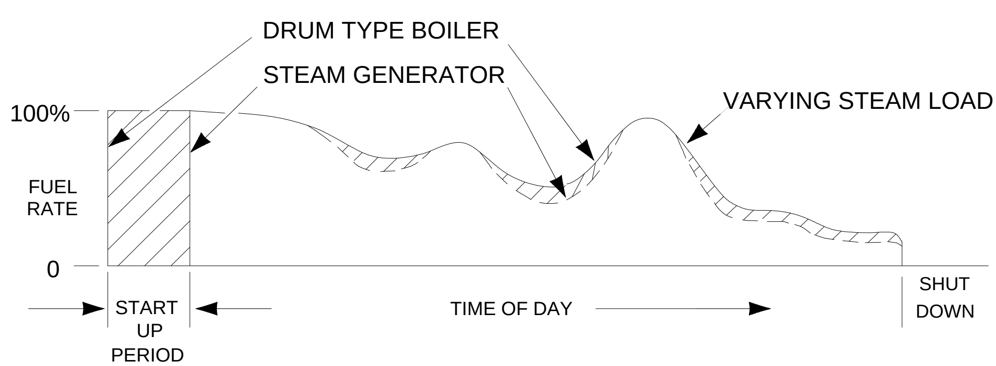
Losses due to extended start-up times with fire-tube boilers vary depending on frequency of start-up, boiler size and steam system. A conservative calculation of this loss would be to estimate a 60-minute start-up at the beginning of a nine-hour day:

1 hour ÷ 9 hours = 11 % start-up loss

Over a longer period of time, such as a year or even a month, it is clear that losses due to extended start-up times can amount to thousands of pounds.

In order to avoid long start-up periods each day, many operations keep their fire-tube boilers running at low levels throughout the night and bring them up to full fire each day. This also wastes fuel because of the dramatically decreased operating efficiency of the fire-tube boiler at lower firing levels.

The unique design of the Clayton Steam Generator lends itself to rapid start-up for two basic reasons : 1) The smaller mass of steel and water heats up quickly and evenly, and 2) the forced flow through the monotube coil ensures controlled temperature gradients, even with sudden load changes. Moreover, the monotube coil design is extremely flexible and therefore is not vulnerable to damage because of sudden temperature changes brought on by rapid start-up.



COMPARISON FOR TYPICAL DAY'S OPERATION

SECTION EIGHT
Blowdown

All boilers require blowdown for proper maintenance. However, blowdown losses for Clayton Steam Generators are generally less than for fire-tube boilers due to Clayton's significantly higher tolerance for dissolved solids. Lower blowdown rates translate to savings in three areas: less total water is used, less water treatment is required and less heat is wasted. The latter results in large fuel savings in total boiler operation. Figure 8A dramatically demonstrates the difference in blowdown flow rates of the Clayton Steam Generator versus the fire-tube boiler.

Clayton Steam Generators can tolerate up to 11 times more dissolved solids than fire-tube boilers (40,000 ppm as opposed to 3,500 ppm) without affecting moisture carryover. This is due to the method of steam-water separation. The Clayton design incorporates a high velocity centrifugal separator whose function is totally unaffected by high concentration of dissolved solids. In this design, water is quickly and forcibly removed from the steam flow path. With fire-tube boilers, on the other hand, dissolved solids are critical due to the tendency of the water surface in the steam drum to foam and surge over as solids concentration increases.

There is about a four to one concentration of dissolved solids from the coil inlet to the coil exit due to the generation of steam in the coil. Thus, if water entering the coil has a concentration of 5000 parts per million, it will contain 20,000 parts per million ath the core exit. For simplicity of monitoring and control, we refer to the concentration of the feedwater entering the coil.

In addition to affecting moisture carry-over, the amount of dissolved solids in the system affects scale formation on the heating surface. Due to the forced flow of water in the Clayton design, a much higher concentration of dissolved solids is tolerated without increasing scale build-up.

The Clayton standard design incorporates a continuous, proportional, automatic blowdown system. Water that is drained during blowdown is replaced by feedwater that contains a much lower level of dissolved solids. In this manner, an acceptable dissolved solids concentration is maintained while the steam generator is in operation. Blowdown water is drawn from the zone of highest concentration of dissolved solids, the steam separator.

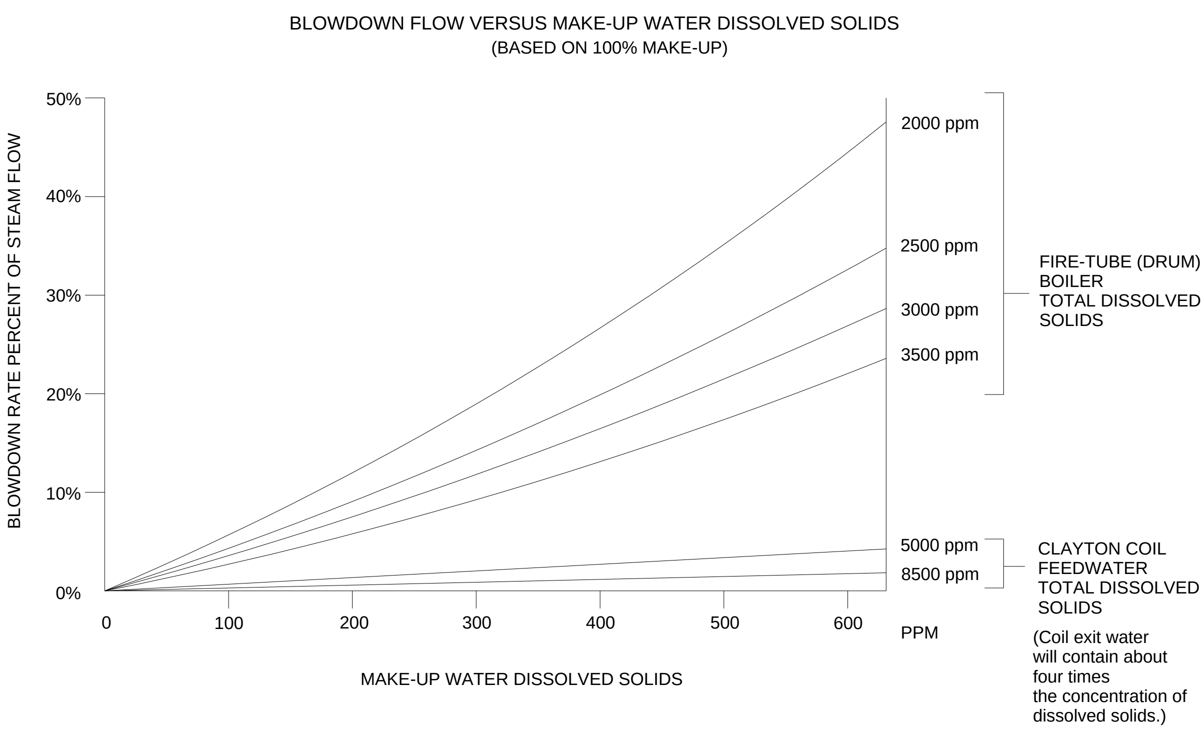


FIGURE 8A

SECTION NINE
Soot and Scale Control

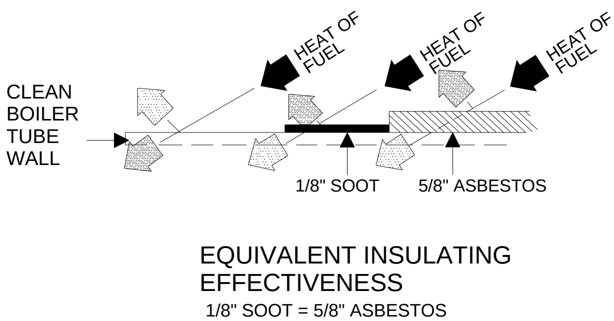


FIGURE 9A

Control of soot and scale build-up is a critical factor in maintaining fuel economy in any type of steam producing equipment. They act as insulation and inhibit heat transfer so that more fuel is required to generate the same level output. In fact, one-eighth of an inch of soot build-up provides approximately the same amount of insulation as five-eighths of an inch of asbestos.

It is easy to see how this accumulation of fire side soot and water side scale translates into increased fuel consumption and operating costs.

Soot. All oil fires create some soot. As soot accumulates in fire-tube boilers and steam generators, its presence is detected by increases in stack temperature. The Clayton Steam Generator is equipped with a standard built-in steam soot blower that is designed to be used in the course of normal operation. Soot blowing on a daily basis is encouraged to ensure continuing high level performance. Fire-tube boilers on the other hand do not offer steam soot blowing as standard equipment.

Typically, fire-tube boilers require extensive cleaning with rods and brushes - an expensive and time-consuming process, requiring boiler shut-down.

In contrast, the Clayton Steam Generator design allows soot removal during operation or by flushing the unit out with water without major shut-down. For this reason, soot removal is done much more easily on the Clayton unit, helping to maintain peak efficiency.

Scale. All steam generating equipment must be monitored for scale accumulation. Although it can be prevented through water treatment and maintenance, it is an advantage to be able to monitor for scale build-up and to remove it easily when it does occur.

Because of Clayton's unique monotube coil design, scale is positively detected during operation by simply observing feedwater pressure. Increased pressure means scale is forming. This is not the case with a multipass fire-tube boiler which must rely on stack temperature increases or shut-down and physical inspection to detect scale build-up.

If scale does accumulate in a Clayton Steam Generator, the forced flow design allows for a reverse flow "blowdown" to remove sludge and soft scale. In more severe cases hard scale may be removed by acid washing using the steam generator pump for circulating the acid. Scale removal in a fire-tube boiler is much more tedius and time consuming. Mechanical access to all areas is impossible and washing is difficult and uncertain. Clayton's monotube design ensures that every square foot of surface is washed.

In summary, all types of steam generating equipment are subject to impaired efficiency due to the accumulation of soot and scale. Clayton's steam generator design incorporates several features that make monitoring and removal of soot and scale faster and easier to accomplish. Clayton Steam Generators are designed to stay in peak operating condition throughout the most demanding work schedules. In contrast, fire-tube boilers have many disadvantages when it comes to monitoring and removing soot and scale, making it more difficult and expensive to keep them running efficiently.

1/16"	**of scale requires**	**15% more fuel**
1/8"	**of scale requires**	**20% more fuel**
1/4"	**of scale requires**	**39% more fuel**
3/8"	**of scale requires**	**55% more fuel**
1/32"	**of soot requires**	**12% more fuel**
1/16"	**of soot requires**	**29% more fuel**

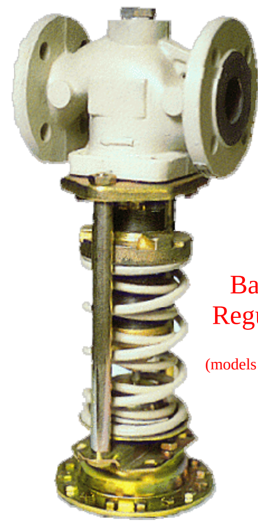
FIGURE 9B

BACK PRESSURE REGULATING VALVE

When steam loads fluctuate rapidly or when a sudden high steam demand occurs on any steam system, instability due to low steam pressure can be the result. The Clayton Back Pressure Regulator is designed to prevent this by ensuring that the pressure in the steam generator does not fall below a preset limit.

The Clayton Back Pressure Regulating Valve is a self-operated steam pressure regulator which is mounted in the steam outlet line from the Clayton Steam Generator. The valve taps it's actuating energy directly from the steam itself and ensures that a minimum upstream pressure is maintained.

If the upstream pressure falls below the set point the valve will starts to close until the minimum desired pressure is achieved. The Clayton Back Pressure Regulating Valve is extremely reliable and versatile.



Back Pressure Regulating Valve

(models may vary from the one shown)

ADVANTAGES

A sudden drop in steam pressure is undesirable for several reason. In particular it can produce 'flash steam' and water carryover. However by controlling the minimum pressure, the steam generator system is maintained in a balanced condition at all times. An added benefit of using the regulator is that it allows faster heat up after initial start and faster recovery following a period of overload.

By providing stable operation of the steam system the Clayton Back Pressure Regulating Valve also gives additional protection to the helical water coil.

AUTOMATIC START

The Clayton Back Pressure Regulator is indispensable where the steam generator is started automatically by means of a timer or by a manual switch. During automatic start-up the regulator will gradually open and allow steam into the main only when the pressure is at the correct set point. This avoids the need for operator intervention to manually open valves at the correct time.

MULTIPLE STEAM GENERATORS

On multiple steam generator installations the Clayton Back Pressure Regulator will provide stable operation on start-up and during operation and will maintain the system in balance. On multiple installations separate regulators are required on each steam generator.

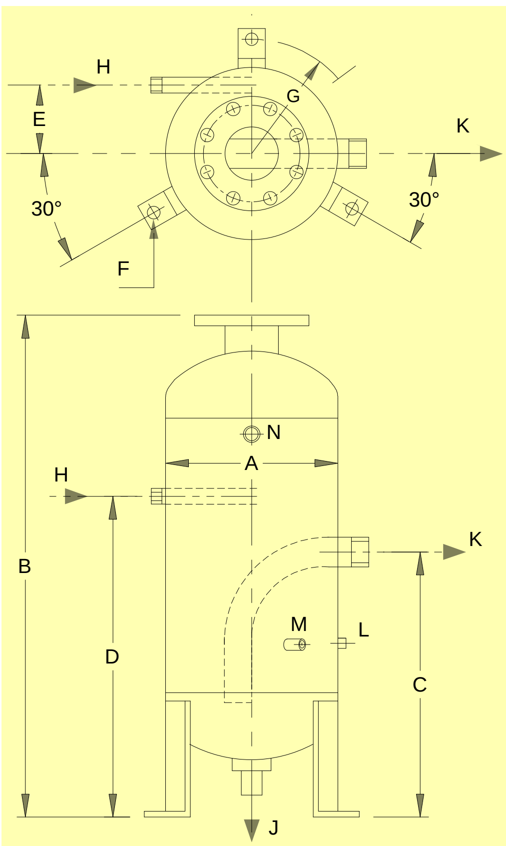
BLOWDOWN TANKS

IN COMPLIANCE WITH PM60 FROM THE UK HEALTH & SAFETY EXECUTIVE

The Clayton Blowdown Tank is designed to safely handle the discharges from the automatic blowdown on the Clayton Steam Generator. Water is collected in the sump of the vessel so that it cools naturally. Any additional water entering the tank replaces this standing water, which overflows into the outlet.

If required, a thermostatically controlled forced cooling system can be provided which will reduce the water temperature to around 40^{O}C. This system is particularly useful when several boilers are connected to the same tank.

Designed to PD5500:2000 Cat 3 (Lloyds inspected) PED compliant. Design pressure 7 barg. Design Temperature 171 Deg C. Material BS1501-151 Grade 430A



	135286UK	135287UK	135288UK	135294UK	135301UK
Standing Water (L)	25	40	90	200	350
Vessel Volume (L)	50	80	180	400	700

Dimensions

A (mm)	305	305	457	610	762
B (mm)	1100	1500	1595	1845	2085
C (mm)	625	825	900	1025	1150
D (mm)	750	1050	1100	1275	1450
E (mm)	120	120	175	235	290
F (Dia) (mm)	15	15	15	15	15
G (mm)	220*	220*	308*	385*	475*
*approximate					

Connections

H (Inlet)	1" BSP	1" BSP	1 ¼" BSP	1 ½" BSP	2" BSP
I (Vent)	100NB PN16	100NB PN16	125NB PN16	150NB PN16	200NB PN16
J (Cleanout)	2" BSP	2" BSP	2" BSP	2" BSP	2" BSP
K (Outlet)	1½" BSP	1½" BSP	2" BSP	2" BSP	80NB PN16
L (Cooling Water)	¾" BSP	¾" BSP	¾" BSP	¾" BSP	¾" BSP
M (Temp Sensor)	1" BSP	1" BSP	1" BSP	1" BSP	1" BSP
N (Press Gauge)	3/8" BSP	3/8" BSP	3/8" BSP	3/8" BSP	3/8" BSP
Inspection Opening	2" BSP	2" BSP	150NB PN16	150NB PN16	200NB PN16

SKID MOUNTED BOILER ROOMS

Clayton Industries have perfected a range of steam supply packages which have eliminated the traditional boiler house concept.

Because of the small size and weight of the Clayton design it is easily possible to provide the steam generator with the necessary tanks, pumps, water conditioning, blowdown, and other accessories on a skid base as a packaged unit.

The complete boiler system is pre-piped, wired, inspected and tested before delivery - ready for hook-up on site. A separate boiler house or permanent operator attendance is not required.

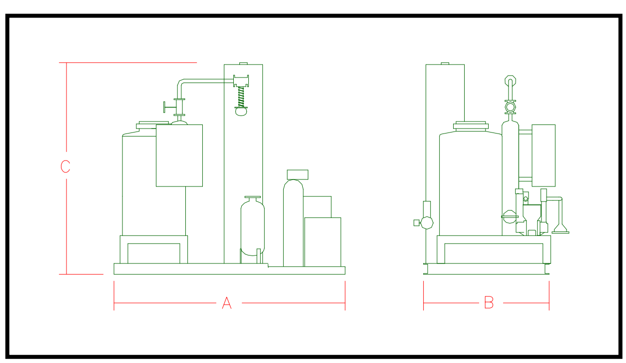
Options

As well as the standard equipment a number of options are available such as:-

- BP Regulating Valve
- Auto-Start
- Chemical Dosing
- Water Softener
- Sample Cooler
- Conductivity Control
- Hardness Control
- Bund Tank
- Blowdown Cooling

Approximate Overall Dimensions

Model	Equivalent Steam Output kg/h	A (mm)	B (mm)	C (mm)
E 10	157	2600	1500	2500
E 15	235	2600	1500	2500
E 20	313	2600	1500	2500
E 26	407	2600	1500	2500
E 40	626	2600	1500	2500
E 50	783	2600	1500	2500
E 60	939	3000	1600	2700
E 80	1253	3500	1600	2800
E 100	1566	3500	1600	2800
E 125	1957	3500	1600	2800



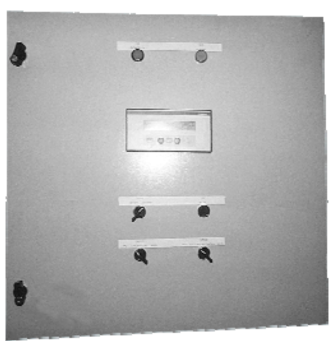
SEQUENCE CONTROL PANELS

CLAYTON PLC MASTER SEQUENCE CONTROL PANELS are easy to operate and provide flexible, sophisticated control and sequencing of two or more plc controlled steam generators. They work in conjunction with the individual control panels fitted to each Clayton Steam Generator assembly. The control is designed to harness the rapid start-up and response capabilities of Clayton Steam Generators to give process advantages to the user.

GENERAL DESCRIPTION

The Sequence Panel has only a small number of operator switches and a front mounted plc display. The display unit has two lines of 20 characters as well as keys for selecting operating conditions and adjusting parameters. The settings are password protected. Connection between the sequence panel and the generator panels is by means of modbus serial communication modules. Modbus communication can also be included in the sequence panel for client use.

A time clock is incorporated into the display unit which can be set to start and stop steam generation at different times each day.



SEQUENCING

A pre-determined sequence of generator operation is automatically performed based on steam demand, signalled by pressure fluctuations in the steam main.

Various sequences can be set on a manually adjusted generator priority by a menu system on the plc display. This means that, for example - when one generator is at a particular firing rate for longer than a set time the other generator can be arranged to come in when additional steam is required and the load can be shared - and so on.

Switching on steam generation from the sequence panel will therefore automatically run the entire system.

ADDITIONAL FUNCTIONS

●**Shut-down -** Actuation of the emergency stop on the sequence panel will shut down all steam generators.

● **Hotwell Level Control** – The hotwell water level is controlled from the sequence panel and a three-way switch on the panel front allows selection of automatic hotwell fill, manual fill or off.

● **Chemical Pump Control** – Control of hotwell chemical dosing takes place from the sequence panel. A three way switch is also provided for the chemical pump to permit selection of Automatic / Manual / or off.

● **Hotwell Heating** – Where hotwell heating is regulated by means of a steam valve this is controlled from the sequence panel.

● **Blowdown** – On systems with automatic blowdown the sequence panel will send signals to operate the automatic blowdown as required.

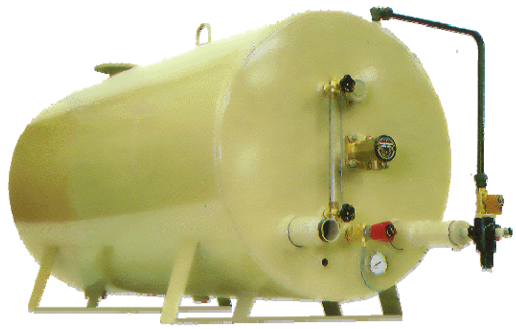
●**Alarm -** A common alarm signal is provided..

Clayton

CLAYTON HOTWELLS

The Clayton Hotwell has been specially designed for use as a multi-function vessel which will:-

- **Provide a Continuous Flow of Water to the Clayton Steam Generator**
- **Receive Returned Condensate**
- **De-gas the Raw Feedwater**
- **Blend Water Treatment Chemicals**



Horizontal Hotwell

The feedwater supply from the Clayton Hotwell can be fed to one or more steam generators. The water content is automatically maintained at the correct level to ensure sufficient supply for all phases of operation. The Clayton Hotwell also acts as a break tank.

Low pressure condensate returned from steam-using equipment can be fed directly into the Clayton Hotwell. A feature of the Clayton design is that condensate from the steam trap on the Clayton Steam Generator is recovered and directed to the hotwell to save water, energy and chemicals. The hotwell is also used as a collecting vessel to assist the rapid start-up that the Clayton Steam Generator is well known for.

Degassing of raw feedwater dispels oxygen to protect the metal surfaces of a boiler against corrosion. The Clayton Hotwell is an atmospheric partial deaerator in which the temperature is maintained at around 95^{O}C by means of an automatic steam heating system to supplement heat provided by any returned condensate. The high temperature and residence time in the hotwell dispels oxygen and carbon dioxide. The cost of chemical treatment is therefore reduced to a minimum.

The Clayton Hotwell is a convenient place to blend water treatment chemicals since the elevated temperature and residence time in the hotwell assists chemical activation.

CONTROLS AND FITTINGS

Every Clayton hotwell is provided with automatic controls to maintain water level and temperature. Indicators are also supplied so that the operator can monitor level and temperature. Condensate and steam for heating is injected under the water level by means of specially designed sparger pipes which are supplied as standard equipment.

HOTWELL SELECTION

Clayton Hotwells are either horizontal or space-saving vertical vessels and are selected to match the Clayton Steam Generator system being supplied. If the height of the hotwell does not provide sufficient head of water for the Clayton Feedwater Pump a small booster pumps can be used.

On systems where there is a large volume of returned condensate or high pressure condensate, consideration should be given to the use of a pressurise deaerator or receiver which can reduce running costs.

Vertical Hotwell

FEEDWATER TEST KIT

The Clayton Feedwater Test Kit **provides a simple and practical means of testing the quality of the feedwater to a Clayton Steam Generator.**

The kit comes complete with full instructions.

All types of boilers and steam generators must be supplied with properly treated water and the water quality must be regularly checked.

The water quality requirements for a Clayton Steam Generator are shown on a plaque which is fixed to every unit and the Clayton Feedwater Treatment manual explains, in detail, how the desired quality can be achieved.

The Clayton Test Kit includes the following items.

- **Sulphite Test Strips** – Sulphite is an oxygen scavenger and the presence of excess sulphite indicates the level of protection against oxygen.
- **Water-resistant pH Meter** – The pH level required must be maintained at the specified value to avoid corrosion.
- **Water-resistant TDS Meter** – Measures the amount of dissolved solids which are particles left behind once water has been evaporated.
- **Hardness Solutions** – Allow a simple test for hardness in the water and is a check that the water softening plant is functioning correctly.

Health and Safety Data Sheets are provided with each kit.

CLAYTON FEEDWATER SKIDS

Care and control of feedwater is essential for all types of boiler. Fortunately the feedwater requirements for the Clayton Steam Generator can be easily achieved using only a few main components.

FEEDWATER SYSTEMS

The correct selection of feedwater equipment will ensure trouble-free operation of the steam generating plant. Clayton offer a range of ancillaries which are matched to the particular Clayton Steam Generator and are designed and manufactured to the same high standards.

A common system - which suits most raw water types - includes a feedwater tank, a simple chemical dosing system, a water softener and a blowdown tank.

The equipment can be supplied as individual items to be installed separately or as a skid mounted package which will minimise site costs as well as installation time.

THE CLAYTON FEEDWATER SKID

The Clayton Feedwater Skid is a factory assembled packaged feedwater system. All of the skid mounted equipment is completely piped and wired before despatch. The package also includes all necessary valves, fittings, filters and controls.

The Clayton Feedwater Skid is designed and manufactured by our specialist engineers and is thoroughly inspected and tested before it leaves the factory.

Control of the skid mounted equipment is from an integral panel which can interface with the Clayton Steam Generator control system if required.

The use of a Clayton Feedwater Skid means that pipework and electrical wiring on site is reduced to a minimum.

Our engineers will be pleased to discuss the available options and agree the best solution for each application.

CONTAINERISED BOILER HOUSES

The Clayton Containerised Boiler House is a completely weatherproof steam supply system that can be quickly connected on site and easily re-located when required.

Because of the small size of the Clayton Steam Generator it can installed in a limited space along with all of the necessary boiler house ancillary equipment to provide an accessible and compact steam plant that has all of the advantages of the Clayton design and is safe to operate.

CONSTRUCTION

All containers are of a heavy duty construction and customised by Clayton with openings, flooring, bracketing and doors as necessary to suit the application.

The Clayton Steam Generator, along with other Clayton accessories 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 Intakes
- ❒ Automatic Dampers
- ❒ Cooling
- ❒ Frost Protection
- ❒ Lighting
- ❒ Fire Protection
- ❒ Lagging

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.

Clayton

CHEMICAL COMPOUNDS

Clayton Water Treatment Chemicals have been formulated to provide a combination of treatments in one compound.

In all boiler systems it is necessary to maintain the correct water conditions to maintain efficient and trouble-free operation. Clayton Chemical Compounds have been specifically developed to be suitable treatments for the feedwater supply to Clayton Steam Generators.

Clayton also supply chemical dosing pumps and chemical tanks designed for use with Clayton chemicals as well as a range of water softening plant and water quality testing equipment.

The following Clayton Conditioning Compounds are available.

- **A1 Compound** – This can be supplied as a powder or in a concentrated liquid form (Claytaliquid). It is normally used when the water supply is from a demineralised source. The powder form is supplied in 50 kg drums and the liquid is supplied in 25 litre drums.

- **A4 Compound** – This is the most commonly used Clayton Compound and is available in powder form. It is normally suitable when a towns water supply is being used. This is supplied in 50 kg drums.

The feedwater supply to boilers and steam generators must be adequately treated at all times. The concentration of chemicals and level of dosing required must be determined by regular tests and adjusted as necessary to ensure that the correct water quality requirements for the Clayton Steam Generator are being maintained.

These requirements are shown on a plaque which is fixed to every unit and the Clayton Feedwater Treatment manual explains, in detail, how the desired water quality can be achieved.

CHEMICAL DOSING SYSTEMS

Maintaining correct chemical treatment of the water supply is essential for all types of boiler to ensure long life and trouble-free operation. Clayton use a straightforward and convenient method of adding chemicals to the feedwater of a Clayton Steam Generator.

The chemicals are stored in a tank and fed into the feedwater by means of an adjustable microprocessor controlled diaphragm dosing pump which is specifically designed for this purpose.

CHEMICAL DOSING PUMP

The standard chemical dosing pump has an impact resistant, glass fibre reinforced body. The operating condition is clearly shown on the front by means of three LED indicators which are coloured green, yellow and red.

Manual adjustment is by means of a multifunction switch on the front and the pump can also be linked to the control panel of the Clayton Steam Generator to ensure synchronised operation.

The chemical dosing pump is virtually maintenance free and can provide accurate, reproducible metering by precise adjustment of the dosing frequency.

CHEMICAL STORAGE TANK

The Clayton chemical storage tank is of a rigid polyethylene construction supplied as part of the chemical dosing system and sized to suit the particular Clayton Steam Generator model. The tank has graduated marking on the side and the chemicals to be dosed are mixed in the tank as required.

The storage tank can be fitted with an optional low level switch that can be arranged to let the

operator know when the tank needs to be refilled.

WATER TREATMENT ADVICE

It is recommended that feedwater treatment should be continuous and water quality should be regularly checked. Clayton provide comprehensive feedwater treatment instructions and our engineers will be pleased to advise on treatment requirements.

Alternative chemical dosing systems can also be supplied to suit particular circumstances or to meet specific client requirements.

Clayton

CLAYTON WATER SOFTENERS

Water from most sources contains some hardness - which is calcium and magnesium that is picked up by rainwater as it filters down through the earth. Hard water is just as undesirable in boilers as it is in air-conditioning systems, cooling towers, refrigerating plants and other industrial equipment that uses hot water.

This is because some of the magnesium and calcium in the water reverts to it's solid state and changes to hard scale which can bake onto hot surfaces. In a boiler or steam generator, scale formation can cause reduced heat transfer, thermal stress, deposit corrosion and blockages.

SCALE PREVENTION

To prevent scale in a Clayton Steam Generator a dedicated water softener can be supplied as part of the steam raising plant. The principle behind the operation of a water softener is simple. The calcium and magnesium ions in the water are replaced with sodium ions and - since sodium does not precipitate out in the steam generator - the problems associated with hard water are eliminated. The sodium in a water softener is provided by salt which is dissolved in a brine tank to replenish the softener when required.

SOFTENER OPERATION

The heart of a water softener is a cylinder filled with small plastic beads (resin). As the incoming hard water passes over the beads the calcium and magnesium ions, which have a natural positive charge, are attracted to the beads which have a negative charge. The calcium and magnesium ions displace the sodium on the beads and the result is soft water at the outlet of the cylinder.

After a period of time - which depends on how hard the water is - the resin becomes saturated with calcium and magnesium and this must be removed and replaced with fresh salt. This is done by a regeneration cycle.

REGENERATION CYCLE

To regenerate a water softener the cylinder is first backwashed to flush out dirt and to expand and loosen the resin. A large volume of a strong salt solution from the brine tank is then passed over the resin to drive off and replace the calcium and magnesium. Finally the cylinder is given a slow rinse and then a fast rinse to remove any excess salt.

A water softener can be regenerated manually by the operator or it can be fitted with an automatic regeneration system which starts the cycle after a fixed length of time or when a pre-determined amount of water has been treated.

SOFTENER TYPES

Since the water softener will be out of action during the regeneration cycle, a single cylinder softener (simplex) must be sized so that it's daily operation will coincide with the operating time of the steam generator.

It the steam generator operates continuously, a twin cylinder (duplex) softener is needed so that the water treatment will continue in the second cylinder while regeneration is taking place in the first.


Duplex Water Softener

A water softener consists of one or more resin tanks, a controller to instigate and sequence the regeneration cycle, a valve arrangement to direct flow during normal operation and regeneration and a brine tank where salt is dissolved as necessary.

SIZING A WATER SOFTENER

The size of water softener required depends on the hardness of the water being treated and on the daily operating time. Our engineers will be pleased to advise on softener sizing. Where the water hardness figure is not available, a standard unit based on normal conditions can be offered and this should be checked once the actual water hardness is known.