HEAT RECOVERY STEAM GENERATOR DESIGNS TO MEET CURRENT AND FUTURE NEEDS

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Presented at
ABMA 1994 Clean Power for the 90s--
World Class Technology Conference & Exhibition

May 12, 1994

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1.0 Introduction

In the combined cycle process the heat recovery steam generator (hrsg) is a key element to the realization of high cycle efficiencies. The hrsg has proven to be a flexible, reliable connection piece between gas and steam turbine. These three components can be defined as key components of the process (1). The market development of the heat recovery steam generator system is very close to that of gas turbines for combined cycle plants. This development is in correleation to the worldwide orders for gas turbines (MW in 1979 = 100 %) (2) as shown in Figure 1. The curve shows the growing importance of the combined cycle process, especially since the beginning of the nineties. For more than a decade the orders per year nearly kept constant. This period was followed by-an increase to a--level, which is about 2.5-times higher than it was before.

An explanation for the mentioned increase is the growing confidence of clients into the advantages as

- low investment costs;
- short delivery periods;
- high-efficiencies;
- short start-up time and quick load changes;
- modular installation to reduce installation time

together with the growing confidence in the availability of the combined cycle process.

The mentioned business development is accompanied by a technical development of all components related to the heat recovery steam generator systems. The following items were the main areas of development during the past and they will remain the main items for future applications:

The development of higher capacities of gas turbines, up to 200 MW, leads to increased boiler dimensions together with a more complex water/steam system (dual pressure, triple pressure, reheating).

The development. of_coal gasification offers new possibilities for combined cycle plants. The heat recovery steam generator system is connected in a sophisticated manner with the heat supply for the gasification process.

Utility companies may use the heat recovery steam generator systems for the production of steam for the steam turbine together with heat supply for district heating. The widely varying levels of demand for electricity and district heat requires a highly flexible heat recovery steam generator system. This can be realized with supplementary firing systems al-lowing nearly independant operation of the district heat producing unit.

The installation of gas turbines in industrial plants together with. heat recovery steam generator systems for process steam supply requires reliability and availability to be as high as possible. Therefore independant operation of boiler to supply the process steam when the gas turbine is tripped or out of operation for maintenance is advantageous.

The integration of gas turbines and heat recovery steam generators into the water/steam process of conventional boiler plants. The heat recovery steam generator is either connected on the water, the live steam or on reheat side with the water/steam process of the conventional boiler plant.

The following examples of heat- recovery steam generator systems supplied by Deutsche Babcock show solutions to the different requirements of the above mentioned modes of applications.

2. Heat Recovery Steam Generator Systems for Advanced Applications

2.1.. Heat. Recovery. Steam Generator System behind a 200 Mw Gas Turbine in a Coal Gasification Process

In 1992.Deutsche Babcock.received...an.order..for a ..heat recovery steam generator system behind a 200 MW gas turbine, one of the largest in the world, which is included into a lignite coal gasification process. The boiler_ will produce high-pressure steam, reheated steam and will have a condensate preheater. The technical data are shown in Table 1. The general layout is shown in Figure 2 and the water/steam scheme in Figure 3. According to the gasification process requirements the water/steam side of the boiler is connected to various points of the gasification process. Additionally the flue gas from an ammonia vapor combustion system is fed to the boiler.

Boiler Design - Flue Gas

The high gas turbine exhaust flow requires a cross-section area of the heat exchange section of approximately 10 meters x 20.5 meters (32.8 feet x 67.3 feet). The heating surfaces are designed as prefabricated modules each with a width of 3.3 meters (10.8 feet), a length of 25 meters.(82 feet) and heights between 2.0 and 2.5 meters (6.6 and 8.2 feet). The maximum weight per module will be about 260 tons. The prefabrication of such modules, which requires special provisions for fabrication and transport, reduces the erection time to a minimum. The complete erection time for the heating surfaces at site will be 6 weeks only. In total the heating surfaces consist of 12 prefabricated modules. In the modules the finned tubes are supported by perforated plates. The tubes have a staggered arrangement. Every module is also provided with all connection bends, the necessary inlet and outlet headers and with anchor elements, which connect the modules with each other in vertical direction. The horizontal connection between the heating surface modules will be made by two circular welds for each header on.site.

In the direction of the flue gas flow the first set of modules consist of the interlaced heating surfaces of HP-superheater 2 and reheater 2, the HP-superheater 1 and reheater 1 are arranged also in an interlaced manner in the second module layer, which also contains the HP-evaporator. The third layer contains the HP-eco 2 and the MP-evaporator. Finally the forth module layer consists of the interlaced heating. surface tubes for MP-eco and HP-eco 1 and the condensate preheater.

During operation of the gas turbine with gas from the gasification process the ammonia vapor generated in the gasification process will be burned in a special combustor. The flue gas from that combustor will be fed-into the flue gas duct between gas turbine and boiler inlet. The NH_3-combustion-system is only in operation together with the gas turbine.

Boiler Design - Water/Steam

The HP- and MP-water/steam systems are designed as forced circulation systems. The HP-feedwater pumps will feed the feedwater to the HP-economizer, which is divided into HP--economizer 1 and 2.- for. thermodynamical..reasons- Downstream of the economizer the majority of the feedwater is drawn off and fed to the raw-gascooler of the gasification process. The remainder flows into the HP-drum and then to the HP-evaporator. Saturated steam is produced by the forced circulation evaporator system.

The steam from the HP-drum is mixed with saturated HP-steam from the raw-gas-cooler. As a result of the transfer to and from the raw-gas-cooler- there is a pressure difference of approximately 10 bar between the steam coming from the raw-gas-cooler and the steam produced by the forced circulation system. Before entering the HP-superheater the pressure of the saturated steam is reduced to the required boiler pressure. The water content generated by the expansion of the saturated steam has to be considered for the design of the superheater.

The HP-superheater is arranged together with the reheater in an interlaced manner.. According to the required process parameters and to prevent non-equal temperature distribution on the water-steam side the interlaced heating surfaces of HP-super-heater and reheater are divided into heating surface sections 1 and 2 with different interlacing arrangements.

The MP-system shows a design.similar to that one of the HP-system. Coming from the feedwater tank and leaving the MP-economizer the mass flow is also divided into two flows. The main part is transferred to- the raw-gas-cooler of the gasification process and the remaining amount is fed to the MP-drum of the boiler. After passing through the MP-evaporator and separating the water from the saturated steam the various flows are mixed together, i.e. saturated MP-steam from the boiler drum, steam from the steam turbine to be reheated, steam from the raw-gas-cooler and from the heat exchanger installed for use of the waste heat from the gas turbine compressor. For the mixing of the various steam flows a temperature difference of about 90 °C (194 °F) has to be considered. The total mix flow is passing the reheaters 1 and 2, which are arranged in an interlaced manner as explained before. The._r.eheated.steam is fed-back to the-reheat section of the steam turbine.

For both systems, HP and MP, a spray attemperator system is provided behind the second superheater stage to control the steam temperature. A steam warm-up-system is provided for the evaporator systems to realize minimum start-up times.

2.2 Heat Recovery Steam Generator System in a Combined Cycle Plant Producing Electricity and District Heat

For a heat- and power station in Dresden/Germany Deutsche Babcock is supplying three heat recovery steam generator systems behind three 60 MW gas.turbines. The water /steam cycle comprises a HP-system for steam generation and a hot water-heat exchanger for district heating. The technical data are summarized in Table 2.

The requirements the plant has to fulfill are the following:

The hot water produced by the heat exchanger is used for district heating with an existing hot water net and the HP-steam for electricity production by the steam turbine.
The mode. of operation is controlled by the demand of district heating.
Because the demand of district heating is independent and different from the electricity demand, it is necessary to have a separate and independent production of steam for both purposes.
Regarding the emissions of CO and NOx, the German codes for emission limits have to be fulfilled.
Even in case one gas turbine trips the boiler connected hereto has to supply a certain steam flow to the steam turbine. In this case the other two heat recovery boilers have to increase their steam flow by using the supplementary firing system to ensure the steam supply in a wide range of operation modes.

Beside these operational requirements following additional technical requirements have to be fulfilled, i.e.

the boiler has to-be designed-with completely uncooled ducts;
the maximum flue gas temperature is limited to 600 °C (1112 OF);
the boiler arrangement has to be designed with vertical flue gas flow because of limited space, and the height of the complete boiler house is restricted to 31 meters (101.7 feet) for architectual reasons;
the availability should be as high as possible;
the power consumption for boiler operation should be as low as possible;
caused by comparably low oxygen content of gas turbine flue gas-it-is--required to provide a direct supplementary air feed to the burner systems;
architectual considerations do not permit separate bypass stacks, which are a technical requirement;
the requirement of a possible operation without gas turbine results in the installation of a fd-fan.

To meet all-the mentioned requirements and to fulfill the various operation conditions a design was developed by Deutsche Babcock, which is shown in Figure 4.

Boiler Design - Flue Gas and Firing system

As it .can be-seen from Figure 4 the boiler is designed as vertical type to enable an arrangement within the limited space available. It is also shown that the boiler outlet is connected to the bypass stack to realize only one common stack per boiler. This solution provides the most economic design. A design for the bypass system connecting the bypass horizontally to a vertical boiler outlet duct would require a more complicate duct arrangement inside the boiler house exceeding the limited height of the boiler housing of 31 meters (101.7 feet).

The flue gases enter the horizontal duct directly after leaving the diffusor element. The T-box of the bypass is designed with two double multi-louvre dampers, one in the boiler inlet, the other in the bypass. Directly behind the boiler damper the supplementary air inlet for the first burner stage is connected to the GT-exhaust.duct. The first burner stage is installed in the horizontal duct to reduce the height of the boiler. The burner has a maximum capacity of about 40 MW. During operation of the first burner level the maximum flue gas temperature is limited to a maximum value of 600 °C (1112 °F), which will be ensured by the addition- of excess air. Therefore, uncooled ducts with external insulation are possible.

The first heating surface in the vertical part of the boiler is the second superheater stage. To prevent excessive peak temperatures of fins this heating surface is designed with bare tubes.- All. following heating surface tubes are designed with helical fins. The next heating surface passed by the flue gas and arranged in the same module is the first superheater stage. The next module consists of the evaporator and the economiser surfaces. Between both heating surface sections a maintenance and inspection space is provided.

To realize the independent district heating system a second burner stage with a capacity about 97 MW is installed in the vertical part of the heating surface casing to increase the enthalpy of the flue gas before entering the hot water heat exchanger. The duct burner can be operated in arrange of 10 : 1 and therefore enables a wide range for the operation of the district heating system. This burner level also has its own air supply and the maximum flue gas temperature is limited to 545 °C (1013 °F). Between the hot water heating surface and the burner equipment a free space area is provided to ensure an equal temperature distribution of the flue gas and to protect the heating surface tubes against excessive temperatures. Additionally the heating surface tubes in the lower part of the hot water heat exchanger is designed with serrated fins to prevent tensions inside the fins above the permitted level, because of the high temperature difference between flue gas (550 °C, (1022 °F)) and water (170 °C (338 °F)). Also the very strong temperature decrease of flue gas from 550 °C(1022°F) down to a stack temperature of about 100 °C (212°F) across a heating _surface. of only 2 meters (6.6 feet) height has to be considered. To prevent excessive tension and subsequent sagging of the bundle the design provides possibilities for thermal expansion inside the module. Directly behind the supporting bars the flue gas duct is connected horizontally to the common stack.

Because of the second burner stage the boiler has two fix points in the vertical direction. The lower fix point is located above the suspension anchors for the steam producing heating surfaces. Therefore the supporting level of the second burner stage has a minimum thermal movement. From this point the lower part of the boiler is suspended and expands downwards. The second fix point is located in the level of the supporting bars for the hot water heating surface.

The hot water heat exchanger also expands downwards from that point. To compensate this expansion towards the lower fix point of the HP-steam system a compensator is installed between upper and lower part of the boiler.

Boiler Design - Water/Steam

The feedwater coming from the.feedwater tank enters the HP-ecnomizer and from,there via connection pipes to the HP-drum. The evaporator is fed from the HP-drum via downcomers. A start-up circulation pump is installed in a bypass line parallel to the downcomers.

All heating surface tubes in the vertical duct section are arranged horizontally. But nevertheless the evaporator circulation system is a natural one. The density difference of the evaporator system between the downcomers and the water/steam mixture of the evaporator bundle as well as the connection to the drum result in a natural circulation even without circulation pumps. The proper design of the system considers a -sufficient geodatical height between drum and evaporator bundle. Only for start-up and low load operation is.-a circulation pump installed. After start-up and in full load operation the boiler is operated with natural circulation. Operation experience and research by Deutsche Babcock as well as investigations done by others (3) have proven the reliability of this design. The advantage of lower power consumption for conventional design of natural circulation boilers is now also achieved by vertical type of heat.recovery boilers.

The saturated steam from the evaporator system is fed to the superheater, which is of a two stage design. Between stage one and two a spray type attemperator controls the live steam temperature to-limit.the-steam temperatures during GT peak load or operation of the::supplementary firing system.

The hot water heat---exchanger generates the required heat for the district heating system. Because of the comparatively low inlet temperature of the water this system enables a low flue gas temperature at boiler outlet. To ensure a water inlet temperature, which will be above the sulphur dew point, a recirculation system is installed to be operated, if the gas turbine is fired with oil.

2.3 Heat Recovery Steam Generator System in an Industrial Process

For the production of process steam used in an Italian refinery Deutsche Babcock supplied two heat recovery steam generator systems. The technical data are summarized in Table 3 and the principal arrangement is shown in Figure 5.

To keep the availability of the refinery process as high as possible it was requested to design a boiler, which can be operated with flue gas from the gas turbine as well as with a fd-fan. Both operation modes shall generate the same capacity of steam. Switching over. from one mode to the other should be possible without significant change of the steam flow. Additionally it was required to operate the supplemetary firing system with heavy -fuel. oil .from-the refinery process.

Boiler Design - Flue Gas and Firinq Svstem

The boiler is-of..horizontal type with vertical heating surface tubes. Between gas turbine and boiler a bypass is provided. The flue gas coming from the gas turbine enters via the burner equipment the combustion chamber. The combustion chamber is built by water-cooled membrane walls. The membrane walls are welded gas-tight. The length of the combustion chamber is designed according to the required combustion time of heavy fuel oil to prevent generation of soot and to protect the first tubes of the heating-surface against flame contact.

At the outlet of the combustion chamber an evaporator grid is installed to-protect--the-superheater bundles against radiation. Downstream of this evaporator grid the flue gas passes the superheater, the evaporator and the economizer. At the boiler outlet a multi-louvre-damper is arranged. In the sections of high flue gas temperatures the heating surface casing is of membrane walls construction. From the evaporator outlet up to the boiler outlet-the-boiler.-casing-is made by uncooled ducts with external insulation.

The boiler includes a fd-fan, which is located below the boiler. The ambient air is fed via an air duct to the burners at the boiler inlet. Two burners are installed to burn heavy fuel oil and refinery gas. The burners allow a large control range of approximately 40: 1 and they have a very low pressure drop on the flue gas side of only 2 mbar (0.8 i.w.g.).

In case of a gas turbine trip or of a scheduled gas turbine shut down.the automatic switch over from gas turbine operation to fd-operation takes place as it is shown in Figure 6. Immediately after shut-down of the gas turbines the ignition burners will start. After the ignition flame is detected the bypass damper begins to open, the fd-fan starts and the inlet vanes are adjusted into ignition position. When from the bypass damper the signal "open" is detected the boiler damper at the boiler inlet begins to close and the throat dampers of the burners also close. With detected signals "closed" from the boiler inlet **damper and "running" from the fd-fan the ambient air damper opens. With fully opened ambient air damper the main burners are started automatically and the ignition burners are switched off. The complete switch-over procedure takes only a time of 35 seconds.** In **a similar manner the switch-over procedure takes place from fd-operation to gas turbine operation. The switch-over is also possible, if gas turbine is in operation together with the fd-fan.**

Boiler Design - Water/Steam

The boiler is designed with a natural circulation system. Coming from the feedwater tank the feedwater passes the economizer with fin tubes in counterflow to the flue gas and enters the drum. Via *downcomers and connection pipes the drum is connected to the evaporator system. The evaporator system consists of the membrane walls for side walls, roof and floor of the combustion chamber, of the evaporator grid made from bare tubes and of the evaporator bundles made of fin tubes. All evaporator heating surface tubes are built as risers. The saturated steam is conveyed to the superheater, which also consists of fin tubes. An attemperator system behind the superheater outlet controls the steam temperature.

During the switch-over-procedure described above the behavior of steam flow, steam **temperature and steam pressure can be obtained from Figure 7. As it is shown by the curves pressure and temperature.are kept nearly.constant. The variations of about - 1 bar (14.5 psi) for the pressure and about + 3°C (5.4 °F) for the temperature do not influence the refinery process. The variation in steam flow depends on the mode of operation during the switch-over.** The **deviation is always acceptable by the refinery process and will occur only during a short period of about 1 minute.**

3. Conclusions

The different purposes heat recovery steam generator systems are used for often require a special design. Also technical requirements provided by-the clients._ create the need for a wide range of design solutions. The tailor-made design results in high efficiencies and a very flexible heat recovery steam generator system.

Minimum power consumption even with vertical boiler design and limited space available has been achieved by a design of the evaporator system without the necessity of circulation pumps during normal operation.

A sophisticated arrangement of separated burners enables a high flexibility, between the various demands of steam for electricity production and hot water for district heating. A special design results in a fired boiler with uncooled ducts made from non-austenitic materials with external insulation.

A heat recovery steam generator system with supplementary firing with fd-fan designed for the requirements of a refinery process ensures constant steam supply without gas turbine in operation and also during the switch-over procedure from GT- to fd-operation mode.

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Table 1: Technical Data of Heat Recovery Steam Generator System behind 200 MW Gas Turbine Fired with Gas from a Coal Gasification Process

Flue gas flow from GT	kg/s	611.63
Flue gas temperature at boiler inlet	°C	549.4
Flue gas temperature at boiler outlet	°C	115
HP-steam flow	kg/s	104.6
HP-steam operating pressure	bar	113
HP-steam temperature	°C	525
MP-steam flow	kg/s	117,3
MP-steam operating pressure	bar	30,5
MP-steam temperature	°C	525
Condensate preheater mass flow (without recirculation)	kg/s	127,9
Condensate preheater inlet temperature (without recirculation)	°C	49
Condensate preheater outlet temperature	°C	75

Table 1(E): Technical Data of Heat Recovery Steam Generator System behind 200 MR Gas Turbine Fired with Gas from a Coal Gasification Process

Flue gas flow from GT	pph	4,854,238
Flue gas temperature at boiler inlet	°F	1021
Flue gas temperature at boiler outlet	°F	239
HP-steam flow	pph	830,164
HP-steam operating pressure	psia	1639
HP-steam temperature	°F	977
MP-steam flow	pph	930,958
MP-steam operating pressure	psia	442
MP-steam temperature	°F	977
Condensate preheater mass flow (without recirculation)	pph	1,015,086
Condensate preheater inlet temperature (without recirculation)	°F	120
Condensate preheater outlet temperature	°F	167

Table 2: **Technical Data of Heat Recovery Steam Generator System in a Combined Cycle Plant Producing Electricity and District Heat**

Flue gas flow from GT	kg/s	201.54
Flue gas temperature at boiler inlet	°C	526
Flue gas temperature at boiler outlet	°C	100
HP-steam flow	kg/s	32.0
HP-steam operating pressure	bar	79
HP-steam temperature	°C	500
District heat exchanger mass flow	kg/s	227.1
Inlet temperature	°C	80
Outlet temperature	°C	170
Capacity of firing system 1	mw	40
Capacity of firing system 2	mw	97
Co-emission, 3 Vol.-% 02	mg/mN-3	100
NOx-emission, 3 Vol.-% 0.	mg/mN-3	100
Fuel for supplementary firing system		gas/diesel oil

Table 2(E): Technical Data of Heat Recovery Steam Generator System in a Combined Cycle Plant Producing Electricity and District Heat

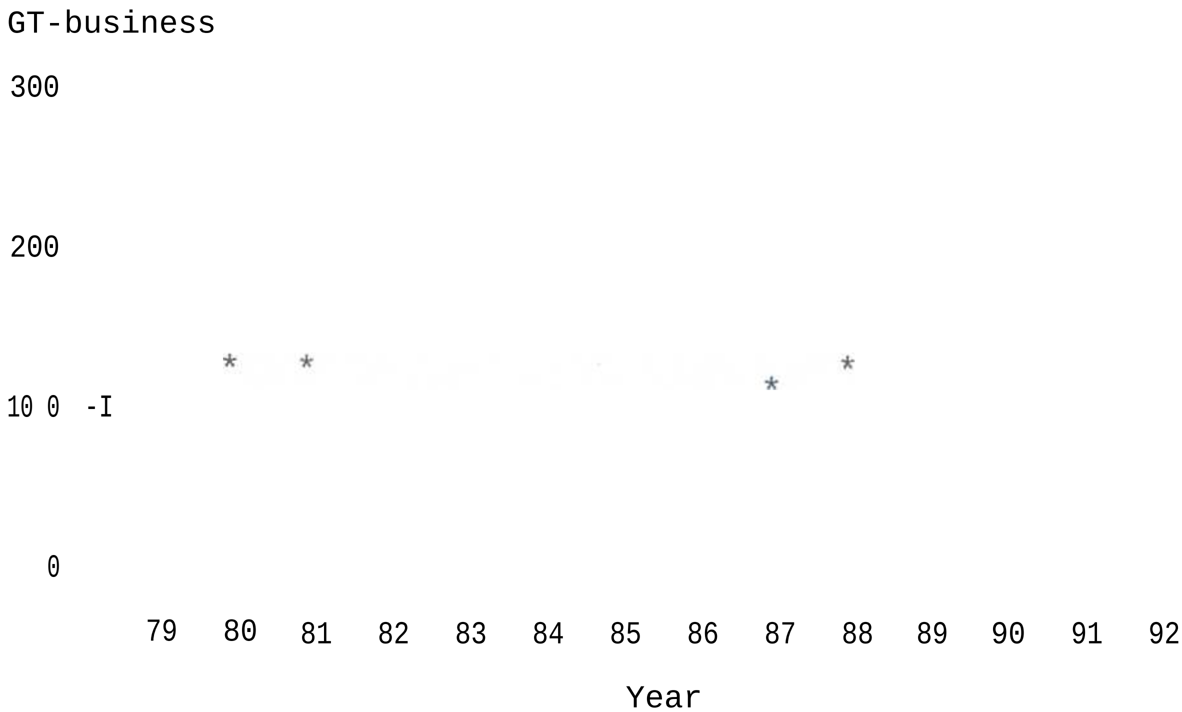
Flue gas flow from GT	pph	1,599,534
Flue gas temperature at boiler inlet	°F	979
Flue gas temperature at boiler outlet	°F	212
HP-steam flow	pph	253,970
HP-steam operating pressure	psia	1145
HP-steam temperature	°F	932
District heat exchanger mass flow	pph	1,802,393
Inlet temperature	°F	176
Outlet temperature	°F	338
Capacity of firing system 1	mw	40
Capacity of firing system 2	mw	97
Co-emission, 3 Vol.-% 02	mg/mN-3	100
NOx-emission, 3 Vol.-% 0.	mg/mN-3	100
Fuel for supplementary firing system		gas/diesel oil

Table 3: **Technical Data of Heat Recovery Steam Generator System in an Industrial Process**

Flue gas flow from GT	kg/s	127.2
Flue gas temperature at boiler inlet	°C	476
Flue gas temperature at boiler outlet	°C	160
Steam flow with GT in operation	kg/s	16.7
Steam flow with fd-fan in operation	kg/s	16.7
Steam flow with GT and fd-fan in operation	kg/s	33.4
Steam temperature	°C	310
Steam operating pressure	bar	17
Fuel for supplemetary firing system		heavy fuel oil

Table 3(E): **Technical Data of Heat Recovery Steam Generator System in an Industrial Process**

Flue gas flow from GT	pphl,009,530	
Flue gas temperature at boiler inlet	°F	889
Flue gas temperature at boiler outlet	°F	320
Steam flow with GT in operation	pph	133,075
Steam flow with fd-fan in operation	pph	133,075
Steam flow with GT and fd-fan in operation	pph	266,150
Steam temperature	°F	590
Steam operating pressure	psia	247
Fuel for supplemetary firing system		heavy fuel oil



* - Gas Turbine Business (MWe), worldwide, 1979 = 100

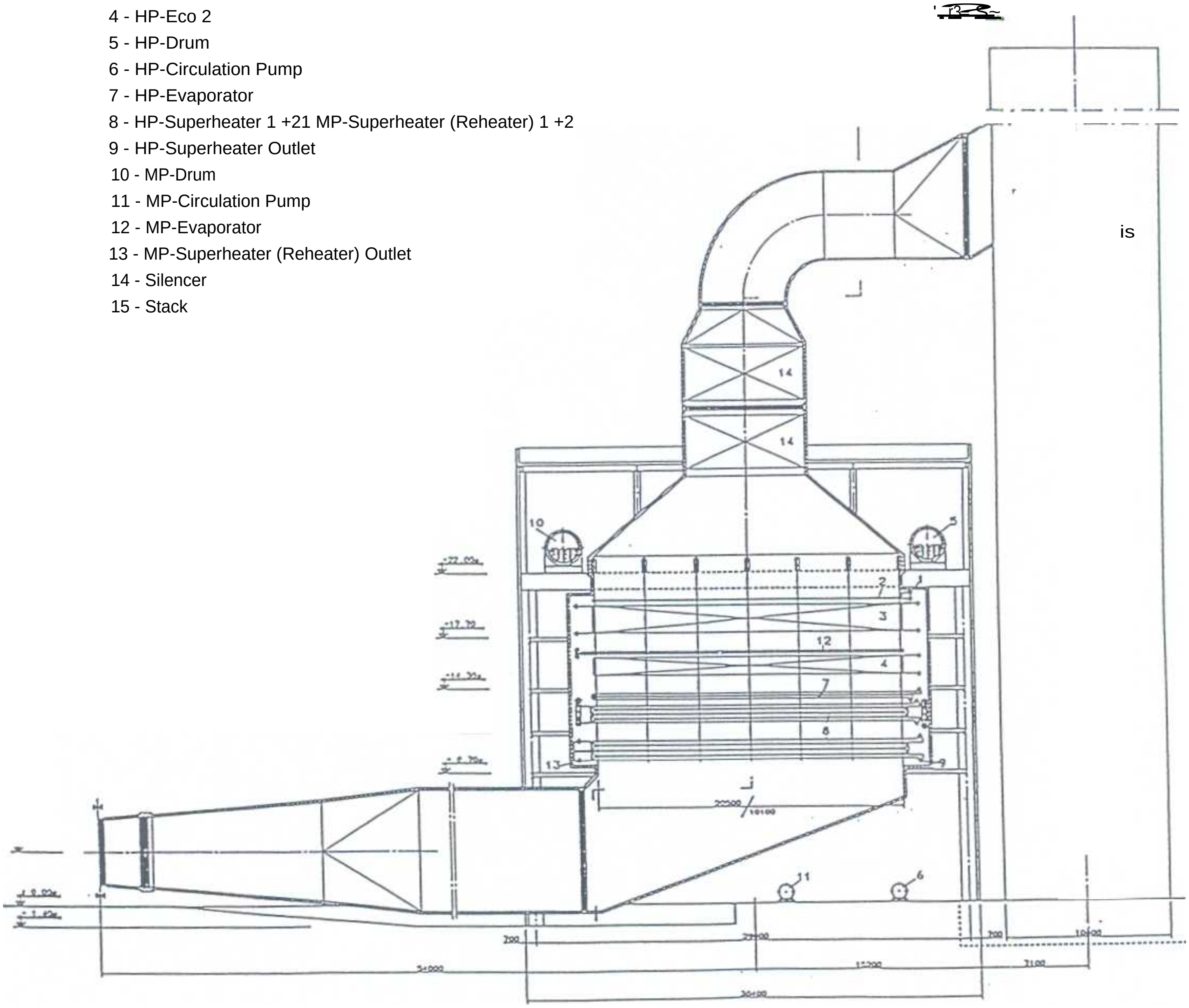
BUSINESS DEVELOPMENT OF GASTURBINES

FIGURE 1

R EY

BABC<#>CK
DEUTSCHE t3ABCO(X
KRAFTWERKSTECHNIK
GMBH

1 - Condensate Preheater Inlet
2 - Condensate Preheater
3 - HP-Eco 1 / MP-Eco
4 - HP-Eco 2
5 - HP-Drum
6 - HP-Circulation Pump
7 - HP-Evaporator
8 - HP-Superheater 1 +21 MP-Superheater (Reheater) 1 +2
9 - HP-Superheater Outlet
10 - MP-Drum
11 - MP-Circulation Pump
12 - MP-Evaporator
13 - MP-Superheater (Reheater) Outlet
14 - Silencer
15 - Stack



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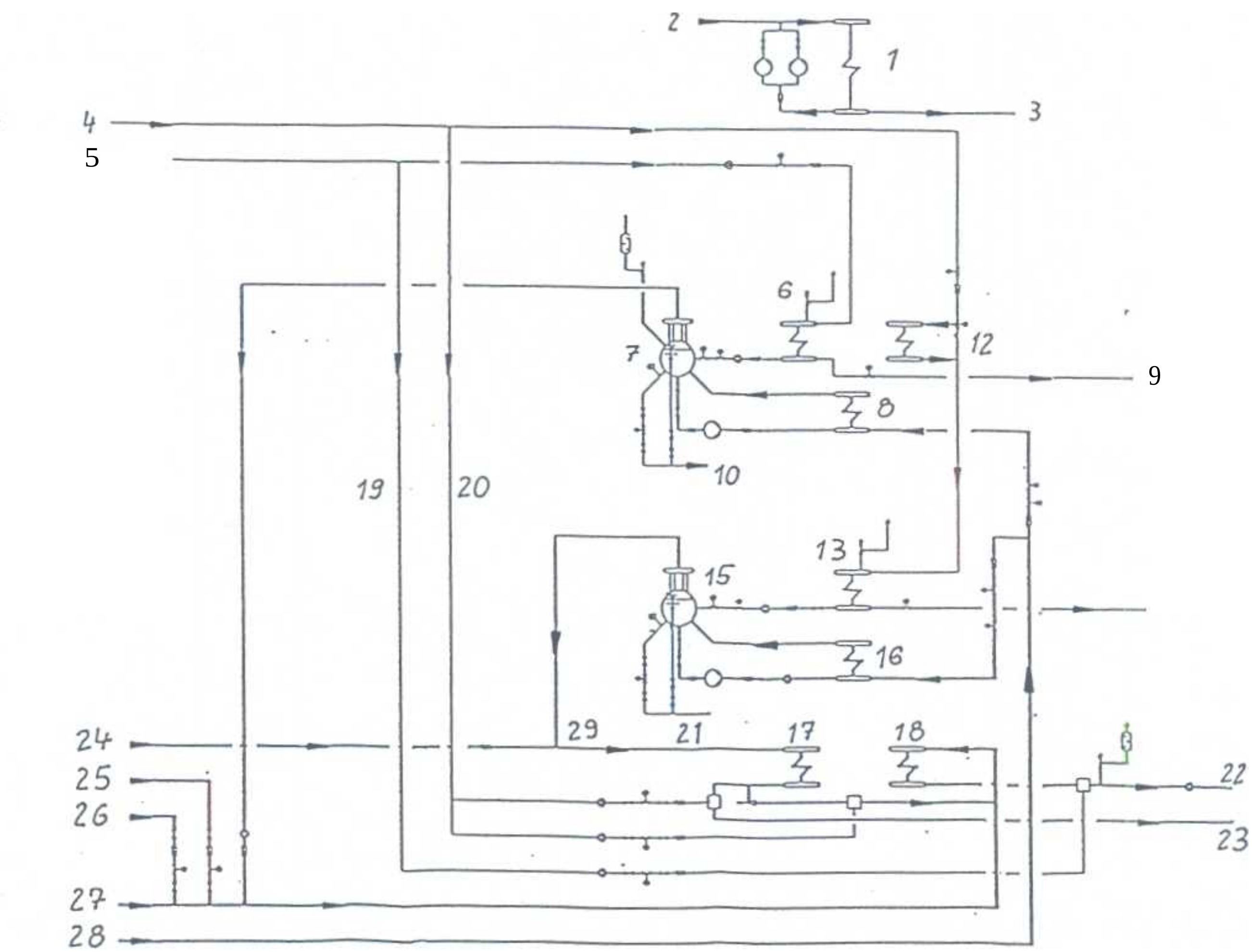
HEAT RECOVERY STEAM GENERATOR BEHIND A 200 MW GAS TURBINE IN A COAL GASIFICATION PROCESS - BOILER DRAWING

FIGURE 2



1 -Condensate Preheaterwith Recirculation
2 - Condensate from Process Gas Cooling
3 - To Feedwatertank
4 - HP-Feedwater
5 - MP-Feedwater
6 - MP-Eco
7 - MP-Drum
8 - MP-Evaporator
9 - MP-Feedwater to MP-Raw Gas Cooler
10 -To Flashtank
11 - MP-Saturated Steam Mixing
12 - HP-Eco 1
13 - HP-Eco 2
14 - HP-Feedwater to HP-Raw Gas Cooler
15 - HP-Drum
16 - HP-Evaporator
17 - HP-Superheater 1 +2
18- MP-Superheater (Reheater) i +2
19-To MP-Attemperator
20 - To HP-Attemperator
21 -To Flashtank
22-To MP-Steamturbine (Hot Reheat)
23-To HP-Steamturbine
24 - HP-Steam from HP-Raw Gas Cooler
25 - MP-Steam from MP-Raw Gas Cooler
26 - MP-Steam from Process Equipment
27-MP-Steam from Steamturbine (Cold Reheat)
28 - Steam for Warm-Up System
29-HP-Saturated Steam Mixing

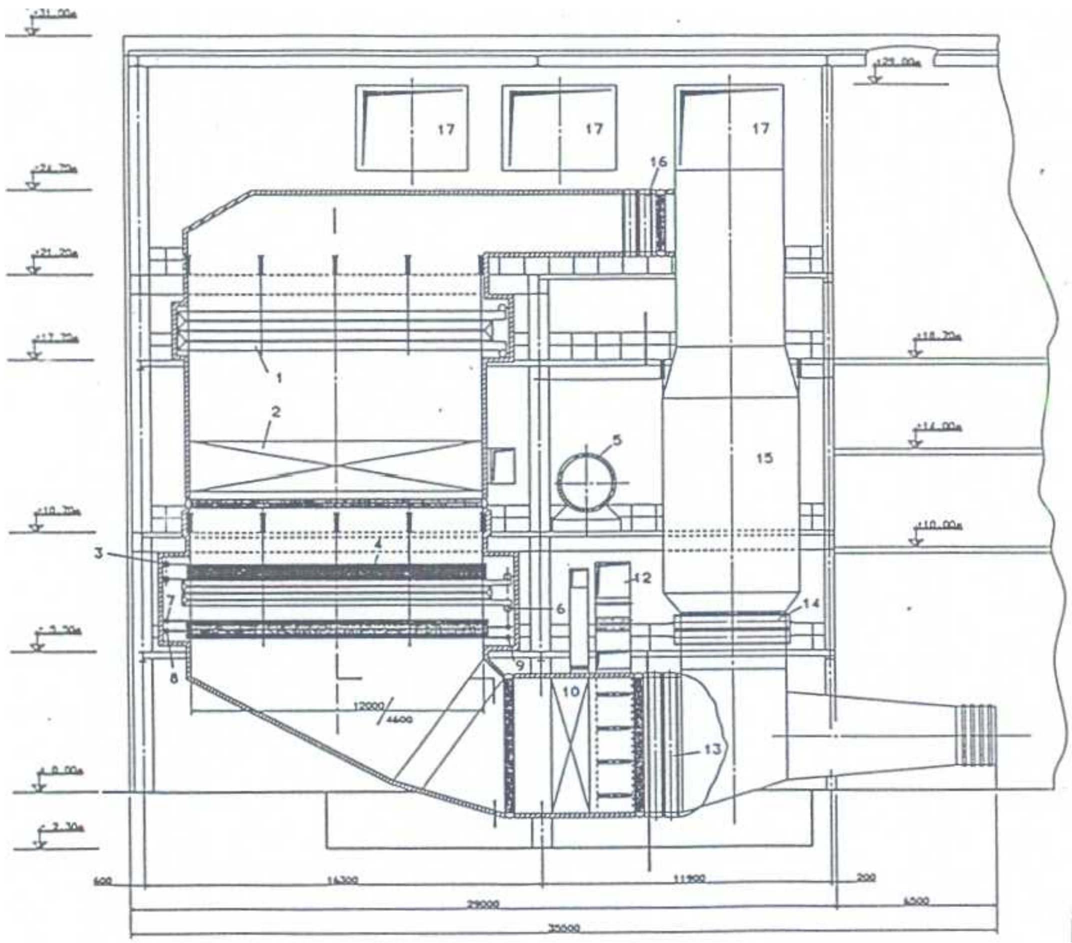
po- - r3

HEAT RECOVERY STEAM GENERATOR BEHIND A 200 MW GAS TURBINE IN A COAL GASIFICATION PROCESS - WATER/STEAM SCHEME

FIGURE 3

C~> RILEY

BABC4,'>CK
DEUTSCHE B,AB000K
KRAF TINERKSTECHNIK
GMBH



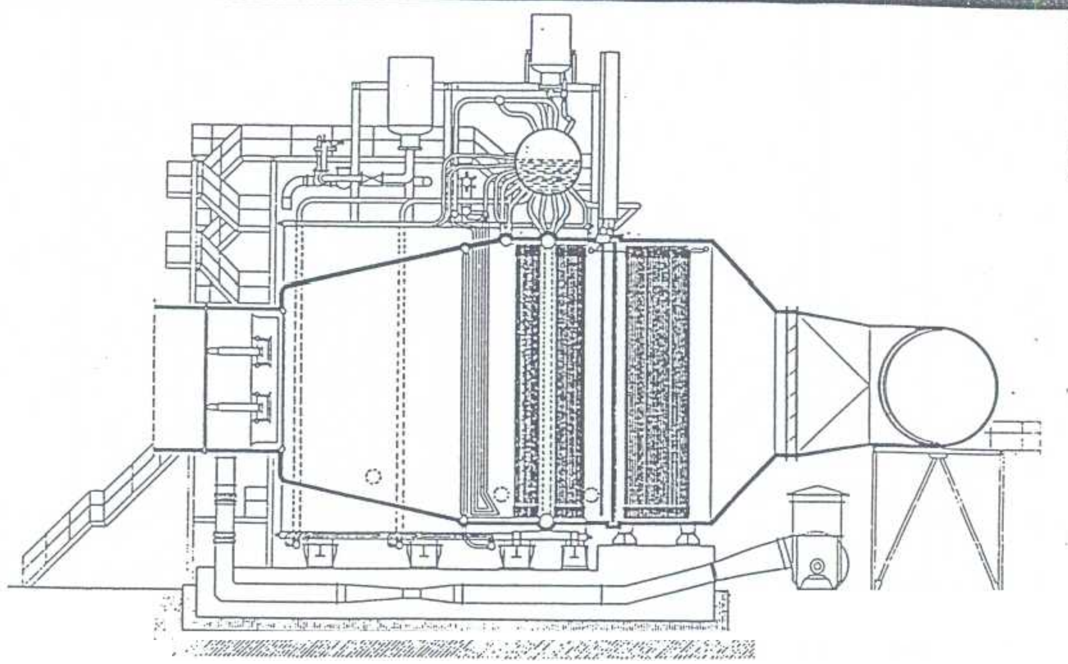
1 - District Heat Heating Surface
2 - Supplementary Firing System 2
3 - Eco Inlet
4 - Economizer
5 - Drum
6 - Evaporator Inlet
7 - Superheater 1 Inlet
8 - Superheater 2 Inlet
9 - Steam Outlet

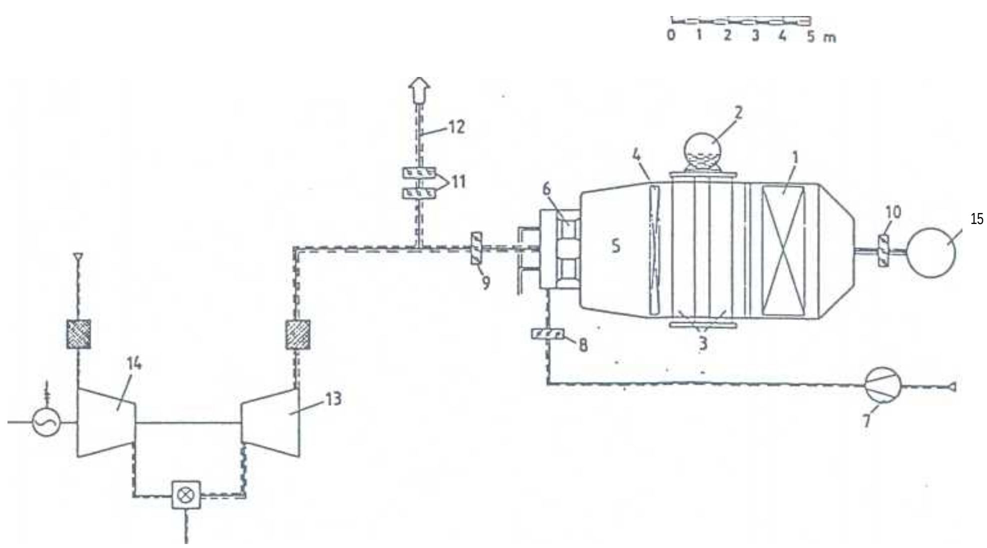
10 -Supplementary Firing System 1
12-Air Duct
13 - Boiler Inlet Damper
14 - Bypass Damper
15 - Bypass Silencer
16 - Boiler Outlet Damper
17 - Flue Gas Ducts

HEAT RECOVERY STEAM GENERATOR IN A COMBINED CYCLE PLANT
PRODUCING ELECTRICITY AND DISTRICT HEAT

FIGURE 4

E3 A E3 C<*>OK
DONSCHE EWCOCK
MAFTWERKSTECHNIK
G M BMH





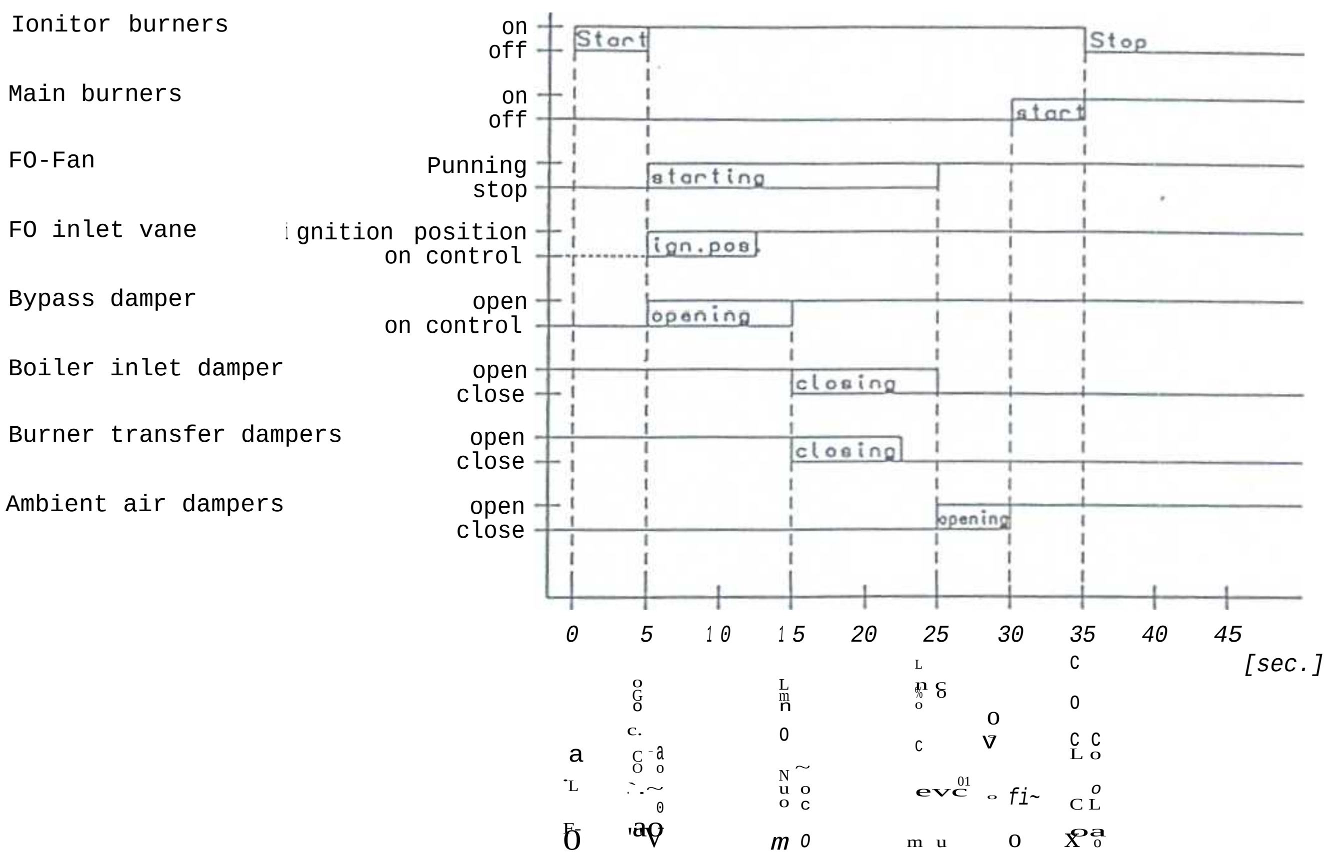
1) Economizer
2) Drum
3) Evaporator
Q SWA"ter
5) Furnace
6) Burner
n FD-(an
W M inlet damper

9) Boiler inlet damper
1 1 Boiler outlet damper
11) Bypass damper
12) Bypass stack
13) Gas-turbine
14) Compressor
ly Stack

power5

HEAT RECOVERY STEAM GENERATOR IN AN INDUSTRIAL PROCESS

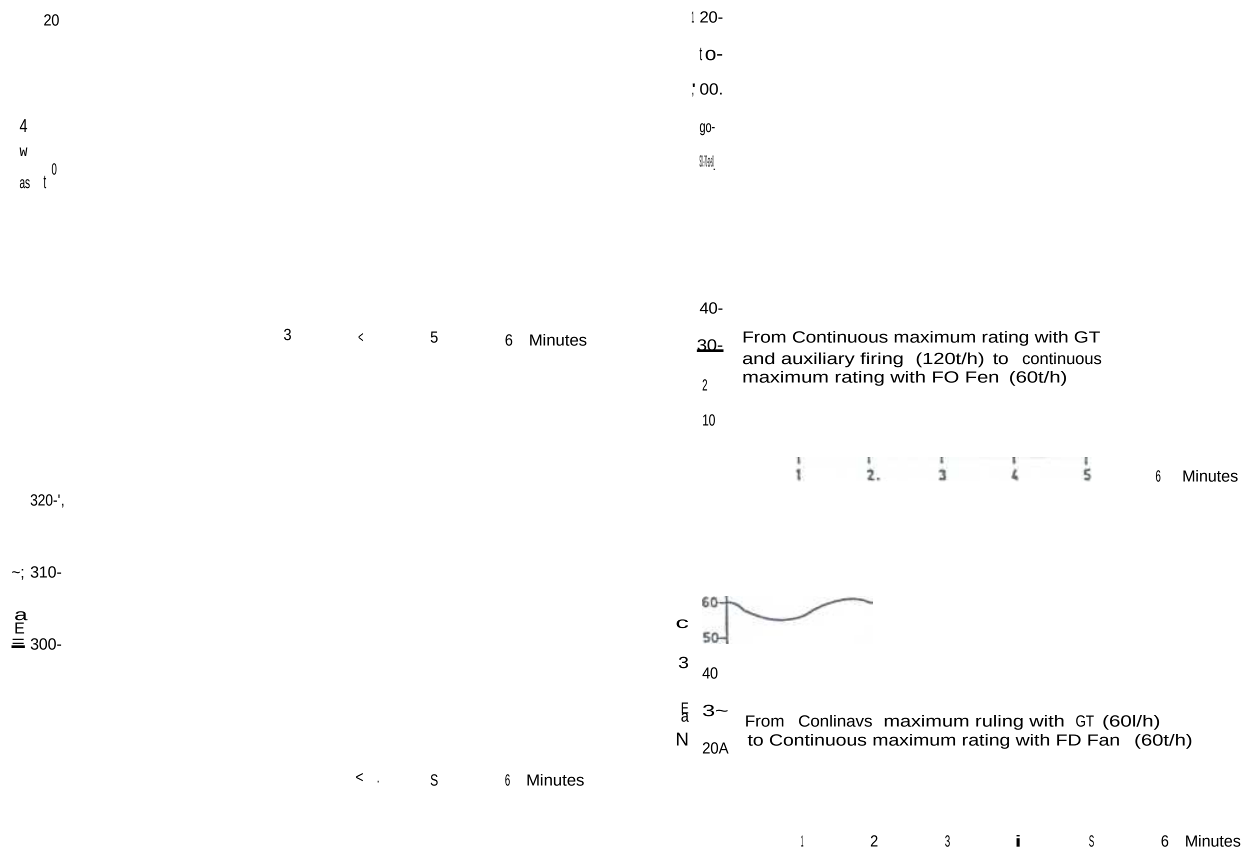
FIGURE 5



powers

SWITCH OVER PROCEDURE FROM GTOPERATION TO FD-OPERATION

FIGURE 6



power7

VARIATION OF MASSFLOW, PRESSURE AND TEMPERATURE DURING SWITCH OVER PROCEDURE FROM GT-OPERATION TO FD-OPERATION

FIGURE 7