Neptune
Thermal Power Plant Trainer

TPP

User's Manual

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Issue No.	ECO No.	Paragraph No.	Paragraph Heading/ Description of Change
B	MP-1677		Added Appendices.
C	MP-1703		Change Appendices. B, G & H.
D	MP-1828		Implemented treatment plant sequency description

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1 INTRODUCTION TO THE TPP

1.1 Introduction

Kongsberg Maritime a.s has designed a PC based system, containing a Thermal Power Plant Trainer. The trainer is based on an existing Thermal Power Plant.

The purpose of the trainer is to make the students capable of operating a complete Thermal Power Plant, and to enter malfunctions to see the consequences for the plant.

The trainer do also include the subsystems for cleaning of flue gas called Denox and Desox plant.

The trainer are run and operated locally on each student station. The instructor has his own computer, where the models can be manipulated and operated.

This system allows the instructor to generate new scenarioes and malfunctions, which will make it possible to start simulation from different operational states.

The function of all subsystems and units used in the models, are described in chapter 4. Operation of the subsystems are described in chapter 5.

The Power Plant Trainer is connected to other systems:

2 FUNCTIONAL DESCRIPTION

2.1 Simulator Objectives

The main purpose of the Thermal Power Plant simulator is to train and assess operators in the operation of Distributed Control Systems (DCS) and in plant operation, including training in plant start-up and shut-down, emergency situations and safety procedures.

The simulator will be used as a powerful tool for engineers and plant management to verify process design and control strategies prior to start-up of a plant and to investigate and test operational problems which they are normally not allowed to do in a real plant.

The simulator delivered by KONGSBERG MARITIME has the ability to be used in a number of different ways in order to suit the changing needs. Some of these uses are, in chronological order:

* Test and tune control loops before implementing on a real system.
* Test and modify logic in a dynamic environment.
* Familiarise commissioning engineers with the plant and process dynamics.
* Allow commissioning engineers to test out different start-up procedures.
* Modify control and logic before installing on the real system.
* Check out new controls and operating strategies.
* Verify process design and study effects of modifications to the process by altering the model.
* Optimise the control system and process to maximise economic performance.
* Re-train experienced process operators to identify abnormal process conditions and methods of dealing with them.
* Re-train experienced operators to optimise the process for maximum economic performance.

2.2 Definitions, Acronyms and Abbreviations

This section provides the definitions of terms, acronyms and abbreviations required to properly interpret the DFS.

Term	**Definition**
Console	A cabinet containing VDUs, keyboards and other equipment
DCS	Distributed Control System
DFS	Detailed Functional Specification
ECO	Boiler economiser
ESD	Emergency Shutdown
EVA	Boiler evaporator
Ext	Extraction
FAT	Factory Acceptance Test
Fidelity	The faithfulness with which a dynamic simulation model replicates the physical, dynamic behaviour of a plant.
FL	Boiler water separation unit
FO	Fuel oil
FW	Feed water
HP	High pressure
HP computer	Hewlett Packard computer
IC	Initial Condition
IP	Intermediate pressure
IPC	Intermediate pressure cold steam line
IPH	Intermediate pressure hot steam line
KK	Cold condenser
LP	Low pressure
MCT	Main Condensate Tank
MD	Mimic Drawing
MD	Main Drain system
QA	Quality Assurance
OTISS	Operator Training Industrial Simulation System
RH	Reheater
SAST	Special Analysis Simulation Technology Ltd
SAT	Site Acceptance Test
SCR	Selective Catalytic Reduction
SH	Boiler steam super heater
SRC	System Requirement Specification
TEC	Training, Evaluation and Control
UH	Utility heating system
UW	Utility water
VDU	Visual Display Unit

2.3 Process and Utility Models

The simulator consists of a number of fully integrated process and utility models. It allows for the training and assessment of personnel in their response to process upsets and emergencies as well as to provide familiarisation and training in basic operating techniques.

The scope of the process and utility models included in the Simulator are defined in the table below. The subsection "Model Fidelity" defines high, medium and low, while the subsection "Power Generation Process Description" defines the special fidelity.

AREA	FIDELITY
Fuel oil system	Medium
Secondary steam system	Medium
Burner planes	Medium
Combustion Air/Flue gas system	High
Hot water/steam air preheaters	High
Boiler water system	High
Boiler steam system	High
Main steam lines	High
Steam plant overview	High
Steam turbines	High
Electric generator	Medium
Cold condenser system	High
Main condensate system	High
Low pressure feed heaters	High
Feed water tank system	High
High pressure feed heaters	High
Make-up Deaerator	High
Hot condenser system	High
Direct heater system	High
Denox plant	High
Desulpurization plant	High

2.3.1 Colours used in mimic panels

The following colours are used to identify the various mediums:

Medium	Colour
Oil	Magenta
HP steam	Red
Air	White
Water	Blue

2.3.2 Process boundary conditions

Every simulated system must have boundaries, such as pressures and temperatures of the environment. The instructor controls the boundary conditions by means of the Variable lists. Like all other data in the simulator, the boundary conditions will be defined in the Initial Conditions and can be used in scenarios and events during set-up and run of the simulator exercises.

2.4 Variable lists

All model variables are listed in pop-up lists provided. The variable lists are activated by the dedicated push button on the keyboard. The lists include tag-name, descriptive text and alarm status, where applicable, in addition to the actual value at the present state of the simulation.

The value of an independent variable can be changed in the variable list. However, the dependent variables are those which are continuously updated by the simulator, and attempts to change those will fail.

2.5 Malfunctions

Many of the components included in the simulator are capable of being in a faulty condition or having malfunctions. The instructor can set/reset faults on the malfunction pages, which are pop-up lists similar to the variable lists. The student does also have access to the malfunction lists, but the state of the malfunction is hidden for the student.

2.6 Help system

The simulator includes a help system. For each main display it is possible to activate sub displays with relevant help information.

2.7 Mathematical Model

The simulated plant produces both electricity to the power grid and hot water to the local utility heating. The boiler is of once-through type.

The simulated plant is made available to be fuelled with oil (mainly for start-ups with special start-up burners) or coal. At pure condensation operation the block produces a net electrical output of 255 MW (190 MW for coal). The utility heating hot water effect at back pressure operation is 350 MW with oil, and 260 MW for coal.

The process model delivered with the simulator includes:

- Choice of combustion of oil or coal.

- Boiler with superheaters, economisers, coal powder burners and oil burners.

- Air, flue gas, and fuel systems with coal mills, boilers, air preheaters, air filters, primary and secondary combustion air supplies.

- Turbine with steam control valves, all turbine stages (high pressure, medium pressure and low pressure stages) and all steam drain pipes.

- A simple electricity distribution grid. It consists of a relay interlocking plant, transformer station and a couple of electricity consumers. The variation of the power demand input will vary according to reasonable day, night and season distribution. In addition, there is a possibility to connect/disconnect specific branches of the grid both from the students and the instructors workstation.

- Generator with associated equipment for magnetisation and control of reactive power output.

- Condenser and feed water system with cold condenser, condenser pumps, vacuum pumps, condensate tank, all preheaters (high and low pressure preheaters), drain water collection tank, feed water tank with de-gasification, feed water pumps, boiler water separation unit and tank for separated water.
- Utility heating unit including heat exchangers and pumps specified in VHS B2.1. A simple model of a hot water distribution system. Connection/disconnection of specific heat users from both student's and instructor's workstation. The variation of heat demand is according to a reasonable day, nigh and season distribution.

- Auxiliary systems as described in VHS B2.1. Examples of auxiliary systems are air and flue gas throttles, control, safety, back and steam dumping valves.

- Semidry de-sulphurization unit. The description of the plant and its control system is given in VHS SB2.6. All the components of the plant which are relevant for the understanding of the process is included.

- Denox unit. The description of the DeNOx unit and its control system is given in VHS SB2.1.6. All the components of the plant which are relevant for the understanding of the process is included.

The following run-modes is supported by the simulator:

- From start-up of the plant, from cold state to phase co-ordination with the external electric grid.

- From start-up of the plant, from warm state to phase co-ordination with the external electric grid.

- Pure condensation operation with varying operating points (50-190 MW electricity for coal combustion and 50 - 255 MW electricity for oil combustion).

- Pure district heating operation (the steam is by-passed the high pressure turbine into a direct heat exchanger) at varying operating points (100 - 350 MW heat for coal combustion and 50 - 350 MW heat for oil combustion).

- Combined heating and power operation.

- Load reduction of the plant until shut down.

- For the in VHS A2.3.24 described disturbances, there will be an automatic load reduction of the turbines, to only support the internal needs of electricity (release of aggregate switch), or reduction of the turbine load to zero. (Quick shutdown valves). An alarm message will be given to the student with a pre-defined time margin, and a proposal of action (see VHS B2.4).

- Combustion of oil or coal. (Not both at the same time, except for the short time period when the start-up oil burners are being replaced by the coal burners).

2.8 Requirements of model accuracy

The model will take into account deposit on heat transfer surfaces such as boiler tubes and heat exchangers. The pump flow will vary according to pump and system characteristics. Heat transfer coefficients will vary with fluid flow rates and temperatures. The effect of air accumulation in heat exchangers will be considered in the model. It will be possible to simulate vibrations in the rotor of the turbine.

Absolute accuracy cannot be guarantied, since it is impossible to design training simulators for this degree of fidelity and still retain a real-time environment within realistic costs and project schedule. However, as a quantitative test on accuracy, we try to match a particular steady state in the simulator (the design case) to a heat and mass balance provided in VHS SB2.5A-C. For high fidelity models, we would expect the following accuracy figures:

Pressure	+/- 1.5% of range
Flow	+/- 2 % of range
Temperature	+/- 2 % of range
Instrumentation	+/- 1.5% of instrument range

When all available measured plant data becomes available, the model can be tuned to match it to similar degrees of accuracy and steady state. Process plant operation tolerance will be within +/-5% across the normal operating range.

We have considerable experience in modelling process equipment, both for training simulators and high fidelity studies and aim to match as closely as possible the simulator response to the behaviour we could expect in the plant.

2.9 Process Model Sub Systems

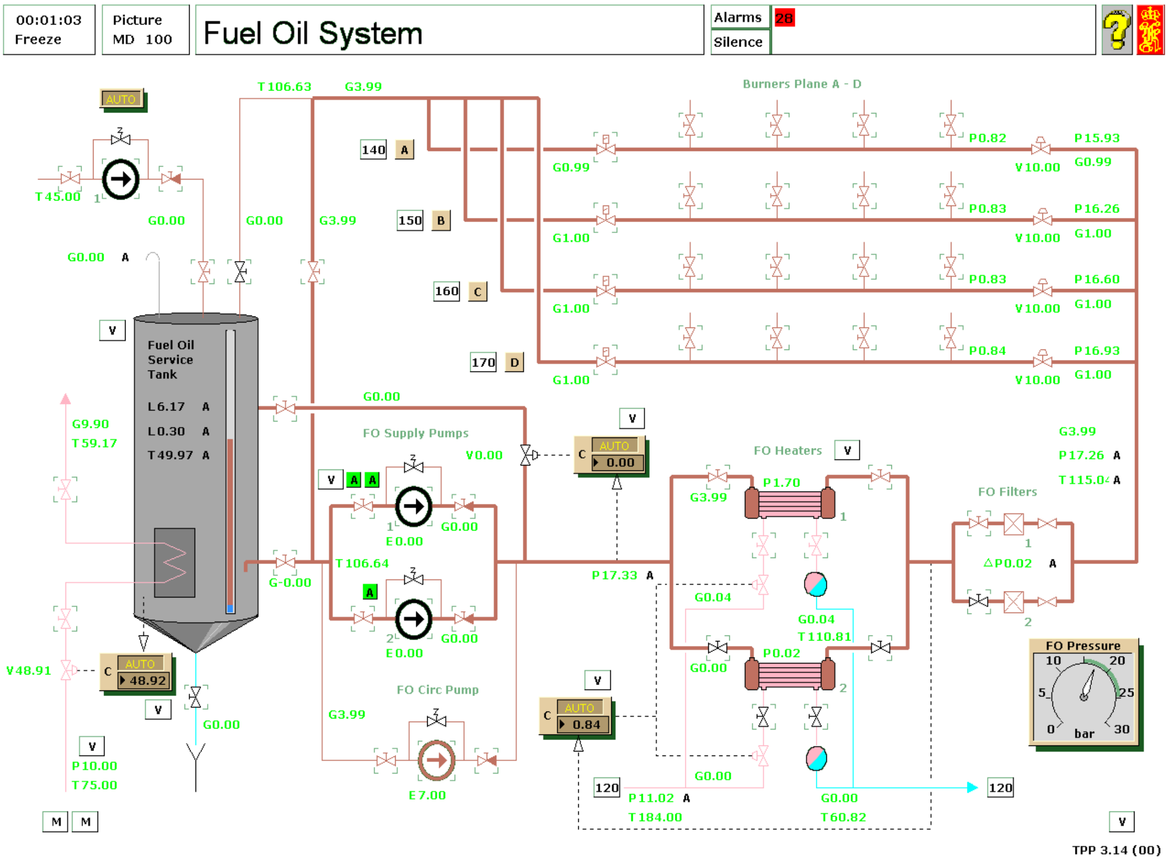
Many of the steam and water pipes are drawn as a single pipe but consist in reality of double. (E.g. the intermediate pressure superheater pipe) and sometimes even triple pipes (E.g. condensate and feed water pipes).

In the same way the direct heat exchanger (DV 41) consists of two parallel systems. The coal and oil burners consist of 4 burner levels (A - D, with the uppermost level named A). Every burner level consists of 4 burners of each kind.

All the components which have multiple notations (a hyphen is used) is understood as a symbolic interpretation of a multiple of equivalent parallel systems.

Some of the parallel equivalent components will be simplified by reducing them to one single unit as long as the dynamics and physical properties of the plant are sufficient. As an example the feed water pipes will be modelled as one single pipe.

2.9.1 Fuel Oil System (MD100)



2.9.1.1 Fuel Oil System Description

The FO service tank is heated by steam, supplied from the low pressure steam generator (MD120).

The tank is filled by means of a FO transfer pump which operates automatically with a level control system. The suction is taken from one of the bunker tanks (always assumed full). Possible water settled out in the tank should be drained off.

The fuel oil to the main burner deck A-D is supplied by a pair of FO supply pumps. Pressure after pumps is controlled by recirculation of oil back to the service tank.

The pressure control valve is under PID control.

The FO is heated to normal operating temperature by either of two steam heaters, before it flows to burner deck A-D.

There is recirculation of fuel from the burner decks to the service tank during preheating or trip.

The temperature of the fuel oil, which is measured in the common line after the FO heaters, is controlled by a temperature controller (PID) which controls the steam flow through the heaters.

The system has double delivery filters.

Main Fuel controller

The aim of the main fuel controller is to control the fuel flow to the boiler depending on the actual load independent of the kind of fuel or combination of fuels which is used.

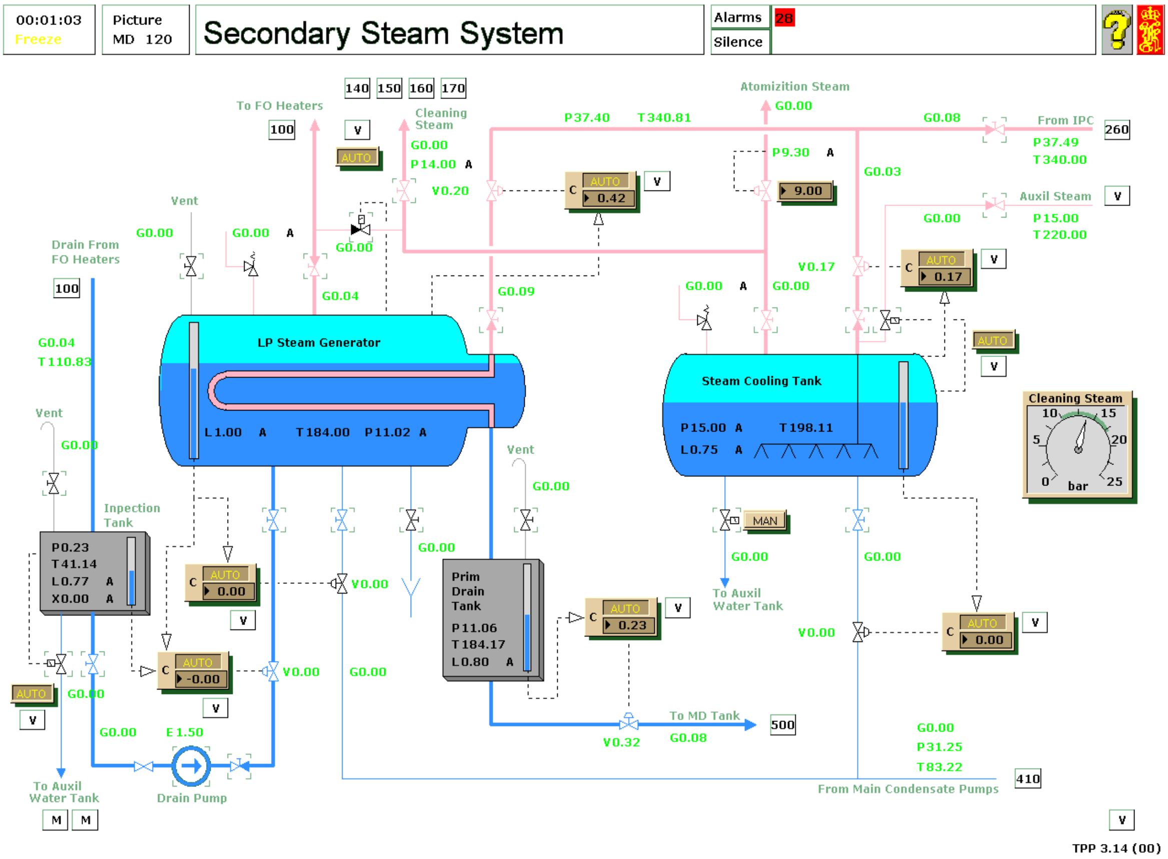
The main fuel controller (01-HB) gets its set point value from the block load controller (10-BLM) which is compared to the total measured amount of supplied fuel. The total amount of supplied fuel is the sum of the oil flow from the oil measurement equipment and the equivalent amount of coal measured from the speed of rotation of the coal feeders.

The output from the fuel controller (01-HB) is distributed to the different burner levels via multiplication units (01-HB A-D). These proportioned signals are input to the coal feeder controllers (01-KM A) and the oil flow controllers by means of the gain (10-BO A), where the coal flow is subtracted before the signal continues to (08-BO A) where the signal is compared with the total measured amount of oil supplied to the burner level.

Oil temperature control

The oil temperature is controlled by a PI-controller. It affects the steam supply valve (OT) on the oil preheater.

2.9.2 Secondary Steam System (MD120)



2.9.2.1 Secondary Steam System Description

The LP steam generator produces secondary, low pressure steam to be used for the following purposes:

- main boiler steam atomisation
- heating of storage and service tanks
- heating of HF to burner deck A-D
- production of cleaning steam

The primary steam to the LP steam generator is normally supplied from the IP bleeder system.

If the Intermediate turbine bleeder pressure is too low, steam is provided from the auxiliary steam system.

In cases of emergency, the steam source is from the auxil. steam system.
The flow of steam to the heat exchanger in the steam generator's steam drum is automatically controlled to keep the secondary steam pressure constant.

The condensate from the heating coil is drained to a separate primary drain tank before it is discharged to the make-up deaerator.

The rate of primary condensate discharge is controlled so that the drain cooler always is filled with water.

Secondary drain from miscellaneous heaters is collected in the inspection tank. This is designed for easy observation and removal of possible oil contamination.

For production of cleaning steam and atomising steam a special steam cooling tank is provided.

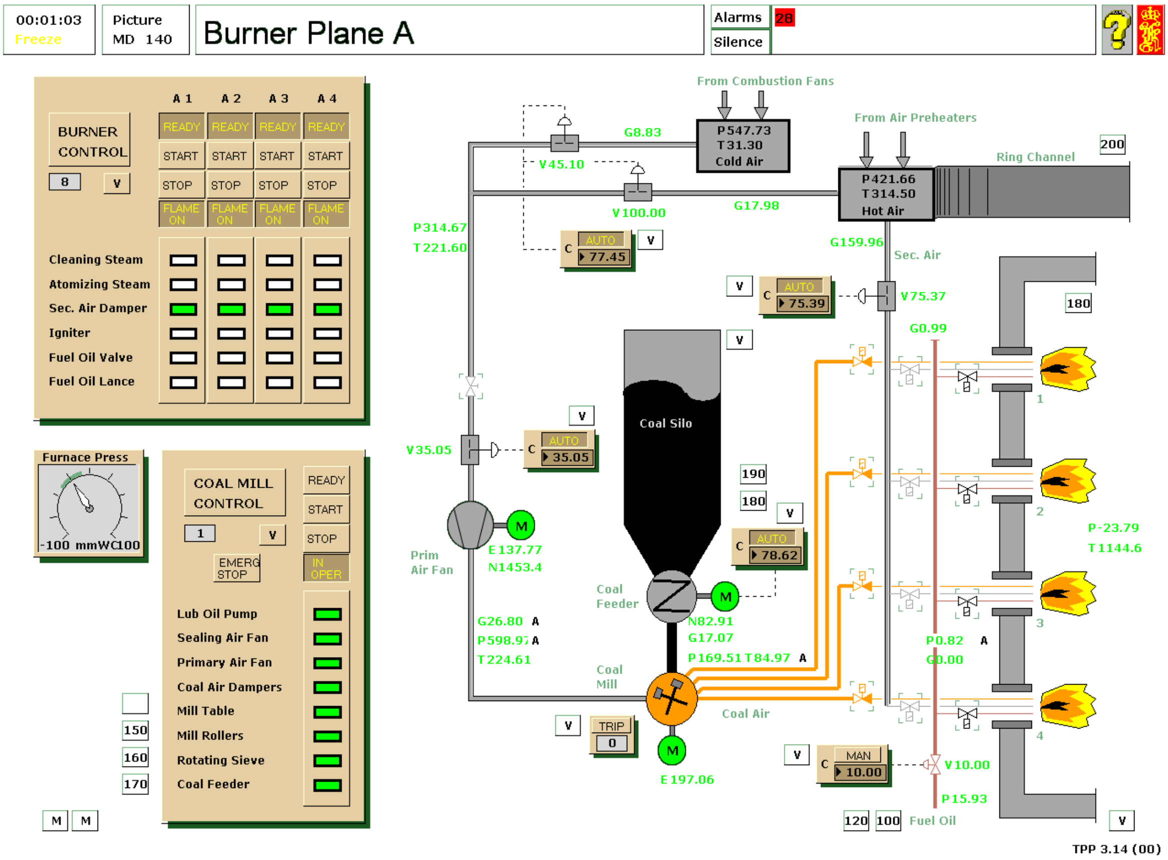
Supply to the steam cooling tank spray nozzles taken from the IP line.

Both LP steam generator and steam cooling tank has a level control system, and make-up water is taken from main condensate pumps.

Oil flow controllers (BO A-D)
Each burner has got its own oil control valve (OD A-D) with respective oil flow controller (01-BO A). The burner nozzle supplies 3800 kg oil/h at an oil pressure of 15 bar and supports a range of oil flow from low load to full load (790 ton steam/h). The pressure is measured before the burners and is compared with the set minimal pressure in the P-controller (05-BO A) in such a way that the oil controller makes sure that the minimal pressure is maintained.

A summation of the oil flow to the burner levels is done in the P-controller (09-BO A). This signal is then used for controlling the secondary air flow.

2.9.3 Burner Plane A-D (MD140-170)



2.9.3.1 Burner Plane A-D Description

Picture MD140-MD170 has the same function and will be described only once.

Supply of fuel to the burner deck is from the FO system (MD100).

The burner deck has four burners. They are operated by push button commands on the burner control panel.

Burner 1 to 4 are normally lighted off on fuel from cold plant start-up.
The option of firing with coal can only be performed when burners are already fired on FO.

The burners shall always be lit off in the following sequence 1,3 and 2,4.
The light off sequence will be indicated. Ignition is confirmed by the flame scanner signals.

It is possible to change to coal firing, this requires that system for coal transportation system is running.
Hot and cold air are mixed by a temp. controller, and a primary air fan supplies air to the coal grinder.

The coal silo supplies coal to the coal feeder system. The coal feeder system supplies coal to the coal grinder.

The Coal dust is fed to the burners with conveyer air from primary air fan.

The coal feeder system is controlled by a coal mill control panel.

To light off a burner, press the START button and the following light off sequence will be executed:

- air damper opened
- igniter inserted and excitation switched on
- fuel oil valves 1/2 opened
- igniter de-energised and retracted when flame scanner detects flame (within 10 sec).

The FO flow can be adjusted by manually controlled throttle valves.

A boiler safety system closes the boiler trip valve and the fuel oil shut off valves to both burners at the following condition:

- flame out on both burners
- no forced draft fan running
- atomising steam pressure low
- water drum level low
- water drum level high

At trip the recirculation valve is opened. This is automatically closed when fire is detected on any burner.

Secondary air flow control during oil combustion

Each one of the four oil burners on each burner level has its own secondary air flow controller (which is simplified in the model to one controller for each level) with the notation SLA1. Each one of these gets a set point value in the form of a fuel set point value. At start-ups of the plant there is a specified ignition set point value of the secondary air flow. As soon as the start-up commence, the secondary air throttle is opened until the measured value corresponds to the ignition set point value.

The positions of the 16 secondary air flow throttles (4 in the model) are compared, whereas the position of the most open throttle is an input to control the air and flue gas fans.

Coal feeder controllers (KM A-D)
The aim of the coal feeder control is to make sure that the coal feeder feeds coal to the mill according to the required fuel effect on each burner level. There are four coal feeders (on each level) which are responsible for supplying each burner level with coal.
There is no simple way to measure coal flow, but there is a certain speed of rotation/volume relation on the feeder, which makes it possible to use the rotational speed of the feeder as a measure of the coal flow to the mill.

The fuel set value is distributed to the oil flow controllers (10-BOA) and the coal feeder control (01-KMA). The coal feeder controller gives a control signal to the coal feeder which controls the speed of rotation in proportion to the control signal.

Primary air flow controller
The primary air has two main functions, that is to dry the coal in the mill, and to transport it between the mill and the burner. One part of the control problem is to keep the air flow velocity above a certain limit (18 m/s) in the coal powder pipes. Another aim is to get a coal powder/air ratio, which gives satisfactory combustion.

The primary air is extracted from the combustion air system, partially in the form of hot air in the circular air channel and partially in the form of cold air from the pressure side of the main air fans.

The primary air controllers shall have minimal set value of 18 m/s (corresponds to the primary air flow at minimal speed of rotation on the coal feeders). Another signal is proportional to the speed of rotation of the coal feeder, that means proportional to the mill load, and corresponds to 30 m/s in the coal powder pipes at full load. Four parallel primary air controllers is thus required.

The actual value to the controllers is the volume flow at the entrance to the coal mill.

Mill temperature controllers (KT A-D)
The coal which enters the coal mill has got a surface moisture, which has to evaporate by the heat in the primary air flow. The surface moisture is normally between 8 and 12%. To get a temperature of 85dgrC after the mill, an inlet temperature of between 190 and 280dgrC is required, depending on the load and the moisture of the coal.

The mill temperature controller (01-KTA) gets its value from the temperature measurement point at the outlet of the mill. The set point value is normally 85dgrC but for start-ups there is a heating period whereas an integrator increases the set point value from the surrounding temperature with a temperature gradient of 5dgeC/min.

When the outlet temperature from the mill exceeds the set point value, the cold air throttle is opened. If the temperature continues to increase when the cold air throttle is fully open, the hot air throttle will close slightly to supply colder air.

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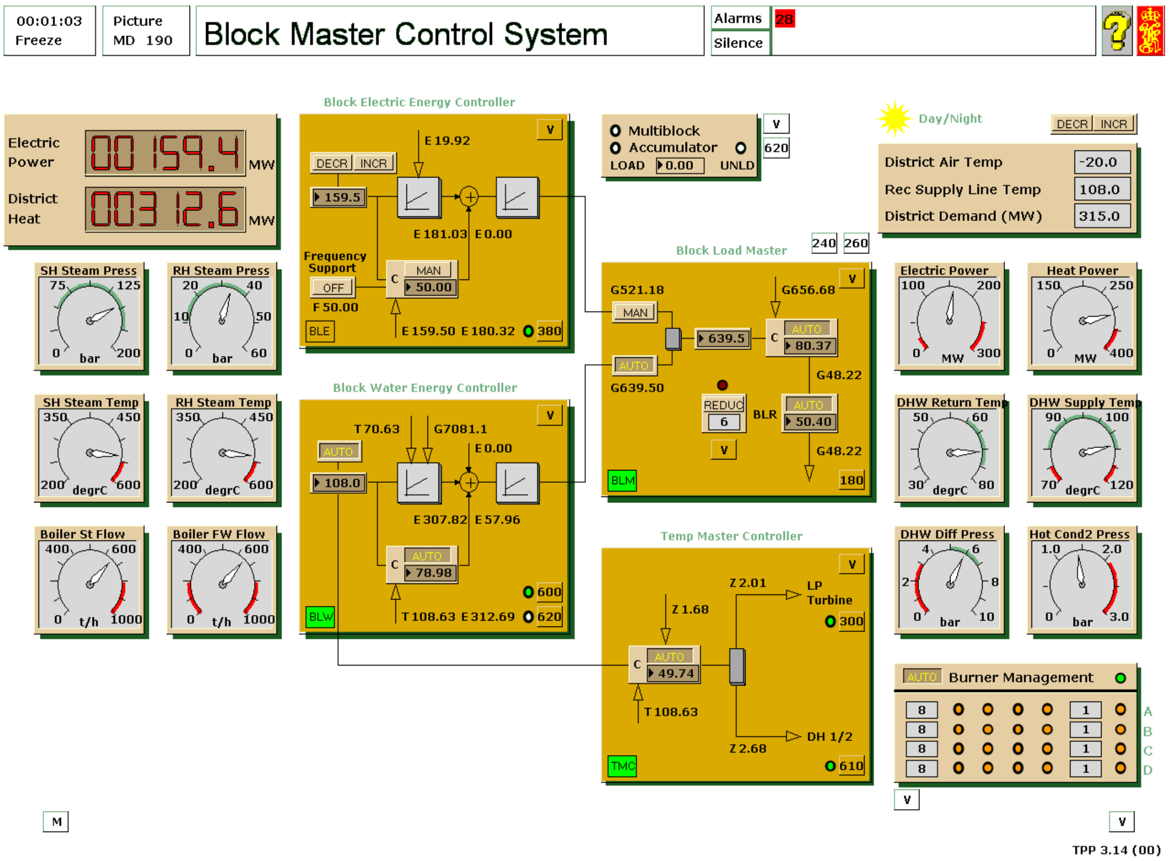
2.9.4 Block Master Control System (MD190)



2.9.4.1 Block Master Control System Description

The Block Master control system consits of two major parts: One part controlling the rate of fuel input to the boiler system and one part controlling where to discharge the blocks' waste heat.

Part one is based on one steam controller (BLM) which has its set point generated either from an electric power controller (BLE) or from a district heat water temperature controller (BLW). The output signal from the steam flow controller is an energy signal for the fuel master control system. It is checked and possibly reduced in a logic system called "block load reduction system" (BLR).

Part two consists of a single temperature controller (TMC). The inlet dampers of the LP turbines and the steam flow to direct heaters are controlled from measured district heat water temperature.

The Block Load Master Controller (BLM) corresponds with the master steam pressure controller of fixed pressure boilers. It controls the steam flow according to set point.

The Block load reduction system (BLR) limits the fuel command from the master controller if necessary.

The limiting value is displayed (G01952). If this limit is exceeded, the BLM controller is switched to Manual, the fuel signal is reduced to limit, BLR alarm will be given (AG05.X01963) and the cause of the limitation indicated by a "reduction index". (To get reduction index text, click on index display.)

An overview of load reduction causes and corresponding limits is given on MVP1901.

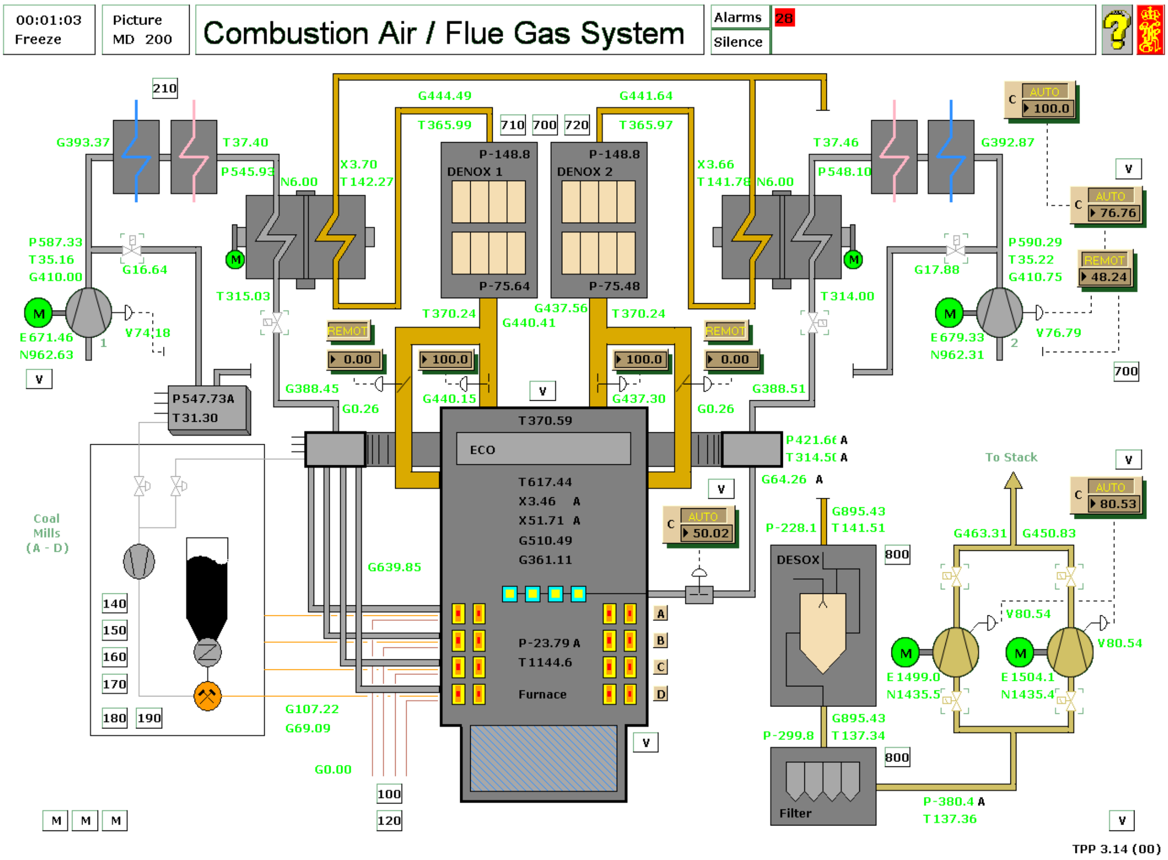
Note that the reduction associated with the turbine trip or main circuit breaker trip, will be overidden if the turbine is not in operation. The inhibition signal for this is taken from the HP turbine supply valve, V03001. When this valve close, BLR reduction 4 & 5 are cancelled.

An BLR action should be followed by manual firing at rates below BLR limit, until the cause of reduction is corrected.

The BLR function is always present, regardless of Manual or Auto mode. In Auto mode, the limit not to be exceeded, G011952 is automatically set according to plant state. In manual mode, the limit must be manually set by the operator at his choice.

In addition to the limiting function, the BLR controller performs rate limitations of the fuel command (up and down). If the source of a block reduction is corrected, the BLR system will slowly increase the fuel command towards the RLM controller command.

2.9.5 Combustion Air / Flue Gas System (MD200)



2.9.5.1 Combustion Air / Flue Gas System Description

The drawing shows the flow of air and flue gas, from forced draft fan inlet to tube stack uptake duct.

Air is:
- entering the forced draft fans
- preheated in the air preheater
- mixed with oil and burned in the furnace space to flue gas

Flue gas is:
- radiating heat to the furnace walls and superheater
- cooled by convection heat transfer in the steam generating tube bank and the superheater
- cooled further in the feed water economiser
- cooled to final flue gas temperature in the air preheater before entering the funnel

Forced Draft Fans

The forced draft fans must be started or stopped manually.

The air flow is controlled by air dampers on the suction side of each fan.

The damper is normally controlled by a signal from the combustion control system but direct, manual position control is provided for when the damper control selector is set to LOCAL.

The forced draft fans are modelled with flow characteristics dependent on suction air damper position in a manner which is typical of large, centrifugal fans.

The electric power consumption is computed. The drive motor can be overloaded. The forced draft fans represent very heavy consumers on the electric power system.

The discharge shut off damper is automatically opened/closed according to whether motor is running or not.

Regenerative Air preheater

There are two Air-preheaters of the regenerative, rotating (Ljungstrom) type. The slowly revolving rotor is driven by an electric motor.
The reduction gear and rotor bearings are lubricated by an auxiliary system which is not modelled in detail.
The dynamic heat transfer response, depending on number of revolutions, rotor masses, air and exhaust temperatures and heat transfer coefficients is, however, modelled correctly.

The effect of the typical air leakage from air to exhaust side, found in rotating air preheaters, is included in the model.

The air side can be bypassed by a manually operated damper. This is to be used at prolonged operation with low boiler load, which can lead to very low exhaust gas temperatures and associated excessive acid formation.

The exhaust side can also be bypassed manually. The exhaust side damper should be completely opened during soot blowing and at high boiler load.

Steam air preheater
The system is also designed with a double set of steam air preheaters.

Combustion control
The aim of the combustion control is to adapt and control the combustion parameters according to the load and number of burners and mills in operation. In addition, the combustion control has to be in operation during start-ups and shutdowns of the boiler. In the simulator the user should experience a physically reliable start-up.

The fuel control and the automatic sequencing of burners and fans are simplified to such a degree that the requirements mentioned above are fulfilled and so that the principles for how a start-up is performed are highlighted to the student (without the need of detailed modelling of each burner controller, coal mill, air- and flue gas-throttle). As an example, one burner level (four oil and four coal burners) can principally be modelled as two burners (one for oil and one for coal). The start-up of the block is governed by an automatic sequence.

The control unit consists of a cascade controller with a main controller and a set value controller to the previous one, which gives the load dependent pressure increase in the circular air channel.

The main controller gets a fixed set point value, which is equivalent to the pressure in the circular channel which is required to ignite the fuel and to supply enough cooling air at low loads. To this a pressure set value is added which is required so that one of the secondary air flow throttles does not exceed a pre definable degree of opening. The measured value in the main controller is the pressure in the circular air channel.

The output signal from the main controller is connected to two multiplication units (17-VL and 18-VL) and becomes proportioned set values to respective air fan controllers (02-VL1 and 02-VL2).

Furnace pressure controller (EP)

The combustion in the boiler takes place at a balanced pressure (which means constant pressure in the furnace independent of the load), which requires a co-operation between air and flue gas fans and the combustion control. Pressure drop in mills, coal powder pipes and burners are taken into account.

The main furnace pressure controller (01-EP) gets its set value from the control panel. The measured value is the furnace pressure. The output from the controller passes through the multiplication unit (05-EP) and is proportioned between the fans. The signal passes to the turnable guide vanes of the flue gas fans. Manual control of the fans is possible to be able to operate at both over pressure and sub-pressure operation.

Main air flow control (HL) and O_2 correction

In the control equipment there is no main air control in any normal sense, since the main air flow is not directly determined from the fuel flow. Instead, the minimal air flow is determined, and the required air excess (in relation to the minimal air flow) with a O_2 correction by means of the main air controller (05-HL).

The main air controller gets three input signals, of which the signal 06-HL is the main factor for the counter 01-SLA at zero load. The two other input signals give complementary information about desired set value to 01-SLA to give the desired O_2 concentration in the flue gas which is desired at any specific load.

The output signal from 01-SLA affects respective secondary air flow controller.

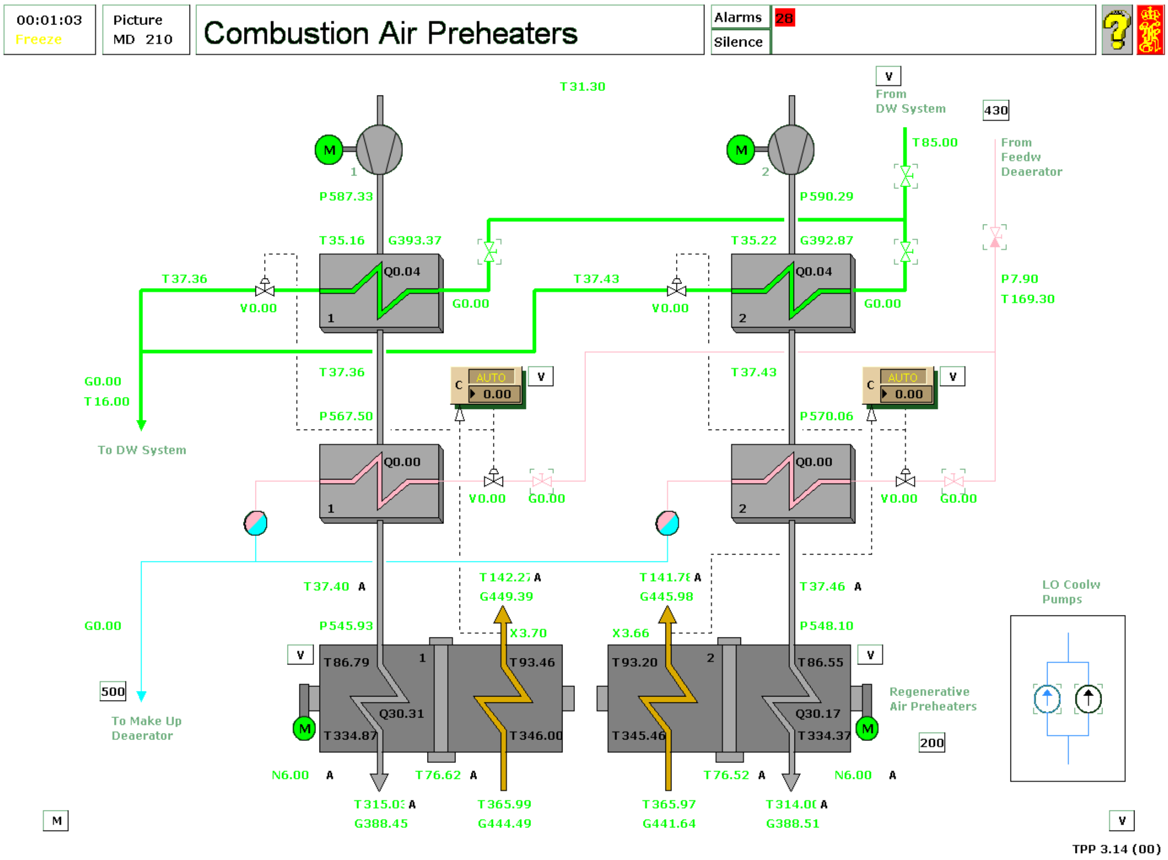
There is also a summation unit (03-HL) which adds the primary and secondary air flows. The output signal of this addition unit is an input to the controller for combustion pressure (EP).

Secondary air control with coal combustion

The secondary air flow has to be adapted to combustion independent of the type of coal used. Coal is supplied from one mill to respective burner level. The secondary air flow to the burner level is proportional to the mill load.

The main air controller and the O_2 correction, makes sure that the combustion is performed according to desired combustion parameters.

2.9.6 Combustion Air Preheaters (MD210)



2.9.6.1 Combustion Air Preheaters Description

There are two sets of hot water/steam air preheaters.

The hot water air preheaters are supplied with hot water from the district heater system.

The steam air preheaters are supplied with steam from the feed water deaerator tank.

The hot water and steam air preheaters has a temperature controller connected.

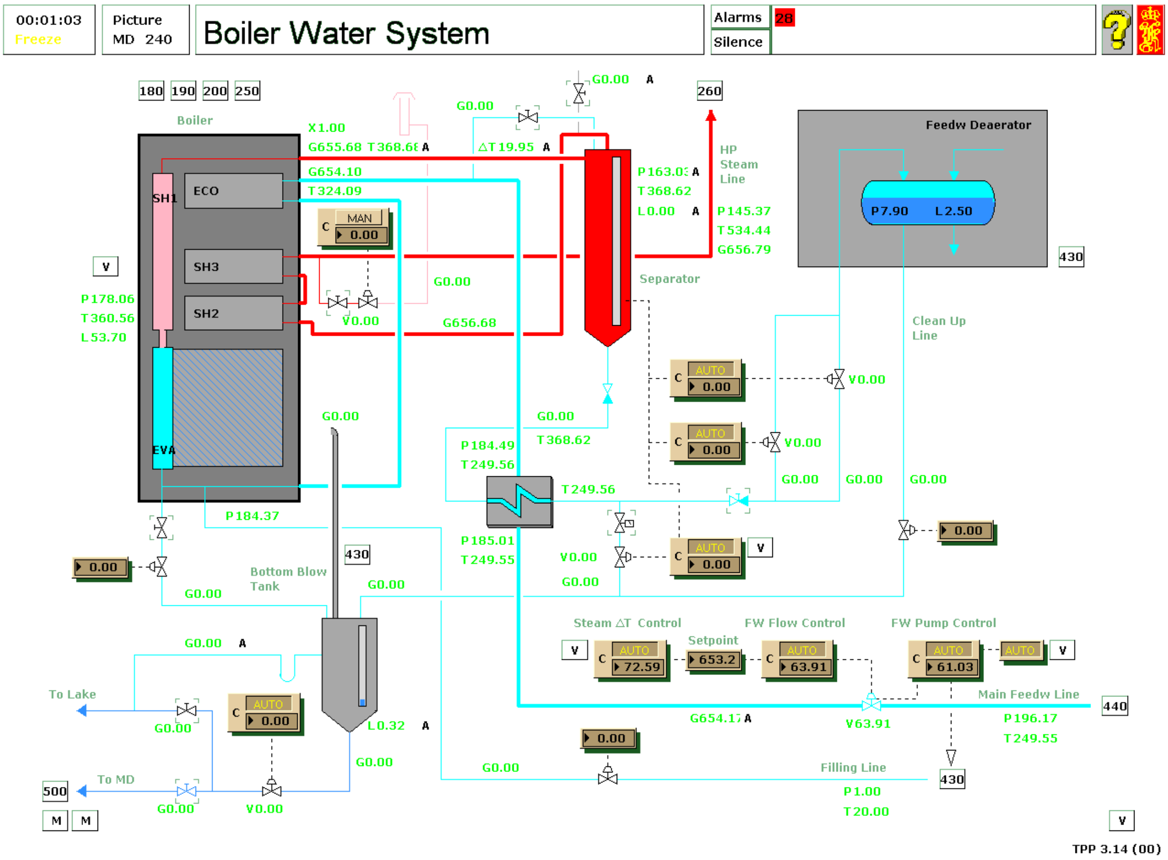
The primary side from the hot water air preheaters are drained back to the district water system.

The primary side of the steam air preheaters are drained to the make up deaerator system.

Temperature control of steam and hot water air preheaters (ÅLUFÖ & HLUFÖ)

The air temperature after the air-preheaters has to be controlled. It is mainly the hot water air-preheater (HLUFÖ) which is controlled. Not until the hot water valve (RV 449 A) is fully open RV 448 A is supposed to open. The corresponding control is applied to the parallel B preheaters.

2.9.7 Boiler Water System (MD240)



2.9.7.1 Boiler Water System Description

The feed water flow from the main feeder line is controlled by the feed water control valve. Its valve position can be set directly in LOCAL control. REMOTE control is from the boiler panel.

The feed water is heated in a preheater before it is supplied to the economiser.
After the economiser the feed water enters into the evaporator.

Steam is produced in the evaporator. The steam is then going to superheater 1.

The superheated steam is then supplied to a steam/water separator which has a certain water level to isolate full steam pressure from the feed water deaerator tank.
The heated water in the cyclone separator is supplied to the feed water preheater on primary side.

The steam is then led from the separator into superheater 2, from this into the desuperheater where the outlet steam temperature is regulated.

The automatically controlled steam temperature valve adjusts the flow to the steam desuperheater so the steam temperature at the second superheater section outlet is correct. The control is done in two steps: control of steam temperature inlet SH2, "temperature after mixing", and control of steam temperature outlet SH3, "final steam temperature" .

The superheater and the steam supply lines are protected by a safety valve after the superheater.

Valves for bottom blow off or top (surface skimming) blow off are included. The blow of goes to a bottom blow tank.

For filling of boiler water a special line is provided called filling line.

Control of water level in water separation tank
In some situations, for example at start-ups or at too large feed water flow, the water level in the separation unit is controlled by the AN-, ANB- and ZR-valves. Hereby the AN-, ANB-valves are responsible for keeping sufficient circulation in the fire tube walls during start-ups and low load operation. The ZR-valve is supposed to control the water level at higher levels, when the other two valves are not sufficient.

The water level ranges of each valve are divided from lowest to highest level in the following order: ANB, AN, ZR. Each valve is opened proportionally to the desired level in the corresponding range. The ZR gets an executive closing signal when the pressure in the water separator tank exceeds a certain value (20 kp/cm^2).

Pre superheater temperature controller (U2E)
The steam temperature at the superheater outlet is controlled to a certain set value by injecting water before the superheater (injection valve U2E). The only task of the controller

is to prevent the superheater from occasional overheating, whereby the set value is set from the control panel.

A PI-controller compares the temperature at the outlet of the superheater with a set point value and corrects the injection valve in proportion to the deviation. The outlet temperature follows a change in the injection flow quite slowly, whereby the value of the temperature after the injection valve is proportionally input to the controller.

Post superheater temperature controller (U3E)
The aim of this controller is to control the steam temperature at the outlet of the two superheaters by adjusting the injection flow according to set point value. The set point value is supposed to decrease with decreasing load below a certain load level. In the same way, it is possible to increase the set point value at start-ups with a pre-defined gradient from a given temperature to a pre-defined output temperature.

The set point value of the post superheater temperature is adjusted from the control panel. However, at a pre-defined load, this set point value is decreased with decreasing load and increased with increasing loads. This is taken care of by an executive set point value controller (which has a pre-defined gradient).

The manner of action of the post superheater temperature controllers is the same as for the pre superheaters (A2.3.5). Only the set point value is common for the two control units by the previously described set value controller. It is also possible to vary the heat absorption proportions between the two superheaters by adding a suitable constant to the measured superheated steam temperature before it is compared with the set value.

Water level control of the tank for clean drainage
Water level control in the tank for clean drainage (BB 41) is realised by controlling a valve (RV 340) with a PID-controller at the outlet of the tank.

Boiler outlet pressure controller (KE)
The aim of the KE-valve is to take away some of the produced steam before entering the superheaters in the first phase of a warm start-up. During this phase the BP-system is not yet ready to control the boiler pressure. Therefore, it must be controlled by the KE-valve.

The boiler outlet pressure controller controls the pressure after the boiler water separation unit, according to a set value which is defined on the control panel.

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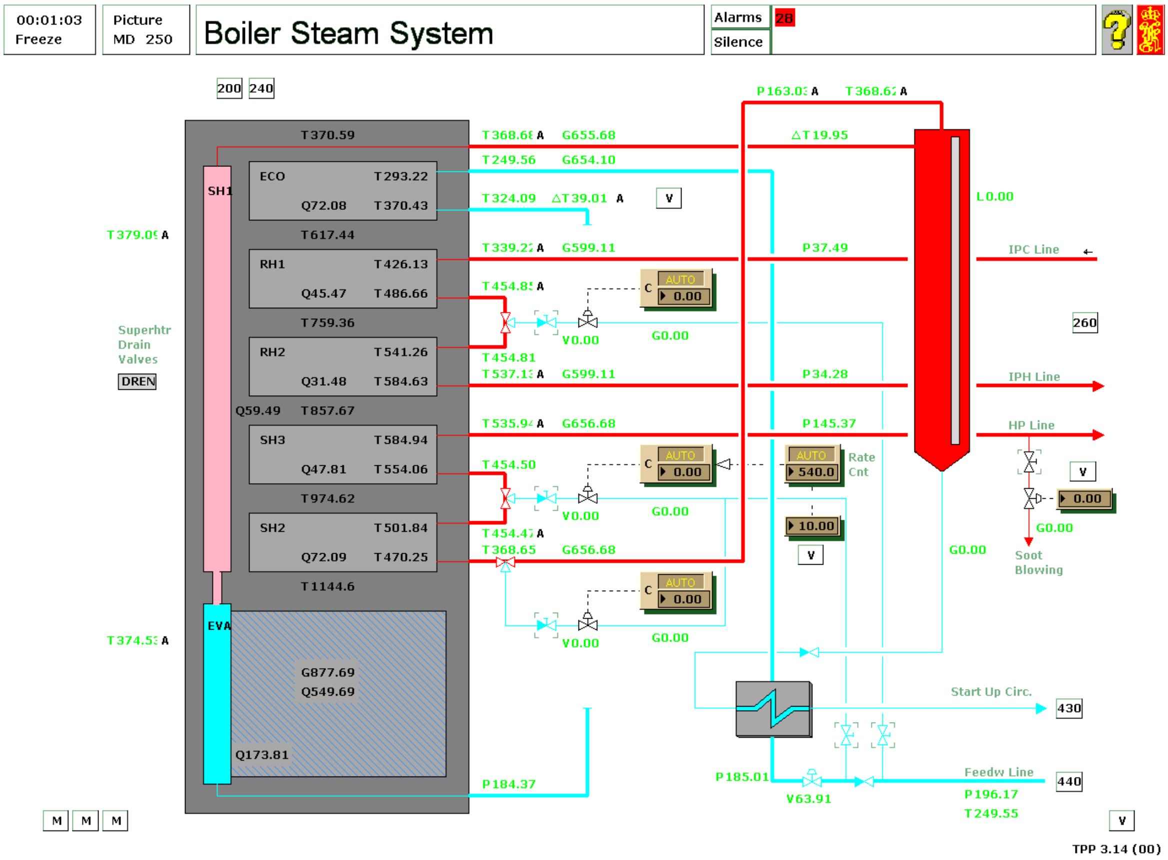
2.9.8 Boiler Steam System (MD250)



2.9.8.1 Boiler Steam System Description

High Pressure steam line
The piping from the boiler superheater 3 outlet is a separate steam line:

- HP steam line to HP turbine.

The main steam line supplies the HP turbine.

The HP turbine has a bypass control system if HP steam shall be fed to the district heater system.

Intermediate Pressure steam line
The piping from HP turbine outlet is the supply for reheater 1.

- IP steam return from HP turbine.

The temperature for the reheated IP steam supply is controlled by a separate temperature controller which mixes the steam with feed water.

The outlet from reheater 2 is the IP steam supply to IP turbine.

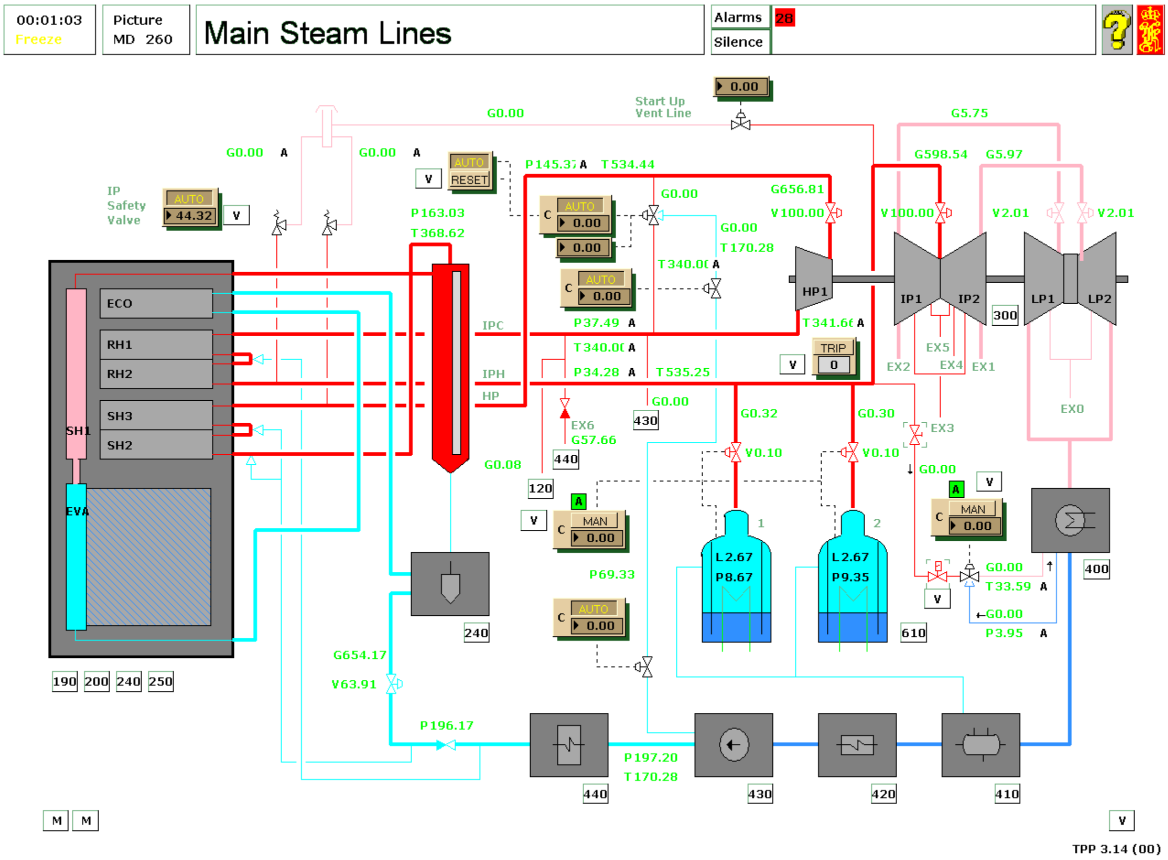
- IP steam line to IP turbine

There are bypass and drain valves for heating and drainage of steam lines before use.

Intermediate superheater temperature controller (ZUE)
The steam temperature in the hot intermediate pressure superheated steam pipe is controlled (kept at a constant level) by injection of feed water through the ZUE-valves. The intermediate superheater steam temperature is not constant over the whole load range but is reduced at decreasing load. This is why the PI-controller holds a set point value which is valid at 100 % load and a correction value at decreasing load. The actual set point value to the controller is equal to the mean temperatures at the outlets of the two hot ZUE-pipes.

A set point value which is adjustable from the control panel affects the two ZUE-injection controllers (of type PI). The measured value is also in this case identical to the mean value of the temperatures at the outlets of the two ZUE-pipes which each is connected to the injection valves (ZUE).

2.9.9 Main Steam Lines (MD260)



2.9.9.1 Main Steam Lines Description

The piping from the main boiler outlet is branched to three separate steam lines:

- HP steam line
- IP steam line from HP turbine
- IP steam line from reheater 2

The HP steam line supplies the HP turbine.

The IP steam line from reheater 2 supplies the IP turbine.

There are a bypass control system for the inlet to HP turbine.

Following subsystems are implemented but not described in detail:

Direct heater system.	(MD610)
Cold condenser system	(MD400)
Main condensate system	(MD410)

Low pressure feed heaters	(MD420)
Feed water deaerator system.	(MD430)
High pressure feed heaters.	(MD440)
Boiler water system.	(MD240)

Bypass controller (BP, BPE)

The bypass control before the HP turbine consists of a three way control valve (BP) which is opened and in this way determines the amount of steam which enters the HP-turbine. One of the inlets in this valve injects feed water from another control valve (BPE).

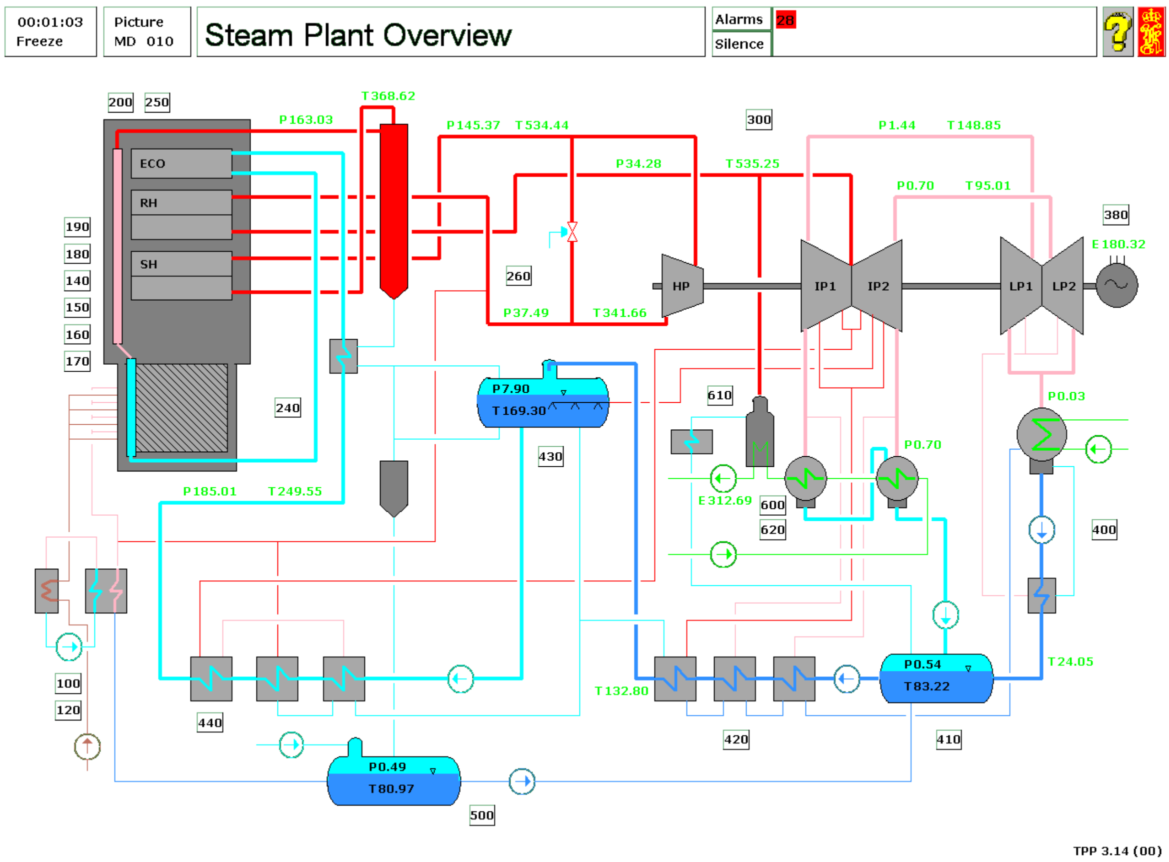
This control system has different aims depending on the operational mode (normal operation, operation without turbine, start-ups or shutdowns).

Normal operation:
At normal operation the BP-control system is ready to keep the boiler pressure (set point value) within certain limits when there are disturbances such as changes in the steam flow (to turbine) or changes in the steam production. The set point value is also supposed to follow the glide pressure curve. When the pressure rises, the BP-valves open simultaneously so that the pressure is kept at the set point value. If the disturbance is causing a pressure drop the BP-valves closes somewhat to keep the pressure constant. Another important function is to keep the pressure time derivative below a certain limit. The BP-valves are should also protect the boiler from exceeding the maximal boiler pressure (in order not to get frequent use of the security valves).

Operation without turbine:
When the heat production under certain conditions has to be maintained even without the use of a turbine, the BP-controller maintain the boiler pressure. The boiler pressure then has to be controlled at a constant value. It is possible to adjust the desired pressure on the control panel.

Start-ups and shut downs:
At start-ups and shutdowns of the block, the BP-control system (in some cases in co-operation with the KE-control system and the turbine control) has to control the boiler pressure according to a certain procedure. The kind of procedure depends on whether the operational mode is cold start-up, warm start-up or shutdown of the block.

2.9.10 Steam Plant Overview (MD010)



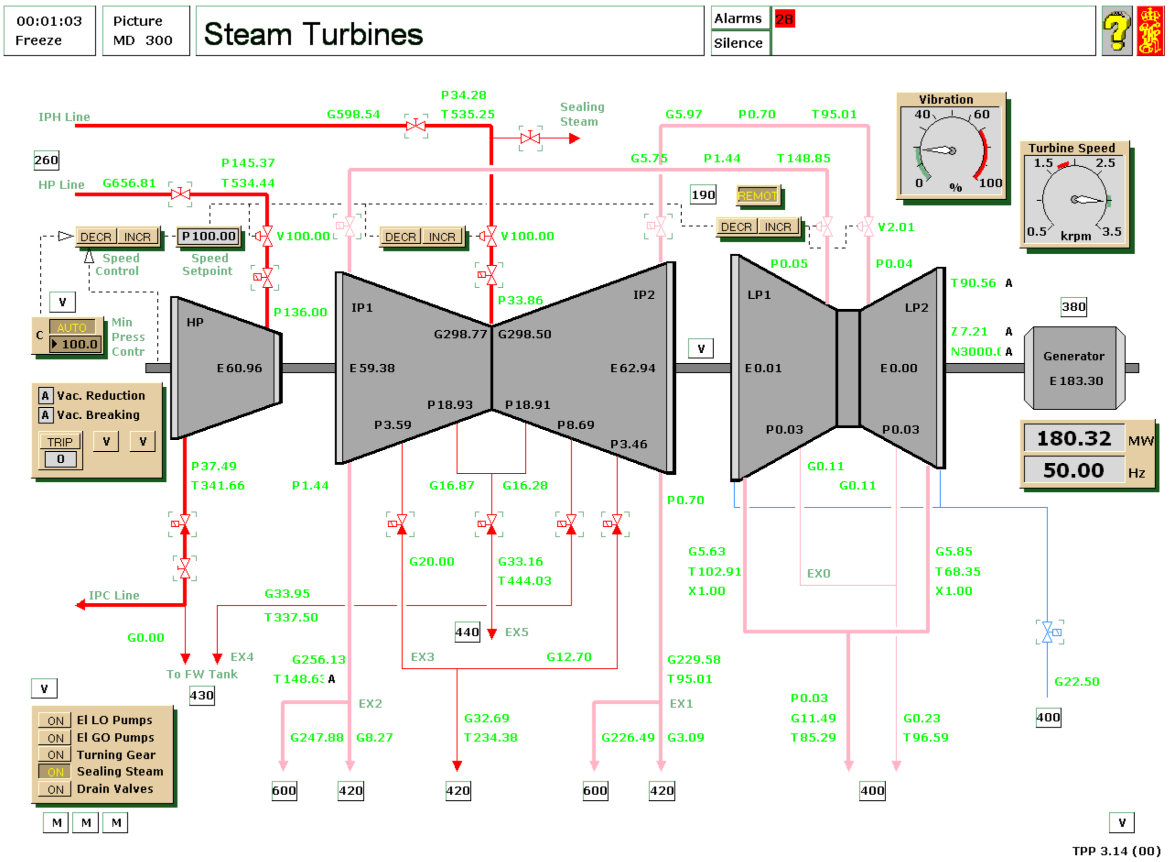
2.9.10.1 Steam Plant Overview Description

The picture is used to give a overview of the main steam lines.

Following subsystems are implemented but not described in detail:

Direct heater system.	(MD610)
Cold condenser system	(MD400)
Main condensate system	(MD410)
Low pressure feed heaters	(MD420)
Feed water deaerator system.	(MD430)
High pressure feed heaters.	(MD440)
Boiler water system.	(MD240)
Hot condenser system	(MD600)

2.9.11 Steam Turbines (MD300)



2.9.11.1 Steam Turbines Description

This picture contains all the information necessary for the steam turbine train.
Control and shut off valves for HP and IP turbine are implemented.
Turbine extraction's are implemented.
The three main steam lines are marked as IPH line, HP line and IPC line.
The generator are implemented.

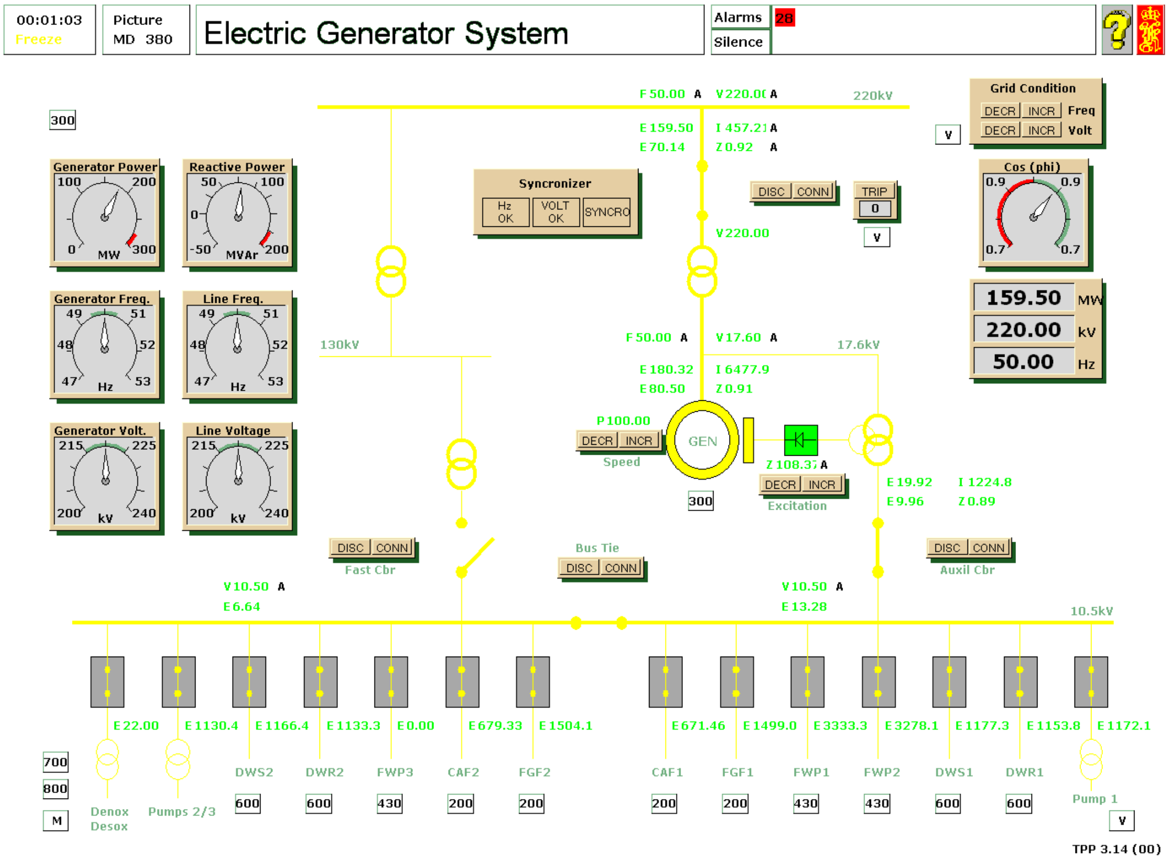
Automatic quick shut down/aggregate switch disconnection of the turbines

A quick shut down of the turbines or an aggregate switch disconnection to power production for internal use only is supposed to occur when any of the following conditions are fulfilled. The block load reduction controller (BLR) takes care of the reduction in boiler effect.

Incident	Limit
High steam pressure at VK 42	>2.55 bar
High steam pressure at VK 41	>2.10 bar
High temperature at HP turbine outlet	>510°C

It is easy for the instructor to add new incidents and the limits which are associated to load reductions like this.

2.9.12 Electric Generator (MD380)



2.9.12.1 Electric Generator Description

This picture includes all the necessary information about the electric generator.

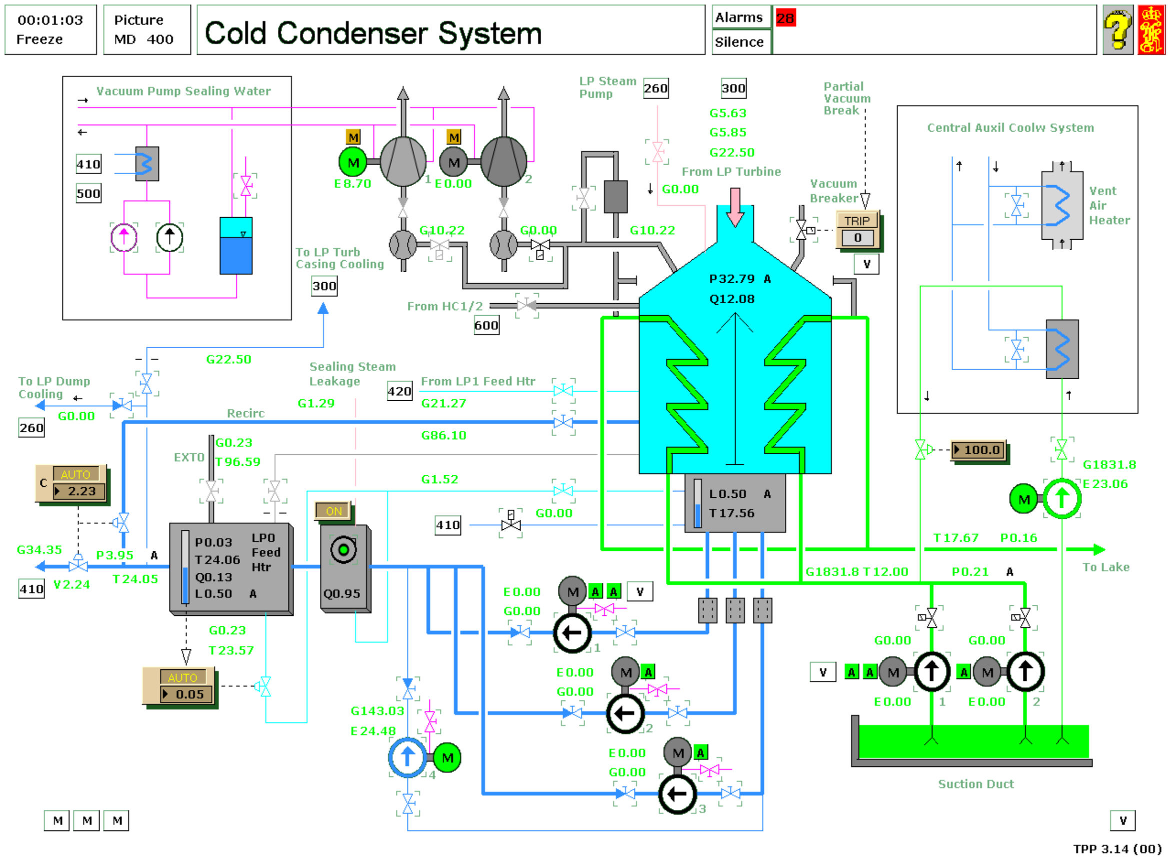
Control of the generator

Control of excitation current and voltage.
Control of main circuit breakers and bus-tie breakers.

Monitoring of the generator

Monitoring of block active load (MW).
Monitoring of block reactive load (MWAR).
Monitoring of generator current (KA).
Monitoring of cosφ.

2.9.13 Cold Condenser System (MD400)



2.9.13.1 Cold Condenser System Description

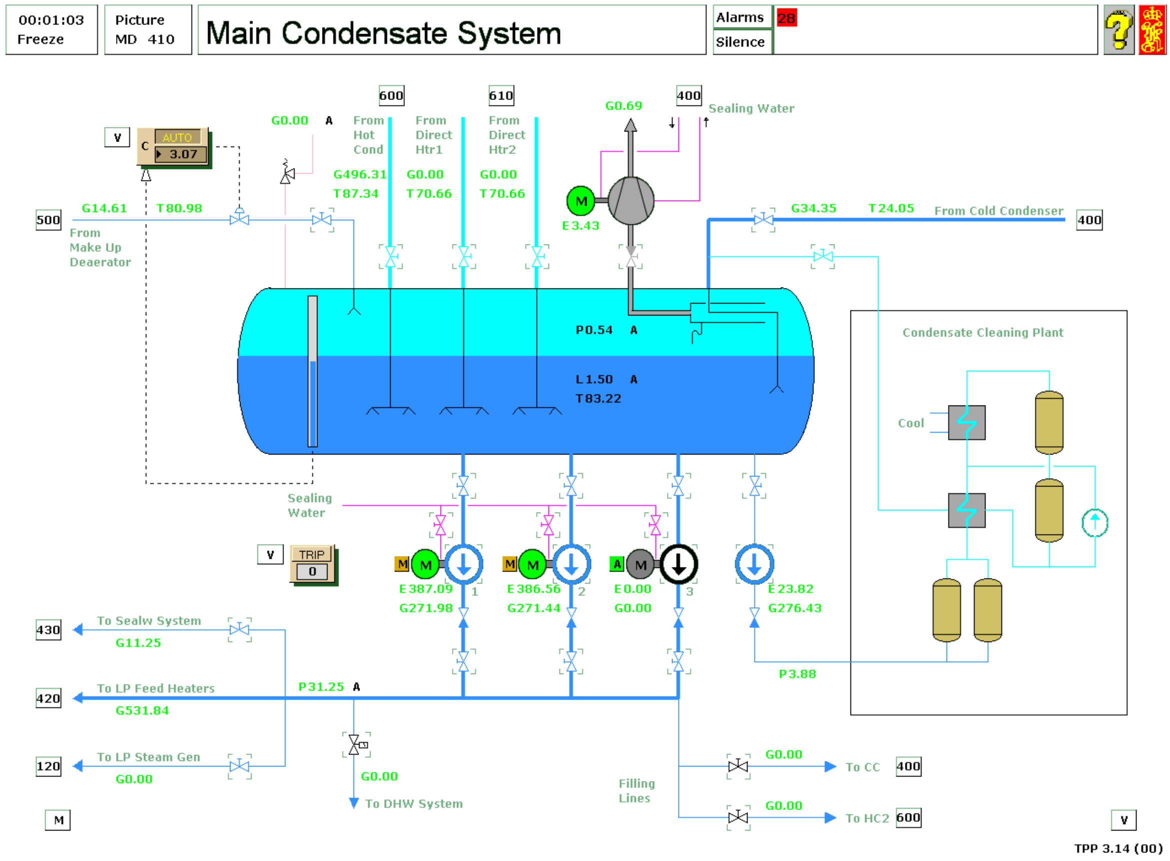
Cooling water to the main condenser is supplied by two pumps which pumps fresh water from a suction duct.
The cooling water is taken from the lake, and returned to lake after the cold condenser.

The vacuum of the main condenser is maintained by two mechanical vacuum pumps. Normally one is in operation at a time.
The vacuum pumps has a special system for sealing water which comprises two pumps.
Steam inlet to the condenser is from the LP turbine (MD300).
The condensate is collected in the hotwell below the condenser shell. Three electrically driven condensate pumps are pumping the condensate from the hotwell to the LP feed heater (MD420), through a gland condenser.
Condensate pump 1 & 2 has the same rate and size, but condensate pump 3 is a smaller pump.

The water level in the condenser is controlled, to protect the main turbine from damage if level is too high, or to prevent the condensate pumps from cavitating, if level is too low. The level is controlled by recirculation of condensate back to the condenser.

Water level control in cold condenser
Water level control in the cold condenser KK4 is realised by controlling valves (RV 427-8) with a PID-controller at the outlet of the condenser.

2.9.14 Main Condensate System (MD410)



2.9.14.1 Main Condensate System Description

The main condensate tank has connected drains from hot condenser, from direct heater 1 & 2 and from the cold condenser.
The main condenser has a separate level control system. If the level is low, the level controller open supply from the make up deaerator tank.
The main condensate tank has a separate vacuum pump with a sealing water system.

There are three main condensate pumps in the system with safety valves, delivery and suction valves. The condensate pumps have a sealing water system.

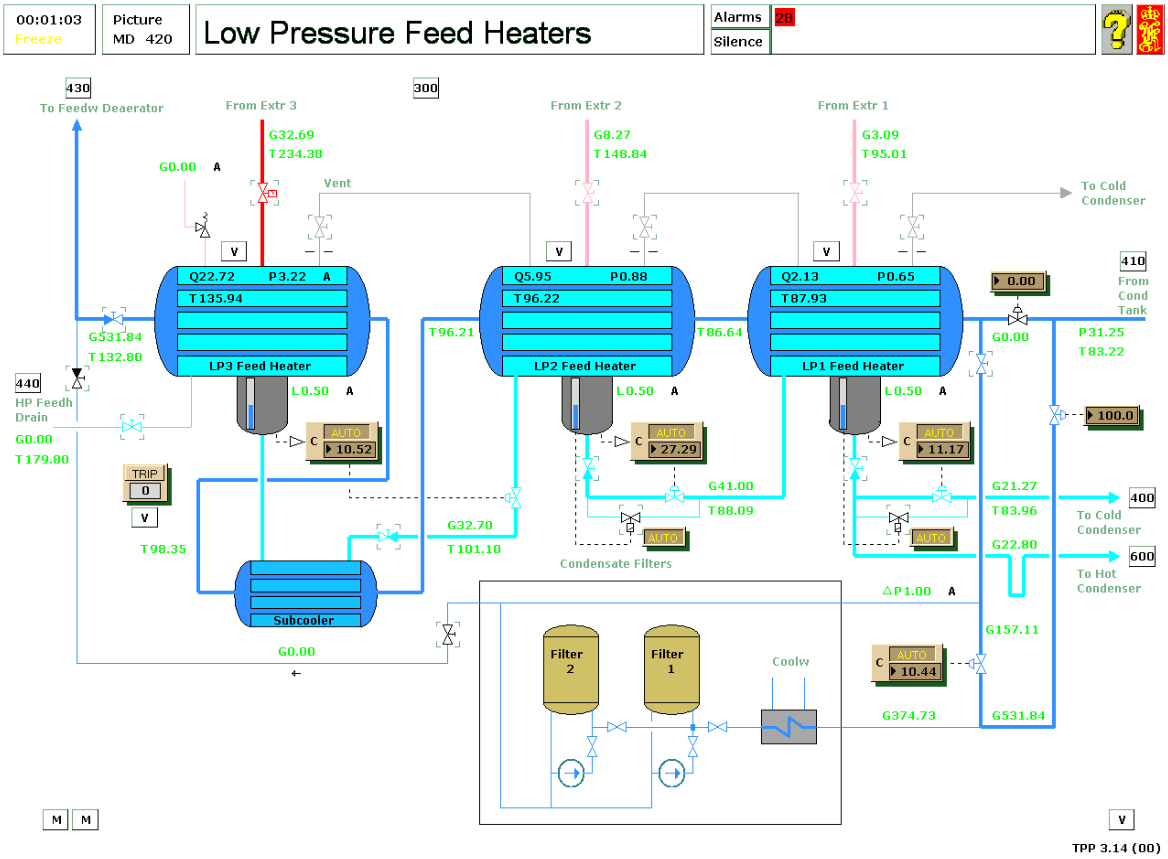
There are implemented a dump valve on the discharge from the main condensate pumps, to make dumping of condensate water possible. The delivery is to the lake.

For the complete thermal power plant there is a common cleaning plant. This is not modelled, just indicated on the picture. It is possible to start a cleaning plant transfer pump for cleaning condensate water from the main condensate tank.
It is also a valve for return of cleaned condensate water.

Water level control of main condensate tank KC 4

After gasification of the water in SP 4 the water is pumped via RV 423 to KC 4. The control is arranged with a PID-controller.

2.9.15 Low Pressure Feed Heaters (MD420)



2.9.15.1 Low Pressure Feed Heaters Description

There are three LP feed water heaters in this system
LP1, LP2 and LP3.

Supply line is from main condensate tank. It is a possibility to run the condensate through a filter plant with 2 POWDEX filters. The system is used as long as the condensate has low temperature (During start up).
After the temperature reaches normal level the filter efficiency is getting too low.

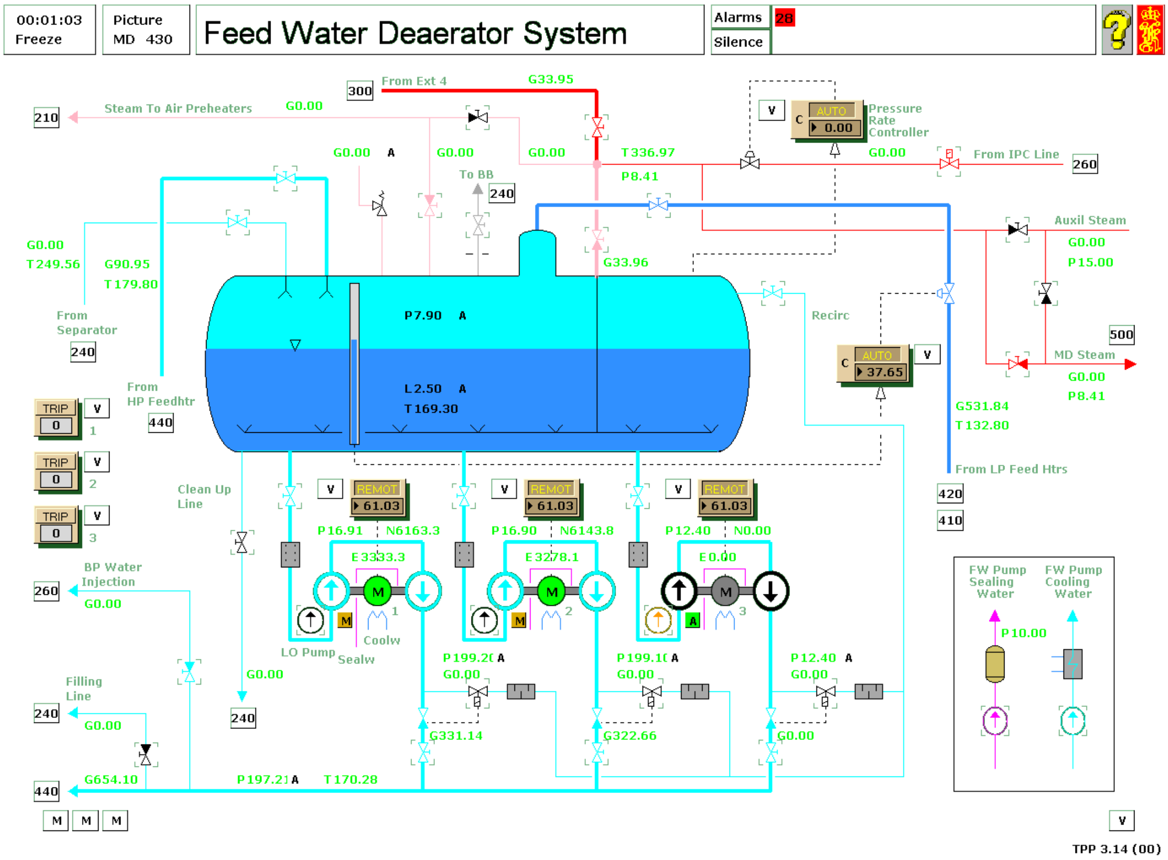
There is ventilation lines between each LP feed heater which have to be opened before starting the system.
Each LP feed heater have a separate level control system. If the level is getting too high the condensate is drained back to the cold condenser.

For heating of the LP feed heaters Turbine extraction's on IP turbine is used (MD300).

The feedwater outlet from LP feed heater 3 is going to the feedwater deaerator tank.

The LP3 feed heater has a safety valve installed.

2.9.16 Feed Water deaerator Tank System (MD430)



2.9.16.1 Feed Water deaerator Tank System Description

The feedwater deaerator tank has supply from LP feed heaters and from separator.

There are three main feed water pumps implemented in the system with a recirculation system back to the feedwater deaerator tank. The recirc. system is pressure controlled through a pressure shock absorber.

The feed water pump motors are water-cooled and the pump has a sealing water system.

The delivery goes through a common feedwater line to a valve and the into the high pressure feed heaters.

The delivery is also divided to the boiler water make up line.

The feedwater deaerator tank has a special clean up line valve for cleaning of condensate before start up.

For temperature control of the feedwater deaerator tank, a line from IPC is implemented with a separate temperature controller.

For level control of the feedwater deaerator tank there is a supply line from the LP feed heaters controlled from a level controller.

Feed water deaerator tank pressure controller (SBD)
There are two main goals of the feed water pressure control system:
- To keep the rate of change of pressure in the feed water tank between certain limits.
- To keep a minimal pressure in the feed water tank to prevent cavitation in the feed water pumps.

When any of the two limits above is exceeded, the pressure is changed by the SBD-valve. This valve is normally closed. It is affected by a PI-controller. If the pressure in the feed water tank falls quicker than the pre-set limit of the rate of change, the valve is opened, while at constant pressure or at a small pressure gradient the valve is kept closed. A second control signal, superior to the first one, opens the valve if the measured pressure is below the minimal feed water pressure (which is set by the control panel). A normal value of the minimal pressure is 2.5 bar.

Feed water level controller (SBN)
The water level in the feed water tank is affected by changes in the feed water flow (control valve SBN).

Feed water controllers (SW, DR).
The aim with the feed water control is to, at any load condition, supply the boiler with the correct amount of feed water.

At low load, the feed water control guarantees that the boiler gets the required amount of water, so that no overheated zones exist in the boiler.

The control equipment comprises a main controller for set point value determination, a flow controller, valve controller, speed control of feed water pumps, and temperature correction control.

The text below describes in short how these controllers are connected and how they work.

- Main controller for set value determination:
  The main signal to control the feed water flow is obtained from the fuel flow signal. This signal is input to the P-controller (20-SW) to which also the correction signal from the temperature correction controller is connected. The output from the controller is a measure of the desired water flow to the boiler based on fuel flow and temperature correction. This output is input to the flow controller.

- Flow controller:
  The output from the set point value controller (20-SW) is the main set point value to the flow controller (10-SW). The controlled variable is the feed water flow, as measured before the economiser.

As a positive input to the controller there is also a fixed set point value. This value represents the minimal feed water flow (approximately 260 ton/h).

The flow controller is of PI type and has double outputs, of which one is input to the valve control and the other is input to the speed control of the feed water pumps.

- Valve control:
  The valve controller affects the actuator on the feed water control valve. The controller is the proportional type and receives a feedback signal from the position of the valve.

  The aim with the feed water controller is to obtain sufficient pressure drop for the injection control and to obtain quick correction of the feed water flow which is required to counteract disturbances. The speed control of the feed water pumps is slow and is not quick enough to counteract disturbances.

- Speed control of feed water pumps:
  The speed control unit consists of a main speed controller (20-DR) of PI-type. The output from the flow controller (10-SW) is input to 20-DR where it is compared to a set value from 28-DR. At deviations the output of 20-DR is affected. With the set value from 28-DR, the position of the feed water valve can be set in advance.
  The output from 20-DR is connected to each of three multiplication units before entering as control signal to the speed controllers (DR 1-3) of the feed water pumps.

- Temperature correction control:
  The aim of the temperature correction is to keep the boiling temperature in the boiler at a suitable value, so that the fluid at the exit of the evaporator keeps at a constant temperature and is slightly superheated.

  The control unit consists of the controller (22-SW) and the D-controller (23-SW) which are connected in cascade. The D-controller has a load-dependent time constant, which is controlled by the block load controller (23-BLM). This is necessary because the time from the exit of the evaporator to the final temperature measuring point differs considerably between low and full load.

  The temperature is measured at the exit of the evaporator and is input to 23-SW. In this way there is a tendency justification of the feed water flow.

  The steam flow after the water separation tank is measured and is also an input to 23-SW with the same effect as previously described.

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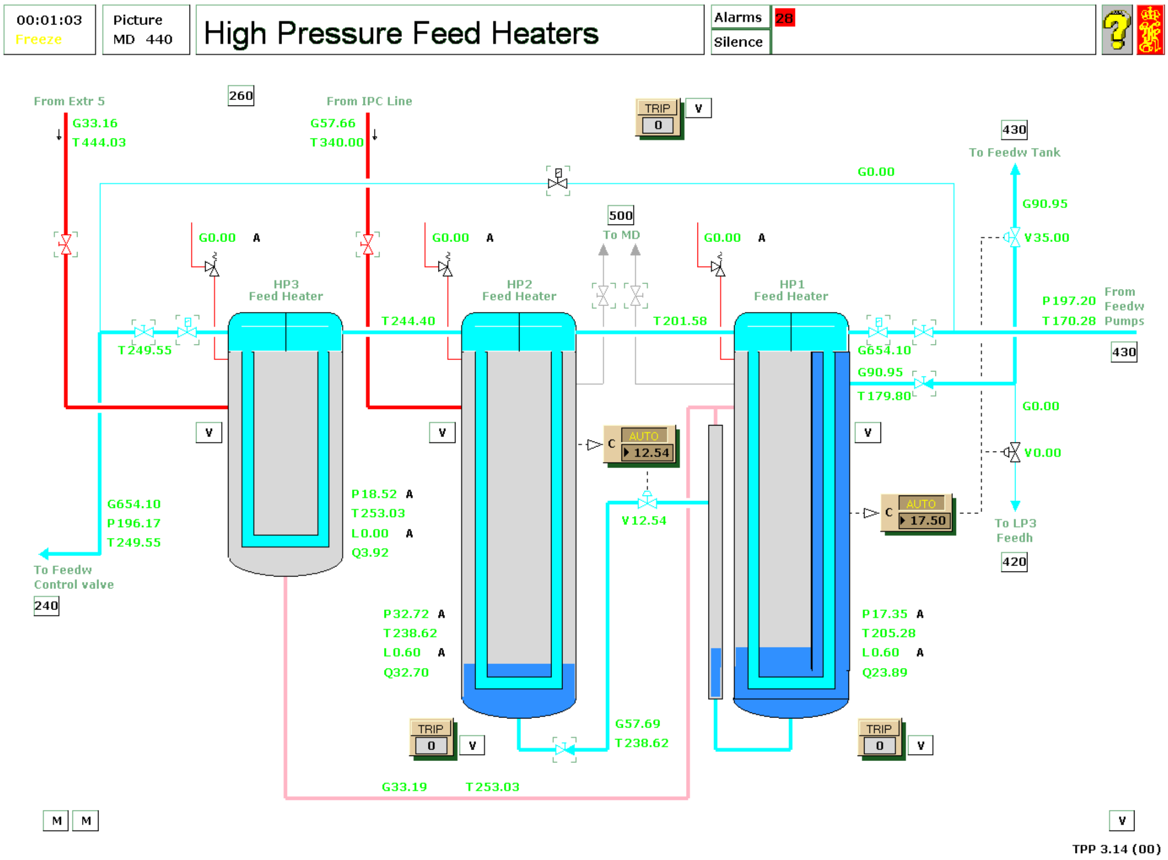
2.9.17 High Pressure Feed Heaters (MD440)



2.9.17.1 High Pressure Feed Heaters Description

The HP feed heaters has input from the feedwater pumps. The feedwater could be made to go by-pass the HP feed heater 1-3.

There are two outlets on the feedwater line for water injection in the superheater 1 and 2.

The level control for the feed heaters are connected back to the feedwater tank or to LP feed heater 3.

HP 3 feed heater has no level control but it has connection to HP 1 feed heater which has level control.

The HP feed heater 2 has separate level control which also drains to HP feed heater 1.

The steam supply for heating is taken from turbine extraction's on IP turbine.
The steam is supplied to HP feed heater 3 and 2.

There is venting valves and lines between the HP feed heaters.
The following components are included in the high pressure feed heater system:

All HP feed heaters has safety valves.

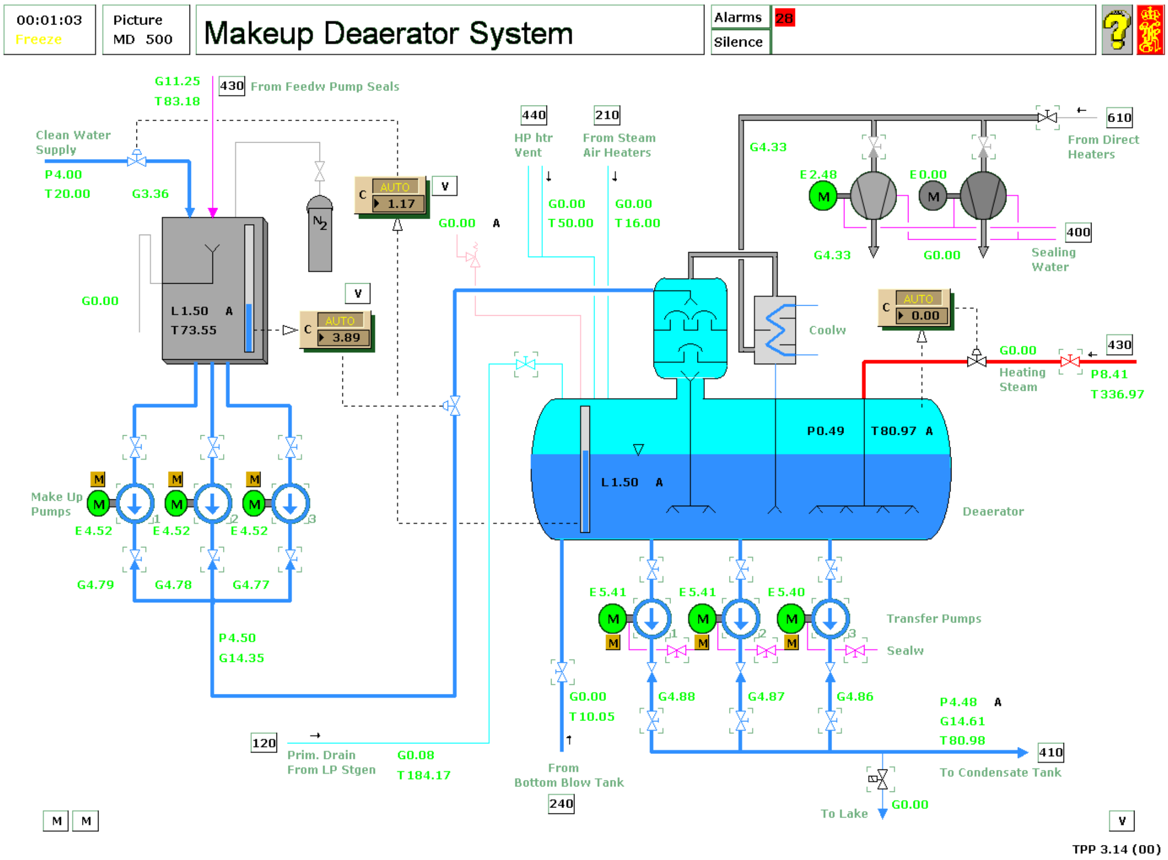
Water level control of the high pressure preheaters FV 45 A-B

The water level control in these high pressure preheaters is realised by controlling valves (RV 433 A-B) with a PID-controller at the outlet of the preheaters.

Water level control of the high pressure preheaters FV 46 A-B

The water level control in these high pressure preheaters is realised by controlling valves (RV 406-7) with a PID-controller at the outlet of the preheaters.

2.9.18 Make-up Deaerator System (MD500)



2.9.18.1 Make-up Deaerator System Description

The main purpose for the make up deaerator system is to make boiler water and to clean boiler water from different drains.

The make-up deaerator system has different inputs:

- From miscellaneous drains and from steam air preheaters.
- From the primary drain LP steam generator.
- From the bottom blow tank.

The make up of the deaerator water level is done from a make up water suction tank.
This tank has connection to a nitrogen bottle. There is also a vent valve connected to this tank.

The level control for this tank controls the delivery valve to the make up deaerator.

The level control for the make up deaerator controls filling of freshwater to the make up suction tank.

There are three pumps which serves as make up pumps.

The filling of make up water is done through a dearation column which is designed with a large surface. This will make separation of water and oxygen easier.
The vapour from this deaerator column is taken through a deaerator cooler for condensation of vapour.

The deaerator cooler is connected to two vacuum pumps. The purpose of the vacuum pumps is for of air.

The temperature control on the deaerator is controlling a steam valve for the heating steam system.(MD430).

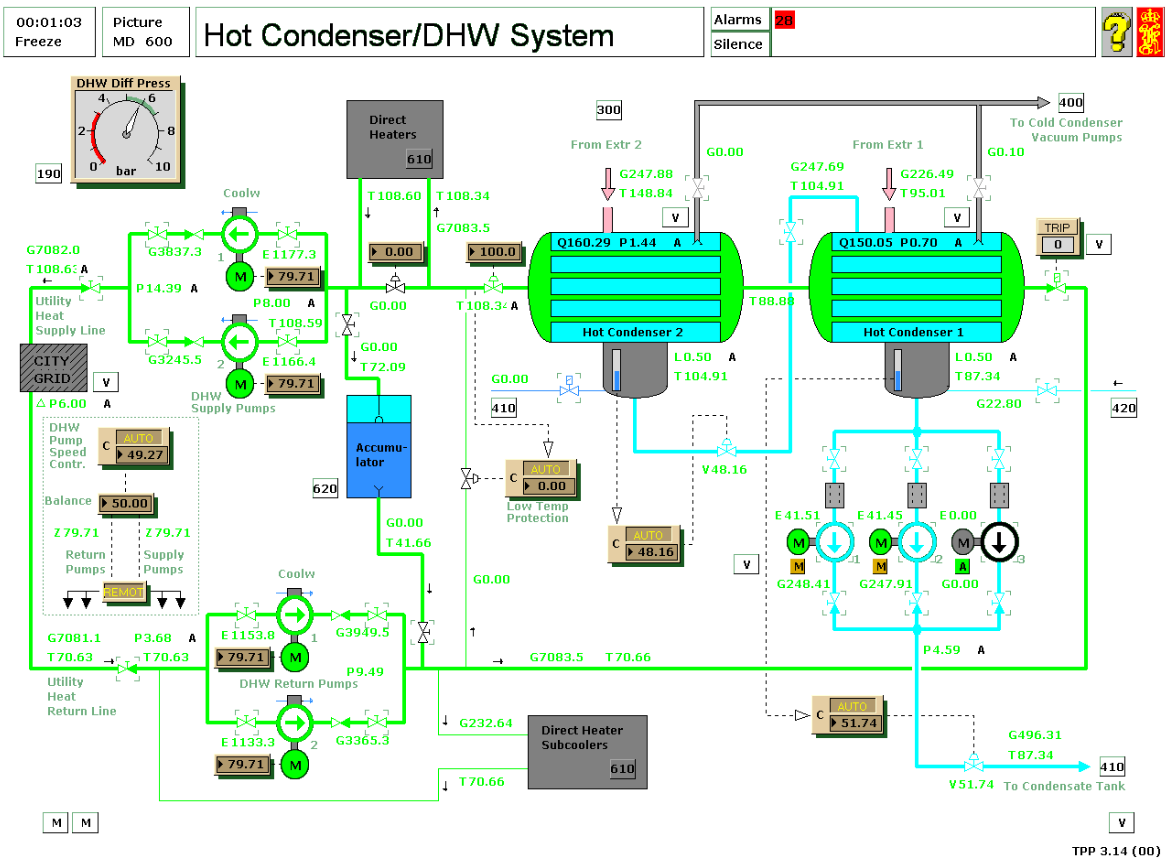
The deaerated water supply to the system is delivered by three make up pumps.

The delivery could be routed to either the condensate tank or to lake. It will be routed to lake if there is to much make up water.

Water level control of make-up Deaerator tank SP4

Water level control of SP 4 is realised through a PID-controller which affects the control valve RV 421.

2.9.19 Hot Condenser System (MD600)



2.9.19.1 Hot Condenser System Description

The main purpose for this system is to heat district heater water system from the IP steam system.

Instead of running the IP turbine at full effect we can open for turbine extraction's 1 and 2 and let some of the reheated steam to heat primary water for the district water system.

The water in the return line from the district heater system is pumped in to the system by means of two district heater supply pumps. The water goes into hot condenser 1 and afterwards to hot condenser 2.

The condensate from Hot condenser 1 and 2 are pumped out of the hot well by three hot condensate pumps.

The level control on hot condenser 1 is controlling a delivery valve on the output of the hot condensate pumps to the condensate tank.

The level control on hot condenser 2 is controlling a delivery valve on the outlet of the hotwell on hot condenser 2 to hot condenser 1.

The Hot condensers have also connection to the vacuum pumps which also is used for the cold condenser system.

The outlet from district heating water supply pumps could also be controlled direct to the direct heater bypass valve if the temperature on district water is high enough.

Level controller in the hot condenser

Water level control in the hot condensers (VK 41-42) is realised by controlling valves (RV 427-8) with a PID-controller at the outlet of the condenser.

Hot water pressure controller (HWD)

The aim with the hot water pressure control is to balance the district heating distribution and to return pumps in such a way, that the required difference pressure between the distribution and return pipes is obtained.

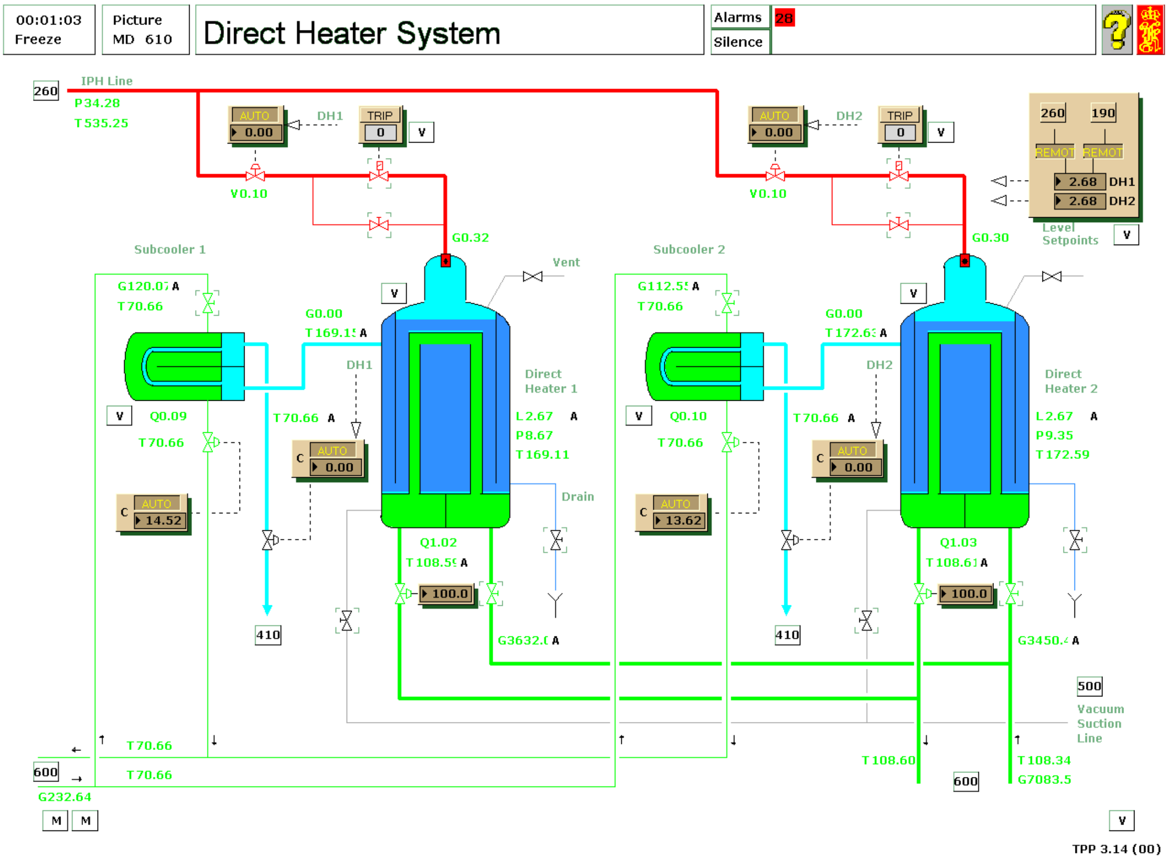
The set point value of this difference pressure is adjusted manually from the control panel. The control signal from the pressure difference controller is input to two speed controllers (BLW 1-2) of the two pumps.

Hot water temperature controller (HWT)

The water temperature at the outlet of VK 42 is controlled by means of bypassing (valve RV 408) the water to the hot condensers (VK 41 - VK 42).

The control is performed by a P-controller which controls the valve in the hot water bypass pipe. The measured value (hot water temperature) is input to the controller. The set value is set manually from the control panel.

2.9.20 Direct Heater System (MD610)



2.9.20.1 Direct Heater System Description

The direct heater 1 and 2 are in fact another set of hot condensers.

The direct heater system is connected to the IPH line so it is possible to use the reheated IP steam to direct heater system.

Inlet to direct heater 1 and 2 has three valves from IPH line, one shut off valve, one steam control valve and one preheater valve which is normally open to keep a minimum temperature in the direct heater.

Both direct heaters has drain and vent. valves.

The district water inlet to direct heater 2 is supplied from hot condenser 2 (MD610).

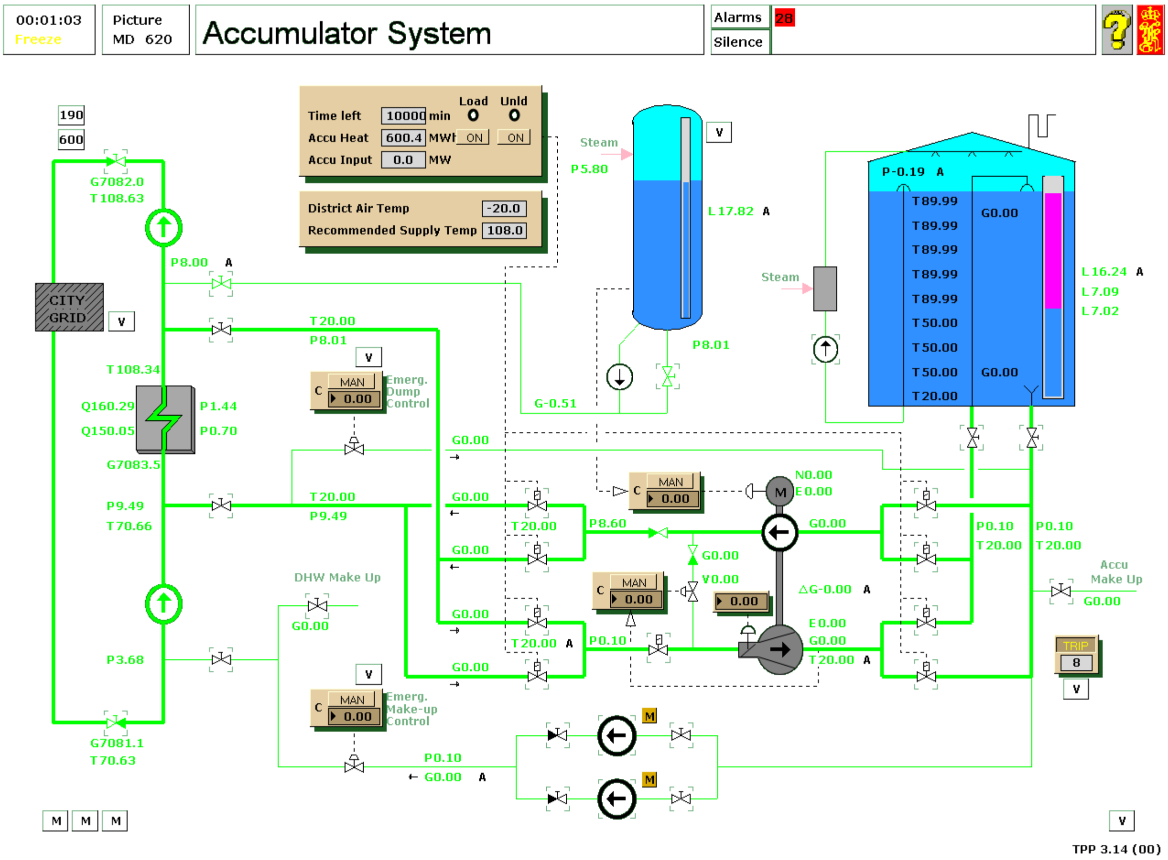
Supply to sub-cooler 1 and 2 are taken from the outlet of the district heating water suction pumps.(MD610). The flow through the sub-coolers is very small compared to the total flow of district water. The return from the sub-coolers is connected back to the district heating water suction pumps.

Both district heaters have a level control system which controls a regulating valve on the outlet off the sub-coolers.

The sub-coolers main purpose is to cool down the condensate from direct heater. In some situations the condensate could be very hot and this condensate is lined back to the condensate tank which contains "cold" water at atmospheric pressure. It is not recommended to supply water with this temperature difference direct to the condensate tank.

The efficiency of the direct heaters are controlled by the condensate level in the direct heaters. For high efficiency condensate level is low and for low efficiency water level is high.

2.9.21 Accumulator System (MD620)



2.9.21.1 Accumulator System Description

The system consists of a large hot water storage tank, an expansion tank, a water turbine, an accumulator pump, auxiliary pumps and necessary valves and pipes.

(a) Accumulator tank

Diameter:	42 m
Height:	18 m
Normal level:	16.5 m
Min charge volume:	19600 cubm
Max charge volume:	22300 cubm
Heat storage capacity:	1100 Mwh

(b) Accumulator pump

Flow:	5000 cubm at head 95 m
Motor:	1000 kW

(c) Turbine

Type:	francis
Design head:	80 m

Shaft power:	50-750 kW
Speed:	700-900 rpm

(d) Expansion tank

Height:	26 m
Normal level:	18 m
Volume:	500 cubm

(e) Make up pumps

Flow:	200cubm at head 55 m
Speed:	2900 rpm
Power:	60 kW

General description

The accumulator tank is used to store heat energy produced by the power plant. The full heat production of 4 hours can be stored for later release. Operation of the heat storage tank will depend on electric power price, weather condition and time of day. The accumulator tank enables a more safe and optimal power plant operation. Normal procedure will be to charge the accumulator at day time and thus producing much electric power at high price, and discharge the accumulator during night when electric power price is lower. Hot water demand varies from hour to hour. For instance high hot water requirement in the morning (showers), high power requirement in the afternoon (cooking) etc. The accumulator makes is easier to meet such changing heat loads and electric power demands.

Accumulator tank

The accumulator tank is operating at atmospheric pressure. It is based on the principle that hot water is lighter than cold water. t is therefor possible to store the water in stable temperature layers with hardly any inter mixing, assuming water is supplied to the tank top, or removed from the tank bottom without turbulence.

The specific water density of 55 dgr C water is 986 kg/cubm, while it is 962 kg/cubm at 95 dgr C. This represents a weight difference of 25 kg/cubm.

The useful load volume of the tank is 22000 cubm and the total heat storage capacity amounts to 1150 MW with a temperature difference of 45 dgrC. The maximum load or unload rate is 5000 cubm/h, which corresponds to approximately 250 MW. This means that the power plant has a good momentary heat reserve in case of disturbances like turbine or boiler trip.
As the working pressure of the DHW pipe line is 80-100 mWL, 60-80 mWL pressure head is available for the water turbine installed to help driving the accumulator pump, pumping water back to the DHW pipe line from the accumulator tank.

Turbine power varies with flow and pressure. It can be as high as 750 kW. Never the less the turbine power is not in any mode of operation sufficient for driving the accumulator pump up to balanced water flow.

The speed of the combined turbine/pump unit is boosted by an electric motor with speed control facility, to control the flows to and from the accumulator tank to desired (usually equal) values.

Flow through the turbine is manually controlled by opening or closing the inlet dampers of the turbine.

The volume difference between unloaded (cold) and loaded (hot) accumulator tank amounts to approximately 575 cubm. This corresponds to an level variation of 0.5 m in the accumulator tank. The pump speed is controlled to keep the expantion tank level constant, and all variations in water density will be reflected in changing accumulator tank level.

Description of accumulator tank interior
In the tank bottom there is a fixed distribution system for cold water. In the tank top there is a movable float arrangement with 4 movable floats mounted on 4 arms. The arms are flexibly connected to the hot water supply pipe in the center of tank. The system is designed to discharge water with as low velocity as possible, to avoid turbulence and mixing of hot and cold water layers.

The volume above the water level is to be held free of oxygen. The air in the zone above the water is removed by a hot water spray system. A collecting arrangement for surface water is used for recirculation of spray water, which is kept at the boiling point by a steam heater. The steam to the heater is controlled according to the tank top pressure. Normal pressure is 30 mmWL above atmospheric pressure.

To active the spray system, start the spray pump. The system is not modeled in detail.

To protect the accumulator tank from excessive over or under pressure, a water seal is mounted a tank top. It opens at 65 mmWL and -40 mmWL. In addition safety valves open at 90 mmWL for extra protection (Not shown on drawing).

The water temperature distribution vertically in the tank is monitored by 20 platina resistance sensors mounted on a vertical wire going from tank top to bottom.

Turbine and pump unit
Between the turbine and the pump is a centrifugal clutch mechanism that releases the turbine from the pump shaft when the turbine shaft speed is below 200 rpm.

The turbine is a francis turbine type with spiral shaped inlet casing. Inlet dampers can be manually set for flow adjustment.
The turbine shut off valve is closed if the electric motor stops, or if any trip signal is present.

The turbine bearings are lubricated by a separate lubrication system including a LO cooler. This system is not modeled.

The accumulator pump is of the same type and capacity as the DHW supply and return pumps. The speed can be controlled by varying the rotor resistance through an electrolytic boiler rheostat, as for all major speed controlled pumps in the power plant system.

Accumulator temperature protection
A temperature control system protects the accumulator tank from being loaded by too hot water. This is done by recirculation of cold water from the accumulator pump to turbine inlet, when necessary. If loading temperature exceeds 101 dgrC for some time, turbine trip signal will be given.

If the turbine is set for accumulator tank loading, and the pump motor is started, an open pulse is given to the recirculation valve, for flushing of cold water through the turbine piping. The open pulse at start lasts for 100 sec.

Expansion tank
The pressure at the DHW supply pumps, called the “intermediate pressure”, is to be controlled within the range 7.5 to 8.5 bar. The pressure is controlled by water flowing back and forth between the supply pumps inlet and the expansion tank, depending on pressure head difference.
The expansion tank has a steam cushion at top controlled by a separate steam system.
The steam system is not modeled in detail. The tank bottom pressure will be the sum of the steam pressure at top and the static liquid pressure head. Normal tank level is 18 m.

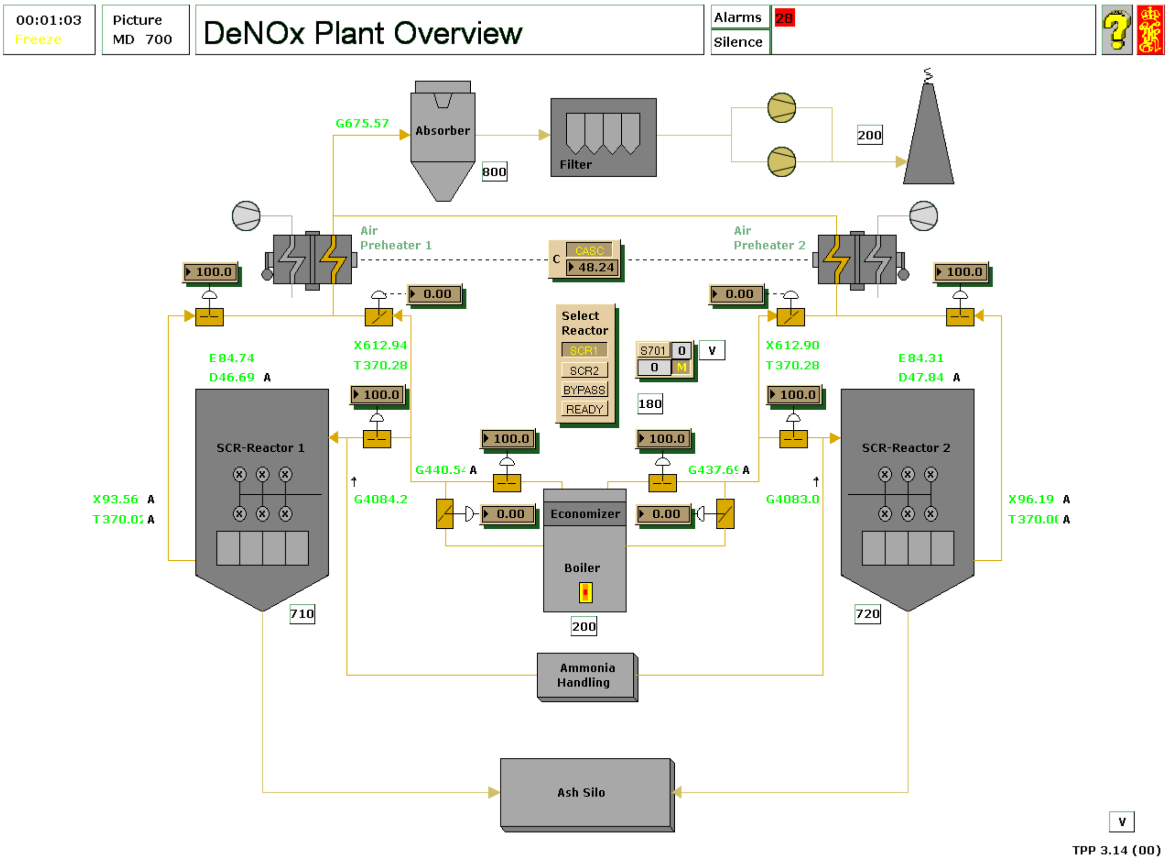
Make up/dump system
If the expansion tank level gets too low for some reason, a special dump valve opens and dumps water from the DHW system to the accumulator tank.

If the expansion tank level is too low, a make up controller opens the make up valve and water is pumped from the accumulator tank to the DHW system.

The make up pumps are automoatically started when the make up valve position is more than 25 % open.

The make up/dump system controlles the expansion tank level at times when the accumulator turbine/pump system is not in operation. Should a major leakage in the DHW net work occur, the make up pumps will start and alarm will be given if the make up flow is above a certain limit (150 t/h).

2.9.22 DeNox Plant overview (MD700)



2.9.22.1 DeNox Plant overview Description

The main purpose of the DeNox plant is for removal of nitrogen oxide from the flue gas. The method is built on a selective catalytic reduction. The medium used for the reduction is ammonia gas.

The plant comprises to SCR (selective catalytic reduction) reactors and an ash silo.

There are different dampers which is channelling the flue gas either into or bypass the SCR-reactor.

Before the DeNox plant can be set into operation a special heating procedure has to be done.

A certain fouling of the catalysators is modelled. The effect of this fouling will be an increase of the difference pressure over the SCR. A manually initiated soot blowing will clean the surfaces in the reactor.

Flue gas distribution

Channels are leading flue gas from the boiler to the reactors. There are two groups of channels, one on each side of the boiler consisting of three channels in front of and two channels after the economiser respectively.

Normally the flue gas is lead through the economiser. In the case of low gas temperature after the economiser, gas is by-passed the economiser via channels and dampers to the outlet in order to keep the temperature at set point. Hence warmer gas from the economiser inlet is mixed with gas from the economiser outlet. On each side of the boiler, outlet channels are joined together. The design of the channels guaranties thorough mixing of gases before gas is lead to the reactors. Each reactor has an inlet and an outlet damper. It is possible to bypass a reactor via a so called by-pass channel. The by-pass channel comprises a damper which is used to control the flow of gas.

After the reactors the flue gas is lead to the sulphur absorber and electric filter via the air preheaters. Combustion air is lead via preheaters and spiral pipes to the boiler. Hot flue gas is used in the preheaters to heat the combustion air.

When heating of a reactor is required, warm combustion air is drawn from the spiral pipes. A fan provides circulation of air through the reactor. A damper at the reactor inlet, and a damper downstream and upstream of the fan are used to control flow of air.

Combustion air drawn from the spiral pipes is also used to seal the by-pass dampers in order to avoid leakage of flue gas.

2.9.22.2 Sequence S701: Ventilation of flue gas canals

Preparation for start of chosen reactor Ventilation of the reactors is carried out in sequence 4 & 5, heating sequences

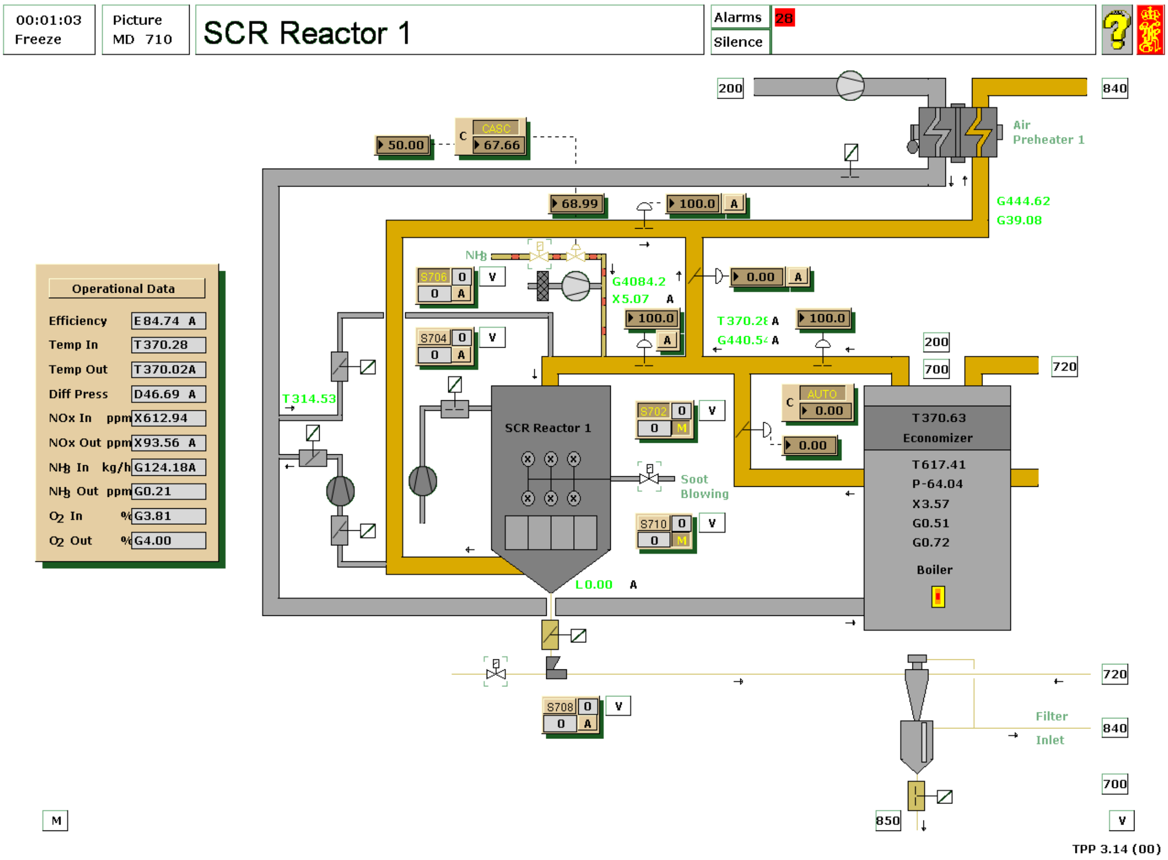
INTERLOCK: Boiler Burning or Combustion air fan and Flue gas fan not running

STEP 1: Boiler outlet temp controllers in auto sequence CAF distribution controller in auto sequence
STEP 2: Dampers After Eco Open
STEP 3: Bypass Dampers Open
STEP 4: Damper Before Eco Closed Inl/Outl Dampers Closed One Flue Gas Fan running

STEP 5: Both Comb. Air Fans running
STEP 6: Boiler Purge State in progress or complete if SCR1 selected if Reactor outlet temp < 65C and Heating on for less than 10 min
set STEP = 7
else set STEP = 8
else set STEP = 8
STEP 7: Wait 8s
STEP 8: if SCR2 selected if Reactor outlet temp < 65C and Heating on for less than10min
set STEP = 9
else set STEP = 10
else set STEP = 10
STEP 9: Wait 8s
STEP 10: Wait 60% of total purge time
STEP 11: Wait 4s
STEP 12: Dampers before eco 14% open
STEP 13: Wait 40% of total purge time
STEP 14: Dampers before eco closed
STEP 15: if By-pass SCR
set STEP = 23
else set STEP = 16
STEP 16: if Select reactor 1 to be ventilated
set STEP = 17;
else Select reactor 2 to be ventilated
set STEP = 20;
STEP 17: Reactor 2 by-pass damper closed Reactor 2 Damper After Economizer closed
STEP 18: SCR2 damper after eco closed
SCR2 by-pass damper closed
Boiler burner started
Combustion air fan 2 not in operation
STEP 19: set STEP = 24;
STEP 20: Reactor 1 by-pass damper closed
Reactor 1 Damper After Economizer closed
STEP 21: SCR1 damper after eco closed

SCR1 by-pass damper closed
Boiler burner started
Combustion air fan 1 not in operation
STEP 22: set STEP = 24;
STEP 23:
STEP 24:

2.9.23 SCR Reactor 1 (MD710)



2.9.23.1 SCR Reactor 1 Description

The boiler has two similar flue gas outlet manifolds, one for each reactor. there are two outlets on each manifold and three outlets before the economiser.
The two outlets is the "ordinary" outlets to the reactor, but if the flue gas temperature is not high enough it is possible to take flue gas from the outlets before the economiser.

Ammonia Injection

The ammonia injection system comprises a high pressure fan, a gas mixer, and 16 nozzle pipes. Guiding vanes are leading air via a filter and a damper to the air fan. A sensor is used to measure air pressure in the channel after the air fan.

The air is lead from the fan via a pipe to a mixing chamber where ammonia is injected, at a ratio of 1 vol. % NH_3 per 20 vol. % air. In the DeNox plant simulator ammonia is supplied from a tank containing ammonia at a given pressure and temperature. It is possible for the instructor to adjust conditions.

The chamber provides a thorough mixing of gases. After mixing the gas is flowing to the nozzle tubes which are inserted into the flue gas channel at the reactor inlet. The tubes furnish a great number of nozzles and the ammonia/air gas mixture is injected and distributed evenly in the flue gas channel. A measuring device (venturi) installed between the fan and mixing chamber is used to measure flow of air. An orifice plate is used to measure consumption of ammonia. The ammonia pipe connected to the mixing chamber comprises a control valve and a shut off valve. A controller is used to control the flow of ammonia gas injected into the mixer. Measurement of NO_x in the flue gas is used as input to the controller. A sensor installed in the reactor outlet channel is used to measure content of ammonia in the flue gas, and an alarm is issued in the case of high content. If the content of ammonia exceeds a certain limit, the supply of ammonia is shut off.

The pipes leading ammonia to the nozzles are furnished with orifice plates. During fine tuning of the plant flow measurements are used to adjust the flow of ammonia.

The reactor itself consists of replaceable catalysator elements, inlet/outlet and soot blowing equipment. The catalysator has a surface which is active and it will react with the flue gas which is injected with ammonia gas.

Nox Controller

Set Point: SP = XNOX
where
XNOXN = "Nominel" (reference) conversion ratio

Conversion ratio = $\frac{\text{Nox in - Nox out}}{\text{Nox in}}$

The slip of ammonia (NH_3 after reactor) is controlled by adjusting XNOXOS (NH_3 slip coefficient).

Feed back: XNOXFB = XNOX + XNOXO
where
XNOX = actual NOX conversion ratio
XNOXOS = NOX conversion ratio offset

NH_3 Control Valve

The valve position is given by POS = N_ NH_3 * PID OUT where
N_ NH_3 = Amount of NH_3 required in conversion of NOX
PID OUT = Output from NOX controller

SCR Reactors
There are two similar reactors.

The cleaning of flue gas is based on the High Dust Principle. The SCR reactor is located in front of the air preheater. The flue gas passing through the reactor has a high content of foreign matter and sulphur.

The reactor is made up of three parts, namely, the inlet, the reactor chamber, and the outlet. The reactor chamber comprises a 13 m tall container with sides 6 x 9 m. Flue gas and ammonia/air mixture enter the inlet at the top of the construction. The inlet furnishes guiding vanes, and the gas is distributed evenly over the inlet area. A total of 54 modules are distributed in the chamber on two planes, each plane containing 27 units. The efficiency of a catalyst unit decreases after approximately 3 years. There are room for more units on a third plane.

The catalysts are of the plate type. Every module consists of a stock with embedded plates. The plates are covered with an active material, which constitutes the real catalyst. Leading plates are installed in order to force the gas through the catalysts.

The flue gas leaves the reactor in the bottom. Matter is formed in the reaction between ammonia and flue gas, and a greater part of this matter drops down into two pockets when the gas-flow suddenly changes direction. Periodically the pockets are emptied via a damper and leading channel into the ejector. The matter is then transported to a cyclone by means of pressurised air. The cyclone is common to both reactors. A differential pressure sensor is used to monitor that product is not clogging the reactor. If the differential pressure exceeds a given limit, an alarm is sounded. The differential pressure is continuously monitored and recorded.

The system supplying pressurised air to the ejectors is furnished with a pressure gauge. A pneumatic shut off valve is installed in front of each ejector. A sensor is used to measure pressure after each ejector.

Soot Blowers
Both reactors are furnished with soot blowers, and pressurised steam is used to clean the catalysts. The soot blowers are operated manually, either from the central control room or from a local panel. This operation is initiated when the differential pressure over the reactor exceeds a given limit.

Reactor heating
When starting up from cold state or in order to keep the reactor warm, hot combustion air is drawn from the spiral channel. See appendix E. A circulation fan is used to force the air through the reactor. In the heating loop one damper is embedded at the inlet while two dampers are located at the outlet, one on each side of the circulation fan.

Reactor drying
In order to keep the reactor dry, for instance during shut down, the reactor is furnished with a dryer. A fan provides circulation of air through the reactor. Moisture is separated from the air when passing through the dryer. One pneumatic damper is located on each side of the fan/dryer.

Reactor product handling
The product handling equipment comprises:
- Four pneumatic product dampers, two per reactor. One for each pocket.
- Four ejectors used to transport solids from the pockets to the common cyclone.
- A cyclone for separation of solid matter from the transport air.
- An intermediate container connected to the cyclone outlet.
- A damper connected to the bottom of the intermediate container.

Reactor product drops from the pockets through the channels and dampers down to the ejectors. From the ejectors the solids is transported to the cyclone by means of pressurised air. From the cyclone the stuff drops into the intermediate tank which has a capacity of 2 m3. A level guard issues an alarm in the case of high level in the intermediate tank.

Further handling of the solids is not to be taken into account in the DeNox plant simulator.

2.9.23.2 Sequence S702/S703: Start/stop Reactor

SCR1: Reactor to be started
SCR2: The other reactor

INTERLOCK This reactor can be started if selected, or the other already in operation

STEP 1: if SCR2 selected
Flow flue gas air preheater 2 > 1000Nm3/h
Air prehtr distribution controller in cascade
Damper after eco open
set STEP = 2
else Air preheater distr controller in cascade
Damper after eco open
set STEP = 3
STEP 2: Boiler outlet temp controller in auto
Air preheater distr controller in cascade
Damper after eco open
STEP 3: Reactor outlet temp > 157C
STEP 4: Ventilation inlet damper closed
Vent outlet damper before fan closed
Ventilation outlet damper after fan closed
Ventilation fan not running
STEP 5: if The other Reactor in operation
Flow flue gas/air preheater other side > 1000Nm3/h
set STEP = 6
else inlet/outlet damper 50% open
or Flow flue gas/air preheater other side < 1000Nm3/h
set STEP = 8
STEP 6: Combustion air fan running
Flow air through air preheater > 50000Nm3/h
STEP 7: if inlet/outlet damper 50% open
STEP 8: Inlet/Outlet Dampers open
STEP 9: if The other Reactor in operation if SCR1 by-pass damper closed and Flow flue gas/air preheater other side > 1000Mm3/h
set STEP = 10
else if by-pass damper closed
set STEP = 11
STEP 10: By-pass damper closed
STEP 11: Reactor outlet temp > 310C
STEP 12: Ammonia injection on-off valve open
Ammonia Controller not in auto
STEP 13:
STEP 51: if the other reactor in operation
Ammonia injection on-off valve closed
Ammonia injection sequence in auto
Flow flue gas through air prehtr other side > 1000Mm3/h

set STEP = 56
else Ammonia injection on-off valve closed
Injection sequence in auto
Flow flue gas air preheater other side < 1000Mm3/h
set STEP = 52
STEP 52: By-pass damper open
STEP 53: Inlet/Outlet dampers closed
STEP 54: Damper before eco closed
Damper after eco open
STEP 55: set STEP = 61;
STEP 56: Air prehtr distr controller in cascade mode
STEP 57: Inlet/Outlet damper to 50%
STEP 58: Flow air through air preheater < 50000Nm3/h
STEP 59: SCR by-pass damper closed
SCR inlet damper closed
SCR outlet damper closed
Damper before eco closed
Damper after eco closed
Combustion air fan not running
STEP 60:
STEP 61:

2.9.23.3 Sequence S704/S705: Heating and ventilation of reactor

SCR1: Reactor to be heated
SCR2: The other reactor

STEP 0:
STEP 1:
STEP 2: Heating outlet fan running
Ammonia injection air fan running
STEP 3: Heating dampers not closed
STEP 4:
STEP 5: Heating dampers closed
STEP 6: Heating dampers open
Heating outlet fan running
STEP 7:
STEP 51:
STEP 52: Heating dampers open
STEP 53: Heating outlet fan not running
STEP 54:

2.9.23.4 Sequence S706/S707: Ammonia injection

STEP 0:
STEP 1: Fan running

Reactor outlet NOx controller in cascade
NH3 injection flow controller in cascade
STEP 2: SCR outlet temp > 315C
STEP 3: Ammonia evaporator sequence ready
STEP 4: Wait 1m
Ammonia injection pressure > 200000Pa
Ammonia injection air flow < 4000Kg/h
STEP 5: On-off valve open
STEP 6: NH3 air fan running
STEP 7:
STEP 51: On-off valve closed
STEP 52: Control Valve closed
STEP 53:

2.9.23.5 Sequence S708/S709: Product handling

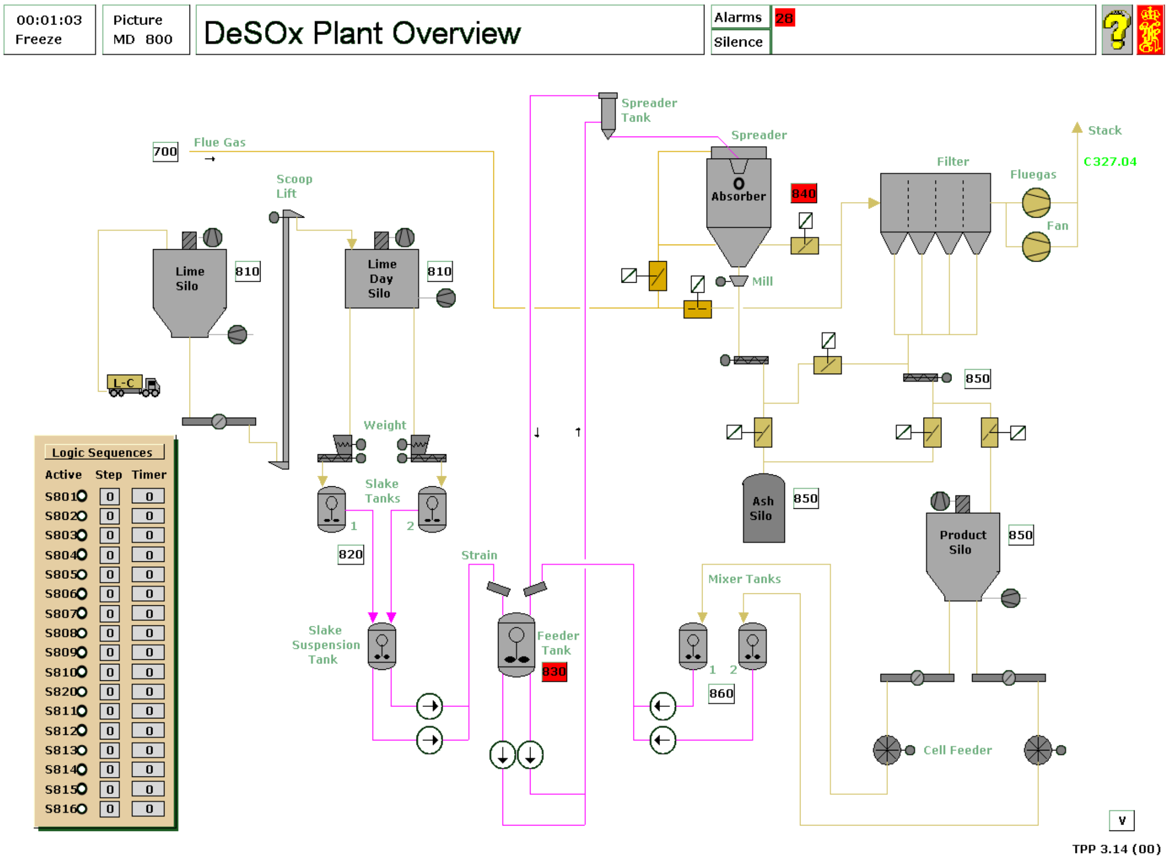
STEP 1: Transport air valve after ejector open
STEP 2: Transport air valve before ejector open
STEP 3: Wait 1m
STEP 4: Product damper open
STEP 5: Reactor product level < 10%
STEP 6: Wait 2m
STEP 7: Product damper closed
STEP 8: Wait 3m10s
STEP 9: Transport air valve before ejector closed
STEP 10: Transport air valve after ejector closed
STEP 11:

2.9.23.6 Sequence S710/S711 : Soot blowing

Soot blowing on the other reactor in progress
Bypass damper open
Inlet damper closed
Outlet damper closed
Flue gas flow to 'this' air preheater low
Reactor outlet temperature low

STEP 1-6: Activate soot blowers
STEP 10: Soot blowing valve open
Wait Soot blowing duration
STEP 51: Soot blowing valve closed
STEP 52-57: Retract soot blowers

2.9.24 De-Sulphurization Plant (MD800)



2.9.24.1 De-Sulphurization Plant Description

The plant has two silos for storage of lime, one main silo and one lime day silo.

The filling of the main silo is done by trucks.

The filling of the lime day silo is done by a conveyer belt and a scoop lift system.

The lime day silo has a filter to remove and separate lime dust.

The lime is transported down to a weight system and a conveyer belt to feed a continuos and correct amount of lime to the slake system.

From here the lime is led into the slake tanks. Lime and water are mixed in the slake tanks with a propeller mixer.

The overflow from the slake tanks are piped to the slake suspension tank where even more water are added to make the suspension pump able.

The slake suspension is pumped to a slake feeder tank through a strainer.

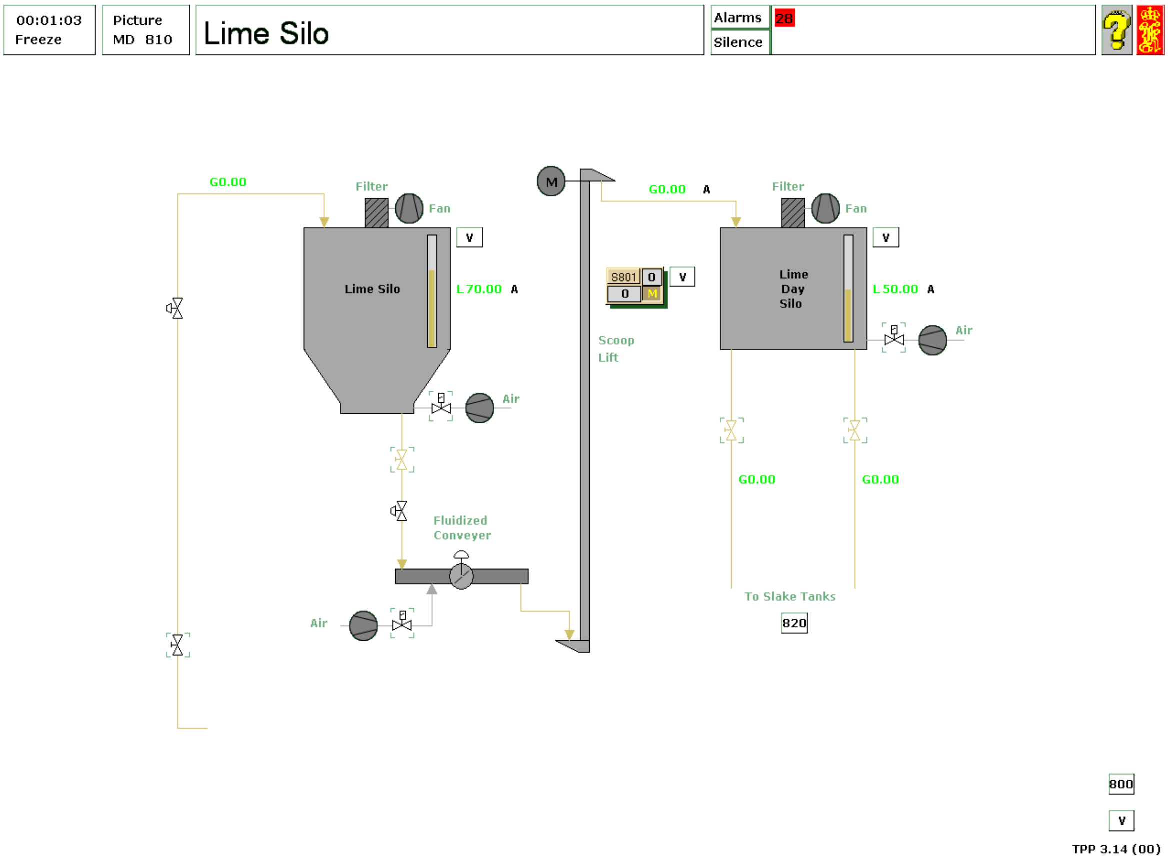
The slake is pumped up to a slake spreader tank and the overflow of this tank is piped back to the feeder tank.

The absorber has two inlets for flue gas, one for 40% (bottom inlet) and one for 60% of the flue gas (on top of the absorber). In the middle the spreader is placed which is fed with slake from the spreader tank. The spreader is rotating with high speed to mix flue gas with slake.

Ash from the absorber is taken out of the bottom of the absorber and out to a powder pump.

There is an electric filter at the end of the system to remove combustion recidues and ash.

2.9.25 Lime Silo (MD810)



2.9.25.1 Lime Silo Description

The main purpose of this picture is to give an overview of the lime filling system.

Lime is filled by truck into the main lime silo, full capacity is 500m^3.

The lime day silo is filled by a conveyer belt and a scoop lift system. full capacity is 20m^3.

The conveyer belt is fluidized with air to transport the lime in a sufficient way.

The operation of the conveyer belt and scoop lift is operated by level switches for high and low level installed in the lime day silo.

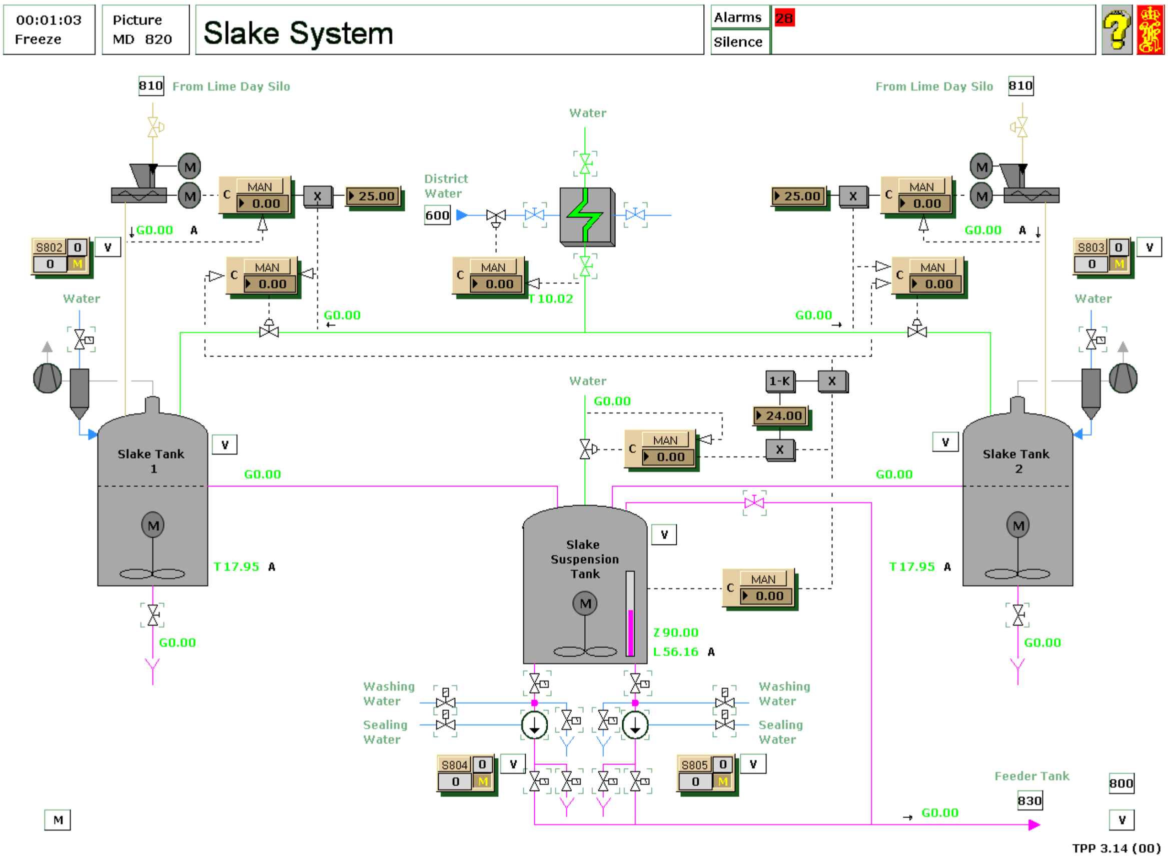
Both silos have an air fan in the bottom of the bottom well to ensure proper delivery.

2.9.25.2 Sequence S801: Filling of Lime Day Silo

INTERLOCK Level < high

STEP 0: Program in wait: check Level in Lime Day Silo
if low, set STEP = 1;
else if high, set STEP = 51;
STEP 1: Filter fan running
Diff pressure over filter < 300Pa
STEP 2: Scoop lift running
STEP 3: Fluid transport fan in operation
STEP 4: Lime silo valve open
STEP 5: Filling in progress
STEP 6: Lime Day Silo Level > 15%
STEP 7:
STEP 51: Wait 5m
Lime silo outlet valve closed
STEP 52: Wait 5m
Fluidised transporter stopped
STEP 53: Filling not in progress
STEP 54: Scoop lift stopped
STEP 55:

2.9.26 Slake System (MD820)



2.9.26.1 Slake System Description

The main purpose of this picture is to get an overview of the slake system.

There are two slake tanks in the system, one in operation and one in reserve.

Lime from the lime day silo is taken into the slake tank via a transport system.

Lime is mixed with water to make a slake suspension. The mixing water is taken from the district water system.

The flow of mixing water and lime is controlled by a controller sensing SOx content in the flue gas.

The slake suspension tank has a mixer system where the slake is mixed with more water to make the slake pump able.

There are two pumps supplying slake suspension to the feeder tank.

These pumps has water supply for washing after they have been stopped and for sealing during operation.

2.9.26.2 Sequence S802/ S803: Filling of slake suspension tank

INTERLOCK High level in Slake suspension tank. Other Slake tank Filling in progress

STEP 1: SST level controller in auto sequence mode
STEP 2: Temperature water supply controller in auto
Water slake tank controller in cascade mode
ST1 lime feeder controller in cascade mode
SST controller in cascade mode
STEP 3: Flow water ST1 < 1m3/h
Lime feeder 1 controller set point < 0.1m3/h
Flow water SST < 0.15m3/h
Level SST < 80%
Flow water other slake tank < 1m3/h
Lime feeder controller other side set point < 0.1m3/h
STEP 4: ST1 Scrubber water valve open
ST1 Scrubber fan started
STEP 5: Flow water ST1 > 6.8m3/h
STEP 6: Wait 12s
Level SST > 3% or waited more than 5 minutes
STEP 7: ST1 flow water < 1m3/h
ST1 filter fan running
Mixer ST1 running
Mixer SST running
ST1 lime feeder running
STEP 8: Wait 1m30s
LDS fluidized bed filter fan running
STEP 9: ST1 water flow
ST1 lime feeder controller set point
STEP 10: Wait 12s
SST level > 10%
STEP 11: ST1 water flow > 1m3/h
ST1 lime feeder controller set point > 0.1m3/h
SST water flow > 0.15m3/h
STEP 12:
STEP 13: SST level > 80%
STEP 14: SST level controller in auto
STEP 15: Water supply temp controller in auto
ST1 water controller in cascade mode
ST1 lime feeder controller in cascade mode
SST water controller in cascade mode
SST level controller in auto
STEP 16: Wait 1m
STEP 51: Lime Day Silo Filter Fan stopped
STEP 52: ST1 flow water controller set point = 0

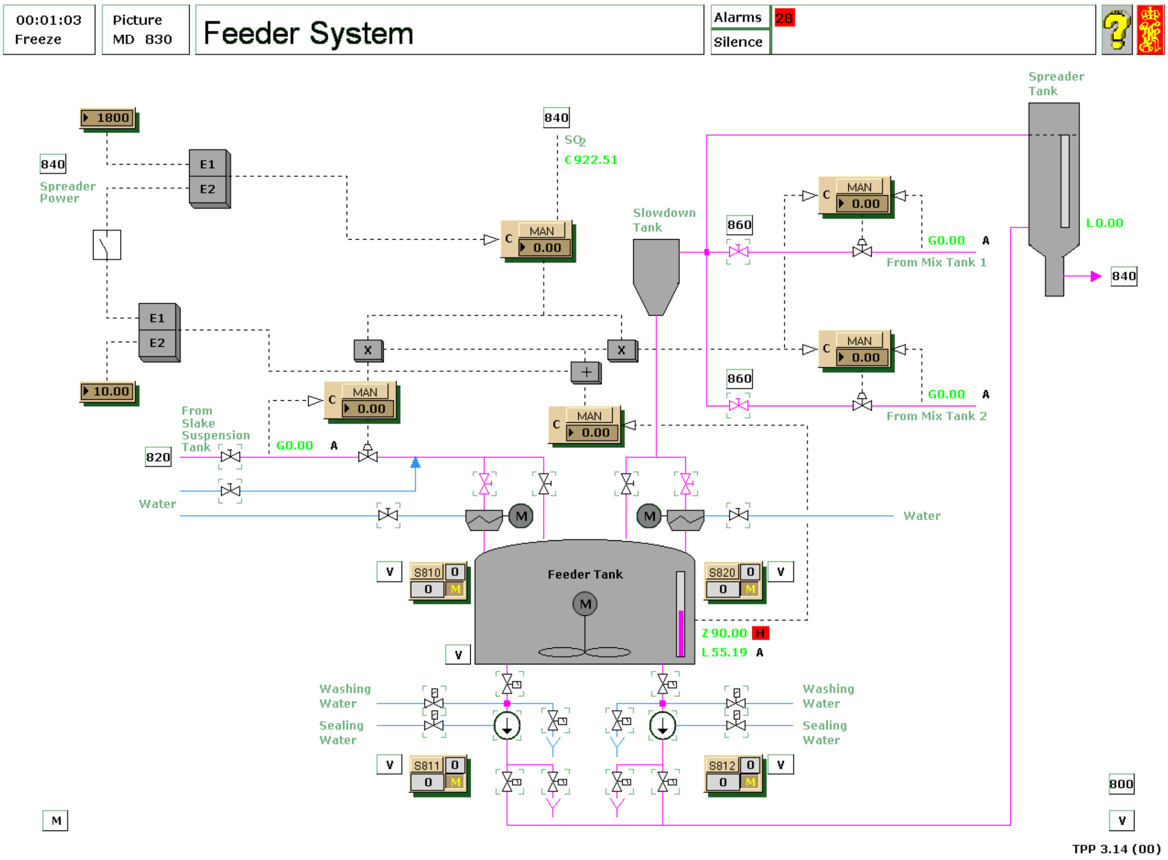
ST1 lime flow controller set point = 0
SST flow water controller set point = 0
STEP 53: ST1 lime feeder stopped
ST1 Scrubber water valve in auto
STEP 54: Wait 1m30s
ST1 Scrubber water valve closed
STEP 55: ST1 flow water controller in manual mode
ST1 flow water < 5%
ST1 lime feeder controller set point < 5%
SST flow water controller in man
SST flow water controller set point < 5%
SST level controller in man
STEP 56:

2.9.26.3 Sequence S804/S805: Operation of slake suspension tank pump

STEP 2: Sealing water valve open
Pump outlet valve closed
Washing water valve closed
Inlet Drain valve closed
Outlet Drain valve closed
STEP 3: Pump inlet valve open
Sealing water OK
STEP 4: Pump running
STEP 5: Wait 8s
Other Pump outlet valve closed
STEP 6: Pump outlet valve open
Pump running
Inlet valve open
Inlet Drain valve closed
Outlet Drain valve closed
STEP 7:
STEP 51:
STEP 52: Outlet valve closed
Inlet drain valve closed
Inlet valve closed
Sealing water valve open
STEP 53: Wait 20s
Pump stopped
Washing water valve open
STEP 54: Inlet valve closed
STEP 55: Wait 20s
Drain valve open
STEP 56: Drain valve closed
STEP 57: Wait 8s

Outlet valve open
STEP 58: Outlet valve closed
STEP 59: Washing water valve closed
STEP 60: Wait 20s
Inlet Drain valve open
STEP 61: Sealing water valve closed
STEP 62:

2.9.27 Feeder system (MD830)



2.9.27.1 Feeder system Description

The slake suspension is pumped from the slake suspension tank into the feeder tank.

The feeder tank is also supplied from mixer tank 1 and 2. The purpose is to mix product from the electric filter with slake suspension.

The slake suspension is supplied to a spreader tank which supplies the electrically driven rotating spreader.

The overflow of this tank is returned to the feeder tank.

The delivery out of the feeder tank is controlled by the level in the feeder tank, and the level is controlled by the filling from the slake suspension tanks. The setpoint is taken from the power used by the spreader.

Processing of Feeder Slurry

Slake suspension and product slurry is mixed in the feeder tank, and the resulting slurry is fed to the spreader at the absorber.

The total amount of slake suspension and product slurry that is fed to the feeder tank is determined by controller LIC816's output signal and consumption of feeder slurry. The flow of slurry to the absorber is proportional to the spreaders power consumption. The proportion of slake suspension to product slurry is determined by SO_2 controller QIC820. The content of SO_2 in the flue gas is measured at the chimney. The measurement is input to the SO_2 controller. The controller adjusts the multiplication factor of the multiplication units connected to slake suspension flow controller FIC818 and product slurry flow controller FIC817 respectively. As shown in the diagram the proportion of slake suspension increases with increasing content of SO_2 in the flue gas.

The spreaders power consumption is proportional to the flow of feeder slurry to the absorber and is used to adjust the integration time of controller QIC820. The integration time decreases with increasing flow of feeder slurry.

2.9.27.2 Sequence S810/S820: Filling of feeder tank

INTERLOCK Level Feeder tank high or Filling from other tank in progress

STEP 1: FT level controller in auto sequence
STEP 2: FT level controller set point = 0
Product slurry controller in cascade mode
Slake suspension controller in cascade mode
SO2 controller in auto sequence
FT controller in auto sequence
Mixing tank 1 product flow < 4.2m3/h
Slake suspension flow < 4.11m3/h

STEP 3: Slake suspension strainer on
Product slurry strainer on
SO2 controller in auto sequence
STEP 4: Slake suspension shut-off valve open
Valve from Mix tank 1 open
STEP 5: FT level controller in auto sequence
Mixing tank product slurry > 4.2m3/h
Slake suspension tank flow > 4.11m3/h
STEP 6: Level feeder tank > 25%
STEP 7: FT mixer on
if FT level > 80%
set STEP = 9;
else set STEP = 8;
STEP 8: FT level > 80%
STEP 9: Wait 4s
FT level > 80%
Flow product slurry from other mixing tank < 4.2m3/h
Flow slake suspension < 4.11m3/h
STEP 10:
STEP 11: FT mixer in operation
FT level controller in auto
MT1 Product slurry controller in cascade mode
FT slake suspension controller in cascade mode
SO2 controller in auto
STEP 12: Wait 1m
STEP 51: Slake suspension shut-off valve closed
Shut-off Valve Mix tank 1 closed
STEP 52: FT level controller in man
Product slurry mixing tank controller in man
Slake suspension controller in man
SO2 controller in man
STEP 53:
STEP 54:

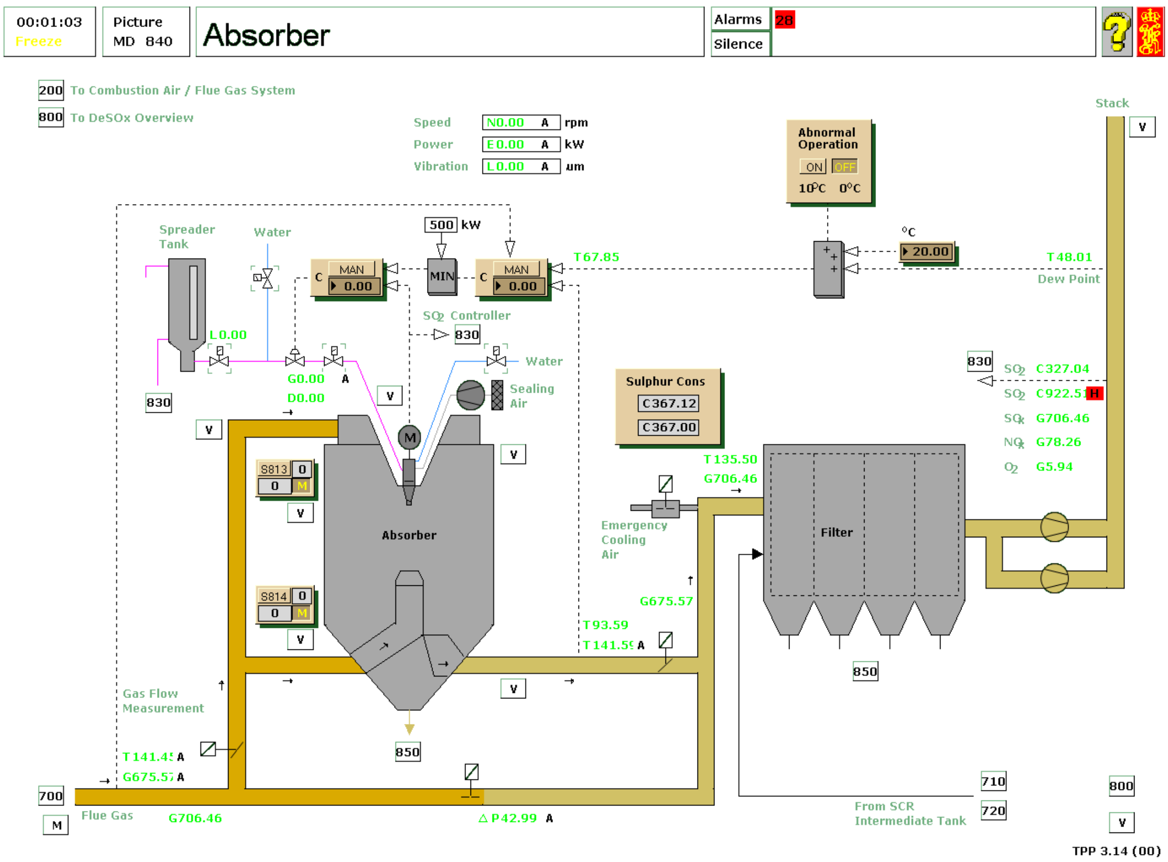
2.9.27.3 Sequence S811/S812: Operation of feeding pump

INTERLOCK Level Feeder tank low

STEP 1: SW valve open
P1 outlet valve closed
Washing water valve closed
Outlet drain valve closed
Inlet drain valve closed
STEP 2: FT product slurry strainer on
P1 inlet valve open
SW valve open

STEP 3: P1 in operation
STEP 4: Wait 8s
P2 outlet valve closed
STEP 5: P1 outlet valve open
P1 running
P1 inlet valve open
Outlet drain valve closed
Inlet drain valve closed
STEP 6:
STEP 51: Sealing water flow OK
Inlet valve open
Outlet valve closed
Drain inlet valve closed
STEP 52: Pump 1 stopped
Washing water valve open
STEP 53: Inlet valve closed
STEP 54: Drain outlet valve open
STEP 55: Drain outlet valve closed
STEP 56: Outlet valve open
STEP 57: Outlet valve closed
STEP 58: Washing water valve closed
STEP 59: Wait 20s
Drain inlet valve open
STEP 60: Sealing water flow = 0
STEP 61:

2.9.28 Absorber (MD840)



2.9.28.1 Absorber Description

Absorption

The picture shows schematically the absorber, electric filter, and flue gas channels with dampers and fans. The diagram does also give an overview of transducers and control systems. From an economic point of view, it is important to keep the consumption of lime as low as possible. The optimum is reached when the flue gas temperature in the chimney is close to the dew point. How close to the dew point it is possible to operate the plant depends on the spreaders and absorbers function and the control systems response to load variations. The humidity of the de-sulphurization product increases rapidly as the operating point gets close to the dew point. Together with the dew point, the humidity of the de-sulphurization product are important parameters indicating process efficiency and operational economy.

The dew point sensor is located in the chimney close to the SO_2 sensor. The sensor is denoted TI739 in the diagram, see appendix 6. Actually there are two sensors. The highest value of the measurements is input to an addition unit where a value corresponding to 10^{o} C is added. This ensures that the set point to the controller is at least 10^{o} C higher than the flue gas dew point.

At start up, during heavy changes of load, and during abnormal operations, safety precautions require a flue gas set point with a higher margin to the dew point. During the above mentioned conditions, a safety margin of 20^{o} C is added to the set point by pushing a button on the control panel as indicated in the diagram. The same procedure is also followed in the case of soot blowing of catalysts in the reactor since the steam flow adds humidity to the flue gas. The variation of steam flow depends on the intermittent operation. Controllers TIC821 and EIC822 are connected in cascade, that is the output signal from temperature controller TIC821 is set point for power controller EIC822. Temperature controller TIC821 controls the temperature of the flue gas at the absorber outlet. The output signal from the temperature controller is limited by a unit, hence the input is limited so that the spreader motor is not overloaded.

The spreaders power is proportional to the flow of feeder slurry. Therefore the motor power is used to control the flow. The power is given as function of feeder flow as shown in the diagram.

The signal denoted H1 corresponding to flow of flue gas is input to the temperature controller TIC821. The controller's gain increases with increasing load or flow of flue gas. The flow is proportional to the square root of pressure drop over the absorber. The gas flow is also indicated on FI749 by Aroskraft. They determine the flow based on measurements of the flow of combustion air.

The temperature is measured both before and after the absorber. The SO_2 and dew point instruments is located in a shed on plane +41. Sensors are installed in the flue gas channel at the fans outlet.

The spreader tank is filled with a mixture of product slurry and lime suspension.

The absorber has two inlets for flue gas, one for 40% (bottom inlet) and one for 60% of the flue gas (on top of the absorber). In the middle the spreader is placed which is fed with slake from the spreader tank. The spreader is rotating with high speed to mix flue gas with product slurry.

There in only one outlet for flue gas.

The Flue gas enters a diffuser in lower and upper section which makes the flue gas rotate and spreads out so the mixing effect between flue gas and product slurry is maximum.

The rotating spreader is giving the product slurry a great speed when entering the absorber. The speed of the spreader is about 11000 RPM.

There are also a valve to operate the absorber in by-pass.

2.9.28.2 Sequence S813: Operation of spreader

STEP 2: Air fan running

Oil valve open
STEP 3: Oil pump running
Bearing oil OK
Gear oil OK
Oil filter OK
STEP 4: Wait 1m
Spreader inlet valve closed
Protection water off
Spreader power off
Thermo protection OK
Spreader motor not running
STEP 5: Wait 30s
Motor running
Thermo protection OK
STEP 6: Spreader protection water OK
STEP 7:
STEP 51: Wait 16s
Outlet valve closed
Washing water valve closed
STEP 52: Wait 8s
Spreader inlet valve closed
STEP 53: Spreader power off
STEP 54: Wait 9m
Protection water valve closed
Motor stopped
STEP 55: Oil pump stopped
Oil cooler closed
Bearing oil low
Gear oil low
STEP 56:

2.9.28.3 Sequence S814: Operation of absorber

INTERLOCK Spreader stopped or feeder tank level low or Feeding pumps stopped

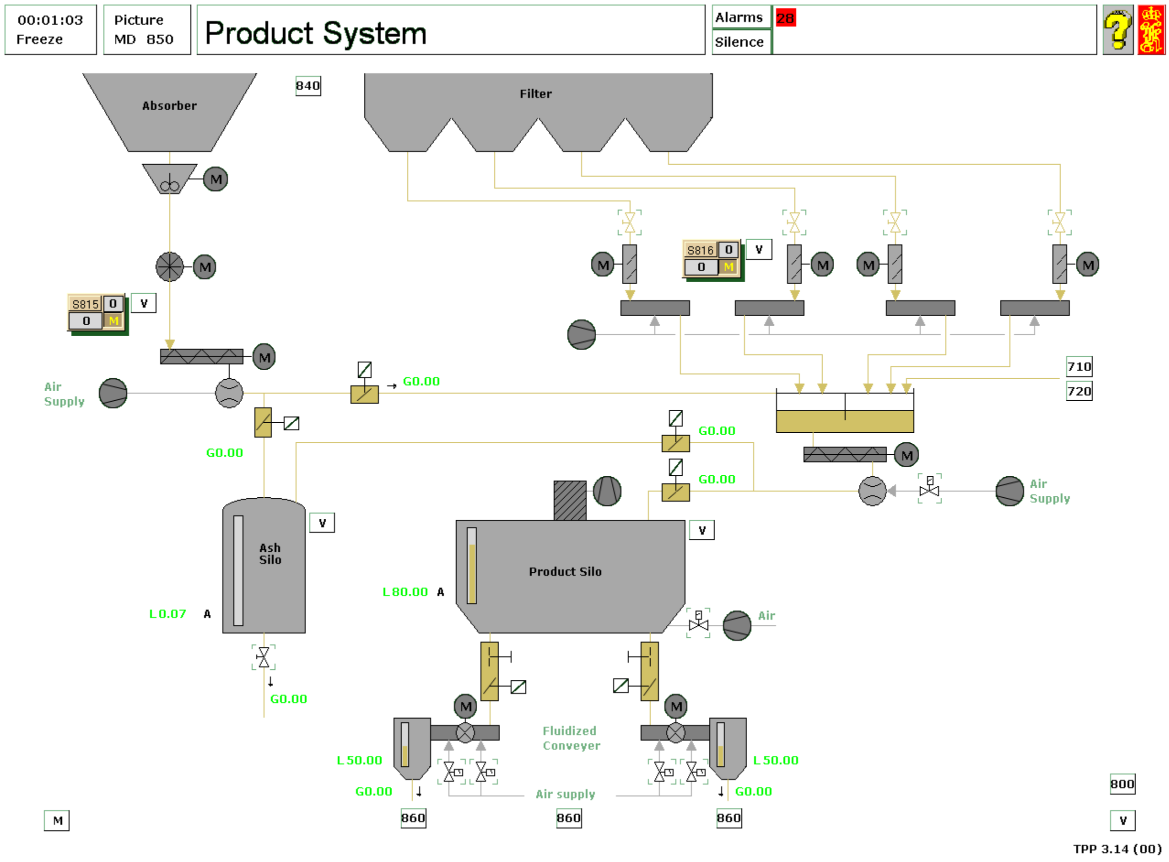
STEP 1: Wait 10s
Spreader running
Spreader protection water OK
Absorber inlet damper open
Absorber outlet damper open
Absorber gas flow (pressure drop) > 10000Nm3/h
Absorber inlet temp > 100C
Absorber bypass damper closed
STEP 2: Wait 10s
Spreader power controller in auto sequence
Spreader power controller Set point = 0

STEP 3: Wait 10s
Absorber outlet temp controller in auto sequence
STEP 4: Wait 10s
Absorber outlet temp controller in auto sequence
Absorber outlet temp controller set point > 94C
STEP 5: Wait 10s
Spreader power controller in auto seq. mode
STEP 6: Wait 10s
Spreader controller output = 0
Spreader power < 45kW
STEP 7: Wait 10s
Inlet damper closed
STEP 8: Washing water valve open
STEP 9: Spreader tank outlet valve open
STEP 10: Washing water valve closed
STEP 11: Spreader inlet valve open
Spreader power < 45kW
STEP 12: Spreader power > 45kW
STEP 13: Wait 3m
Absorber outlet temp controller in auto
Power controller in cascade mode
Absorber outlet temp > 90C
Absorber outlet temp < 110C
STEP 14: Wait 2m
Temp controller in cascade mode
Power controller in cascade mode
Spreader tank outlet valve open
Spreader inlet valve open
Washing water valve closed
Spreader in operation
STEP 15: Wait 10s

STEP 51: Wait 10s
Spreader in operation
Absorber inlet damper open
Absorber outlet damper open
Absorber Bypass damper closed
Absorber gas flow (pressure drop) > 10000Nm3/h
Absorber inlet temp > 100C
STEP 52: Wait 10s
Power controller in auto or cascade mode
STEP 53:
STEP 54:
STEP 55: Spreader tank outlet valve Closed
STEP 56: Wait 20s
Power controller in auto sequence mode

Spreader power < 45kW
STEP 57: Inlet valve closed
STEP 58: Washing water valve open
STEP 59: Spreader tank outlet valve closed
STEP 60: Wait 20s
Spreader tank outlet valve closed
Effect controller output = 0
Absorber gas flow (pressure drop) > 10000Nm3/h
Absorber inlet temp > 100C
Absorber outlet temp > 65C
STEP 61: Spreader Inlet Valve open
STEP 62: Power controller in auto sequence
Spreader Power > 45kW
STEP 63:
STEP 64: Wait 30s
Washing water valve closed
Spreader Power < 45kW
STEP 65: Inlet valve closed
Spreader power controller in man
Spreader power controller set point = 0
STEP 66:

2.9.29 Product System (MD850)



2.9.29.1 Product System Description

When the SO_2 absorber (slake and product slurry) is spread into the hot flue gas with the rotating spreader a reaction will be established. The reaction in the absorber is carried out in two ways. The absorbent will partly react with the flue gas content of sulphur dioxide and chlorides and the water content of the absorbent will be evaporated.

The evaporation process is total so the remainings is a dry powder which is separated in the El-filter after the absorber. Some of the recidues is also falling down into the bottom of the absorber.

The recidues from the absorber is taken to an ash silo. This delivers ash for production of a product called cefill.

The recidues from the El-filter is transported with a powder pump to a product silo for recirculation.

The product slurry system has two parallel lines, where one is in reserve.

2.9.29.2 Sequence S815: Transport of product from Absorber to ash silo or Product container

INTERLOCK Inlet Ash Silo and Product Silo closed

STEP 1: PS filter fan running
STEP 2: Cell feeder fan running
STEP 3: Conveyor running
STEP 4: Cell feeder started
STEP 5: Absorber mill running
STEP 6:
STEP 51: Wait 20s
Absorber mill stopped
STEP 52: Wait 40s
Filter outlet damper closed
STEP 53: Wait 2m
Cell feeder transporter stopped
STEP 54: Cell feeder fan stopped
STEP 55:

2.9.29.3 Sequence S816: Product transport from filter to product and ash silo

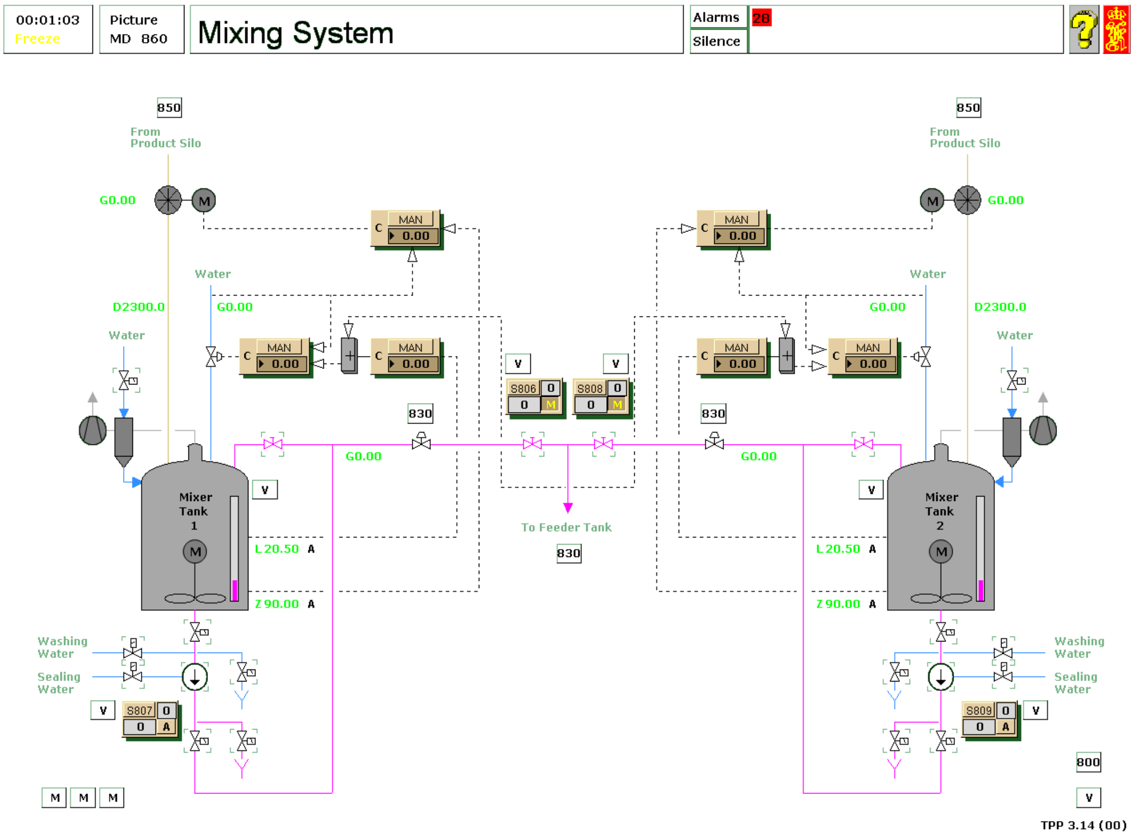
INTERLOCK Inlet Ash Silo and Product Silo closed

STEP 1: Product silo filter fan running
STEP 2: Product silo transport air fan valve open
STEP 3: Product silo transport air fan running
STEP 4: Product silo level < 90%
STEP 5: Product silo inlet damper open
Ash silo inlet damper closed
STEP 6: Product silo transporter running
STEP 7: Product silo fluidizing fan running
STEP 8: Flue gas filter outlet dampers open
STEP 9: Product silo level > 90%
STEP 10: Flue gas filter outlet dampers closed
STEP 11: Product silo fluidizing fan stopped
STEP 12: Wait 3m
STEP 13: Ash silo inlet damper open
STEP 14: Product silo inlet damper closed
STEP 15: Product silo fluidizing fan running
STEP 16: Flue gas filter outlet dampers open
STEP 17: Product silo level < 90%
STEP 18: Flue gas filter outlet dampers closed
STEP 19: Product silo fluidizing fan stopped

STEP 20: Wait 3m
Set STEP = 5

STEP 51: Flue gas filter outlet dampers closed
STEP 52: Wait 30s
STEP 53: Transporter stopped
STEP 54: Wait 3m
STEP 55: Product silo transport air fan stopped
STEP 56: Product silo transport air fan valve closed
Product silo filter fan stopped
STEP 57:

2.9.30 Mixing System (MD860)



2.9.30.1 Mixing System Description

Processing of Product Slurry

The slurry is composed of water, de-sulphurization product from the absorber, and product from the electric filter. It plays an important role in the process where it is used to increase the contact area between slake suspension and flue gas.

There are two independent processing lines. One line may be in operation while the other is in a state of preparation. As soon as a mixing tank contains slurry, the slurry is pumped via the pipes to the shut off valve in front of the feeder tank. A density meter is installed at the discharge side of the slurry pump. The measurement is used to compute content of pulp in the slurry and is input to controllers DIC810 and DIC814.

The flow of product slurry is measured at the inlet of the feeder tank. Measurements of flow and level (output from level controller LIC812) are combined, and the result is used as set point value for flow controller FIC813. The set point must exceed a certain threshold before the controller starts to open the water valve at the mixing tank. The measurement of water flow is input to controller FIC813. The water flow measurement is combined with a factor from the density controller DIC814, and the result is used as control signal for frequency transformer controller FFIC814. This controller controls the cell feeder at the product silo outlet. The density controller's output signal is input to unit DFY814 (DFY810). The output of this unit represents a signal which is proportional to amount of product needed in the absorption process.

2.9.30.2 Sequence S806/S808: Filling of mixer tank

INTERLOCK Level mixer tank high or Pulp content in mixer tank high

STEP 1: Level mixing tank controller in auto seq. mode
STEP 2: Water mixing tank controller in auto seq. mode
Density mixing tank controller in auto seq. mode
Cell feeder controller in auto seq. mode
STEP 3: Water FLow MT1 < 1m3/h
Density MT1 controller output < 1%
Cell feeder not running
STEP 4: if Level in MT1 < 25%
set STEP = 5;
else wait 8s
set STEP = 8;
STEP 5: MT1 slurry pump stopped
MT1 feeder tank slurry flow controller output < 1%
STEP 6: Water Flow MT1 > 25m3/h
STEP 7: Mixing tank level > 25%
STEP 8: Water Flow MT1 < 1m3/h
Mixer running
STEP 9: Wait 10s
Filter fan product silo running
MT1 filter fan running
MT1 filter water flowing
MT1 slurry pump running (S07 == 1)
P1 inlet/outlet valves open
STEP 10: Product silo transporter fluidising system OK
STEP 11: Product silo valve open
Level product transporter tank > 80%
STEP 12: if Mixing tank pulp fraction < 2.5%
set STEP = 13;
else wait 8s
set STEP = 15;
STEP 13: Cell feeder in auto sequence
Cell feeder running
STEP 14: if Mixing tank pulp fraction > 2.5%
set STEP = 15;
else wait 5m
set STEP = 19;
STEP 15: Cell feeder stopped
STEP 16: if MT1 level < 80%
set STEP = 17;
else wait 8s
set STEP = 19;
STEP 17: MT1 water flow > 3m3/h

Cell feeder running
STEP 18: MT1 level > 80%
STEP 19: MT1 water flow < 1m3/h
Cell feeder stopped
STEP 20: MT1 content of pulp > 2.5%
MT1 content of pulp < 60%
STEP 21: Mixer running
MT1 slurry pump running
MT1 level controller in auto
MT1 water controller in cascade
MT1 density controller in auto
MT1 cell feeder controller in cascade
Product silo transporter level controller in auto
STEP 22: Wait 1m
STEP 23:
STEP 51: Product silo valve closed
Cell feeder controller in auto seq.
PS transporter level controller in manual
MT1 level < 90%
MT1 density < 60%
STEP 52: Wait 30s
Cell feeder running
Level product transporter < 20%
STEP 53: Wait 2m
Level product transporter < 20%
STEP 54:
STEP 55: Cell feeder stopped
STEP 56: MT1 flow water < 1m3/h
Cell feeder controller set point < 1%
STEP 57: Product silo transporter filter fan stopped
Scrubber water valve closed
STEP 58: MT1 density controller in man
MT1 level controller in man
MT1 water controller in man
Cell feeder controller in man
Level product transporter in man
STEP 59: MT1 flow water < 1m3/h
MT1 cell feeder stopped
STEP 60:

2.9.30.3 Sequence S807/S809: Operation of mixing tank pump

STEP 1: Wait 10s
Sealing water valve open
Pump outlet valve closed
Washing water valve closed
Drain valve closed

STEP 2: Wait 12s
Pump inlet valve open
Sealing water OK
STEP 3: MT1 feeding tank inlet valve closed
Pump running
STEP 4: Pump outlet valve open
STEP 5:

STEP 51: Outlet valve closed
Inlet valve closed
Sealing water flow OK
STEP 52: Inlet valve open
STEP 53: Wait 20s
Pump stopped
Washing water valve open
STEP 54: Inlet valve closed
STEP 55: Wait 2m
Outlet valve closed
STEP 56: Feeding tank valve open
STEP 57:
STEP 58: Feeding tank inlet valve closed
Washing water valve closed
STEP 59: Wait 2m
Drain valve open
STEP 60: Wait 20s
Outlet valve closed
STEP 61: Sealing water valve closed
Sealing water flow = 0

2.10 Measurements

The process model is divided into subsystems (Air, flue gas, fuel, steam, condensate, feed water, district heating distribution and power distribution). One subsystem at a time is displayed on the operators request. Visualisation of signals and measurements is by means of figures, instruments and trend curves. It is possibility to display 1 to 8 trend curves on the screen simultaneously in order to study the process dynamics. If desired all digital and analogue instruments may be displayed simultaneously for one subsystem. Moreover, a list of measurements with corresponding values may be displayed on the screen. It is also possible to take a hard copy of the screen at any time during a session.

Signals marked with an asterisk * do not have the same tag number as is used locally at the plant. The notations used for high pressure, intermediate pressure and low pressure steam are HP, IP and LP respectively.

No	Tag Name	Description	Unit
1.		Electric power to grid	MW
2.*		Auxiliary power	MW
3.*		Total heat effect	MW
4.*		Direct heat effect	MW
5.*		Back pressure effect	MW
7.		HP steam after boiler	bar
8.		HP turbine inlet pressure	bar
9.		IP steam before boiler	bar
10.		IP steam after boiler	bar
11.		IP turbine inlet pressure	bar
12.		Pressure at A45	bar
13.		Pressure at A 44	bar
14.		Pressure at A43	bar
15.		Pressure in SP4	bar
16.		Pressure at A40	bar
17.		Pressure in KK4	bar
18.		Pressure after KKP	bar
19.		Pressure in VK42	bar
20.		Pressure in VK41	bar
21.		Pressure in FV46A	bar
22.		Pressure in FV46B	bar
23.		Pressure in FV45A	bar
24.		Pressure in FV45B	bar

25.	Pressure in FV44	bar
26.	Pressure in FV45	bar
27.	Pressure in FV42	bar
28.	Pressure in FV41	bar
29.	Pressure in FV40	bar
30.	Pressure in KC4	bar
31.	Pressure after HKP	bar
32.	Pressure after MP	bar
33.	FW pressure before EKO	bar
34.	FW pressure before ÖH	41 bar
35.	Steam pressure bef. ÖH42	
36.	Steam press. before MÖH	42 bar
37.	Distr. heat press. bef. VK41	
38.	Pressure after VKP	bar
39.*	Distr. heat outlet temp.	°C
40.*	Distr. heat return temp.	°C
41.	FW flow after HTFV	ton/h
42.	Injection flow to ÖH	ton/h
43.	Injection flow to MÖH	ton/h
44.	Main condensate flow	ton/h
45.	Hot condensate flow	ton/h
46.	Cold condensate flow	ton/h
47.*	Distr. heat outlet flow	ton/h
48.*	Cooling water flow	ton/h
49.	Drainage from HTFV A	ton/h
50.	Drainage from HTFV B	ton/h
51.	Oil flow	ton/h
52.	Hot water flow through VK	ton/h
54.	Condensate flow from SP	ton/h
55.	HP steam temp. after boiler	°C
56.	IP steam temp. bef. boiler	°C
57.	IP steam temp. after boiler	°C
58.	Temperature at A45	°C
59.	Temperature at A44	°C
60.	Temperature at A43	°C
61.	Condens. temp. after KK4	°C

62.	Drainage temp. FV 40	°C
63.	Condens. temp. after HKP	°C
64.	Drainage temp. FV 41	°C
65.	Condens. temp. bef. FV 42	°C
66.	Drainage temp. FV 42	°C
67.	Condens. temp. after FV 43	°C
68.	Drainage temp. FV 43	°C
69.	Condens. temp. after FV 43	°C
70.	FW temp. before FV 45 A	°C
71.	Drainage temp. FV 45 A	°C
72.	Drainage temp. FV 45 B	°C
73.	FW temp. before FV 46 A	°C
74.	FW temp. before FV 46 B	°C
75.	Drainage temp. FV 47 A	°C
76.	Drainage temp. FV 46 B	°C
77.	FW temp. before FV 47 A	°C
78.	FW temp. before FV 47 B	°C
79.	Drainage temp. FV 47 A	°C
80.	Drainage temp. FV 47 B	°C
81.	FW temp. after FV 47 A	°C
82.	FW temp. after FV 47 B	°C
83.	Distr. heat temp. bef. VK 41	°C
84.	Distr. heat temp. bef. VK42	°C
85.	Distr. heat temp. aft. VK 42	°C
86.	Drainage temp. VK 42	°C
87.	Drainage temp. VK 41	°C
88.	Cool. water temp. aft. KK4	°C
89.	Cool. water temp. bef. KK4	°C
90.	Condens. temp. aft. FV	°C
91.	Drainage temp. OFV	°C
92.	Oil temp. before OFV	°C
93.	Oil temp. after OFV	°C
94.	FW temp. before ÖH 41	°C
95.	Stem temp. before ÖH 42	°C
96.	Steam temp. before ÖH 43	°C
97.	Stem temp. after MÖH 41	°C

98.	Flue gas temp bef. LUFO 41	°C
99.	Flue gas temp bef. LUFO 42	°C
100.	Flue gas temp aft. LUFO41	°C
101.	Flue gas temp aft. LUFO 42	°C
102.	Air temp. bef. LUFO 41	°C
103.	Air temp. bef. LUFO 42	°C
104.	Air temp. after LUFO 41	°C
105.	Air temp. after LUFO 42	°C
106.	Condensate temp after SP 4	°C
107.	Drainage temp after DV 41	°C
110.	Drainage flow DV 41	ton/h
112.	Total air flow	km $_n{}^3$/h
113.	[O_2] before LUFO	%
117.	Drainage flow bef. FL 4	ton/h
118.	FW temp. before FV 48	°C
119.	FW temp. after FV 48	oC
120.	Pressure in DV 41	bar
122.	Water level in DV 41	m
125.	[CO_2] before LUFO	ppm
126.	[NO_x] after electric. filter	ppm
127.	[SO_2] after electric. filter	ppm
128.	Air temp. before LF 41-42	°C
129.	Air. temp. after LF 41	°C
130.	Air temp. after LF 42	°C
131.	Flue gas temp. bef. ÖH 42	°C
133.	Flue gas temp. before EKO	°C
137.	Air pressure after LF 41	bar
138.	Air pressure after LF 42	bar
139.	Air pressure before burners	bar
140.	Fireplace pressure	bar
149.	Primary air temp. (level A)	°C
150.	Primary air temp. (level B)	°C
151.	Primary air temp. (level C)	°C
152.	Primary air temp. (level D)	°C
153.	Primary air flow (A)	km $_n{}^3$/h
154.	Primary air flow (B)	km $_n{}^3$/h

155.	**Primary air flow (C)**	**km $_n^3$/h**
156.	**Primary air flow (D)**	**km $_n^3$/h**
157.*	**Secondary air flow (A)**	**km $_n^3$/h**
158.*	**Secondary air flow (B)**	**km $_n^3$/h**
159.*	**Secondary air flow (C)**	**km $_n^3$/h**
160.*	**Secondary air flow (E)**	**km $_n^3$/h**
161.	**Temperature after mill A**	**°C**
162.	**Temperature after mill B**	**°C**
163.	**Temperature after mill C**	**°C**
164.	**Temperature after mill D**	**°C**
173.	**Speed of coal feeder A**	**rpm**
174.	**Speed of coal feeder B**	**rpm**
175.	**Speed of coal feeder C**	**rpm**
176.	**Speed of coal feeder D**	**rpm**
177.*	**Fuel analysis**	

DeNox Measurements:

Measuring Points connected to the SCR-reactors:

	Flue gas flow from boiler	kg/h
	Flow of NOx in flue gas from boiler	kg/h
	Flue gas flow after SCR	kg/h
	Flow of NOx after SCR	kg/h
	Flow of NH3 after SCR	kg/h
	Blowout NH3 gas content	ppm
4HSD10-20 CP001	Difference pressure over SCR	
4HSK10-20 CF001	Air flow to NH3 mixing chamber	kg/h
4HSK10-20 CF002	Flow of NH3 vapour to NH3 mixing chamber	kg/h
4HSK10-20 CP002	Pressure of NH3 vapour	bar
4HSK10-20 CT001	Temperature of NH3 supply	°C
4HSP30 CL301	Level in intermediate debris tank	m

2.11 Functional description of control equipment and automatic sequences

The most important parts in terms of functionality of the plant control system are to be implemented in the simulator model. The basic idea is to develop a comprehensive and manageable system as seen from the instructor and trainees point of view. This necessitates reduction of complexity. The following sections contain a functional description of control equipment and automatic sequences which are to be implemented.

2.11.1 Automatic sequences at start-ups

At start-ups of the block (warm and cold) power supply to the fans, mills, coal feeders, pumps etc. are supposed to be switched on automatically in the same order as in the real plant.

2.12 Alarms

The following incidents will give an alarm and an error message to the student. In some cases the computer will provide a proposal of action. Examples of actions are given in some cases below. The limits which are set to the alarms will be the same as in the real plant. It will be easy for the instructor to generate new alarms if he desires by use of malfunctions.

1. LUFÖ 41 does not rotate.
2. LUFÖ 42 does not rotate.
3. High pressure in the circular air channel. Action: Check the control of the air fans and the secondary air throttles.
4. Inaccurate furnace pressure. Action: Check the flue gas fan.
5. Low pressure after the oil pump. Action: Check the OD-controller.
6. Low oil temperature. Action: Check the temperature control and the steam flow to ODV.
7. Tripped burner.
8. The oil pressure to the burners have passed the limit. Action: Check the OD-controller, oil burners and oil pumps.
9. Block reduction (BLR) is blocked. Action: Should be blocked at direct heating operation. The alarm is acknowledged with BLR. Reset.
10. Low level in FV 45 A. Action: Check the control valve and the level controller.
11. Low level in FV 45 B. Action: Check the control valve and the level controller.
12. High level in FV 45 A. Action: Check the level control. If the control valve is fully open check for leaks.
13. High level in FV 45 B. Action: Check the level control. If the control valve is fully open check for leaks.
14. High level in FV 46 A. Check the level control. If the control valve is fully open check for leaks.
15. High level in FV 46 B. Check the level control. If the control valve is fully open check for leaks.
16. The KE-valve is open.
17. The ZR-valve is not closed.
18. High water level in feed water tank (FV 44). Action: Check the SBN-controller.
19. Low water level in feed water tank (FV 44). Action: Check the SBN-controller.
20. High level in the boiler water separation unit (FL 4). Action: Check the ZR, AN and AND valves at low load.
21. Feed water flow before ECO too low. Action: Increase the feed water flow.
22. Overheating after the boiler water separation unit (FL 4) too high. Action: Increase the feed water flow and check the combustion.
23. High pressure security valves open. Action: Check the boiler pressure, try to decrease the combustion effect.
24. Intermediate pressure security valves open. Action: Check the intermediate pressure.
25. High temperature in the high pressure turbine outlet. Action: Increase the steam flow through the high pressure turbine. Decrease the pressure in the intermediate superheater.
26. High level in VK 41. Action: Start an extra VKP pump. Check a level controller.

27. High level in VK 42. Action: Start an extra VKP pump. Try to open a bypass value. Check a level controller.
28. Low level in VK 41. Action: VKP pumps. Check the level controller.
29. Low level in VK 42. Action: VKP pumps. Check the level controller.
30. High temperature difference between the two intermediate pressure turbines.
31. High level in cold condenser (KK 4). Action: If the condenser load >40%, the start another KKP pump. Check the level controller.
32. Low level in cold condenser (KK 4). Action: Check the level controller. Try to stop KKP pumps.
33. High level in condensate cistern. Action: Check if the HKP pumps are in automatic mode. Check the level control equipment.
34. Low level in the condensate cirstern (KC 4). Action: Check the level in SP4 and pumps leading from it.
35. High pressure in the low pressure turbine outlet. Action: Start an extra VUP pump. Start a large KVP pump.
36. High temperature in the low pressure turbine outlet. Action: Check if the water injection is switched on.
37. High level in FV 43. Action: Check the level and the level controller.
38. High level in FV 42. Action: Check the level and the level controller.
39. Low level in FV 43. Action: Check the level and the level controller.
40. High level in FV 40. Action: Decrease the low pressure turbine load.
41. High level in FV 41. Action: Check the level and the level controller.
42. High level in SP 4. Action: Check the SPKP pumps. Try to start an extra. Check the level controller.
43. Low level in SP 4. Action: Check the level controller.
44. Low level in DV 41. Action: Check the level controller.
45. High level in DV 41. Action: Check the level controller.
46. No coal to mill A.
47. No coal to mill B.
48. No coal to mill C.
49 No coal to mill D.
50. Low primary air flow to burner level A. Action: Check the flow controller.
51. Low primary air flow to burner level B. Action: Check the flow controller.
52. Low primary air flow to burner level C. Action: Check the flow controller.
53. Low primary air flow to burner level D. Action: Check the flow controller.
54. High temperature of the coal/air mixture in mill A. Action: Check the temperature control and the coal feeder.
55. High temperature of the coal/air mixture in mill B. Action: Check the temperature control and the coal feeder.
56. High temperature of the coal/air mixture in mill C. Action: Check the temperature control and the coal feeder.
57. High temperature of the coal/air mixture in mill D. Action: Check the temperature control and the coal feeder.
58. High concentration of particles in the flue gas. Action: Check the combustion and the electrostatic filter.

DeNox Alarms:

Alarms connected to the SCR-reactors:

Blowout gas content > 400 ppm
Blowout gas content > 800 ppm
Pressure before flue gas fan < -6500Pa
NH3 > 7% (High)
NH3 > 10% (HighHigh)
Level in intermediate debris tank > **HOLD**

3 GENERAL INFORMATION

3.1 General Information

Alarms:

Always acknowledge alarms before starting a system (flashing lamps indicate alarms not accepted).

Power Plant Systems:

It is possible to operate the Denox / Desox plants as separate, isolated units.

Operation of the Power plant is covered in chapter 5.1.

Operation of the Desox plant is covered in chapter 5.2.

Operation of the Denox plant is covered in chapter 5.3.

Reference to mimic pictures are given in all operational descriptions. The mimic pictures is placed in a folder after chapter 5.3 in Vol I.

Malfunctions:

At the bottom left corner of each picture is one or more buttons marked M. Clicking on this button with pointing device centre button, displays a window with the malfunctions list. (Buttons are coloured yellow when faults are activated). When in operator mode, (student) only the possible malfunctions are displayed. In instructor mode, display shows active malfunctions and their settings. On the line where the suspected fault is, click with RIGHT pointing device button to rectify fault. A prompt on the screen will verify "repair" attempt.

Scenarios:

On the following pages we will describe four different exercises :

#1 "Dead Plant Start"
#2 "Main boiler running and turbine generator is connected"
#3 "Boiler/Turbine/Denox running"

3.1.1 Cold Plant Start-up

3.1.2 The workstations lined up with power on

3.1.3 Start on 48 hours notice

Operation:

1. Load initial condition "Cold Plant Start"
2. Select various sub-system displays for verifying the dead plant condition. (MD010,240,260,300)
3. Check that the drain valves on the turbine inlet pipes and the turbine casing are open. (MD 300/X13077)
4. Connect the fast circuit breaker X03841 at MD380.
5. Start Lub.oil system for the turbine train. (MD300/X13070). Note: The governing oil pump should not be started yet
6. Start Turning gear. (MD300/X13072). Note: The turbine should never be started unless it has been on turning gear for at least 48 hours.

Observe:

-No steam pressure.
-Air Pressure available.
-District Heating system active.
-El power from net.

-The turbine will gradually accelerate to 42 rpm (Fixed).

3.1.4 Prepare heating of FO service tank

Picture: MD100

The FO service tank is heated by secondary hot water.

Operation:

1. Check hot water supply pressure and temp. into the FO servic tank. (MD100/P1020/T1021)
2. Check that the temp. contr. for the FO service tank is set to Auto.
3. Open necessary valves in the tank heating circuit for making circulation through burner plane A-D. (MD100)
4. Check the temperature controller for the FO service tank, set to Auto with the setpoint 50°C. (MD100)
5. Check temp control setting for the FO heaters (115°C is normal) and set to Auto.
6. Drain water from the FO sevice tank if necessary.
7. Start FO circulation pump.
8. Line up FO transfer pump, set start/stop function to Auto.
9. Check that the level controller for FO service tank is set to Auto.

Observe:

The level in the FO service tank will be controlled automatically within the start/ stop level limits.

3.1.5 Prepare the vacuum pump sealing water system

Picture: MD400

All 5 vacuum pumps in the system are of the water ring type that requires flushing of water for its function.

Operation:

1. Start one sealing water pump. (MD400)
2. Check that the centralized auxilliary cooling system is operative. (MD400/R4090)

Observe:

- Flow in the sealing water system. (MD400)

3.1.5.1 Prepare make up Deaerator System

Picture: MD500/410

Operation:

1. Prepare sealing water for vacum pump1. (MD400/R4062)
2. Prep. and start vacuum pump 1 for the deaerator. (MD500)
3. Prepare and start condensate make up pump 1 and 2. (MD500)
4. Set condensate make up tank level contr. to Auto, setpoint 1,5m. (MD500/C5001)
5. Set make up deaerator level contr. to Auto, setpoint 1,5m. (MD500/C5000)
6. Prepare heating on deaerator.
7. Line up heating steam system from the auxiliary steam supply, open V4325/MD430 and V4346/MD430.
8. Open steam supply valve for make up deaerator and set deaerator temp contr. setpoint to 85°C and set controller to Auto.(MD500)
9. Prepare seal water for condensate transfer pump. (MD500)
10. Line up for starting condensate transfer pump 1. (MD500)
11. Start condensate transfer pump 1. (MD500)
12. Line up supply line from Make up deaerator to condensate tank. (MD410-500)
13. Check that the level controller for condensate TK. is set to Auto, setpoint 1,5m. (MD410)

Observe:

- Vacuum pump running. (MD500)
- One pump is normally running continuously.
- Condensate flows from deaerator to main condensate tank.
- The temperature in deaerator will increase.

3.1.6 Main Condensate System

Picture: MD410

Operation:

1. Check level controller for the condensate tank. Set to Auto. (MD410)
2. Line up supply and retun to condensate cleaning plant. (MD410)
3. Start condensate cleaning circulation pump. (MD410)
4. Prepare and start vacum pump for condensate tank. (MD410)
5. Prepare sealing water for main condensate pumps. (MD410)
6. Line up for main condensate pump 1. (MD410)
7. Start Main Condensate pump. (MD410)

Observe:

- Flow through the condensate pump.

3.1.7 Prepare small clean up Loop

Picture: MD240/420/430/500

Operation:

1. Line up main condensate line (from condensate tank, through the LP feed heaters, to the feed water deaerator tank). (MD420)
2. Open valve on condensate on direct line valve V4206. (MD420)
3. Check that level controller for feed water deaerator tank is set to Auto. Setpoint 2,5m and open feedw. deaerator inlet valve, V4300. (MD430)
4. Line up circulation through condensate filters (POWDEX). (MD420)
5. Open condensate filter supply valve,V4205 and close condensate direct line valve V4206.
6. Set condensate filter differential pressure controller to Auto position. Setpoint 1,0 bar. (MD420)

Operation:

7. Prepare condensate discharge from bottom blow tank, open feedw. deaerator clean up line outlet valve V4320. (MD430)
8. Set level controller in bottom blow tank to Auto, setpoint 1m. (MD240)
9. Open supply valve from bottom blow tank to make up deaerator, V2557. Open bottom blow tank inlet valve V5020. (MD500)
10. Adjust clean up line flow adjust valve,V2531, between the feedwater deaerator and bottom blow tank to approx. 190 t/h. (MD240)

Observe:

Observe that the condensate is flowing from the feedw. deaerator to the bottom blow tank. Then to the make up deaerator, pumped by the transfer pumps to the condensate tank and pumped further by the main condensate pumps through the POWDEX filters back to the feedw. deaerator.

3.1.8 Line up for heating of FO

Picture: **MD120**

Operation:

1. Check water level in the steam cooling water tank. (MD120)
2. Prepare filling of water on steam cooling tank from main condensate line. Open LP steam generator supply valve V4136. (MD410)
3. Open the filling valve V1297 to the inlet of the steam cooling tank. (MD120)
4. Set steam cooling tank level controller to Auto. Setpoint 0.7 m. (MD120)
5. When the level is more than 0.5 m, open the valve from auxiliary steam line to steam cooling tank. (MD120)
6. Check that steam pressure controller for LP steam cooling tank is set to Manual/Off. (MD120)
7. Check that steam pressure controller for LP steam generator is set to Manual/Off, and that the primary steam shut-off valve to FO heaters/cleaning steam and atomizing steam, is closed. (MD120)
8. Open the steam cooling tank FO heater cross-over valve V1217. (MD120)
9. Set inspection tank drain control to Auto. (MD120)
10. Check that LP steam gen. secondary drain return valve is closed. (MD120)

    Note: the drain pump should not be started.

Observe:

- **Heating for steam cooling tank "ON".**
- Steam pressure in steam cooling tank will slowly increase to the pressure in the steam auxiliary line.

3.1.9 Start on 4 hours notice

Picture: MD240/250/300

Operation:

1. Stop dry air conservation system (not moddeled), and close boiler bottom drain valves. (MD 240/V2422/V2423)

2. Keep SH drain valves open. (MD 250/ X 13078)

3. Keep turbine drains open. (MD300/ X13077)

4. Keep separator vent. valve open. (MD240/ V2498)

Observe:

- Observe that the steam turbines turning, gear has been engaged for 48 hours, the small clean up loop is operating, and that the condensate quality is checked by the chemical. dept.

3.1.10 Heating of FO

Picture: MD100/120

Operation:

1. Open the fuel oil service tank recirc. valve V1017. (MD100)
2. Set the HFO supply pressure controller to Auto, setpoint 22 bar. (MD100)
3. Open the steam valve V01299 from steam cooling tank to FO heater 1. (MD120)
4. Open the inlet and outlet valves for FO heater 1. (MD100)
5. Open the FO service tank outlet valve V1015.
6. Line up for starting FO supply pump 1. (MD100)
7. Line up for using FO heater 1. (MD100)
8. Line up FO filter 1. (MD100)
9. Line up heating through burner plane A-D. (MD100) Set all fuel control valves to Manual 10% valve opening. (MD140-170)
10. Open return valve V1016 from burner plane A-D to the inlet on the FO supply pumps.
11. Start FO supply pump 1. (MD100)
12. Operate HFO supply temp. controller manually setpoint 10 %.

    When the temperature has rised to 100ºC, set controller to Auto. Setpoint 115ºC. (MD120)

Observe:

- Observe level at FO service tank
- Observe operation on level controlled transfer pump.

- Observe fuel oil circulation through all burner planes.

- Observe drain return to inspection tank. (MD120)

3.1.11 Filling of boiler by gravity flow

Picture: MD240/430/500

Operation:

1. Prepare and start all condensate make up pumps. (MD500)
2. Prepare and start all condensate transfer pumps. (MD500)
3. Start sealing water pump R4390. (MD 430)
4. Open suction and discharge valves on all FW pumps. (MD430)
5. Check that the bottom blow tank drain line is prepared and set to Auto. (MD240)
6. Set separator level contr.1, 2 and 3 to Auto and open separator drain to BBT, shut-off valve V2520.
7. Open boiler filling line shut-off valve V4387. (MD430)
8. Check that cross-over valve V2503 between economiser and separator is open. (MD240)
9. Check that the vent. valve on separator is open. (MD240)
10. Open the filling line flow control valve V2420 to 100%. (MD240)

Observe:

- Observe the filling flow from deaerator to the boiler. (step 10)

3.1.12 Filling of boiler by forced flow

Picture: MD240/430

Operation:
To save time When the Boiler is half full a feed water pump will be used for making filling faster.

1. Close clean up line flow adjustment valve V2531.
2. Close filling line flow control valve V2420 (MD240), and close boiler filling line shut-off valve V4387. (MD430)
3. Start feed water pump system LO cool water pump.
4. Check that feed water pump 1 speed control is in manual (local), output command 0 %. (MD430)
5. Open feed water deaerator recirc. shut-off valve V4376.
6. Reset feed water pump 1. Trip if necessary. (MD430)
7. Start feed water pump by starting the lub. oil pump R14352, and then the electric motor R14351. (MD430)
8. **Adjust manually the speed control to 15 %. (MD430)**
9. Check that the boiler feed water flow controller is set to minimum flow 260 t/h (G12501), and set the boiler feed water controller to Auto. (MD240)
10. Set boiler feed water pump controller setpoint to 15 % and set boiler feed water valve position controller output to 15 %, tag no. Z12523. (MD240)
11. Set feed water pump speed controller to Auto (Remote)(MD430), and set the boiler feed water valve position controller to Auto. (MD240)

Observe:

- Observe that small clean up loop flow stops.
- Observe stable flow of feed water, 260 t/h, 80 - 90 bars, and that the filling line is shut off.

3.1.13 Prepare Big clean up loop and separator controllers

Picture: MD240/430

Operation:

1. Close clean up line flow adjust valve, V2531 if necessary. (MD240)
2. Close filling line flow control valve and shut-off valve if necessary.
3. If the feedw. pump is not running, start the pump according to procedure described in 5.1.12.
4. When the boiler is full and feed water is flowing from the boiler to separator close the crossover valve V2503.
5. Check that feed water is circulating through the boiler and returning to separator at correct start up rate, 260t/h. Adjust feedwater control if necessary. (MD240)
6. Check that the bottom blow tank level control is operative.(MD240)
7. Check that the separator level control 1 is working and that the control valve is not fully open, it should always have sufficient control margin. (MD240)
8. Open valve for the return line from start-up heat exchanger to the feed water deaerator V2521/MD240 and V4310/MD430.
9. Set separator level control 1 and 2 to Auto. The output signal should be 100% but no flow should be observed due to the static pressure difference between start up heat exchanger and FW deaerator.

Observe:

- Feed water circulation. (step 5)

- Level control 1 activates when level increases to top level. (step 8)

- Observe level in bottom blow tank and that level control is operating.

3.1.14 Prepare for steam generation

Picture: **MD250/260/430**

Operation:

1. Check that the drain valves X 13078 on superheater are open.
2. Open supply valves for injection water, superheater 2 and 3 / reheater 2.
3. Open superheater 2/3 injection water shut-off valves and reheater 2 injection water shut-off valves.
4. Set SH2 steam temp. controller for superheater 2 to Auto and check that the setpoint is correct, 480ºC. (MD250)
5. Set SH3 steam temp. rate setpoint (target) controller for superheater 3 to Auto, setpoint to 420ºC and adjust max. temp rate to 6°C/min. (MD 250)
6. Set SH3 steam temp. controller C2501 to Auto.

Observe:

- None

Operation:

7. Set reheater 2 steam temp. controller C2502 to Auto, setpoint 540ºC. (MD250)
8. Open HP bypass injection water shut-off valve (MD430/V4386).
9. Set HP bypass water diff. pressure controller C2602 to Auto. Setpoint 30 bar. (MD260)
10. Check that HP bypass glide control X12660 is off. (MD260)
11. Set HP bypass steam pressure control C2600 setpoint to 30 bar. Control to Auto.
12. Set HP bypass steam pressure controller (C12618) minimum position to setpoint 12 %. (MD260).
13. Set HP bypass steam temp. controller C2601 to 260ºC. Set to Auto. (MD260)
14. Set LP bypass control setpoint to 6 bar, control to Auto. (MD260/C2610)
15. Open IPH line vent. (free blowing) valve to 35%. (MD260/V2650)
16. Set IP safety valve logic to Auto (glide function). (MD260)

Observe:

- None

3.1.15 Prepare Combustion Air Preheaters

Picture: MD210/430/700/840

Operation:

1. Start cool. water pumps for regenerative air preheaters LO coolers. (MD210/R2098)
2. Start regenerative air preheaters 1 and 2. (MD210)
3. Open hot water supply to water air preheater 1 and 2. (MD210)
4. Check that auxiliary steam supply to FW deaerator is open. Note that heating valve to the deaerator should be closed. (MD430/V4325)
5. Open cross-over steam valve for steam to air preheaters. (MD430/V4362)
6. Open steam supply valve to air preheater, and steam shut-off valves. (MD210/V2086)
7. Check temp. controller for Combust. air pre
   -heaters. Set to Auto. Setpoint 110°C. (MD210)
9. Prepare Denox and Desox plant, and set Denox plant dampers in bypass position, so that the flue gas dosent have to pass through the SCR reactor 1 and 2. (MD700)
   Set Desox plant in bypass operation, so that the flue gas dosent have to pass through the absorber. (MD840)

Observe:

- None

3.1.16 Prepare Light-off of Boiler

Picture: MD100/120/170/200

Operation:

1. Check fuel oil temperature/pressure. (MD100)

2. Open burner fuel supply valve for burner plane D. (MD100)

3. Check cleaning steam system. Open cleaning steam supply valve V1289. (MD120)

4. Check atomising steam system. Adjust pressure setpoint to 9 bar. (MD120)

Observe:

- Observe recirc. of fuel in all planes.

3.1.16.1 Air Purge of Boiler

Picture: MD 700/180/200

Operation:

Note! Before the air purge is commenced, the operator must decide wether the Denox plant is to be started or not. The purging sequence (S701) sets the inlet and outlet dampers according to this choise. To prepare for starting the Denox reactors, one reactor is selected as the primary reactor and must be started first, and stopped last when the system is shut down. If the operator fails to select a reactor, by selecting by-pass, it is his responsebillity to set the dampers in the approperiate positions manually, if he later on should change his mind and want to run the Denox plant.
For training on the Denox or Desox plant, it is possible to run these systems as isolated plants, but this is neither recommendable or normal.

The sequence S701 will stop and wait for start of combustion air fans which has to be done from process picture MD 200.

Operation:

1. Select an SCR- reactor or set Denox control in bypass mode. (MD700)
2. Set furnace pressure controller to Manual / 0% and start flue gas fan 1. (MD200/C2010)
3. Check that the furnace pressure setpoint is correct (-20 mm) and transfer to Auto. (MD200/C2010)
4. Set ring channel air pressure control to Manual / 0% and start combustion air fan 1 and 2. (MD200/C2000)
5. Set ring channel air pressure controller to Auto. (MD200)
6. Check that ring channel air pressure setpoint control (see air damper pos. control) has normal setpoint (=70%) and transfer to Auto. (MD200)

Observe:

- Observe that the furnace pressure is deacreasing.
- Observe opening of the air pre-heater outlet damper.
- Observe opening to cold air box.
- Observe pressure in ring channel.

7. OK signal is received from Denox sequence, and boiler control system. Start air purge by pressing the "start" button on the purge panel. (MD180)

8. When "purge complete" is indicated, the boiler is ready for light-off.

9. When the air shift indicator shows approx. 5 air exchanges, purge complete is indicated. The boiler is now ready for light-off and it has to be completed within 15 minutes indicated by countdown.

Observe:

- None

3.1.16.2 Boiler light-off

Picture: MD 170/180/190/240

Operation:

1. Reset boiler trip. (MD180)
2. Set block load master control to Manual / 10%, 6 t/h. (MD190/C1902)
3. Set block load reduction (BLR) safety system to Auto. (MD190/X1960)
4. Set Fuel Master controller to Manual/0 %, and oxygen controller to Manual/0 %. (MD 180)
5. Activate start pushbutton for burner 1, plane D. (MD170)
6. When furnace pressure has returned to normal value, -20/-30mmwg, continue with light-off of burner 3, plane D. (MD140)
7. Set fuel master controller to Auto. (MD180/C1800)
8. Continue with light-off of the remaining burners 2 and 4. (MD140)
9. Set oxygen control setpoint to 2 % and transfer to Auto. (MD180)
10. Check that the feedwater is circulating steady at 260 t/h and that the water temperature is increasing. (MD240)

Observe:

-Observe preheating of burner lance with atomizing steam.

- Observe the light-off sequence and successful ignition.

- Observe the flame indicators/display. (MD180)

3.1.17 Prepare District Heat Water System

Picture: MD 600/610

Operation:

1. Check that "multi block" operation mode is selected, in the moddel variable pages. (MP6300/X6230)
2. Open DHW return line shut-off valve. (MD600/V6001)
3. Open DHW supply line shut-off valve. (MD600/V6005)
4. Line up DHW supply pump 1 and return pump 1. (MD600)
5. Check that hot condenser 2 outlet valve is closed and hot condenser 1 inlet valve is open. (MD600)
6. Set temp. control to Manual and set valve fully open. (MD600/C6010)
7. Close direct heaters bypass valve. (MD600/V6037)
8. Open inlet and outlet valve to direct heater 1 and 2. (MD610)
9. Start DHW supply and return pump 1. (MD600)

3.1.18 Prepare direct heaters for operation

Picture: MD610/410

Operation:

1. Adjust the pump speed on the supply and return pumps so that the circulation flow is about 4000 tonn/hour. (MD600)
2. Open necessary valves for drain/discharge to main condensate tank from the direct heaters through the subcoolers. (MD410/V4110/V4115)
3. Prepare subcoolers 1 and 2. (MD610)
4. Set subcooler flow controllers to Auto. (MD610)
5. Select DH level setpoint command from LP bypass controller. (MD610/X6150)
6. Set level controllers to Auto. (MD610/C6100/C6101)
7. Open warm keeping valves below the shut-off valves. (MD610/V16131/V26131).
8. Reset trip and open DH 1 and 2 steam safety shut-off valves. (MD610)
9. Set DH 1 and 2 steam inlet control valves to Auto. (MD610/X6120/X6140)
10. Check that DHW flow to each heater is sufficient (>1100t/h). (MD610)

Observe:

- Observe steam flow and pressure to direct heaters.
- Observe that maximum level setpoint 2.7m. will be transfered to both heaters.

3.1.19 Increase firing rate

Picture: MD 180/190/240

Operation:

1. Observe FW return flow from separator, and the function of the start-up heat exchanger. (MD240)

2. When the water swelling is finished in the range of 75 - 90 ºC, the water temperature is approaching 100ºC, and the pressure in the separator is greater than 1 bar, and steam is flowing from ventilation valve, close separator ventilation valve. (MD240)

3. Adjust/check the oxygen controller. (MD180)

4. When the pressure is starting to rise above 1 bar, increase the firing rate gradually from 6 t/h to 9 t/h (15 % on BLM controller). (MD190)

Observe:

- Observe that fire rate increases.

- Observe automatic closing of SH drain valves when steam pressure is higher than 2 bar.

3.1.20 Steam Pressure Rising

Picture: MD 250/260

Operation:

1. Check that steam is flowing through the superheaters, and check the steam temperatures. (MD250)

2. When steam pressure in IPC line is greater than 6 bar, observe that the LP bypass steam pressure controller is getting active. (MD260)

3. Check the operation of the direct heaters. (MD260)

4. Close free blowing ventilation valve gradually as the direct heater get into operation. (MD260/V2650)

3.1.21 Prepare heating of feed water Deaerator tank

Picture: MD260/430

Operation:

1. Check that IPC line pressure is higher than 6 bar. (MD260)
2. Open the deaerator IPC line steam shut-off valve. (MD430/V4340)
3. Open the steam inlet valve to the deaerator. (MD430/V4350)
4. Set FW deaerator pressure control to Auto. (MD430/C4310)
5. When the deaerator steam pressure is higher than the minimum pressure of 2,5 bar, close auxiliary steam supply valve. (MD430)

Observe:

- Observe that the steam pressure in the deaerator will slowly increase to the minimum value at 2,5 bar.

3.1.22 Prepare operation of cold condenser

Picture: MD300/400/410/

Operation:

1. Start filling of cold condencer with water (V4132). (MD410).
2. Set level controller for cold condenser to Auto. (MD400/C4000). Open recirc. valve for cold condenser (V4014).
3. Start governor oil pump (MD300/X13071).
4. Reset vacuum breaker cold condenser (MD400/V4064).
5. Prepare and start vacuum pump 1and 2 (MD400).
6. Open IP turbine steam supply valve (MD300/V3031).
7. When the steam press. is above 6 bar, open turbine sealing steam supply valve and activate the turbine sealing steam system. (V13074/X13073) (MD300)
8. Start Main. Cool.W. pump 1 for cold condenser. (MD400)
9. Set Main. Cool.W. pump 2 to standby. (MD400)
10. Open drain return valve from LP0 feed heater and gland condencer. (MD400/V4010)

Operation:

11. Open cold condenser recirc. shut-off valve. (MD400/V4014)

12. Set cold condenser hot well level controller to Auto. (MD400)

13. When sufficient water level in cold condenser, line up and start main condensate pump 1. (MD400)

14. Set Main Cond. pump 2 to standby. (MD400)

15. Start Gland condenser fan. (MD400)
16. Open cold condenser LP 1 feed heater water drain return valve. (MD400/V4012)
17. Open LP turbine casing cooling water supply valve. (MD400/V4067)
18. Open condensate tank inlet valv.e (MD410/V4100)

Observe:

- Observe flow through condenser.

- Observe vacuum in cold condenser.

- Observe operation of Gland condenser fan.

3.1.23 Prepare operation of hot condensers

Picture: MD410/600/610

Operation:

1. Open air outlet vent. valves, to cold condenser vacuum pumps, on hot condenser 1 & 2. (MD600/V6058/V6088)
2. Open drain valves between hot condenser 1 and 2. (MD600)
3. Start filling hot condenser 2 with water by opening V4134 (MD410) and inlet valve to HC 2. (MD600)
4. Set level controller for hot condenser 2 to Auto. Open drain inlet valve V6053. (MD600)
5. Line up drain return lines from hot condensers to condensate tank. (MD410/V40105)
6. Set hot condencer 1 level controller to Auto. (C6000/MD600)
7. When the water level in hot condenser 1 is normal, start hot condensate pump 1, and set hot condensate pump 2 to stand-by. (MD600)

Observe:

- Observe increased level in hot condenser 1 and 2.
- Observe increased level in cold condenser.

3.1.24 Prepare low pressure feed heaters

Picture: MD420

Operation:

1. Open vent. valves on LP feed heater 0,1,2 and 3.(MD400/420)
2. Line up condenser drain lines between LP feed heater 1,2 and 3. (MD420)
3. Open return line to cold condenser from LP 1 feed heater. (MD420)
4. Set level controllers to Auto. (C4001/C4200/C4201/C4202) (MD400/420)
5. Check that the steam inlet valves, from extractions 1, 2 and 3 are open.
6. Open the crossover connection between LP 1 feedheater and hot condenser 1 V6073. (MD600)

3.1.25 Prepare main turbine for operation

Picture: MD260/300/400

Operation:

1. Check that the HP line pressure is controlled by the HP bypass controller to >25 bar and steam temperature is approx. 350°C. (C2600/MD260)
2. Increase LP bypass controller (C2610) setpoint from 6 bar to 10 bar. (MD260)
3. Check that IPH line pressure increases to 10 bar and steam temperature is approx. 320°C. (MD260)
4. Open HP turbine steam outlet valve. (V3003/MD300)
5. Open HP turbine steam supply valve. (V3001/MD300)
6. Check that the lub. oil system is active. (MD300)
7. Check turbine cooling water system is active. (MD400)
8. Check that the turbine sealing steam system and that condencer vacuum is ok. (MD300/400)

Observe:

- Observe priming lub. oil pressure.
- Observe governor oil pressure.
- Observe cooling water temperature.
- Observe sealing steam pressure.

3.1.26 Rolling up of turbine train

Picture: MD300

Operation:

1. Increase turbine governor setpoint. Observe opening of all safety shut-off valves and steam extraction valves when governor setpoint is approx 5%. (MD300/P13010)
2. Increase setpoint to 8 %. Observe turbine speed increase to approx 1100 rpm. (MD300)
3. Watch turbine vibrations. When vibrations are less than 20% on the indicator, increase governor setpoint to 16%. This shuld give a final turbine speed of about 1500 rpm. (MD300)
4. When the vibration is lower than 30%, indicating evenly heated turbine rotor, increase the speed setpoint from 16 to 36%. Be carefull not to set the speed range 1700-1900 rpm, which are the critical speed ranges. (MD300)
5. Increase the speed setpoint to 58%. When the speed is above 2800 rpm, observe automatic stopping of electric LO pumps and activation of generator exitation. (MD300/MD380)
6. Increase speed setpoint to 68% corresponding to approx 3000 rpm.

Observe:

- Observe that steam inlet temperature is >350ºC and >30 Bar.
- Observe opening of extractions 3, 4 and 5.
- Observe that throttle valves on all turbines opens.

- Observe that the turbines RPM is increasing.

- Observe temperatures, pressures and vibration in the turbine plant.

- Observe that the exitation field breaker connects at 2800 RPM. (MD380)

- Observe that the turning gear disengages automatically when priming Lub.oil pump stops.

3.1.27 Synchronising and connection of main circuit-breaker

Picture: MD300/380

Operation:

1. Adjust the turbine speed untill the syncronoscope shows "HZ OK". (MD380)
2. Increase the generator exitation until the voltage at the main circuit-braker is equal to the line voltage, and the syncronoscope indicates "VOLT OK". (MD380)
3. When the voltage and frequency is correct, then connect circuit-breaker. (Synchronising is automatic). (MD380/X3832)
4. Immediately after connection, increase turbine load by increasing the speed governor setpoint from 75% to 85%, to avoid return power trip of the main circuit-breaker. (MD300)
5. Check MVAR readout and adjust generator exitation if necessary. (MD380)

3.1.28 Load rising (oil burners)

Picture: MD160/180/190/240/260/300

Operation:

1. Set HP bypass contr. (glide function) to Auto. (MD260/X12660).
2. Increase gradually HP bypass steam temp. control setpoint from 260°C to 340°C. (MD260/C2601).
3. Set LP bypass steam pressure control to Manual 0% output and check that the direct heaters are in stand-by(warm. keeping) mode. (MD260/C2610)
4. Ensure that the IP safety valve glide function is activated. (MD260)
5. Prepare light-off of the burners on plane C. (MD160)
6. Ignite the burners 1, 3, 2 and 4 in sequence. (MD160)
7. Set block load master controller output to 25% (15t/h). (MD190/C1902).
8. Check and adjust the boiler oxygen control. (MD180)
9. Check the feed water control. Set the feed water valve position control to Auto. Setpoint 50%. (MD240)
10. When the pressure is above 70 bar, activate turbine min. pressure controller. (MD300)

Observe:

- Observe sufficient operation of the boiler controllers.

3.1.28.1 Connection of auxilliary circuit-breaker (Block Binding)

Picture: **MD 260/ 300/ 380**

Operation:

1. Reduce HP bypass steam press control minimum position from 12% to 0%. (MD260/C12680)

2. Stop steam dumping to direct heater by setting LP bypass steam pressure controller to MAN. Setp.0 %

3. Set HP bypass steam pressure glide controller to Auto. (MD260/X12660)

4. Increase turbine throttle to 100%. (MD300)

5. Check that the generator power is greater than auxiliary block load and connect auxiliary circuit-breaker. (MD380/X3835)

6. Check Cos phi and adjust the generator exitation if reguired. Normal CosPhi is 0.9 - 0.95. (MD380)

3.1.28.2 Set LP steam generator in operation

Picture: MD 100/120

Operation:

1. Line up heating steam from IPC line to LP st.gen.

2. Open necessary valves in primary and secondary steam system and close auxiliary steam supply.(MD120)

3. Start inspection tank drain pump. (MD120)

4. Check, and if necessary adjust the function of level and steam pressure controllers. (MD120)

5. When steam pressure in LP steam generator is correct, then close cross-over valve from steam cooling tank. (MD120)

6. Check that the steam pressure in FO heaters stabilises at correct value. (MD100)

Observe:

-Observe that the flue gas pressure in stack increases.

3.1.29 Prepare high pressure feed heaters

Picture: MD440/430

Operation:

1. Open the ventilation valves on the feed heaters 1,2 and 3.
2. Check that the steam valves in cross-over line from HP feed heater 3 to HP feed heater 1 are open. (They should always be open). (MD440).
3. Open drain valves. (MD440)
4. Set the level controllers to Auto. (MD440)
5. Line up return to feed water deaerator tank and to LP feed heater 3. (MD440)
6. Open the steam extraction valves to HP feed heater.
7. Open the steam line to HP feed heater 2 from the IPC line. (MD440)
8. Check that the level controllers start to operate. (MD440)
9. Open steam supply from ext. 4 to feed water deaerator. (MD430)
10. Check that auxiliary steam supply to feed water deaerator is shut off. (MD430)

Observe:

- Observe load sharing between burner plane C and D.
- Observe pressure and temperatures.

3.1.30 Set burners on plane A and B into operation

Picture: MD010/140/150/180/190/200/240/250/260/280/300/430

Operation:

1. Start the flue gas fan 2. (MD200).
2. Check the furnace pressure control. (MD200/C2010)
3. Ignite the burners on Plane A and B in correct sequence. (MD140/150)
4. Start the feed water pump 2 and set feed water pump 3 in standby. (MD430)
5. Increase the rate of firing gradually by increasing the BLM controller output in steps of 10% (6t/h). Check plant performance after each load change. (MD190/C1902).
6. Check the extraction's pressures and flows. (MD430/MD440)
7. Check the temperatures and pressures in general. (MD010)
8. Check operation of the ring channel pressure controller. (MD200/C2000)
9. Check operation of the rotating air pre-heater. (MD200)
10. Check operation of the furnace pressure controller. MD200)
11. Check operation of the over-fire controller.
12. Check the combust. control system incl. the oxygen content controller. (MD180/MD190)
13. Check the feed water controller operation. (MD240)
14. Check the superheater temperature controller. (MD250)
15. Check the reheater temperature controller. (MD250)

Observe:

- Observe increased firing rate and gen. el. power output.

- Observe that the flue gas pressure in stack increases.

3.1.31 Change to coal firing

Picture: MD140/150/160/170/180/190

Operation:

1. Reduce the load command from the BLM controller to 75% (45t/h). (MD190/C1902)
2. Check the primary air supply to coal mill D, open the primary air fan shut-off valve. (MD170)
3. Activate the start sequence for coal mill Plane D on the operator-panel. (MD170)
4. Observe and adjust the oxygen controller if necessary. (MD180)
5. When the start sequence is finished and all burner are operative on coal, then shut off burners 1 to 4. (MD170)
6. Repeat the procedure for burner planes C, B and A. (MD140/MD150/MD160)

Observe:

- Observe start sequence:

1. Lub.oil pump starts.
2. Sealing air fan starts.
3. Primary air fan starts.
4. Mill table starts.
5. Mill rollers starts.
6. Rotating grid starts.
7. Coal feeder starts.

- Observe ignition/flame on with coal firing.

3.1.31.1 Set FO system in standby mode

Picture: MD100

Operation:

1. Line up and start the FO circulation pump. (MD100)
2. Stop the FO supply pumps. (MD100)
3. Set the fuel oil control valves (plane A-D) to proper heating position (20 %). (MD150/160/170)
4. Check recirculation of fuel oil. (MD100)

3.1.32 Operation of hot condenser and accumulator system

Picture: MD600

Operation:	Observe:
1. Start the hot condensate pump 2, and set pump 3 in standby mode. (MD600)	
2. Check that the hot condenser 1/2 level control is working properly. (MD600)	
3. Open DHW shut-off valves and establish flow to hot condensers. (MD600)	
4. Set DHW temp. (bypass) controller to Auto. (MD600)	- Observe increased district heater temperature.

3.1.32.1 Prepare back pressure operation

Picture: MD300/420/600

Operation:

1. Reduce the LP turbine steam dampers gradually from 100% open to 50% open position. (MD300)

2. Check extraction flows and functioning of the hot condenser 1/2. (MD600)

3. Reduce the LP steam damper position slowly from 50% to minimum opening. (MD300)

4. Check that the LP turbine cooling system is activated at low steam flow. (MD300)

3.1.32.2 Set drain return from Cold condenser to Hot condenser

Picture: MD400/420/600

Operation:

1. Open the drain cross-over valve from LP feed heater 1 to the hot condenser 1. (MD600)

2. Close the cold condenser LP1 feed heater drain return valve. (MD400)

3. Check the hot condenser 1 drain level. (MD600)

3.1.32.3 Set cold condenser to back pressure mode

Picture: MD400

Operation:

1. Line up and start the auxiliary cold condensate pump 4. (MD400)

2. Stop the main condensate pumps. (MD400)

3. Line up and start the auxiliary cooling water pump. (MD400)

4. Stop the main coolwater pump(s). (MD400)

3.1.32.4 Preparation of accumulator tank

Picture: MD620

Operation:

1. Open accumulator top and bottom line valves, V06302/3.

2. If the water level in the accumulator tank is low, normal level is 16.5 m, start filling of water from the make up valve V06318. The filling rate can be adjusted by changing the supply pressure given on page MVP6201.P06318.
   If the tank is overfilled, the filling pressure P06318 can be set to zero and water can be drained back to the storage system.

3. All accumulator tank operations are slow because of the large tank volume involved. To save time, set the speed up factor, MVP6200.Z06300, greater than one.

4. Start the spray pump and check that the tank top pressure changes to normal value (30 mmWL).

3.1.32.5 Preparation of the expansion tank

Picture: MD620

Operation:

1. Check the steam pressure in the tank top. Normal value is 5.8 bar. Adjust steam pressure set point if necessary, see MVP6212.P06369.

2. Open the expansion tank block connection valve, V06370, and inlet valve, V06371.

3. Normal expansion tank level is 18 m. Correct the level if necessary by opening the DHW make up injection valve, V06379. Flow rate and flow direction can be adjusted by the injection pressure, MVP6214.P06379.

3.1.32.6 Preparation of the DHW fill/dump system

Picture: MD620

Operation:

1. Check that suction and discharge valves for the turbine/pump unit are closed, and open the block connection valves V06365/66.

2. Check the expansion tank high level controller, C6203. Normal set point is 19 m. Turn the controller to auto.

3. Check the expansion tank low level controller, C6202. Normal set point is 17 m. Turn controller to auto.

4. Line up DHW make up pumps. Set pump no 1 in stand-by mode, ready for automatic start.

3.1.32.7 Start loading of accumulator

Picture: MD620

Operation:

1. The hot condensers and/or the direct heaters are assumed to be in operation and supply of DHW, flow and temperature, to be correct.

2. Open block connection valves, V06365/66, if necessary.

3. Open turbine top line discharge valve, V06331, and hot DHW line supply valve, V06333.

4. Open accumulator pump bottom line suction valve, V06350.

5. Set pump speed to zero. Start accumulator pump and open cold DHW line discharge valve, V06352.

6. Reset turbine trip. Open turbine shut-off valve, V06323. Set turbine inlet damper to 10-15 % opening and observe turbine beginning to rotate.

7. Increase pump speed command from 0 to 20-30 %, until turbine and pump flows are approximately equal.

8. Set temperature (safety) controller, C6201, to auto. Check

that the turbine discharge temperature is kept below 100 dgrC.

9. Observe expansion tank level. Set level (pump speed) controller, C6200, to auto. Adjust level set point, if necessary, to keep flow deviation between turbine and pump below trip limit (200 ton/h after 5 min).

10. Readjust level set point until normal expansion tank level, 18 m, is reached.

11. Check DHW supply temperature and pressure. Check hot condenser flow, temperature and pressure. Adjust TMC, temperature master controller (MD190), and adjust firing rate if necessary.

12. Observe accumulator heat input, accumulator stored energy and time left to fully loaded accumulator tank.

13. Observe accumulator tank level and temperature distribution, see page MVP6202.

3.1.32.8 Stop loading of accumulator

Picture: MD620

Operation:

1. Prepare block master controller for reduction of heat demand, corresponding to accumulator heat input.

2. Reduce francis turbine damper position slow to zero.

3. Stop accumulator pump motor.

4. Close turbine supply and discharge valves, V06333/31

5. Close pump suction and discharge valves, V06250/52.

3.1.32.9 Start unloading of accumulator

Picture: MD620

Operation:

1. The DHW pumps are assumed to be in operation, but the hot condensers or the direct heaters do not necessarily be active.

2. Open block connection valves, V06365/66, if necessary.

3. Open turbine bottom line discharge valve, V06330, and cold DHW line supply valve, V06332.

4. Open accumulator pump top line suction valve, V06351.

5. Set pump speed to zero. Start accumulator pump and open hot DHW line discharge valve, V06353.

6. Reset turbine trip. Set turbine inlet damper to 10-15 % opening. Open turbine shut off valve, V06323, and observe turbine beginning to rotate.

7. Increase pump speed command from 0 to 20-30 %, until turbine and pump flows are approximately equal.

8. Observe expansion tank level. Set level (pump speed) controller, C6200, to auto. Adjust level set point, if necessary, to keep flow deviation between turbine and pump below trip limit (200 ton/h after 5 min).

9. Readjust level set point until normal expansion tank level, 18 m, is reached.

11. Increase turbine damper position slowly until wanted rate of flow. Watch the hot condenser pressure and flow (G06030 and P06090) carefully. Note that an increase in turbine flow reduces the cooling flow to the hot condensers!

12. Check DHW supply temperature and pressure. Adjust TMC, temperature master controller (MD190), and adjust firing rate if necessary.

13. Observe accumulator heat output, accumulator stored energy and time left to fully unloaded accumulator tank.

14. Observe accumulator tank level and temperature distribution, see page MVP6202.

3.1.32.10 Stop unloading of accumulator

Picture: **MD620**

Operation:

1. Prepare block master controller for increase of heat demand, corresponding to current accumulator heat output.
2. Reduce francis turbine damper position slowly to zero.
3. Stop accumulator pump motor.
4. Close turbine supply and discharge valves, V06332/30.
5. Close pump suction and discharge valves, V06251/53.

3.1.33 Increase thermal load by direct heater system

Picture: **MD260/610**

Operation:

1. Check that the direct heaters are hot and filled with condensate (Max. level). (MD610)

2. Adjust the LP bypass control setpoint to match the current IPH line steam pressure, and change control to Auto. (MD260/2610)

3. Set the DH1/2 level control and the steam valve control to Auto. (MD610)

4. Reduce the LP bypass control setpoint in steps while observing the function of the hot condensers and the turbine. (MD260/2610)

5. Check the DHW temperature. (MD610)

3.1.33.1 Load reduction/fire on plane C and D

Picture: MD260/190/100/140/150

Operation:

1. Take the direct heaters out of operation by gradually increasing the LP bypass controller setpoint. (MD260/2610)

2. Reduce the Block Load Master command gradually to 25% (15 t/h). (MD190/C1902)

3. Start the FO supply pump 1 and stop FO recirc. pump. (MD100)

4. Start all burners on plane A and B on HFO. (MD140/150)

5. Activate stop sequence of coal mill A. (MD140)

6. Activate stop sequence of coal mill B. (MD150)

7. Reduce the Block Load Master command to 15% (9t/h). (MD260/2610)

3.1.34 Prepare disconnection of the main circuit-breaker

Picture: MD260

Operation:

1. When the HP line steam pressure is close to 70 bar, set the min pressure controller to Manual. (MD260)

2. Reduce the IPH line pressure gradually to 10 bar by means of the LP bypass control/direct heaters. (MD260)

3. Reduce the HP line steam pressure gradually towards 30 bar by using the HP bypass control. (MD260/C2600)

4. Set the HP bypass steam press. min. position controller to 12%.(MD260/C12618)

3.1.35 Disconnect main circuit-breaker

Position: MD300/380

Operation:

1. Reduce the generator output by the lower/rise pushbuttons to block power consumption. (MD300)
2. Disconnect the main circuit-breaker. (MD380)
3. Adjust the frequency and voltage to correct values. (MD380)

3.2 Operation of the Denox Plant

The Denox plant is highly automatic, controlled by Programable logic sequences. These are operated by means of logic controllers on the mimic pages. The sequences are:

S701-Purge, S702/703-Start/stop Reactors, S704/705-Heating of Reactors, S706/707-Ammonia Injection, S708/709-Product Handling and S710/711-Soot Blowing

The symbols for the sequences require an explanation;

Sxxx is the sequence number. Select this field to start/stop the sequence. It is shown as “depressed” when active. S shows the step number. These are explained in the help pages. S shows the step number. T is Timer and A is a Auto/Manual indicator. If depressed, M is displayed, indicating that the sequence is started/stopped manually. In Auto mode, the sequence is started/stopped by another sequence.

Some sequences require manual operator action to proceed. In the simulator, most of these actions can be carried out automatically by setting the “Execute Man Actions” on the variable pages. This feature has been included in the simulator to make life easier for the instructor. There are also certain wait timers in the varioussteps. To speed up simulator, a maximum wait timer for each sequence can be specified on the variable pages. On the other hand, some sequences operate so fast that it is difficult to follow each step. A minimum wait time can be specified to slow down the execution.

3.2.1 Start Denox plant

This operational description will simulate the operation of the Denox plant.
After following the guidelines the plant will be in operational condition.
It starts as a continued operation of the previous chapter or it could be operated as a isolated system. This operation requires that the system is set up to be isolated from the rest of the process. This can be done on the “operating condition page. Anyhow, the boiler has to be started and this is done from the variable list.

3.2.2 Preparations for start-up

Operation:

1. Continue from the previous chapter, that means that the 'Main boiler is running and turbine generator is connected, or set up the Denox plant to work as a isolated system.

2. Select various sub system displays in order to verify that the main boiler is running and the turbine generator is connected, if you want to start the plant as a continued operation of the previous chapter.

Observe:

- Observe the same parameter values as print-out from exercise #1.

3.2.3 Start-up on 48 hours notice

Picture: MD700/710/720

Operation:

1. Check that the Denox plant is sealed with dry air, that means that the de-hydration circuit damper is open.
2. Check that the Denox plant is set to by-pass operation.

3.2.4 Start-up on 4 hours notice

Picture: MD700/710/720

Operation:

1. Shut off dry air conservation system by closing the de-hydration circuit damper. (MD710/MD720)

2. Check that the sequence 704 for SCR1 is set to auto. If not, set it to Auto. (For SCR2 the sequence is 705.)

Observe:

- Observe selected reactor Inlet / Outlet dampers.

3.2.5 Ventilation and heating of plant when the boiler is not running

Picture: MD710

Operation:

1. Start sequence 701 for ventilation/heating of SCR1/2.
2. Sequence 704/705 for heating of SCR 1/2 starts automatically.

Observe:

- By-pass dampers to auto position.
- Dampers after economizer and by-pass dampers opens.
- Inlet and Outlet dampers for SCR1 and SCR2 to Auto.
- Dampers before economizer SCR1/2 closes.
- Combustion air ratio controller to Auto. (output signal 50%).
- The signal ready for ventilation received.
- Observe that circulation fan and Ammonia injector air fans are running.
- Observe that dampers for heating opens.
- Observe that heating fans are running.

3.2.6 Start-up of reactor 1

Picture: MD710

Operation:

1. Check that the main boiler is running and the flue gas temp. lies between 315°C and 450°C.
2. Adjust boiler outlet temperature controller if the temperature is wrong. (MD710)
3. Select to use reactor 1.
4. Verify damper position.
5. Check that main boiler is running and flue gas temperature are between 315°C and 450°C.
6. Activate reactor 1 start sequence S 702.
7. The ammonia injection sequence (S 706) starts after a timedelay of 6 mins.

Observe:

- Observe damper after econ. opens.
- Observe that the combustion air fan ratio controller is set to 100%
- Observe that all dampers for reactor 2 is closed.
- **Observe Input /Output damper opens to 50%.**
- **Observe By-pass dampers close.**
- Observe start up of sequence 702.
- Observe opening dampers after economizer.
- Observe heating of reactor stops.
- Observe that inlet and outlet dampers for SCR1 opens to 50%.
- Observe that the by-pass damper closes.
- Observe that controllers are in the correct mode of operation.
- Observe that injection of ammonia sequence starts (S 706).
- Observe that (NH3) injection valve opens.
- Observe that injector fan is running.
- Observe that the NH3 controller is operating in Auto.

3.2.7 Start-up of reactor 2

Picture: MD720

Operation:

1. Activate reactor 2 start sequence S 703.

2. The ammonia injection sequence (S 707) starts after a timedelay of 6 mins.

Observe:

- Observe that the combustion air fan ratio controller is set to 100%.
- Observe that the reactor 2 start sequence starts. (S703)
- Observe that the setpoint to dampers after economizer for SCR2 is adjusted.
- Observe opening of dampers after economizer.
- Observe heating of reactor stops.
- Observe that the output to the combust. air ratio controller is adjusted to 50%.
- Observe that the inlet and outlet dampers for SCR2 opens to 50%.
- Observe that the by-pass damper closes.

- Observe that injection of ammonia sequence starts. (S 707)
- Observe that (NH3) injection valve opens.
- Observe that injector fan is running.
- Observe that the NH3 controller is operating in Auto.

3.2.8 Handling of reactor product SCR1/SCR2

Picture: MD710

Operation.

1. Start sequence 708/709.

Observe:

Discharge of product is automatically initialised every 70 min. and is completed after 7 min.

- Observe that the transport air valve opens.
- Observe that the product inlet damper opens.
- Observe that the product inlet damper closes after 7 min.
- Observe that the transport air valve closes after 3 min.

3.2.9 Soot blowing of reactor 1 and 2 (Manual)

Picture: MD710/720

Operation:	**Observe**
1. Start soot blowing sequence when diff. pressure across the reactor is too high.	**- Observe that soot blowing lances are inserted in reactor.** - Observe steam flow through soot blowing nozzles.

3.2.10 Stop of reactor SCR2

Picture: MD720

Operation:
The reactor which is started last has to be stopped first. That means that the reactor which was selected for starting first shall be stopped last.

1. Activate reactor stop sequence 703.

Observe:

- Injection valve closes.
- Combustion air ratio controller adjusting the output.
- Inlet and outlet dampers closes to 50% and then to closed.
- By-pass damper closes.
- SCR IN/OUT damper closes.
- Temp. controller is turned off.
- Damper before economiser closes.
- Damper after economiser opens.
- By-pass dampers closes.

3.2.11 Stop of reactor SCR1

Picture: MD710

Operation:

1. Activate reactor stop sequence 704.

Observe:

- Injection valve closes.
- Combustion air ratio controller adjusting the output.
- Inlet and outlet dampers closes to 50% and then to closed.
- By-pass damper closes.
- SCR IN/OUT damper closes.
- Temp. controller is turned off.
- Damper before economiser closes.
- Damper after economiser opens.
- By-pass dampers closes.

3.3 Operation of the Desox Plant

The Desox plant is highly automatic, controlled by Programable Logic Sequences. These are operated by means of logic controllers on the Mimic Pages. The sequences are:

S801-Filling of Lime Day Silo, S802/803-Filling of Slake Suspension Tank, S804/805-Operation of slake suspension Pumps, S806/808-Filling of Mixer Tank, S807/809-Operation of Mixer Tank Pumps, S810/820-Filling of Feeder Tank, S811/812-Operation of Feeder Tank Pumps, S813-Operation of Spreader, S814-Operation of Absorber, S815-Absorber Product Transport, S816-Filter Product Transport.

The symbols for the sequences require an explanation;

Sxxx is the sequence number. Select this field to start/stop the sequence. It is shown as “depressed” when active. S shows the step number. These are explained in the help pages. S shows the step number. T is Timer and A is a Auto/Manual indicator. If depressed, M is displayed, indicating that the sequence is started/stopped manually. In Auto mode, the sequence is started/stopped by another sequence.

3.3.1 Start up of Desox plant

This operational description will give a detailed description of how the Desox plant is started, and later a description of the complete start-up procedure of the power plant.

This operational description may start as a continued operation from earlier stages, or it could be operated as a isolated system.

3.3.2 Prepare for operation of Desox plant

Picture: MD700/710

Operation:

1. Specify in the variable pages that DEsox plant shall be operated as a isolated system.
2. If this is a continued operation of the previous chapter select various sub-system displays in order to verify 'Boiler/Turbine/Denox running' condition.

   (MD010/300/700/710)

Observe:

- Observe the same parameter values as print-outs from operational test #2.

3.3.3 Start on 48 hours notice

Picture: MD810/820/840/850

Operation:

1. Check that the transportation system from electric filter to Cefill plant is working. (MD850)
2. Check that the level in product silo is 80%.
3. Check that the Lime silo is filled with Lime (MD810).
4. Check that the ash transport system is in Auto.
5. Check that the lime feeders are ready for operation (MD820).
6. Check dewpoint indicator (MD840).

3.3.4 Fill up lime day silo

Picture: MD810

Operation:

1. Open the valves for air supply to fluidised beds on Lime Silo and Lime day tank.
2. Start the filter fans.
3. Start the air fan for fluidised conveyer.
4. Open the valve for air supply to fluidised conveyer.
5. Start the conveyer and scoop lift manually.
6. Set the position controllers for Lime silos in Auto.

Observe:

- Observe that the level is rising in Lime day silo.
- Observe that the conveyer and scoop lift stops when the level in the day silo has reached the pre-set level.

3.3.5 Prepare and start the mixing system

Picture: MD860

Operation:

1. Start sequence 806.

Observe:

- Sequence 807 will start automatically.
- Observe that the level in the mixer tank increases.

3.3.6 Prepare and start the slake suspension system

Picture: MD820

Operation:

1. Start sequence 802.

Observe:

- Outlet from the lime day silo to the slake tank opens (Local).
- Delivery valve from the lime feeder opens.
- Drain from the slake tank 1 closes.
- Open for water to the slake tanks 1.
- Drain from the slake suspension tank closes.
- Valve for water to the slake suspension tank opens.
- Mixer in the slake tank 1 start.
- Observe filling of the lime feeder 1.

Operation:

2. Set the suspension tank level controller to Auto.
3. When the level has reached 40%, start sequence 804.

Observe:

- Observe that the level increases in the slake suspension tank.
- Slake suspension pump 1 starts.
- Observe that pump 2 is set to Auto.

3.3.7 Prepare feeder tank for operation

Picture: MD830/840

Operation:

1. Line up for filling the feeder tank.
2. Check the feeder tank level controller, and set to Auto. Adjust setpoint to 85%.
3. Check the Desox controller and adjust setpoint to 300 mg SO_2/Nm^3.
4. Set the temperature controller setpoint to a temperature (+20%) above the dewpoint.

3.3.8 Fill the feeder tank

Picture: MD830

Operation:

1. When the level in the slake suspension tank and mixer tank 1 is 80%, start sequence 810.
2. When the level in the feeder tank is above 40%, start sequence 811.

Observe:

- Observe that the level is increasing in the feeder tank.

- Observe that the feeder pump 1 starts.

3.3.9 Start on 4 hours notice/Prepare and start the spreader

Picture: **MD840**

Operation:

1. Start the sealing air fan for the spreader.
2. Open the flue gas inlet / outlet dampers.
3. Close the flue gas by-pass damper.
4. Line up and start transport of product from absorber.
5. When the flue gas has run through the absorber for sufficient time, the absorber walls are hot enough to start the spreader.
6. Start sequence 813.

Observe:

- Observe flow of flue gas through absorber.

- Observe that the spreader starts.

3.3.10 Start ash transport system from absorber

Picture: MD850

Operation:

1. Start sequence 815.

Observe:

- Observe that the transport system starts.

3.3.11 Start absorption

Picture: MD840

Operation:

1. When the level in the feeder tank is 85% the absorption will start automatically when sequence 814 is activated.
2. Set all temp.controller to Auto.
3. Set flow controller to Auto.
4. Set SO_2 controller to Auto.

Observe:

- Observe that absorption starts.

4 Appendix A Process Sequence

DESCRIPTION OF THE PROCESS SEQUENCER

The sequence is controlled by a Process Sequence Agent based on the following principles:

A sequence can be started, stopped, stepped, set or reset.

Step numbers (0,1,2,3,--) will indicate how the sequence is progressing.
A main job step number and a sub job step number will be indicated when the sequence is running or paused. Two text lines corresponding to the main and sub job step numbers will automatically be displayed.

A coloured frame surrounding each control sequence "panel" will change colour according to the following state table:

State 0:	Black	Sequence not started
State 1:	Green	Sequence finished
State 2:	Orange	Sequence going on
State 3:	Blue	Sequence pause
State 4:	Red	Sequence alarm

A vertical "time" bar (0-100 %) indicates amount of work done while estimated time left (in seconds) is shown on a digital display.

An indicating diode labelled "Ready" gives additional information. The diode light can have the four "colours" dark green, green, flashing green or red and must be interpreted relative to present sequence state.

The model drawing associated with the ongoing job is shown on the MD push button placed at the lower right corner.

There is also a push button for easy finding appropriate model variable pages related to the sequence. The first page gives start permitted/set permitted data. The second page contains settable parameters for adjusting sequence execution rate and step type, besides some auxiliary variables. The third page is mainly for future needs.

State 0 / Black frame / Sequence not started

A press on “START” or “STEP” will, if start permitted, activate the sequence and transfer it to state 2, “Sequence going on”.

A green ready-diode indicates that the present process conditions are such that start **is** permitted, while a dark diode indicates that it is **not** permitted. A press on the sequence model variable page button displays the start permitted requirements.

A red ready-diode signals that the sequence has been disabled. The instructor can disable some or all sequences from simulator control model variable pages 0102/0103.

The sequence can be manually set (“marked as finished”) by pressing “SET”. Requirements for set permitted are also displayed on the associated sequence model variable page.

Note that the ready-diode does not reflect any set permit information. A sequence can be set but not started and vice versa, dependent on process conditions, as shown on the sequence model variable page.

State 1 / Green frame / Sequence finished

In “Sequence finished” state one of three additional texts are given as a reminder:

After a normal sequence run the text “Sequence successfully completed” is shown.

If the sequence is manually marked as finished, the text “Sequence manually set” appears. In this case also the time bar will show zero, to further distinguish the properly run and finished sequences from the ones manually set.

If the ready-diode is red the text “Sequence to be checked” is displayed. This means that the set permitted conditions specified on the sequence model variable page, are not fulfilled and that the process appears not to be in a state normally reached after running the sequence.

Pressing “RESET” will transfer the sequence to state 0, “Sequence not started”.

State 2 / Orange frame / Sequence going on

In “Sequence going on” a vertical time bar (0-100 %) indicates time left / work done.

In addition to the time bar, estimated time left (in seconds) is shown on a digital display.

The model drawing associated with the ongoing job is indicated on the MD push button placed at the lower right corner. Pressing the MD button will make transfer to the picture indicated. Note also that an expedite return to the Process Sequence picture is possible by pressing the “Back” push button on the new “MC90-V” type footer bar.

The ready-diode will be flashing green to draw attention to the running condition.

The sequence can be set manually in pause, state 3, by pressing “STOP”.

If the sequence was started by a “STEP” command, it will automatically transfer to state 3, “Sequence pause” when the step is finished. A step can be defined as a long step (= continue until next change in main job index) or a short step (= continue until next change in sub job index). The step type parameter can be set from the sequence model variable page.

The ongoing sequence can be terminated and marked as “completed” by a “SET” command. This requires that the set permit conditions are met. The operator is expected to validate process conditions after such a sequence short cutting.

Each step has been given a maximum time for completion. If the current time limit it exceeded, the sequence will be transferred to state 4, “Sequence alarm”

State 3 / Blue frame / Sequence pause

Press on “START” or “STEP” will reactivate the sequence. The sequence logics is transferred to state 2, “Sequence going on”

Press on “RESET” will abort the sequence and transfer it to state 0, “Sequence not started”.

Press on “SET” will, if set permitted, terminate the sequence and transfer it to state 1, “Sequence finished”

Note that there are taken no process “clean-up” actions if the sequence is manually aborted / terminated. The operator must take responsibility for checking process and make corrective interventions if necessary.

State 4 / Red frame / Sequence alarm

Red, flashing sequence frame is indicating a sequence time-out error.

Press on “RESET” transfers state to 3, “Sequence pause”. A new “START” or “STEP” command will then make the sequencer retry processing the current sequence step, the one that caused time-out.

Press on “START” or “STEP” with flashing red frame will abort the currently failing sub step and make the sequence continue from the next step in line.

Note that the sequence system is presently implemented with no direct connection between actual process alarms and a sequence alarm state.

5 APPENDIX B STEAM PLANT SEQUENCE

```
SEQUENCE 01 - INITIAL PREPARATIONS
----------------------------------


1    Preparing Electric Power Supply

     1.1 Connecting electric bus-tie breaker
     1.2 Connecting fast circuit breaker
     1.3 Connecting electric feeder cbr

2    Checking External Supplies - MVP0100

     2.1 Setting auxil steam pressure/temp
     2.2 Setting auxil DHW supply temp - T00325
     2.3 Setting auxil water supply - T00320

3    Preparing Turbine for 48h Slow-Turning

     3.1 Starting turbine casing drain system
     3.2 Starting turbine lubrication (main lube oil)
     3.3 Starting turning gear (auto clutch)

4    Draining Fuel Oil Service Tank

     4.1 Opening HFO tank bottom drain valve
     4.2 Waiting for water drain to finish

5    Preparing Fuel Oil Supply System

     5.1 Lining up HFO tank transfer system
     5.2 Starting HFO tank heating by sec. hot water
     5.3 Checking HFO tank temperature set-point

6    Preparing Auxil Cooling System

     6.1 Starting auxil coolw (for ventilation/LO etc)

7    Terminating Sequence

     7.1 Resetting alarms ++
```

SEQUENCE 02 - CONDENSATE MAKE UP SYSTEM
--

1 Preparing Make-Up Deaerator

1.1 Activating clean water supply controllers
1.2 Starting condensate make-up pumps
1.3 Setting level controllers to auto
1.4 Waiting for deaerator level > 0.85 m
1.5 Opening make-up deaerator steam supply
1.6 Preparing vacuum pump sealing water system
1.7 Starting make-up deaerator stripper
1.8 Setting start-mode temp setpoint (45 dgrC)

2 Preparing Condensate Transfer

2.1 Opening main condensate tank inlet valves
2.2 Lining up transfer pumps / valves
2.3 Preparing main condensate tank inlet flow cnt

3 Preparing Main Condensate Tank

3.1 Starting main condensate tank vacuum pump
3.2 Opening main condensate tank inlet valves
3.3 Waiting for condensate tank level

4 Preparing Condensate Cleaning Plant

4.1 Opening valves/start circulation pump
4.2 Waiting for stable cleaning plant

5 Terminating Sequence

5.1 Resetting alarms ++

SEQUENCE 03 - SMALL CLEAN-UP LOOP
----

1 Preparing Main Condensate Line

1.1 Opening main condensate pump valves
1.2 Opening sealing water filtering plant feed
1.3 Opening condensate line shut off valves
1.4 Setting in-line condensate filter bypass

2 Preparing Feed Water Deaerator

2.1 Lining up FW inlet valve and level control
2.2 Opening clean-up line supply valve
2.3 Checking vent valve to bottom blow tank

3 Preparing Main Condensate Line Flow

3.1 Starting two condensate pumps
3.2 Setting condensate filter dp control auto
3.3 Opening condensate filter supply line valve
3.4 Closing condensate filter direct line valve
3.5 Setting FW deaerator level control to auto

4 Preparing Bottom Blow Tank Flow

4.1 Setting discharge to Lake
4.2 Increasing return flow to bottum tank
4.3 Discharging dirty condensate to Lake
4.4 Opening make-up deaerator inlet valve
4.5 Changing discharge from Lake to deaerator

5 Preparing Full Clean-up Flow

5.1 Increasing flow adjust valve setting
5.2 Adjusting to final flow (180 t/h)

6 Small Clean-Up Loop in Operation

6.1 Waiting for tank levels to stabilize
6.2 Waiting for condensate system to clean

7 Terminating Sequence

7.1 Resetting alarms ++

```
SEQUENCE 04 - FUEL OIL SUPPLY HEATING
-------------------------------------


1    Preparing Auxil Steam for HFO Heating

     1.1 Lining-up auxil steam supply
     1.2 Preparing to fill cooling tank
     1.3 Preparing to fill LP steam generator
     1.4 Waiting for cooling tank level > 0.50 m
     1.5 Opening auxil steam to cooling tank
     1.6 Opening auxil steam to HFO heating line
     1.7 Setting auxil steam drain return to auto


2    Preparing Fuel Oil Circulation

     2.1 Opening HFO tank circulation valves
     2.2 Opening burner plane A/D supply valves
     2.3 Setting burner plane A/D control valves
     2.4 Opening HFO heater fuel oil valves
     2.5 Starting HFO recirculation


3    Preparing HFO Circulation Heating

     3.1 Opening HFO heater 1 steam valves
     3.2 Adjusting HFO temp by manual control
     3.3 Transfering to automatic temperature control


4    Terminating Sequence

     4.1 Resetting alarms ++
```

SEQUENCE 05 - BIG CLEAN UP LOOP

1 Preparing for Boiler Gravity Filling

1.1 Opening separator X-over / venting valve
1.2 Preparing bottom blow flow to Lake
1.3 Opening FW pump valves / filling line
1.4 Preparing filling line flow
1.5 Waiting for bottom water to clean
1.6 Closing boiler bottom valves
1.7 Setting MD temp set point to normal (75 dgrC)

2 Filling Boiler by Gravity Flow

2.1 Waiting for boiler level to rise > 30 %

3 Preparing Separator Level Control

3.1 Setting separator level controllers auto
3.2 Opening FW deaerator return line valve

4 Filling Boiler by Forced Flow

4.1 Lining up high pressure condensate line
4.2 Preparing FW pump 1 for starting
4.3 Setting FW pump 1 speed to minimum
4.4 Starting FW pump 1
4.5 Preparing FW flow control for 260 t/h
4.6 Setting FW flow control to auto
4.7 Closing separator x-over when forced flow

5 Waiting for Boiler to Fill

5.1 Waiting for over-flow to separator

6 Establishing Big Clean-up Loop

6.1 Waiting for bottum flow to clean
6.2 Changing flow from Lake to MD
6.3 Waiting for flow loop to stabilize

7 Terminating Sequence

7.1 Resetting alarms ++

SEQUENCE 06 - BOILER IGNITION

1 Preparing Boiler SH Control

1.1 Opening boiler SH drain valves
1.2 Opening separator vent valve
1.3 Preparing superheater 2 temp control system
1.4 Preparing superheater 3 temp control system
1.5 Preparing reheater 2 temp control system
1.6 Opening superheater coolw supply valves

2 Preparing HP Line Bypass System

2.1 Setting free-blowing valve to 35 %
2.2 Setting HP line bypass min position to 12 %
2.3 Setting HP line bypass contr auto/15 bara
2.4 Prepare HP line bypass temp control system
2.5 Opening HP line bypass water supply valve
2.6 Setting IP line safety valve to auto

3 Preparing Combustion Air Preheaters

3.1 Opening DHW air heater supply valves
3.2 Opening steam air heater supply valves
3.3 Starting rotary air heaters

4 Making HFO System Ready for Burner Start

4.1 Preparing atomizing steam supply control
4.2 Opening cleaning steam supply valve
4.3 Starting main HFO pump 1
4.4 Changing to HFO tank bypass recirculation
4.5 Increasing HFO temp control set-point to 115 dgrC

5 Preparing Denox/Desox Plants for Purge

5.1 Starting Denox sequence (S701)
5.2 Bypassing Desox absorber

6 Preparing Boiler Flue Gas System

6.1 Setting flue gas fan control to manual
6.2 Starting flue gas fan 1
6.3 Setting flue gas fan control to auto

7 Preparing Boiler Combustion Air System

7.1 Setting air fan balance control to 50 %
7.2 Adjusting economizer damper positions
7.3 Checking ring chanel air pressure controllers
7.4 Starting air fans / set air controllers to auto

8 Preparing Fuel Controllers

8.1 Setting BLM control to manual
8.2 Setting FMC control to manual/0 %

9 Boiler Air Purging

9.1 Waiting for purge start ok signal
9.2 Giving start-purge command
9.3 Waiting for purge-complete signal
9.4 Stopping air fan 2 / air balance to 100 %
9.5 Waiting for comb. air pressure to settle

10 Boiler Ignition

10.1 Opening primary air damper/reset trip
10.2 Burner 1 starting sequence
10.3 Burner 3 starting sequence
10.4 Burner 2 starting sequence
10.5 Burner 4 starting sequence
10.6 Increasing BLM fuel command to 5 %
10.7 Setting FMC fuel controllers to auto
10.8 Waiting for stable fire conditions
10.9 Terminating / resetting alarms

SEQUENCE 07 - PRESSURE RISING TO 15 BAR

1 Starting Denox Reactor Heating

1.1 Increase firing rate to 10 % (6 t/h)
1.2 Starting combustion air fan 2
1.3 Starting Denox 1 heating sequence (S704)
1.4 Starting Denox 2 heating sequence (S705)

2 Making the Boiler Boil

2.1 Waiting for water swell (90-100 dgrC)
2.2 Closing separator vent valve
2.3 Waiting for separator pressure > 2 bara
2.4 Closing superheater drain valves

3 Preparing LP Steam Dump System

3.1 Waiting for condenser vacuum < 300 mbar
3.2 Lining up LP steam dump valves
3.3 Setting LP steam dump control to man/10 %
3.4 Reducing free-blowing valve to 30/10 %

4 Starting Denox 1 SCR Reactor

4.1 Starting Denox 1 NH3 injection (S702/S706)

5 Adjusting Free-Blowing Steam Flow

5.1 Waiting for IPH pressure > 1.3 bara
5.2 Reducing free-blowing valve to 25/5 %
5.3 Waiting for IPH pressure > 2.0 bara
5.4 Reducing free-blowing valve to 15/0 %
5.5 Setting LP steam dump control to auto
5.6 Reducing firing rate to 8 % (4.8 t/h)

6 **Starting Denox 2 SCR Reactor**

6.1 Waiting for SCR 1 start-up to finish
6.2 Starting Denox 2 NH3 injection (S703/S707)
6.3 Waiting for SCR 2 start-up to finish

7 **Increasing Boiler Steam Pressure**

7.1 Closing free-blow if LP steam dump on
7.2 Waiting for HP line pressure > 15 bara
7.3 Increasing LP steam dump control set-point
7.4 Opening IP turbine steam supply valve
7.5 Changing to main sealing steam supply

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 08 - COLD CONDENSER VACUUM

1 Filling Cold Condenser

1.1 Starting cold condenser water filling
1.2 Preparing main condensate pumps

2 Preparing Cold Condenser Cooling

2.1 Preparing main coolw line
2.2 Starting main coolw pump 1

3 Preparing Condensate Recirculation System

3.1 Waiting for hotwell level > 0.25 m
3.2 Opening valves for recirculation control
3.3 Starting main condensate pump 1

4 Preparing Gland Condenser/Sealing Steam

4.1 Opening drain valve / starting glandc fan
4.2 Opening auxil sealing steam supply valve
4.3 Preparing sealing steam control system

5 Preparing LP Steam Dump Coolw Supply

5.1 Opening steam dump coolw /steam valves

6 Preparing Turbine Casing Coolw Supply

6.1 Opening casing coolw supply valve

7 Preparing Condenser Vacuum Pumps

7.1 Checking vacuum pump sealing water system
7.2 Starting governing oil pump
7.3 Closing vacuum breaker valve
7.4 Starting cold condenser vacuum pump 1
7.5 Waiting for condenser press < 300 mbar
7.6 Closing cold condenser filling valve

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 09 - FW DEAERATOR HEATING

1 Starting FW Deaerator Heating

1.1 Waiting for IPC pressure > 1.1 bara
1.2 Starting deaerator steam heating
1.3 Closing auxil steam supply
1.4 Opening FW dearator pressure control valve

2 Putting FW Deaerator in Operation

2.1 Opening steam outlet to boiler air heaters
2.2 Waiting for deaerator temp > 90 dgrC
2.3 Venting inert gas to bottum blow tank

3 Preparing FW Deaerator Pressure Control

3.1 Setting rate/min pressure controller auto
3.2 Closing x-over valve to boiler air heaters

4 Terminating Sequence

4.1 Resetting alarms ++

SEQUENCE 10 - PRESSURE RISING TO 30 BAR
----

1 Checking HP Bypass and Firing Rate

1.1 Setting HP bypass control setp to 30 bara
1.2 Increasing firing rate to 9 t/h (15 %)
1.3 Waiting for IPH line pressure > 3.5 bara

2 Checking/Adjusting LP Steam Dump System

2.1 Checking condenser vacuum < 300 mbar
2.2 Checking LP steam dump valves
2.3 Setting steam dump contr auto / setp 7 bara
2.4 Reducing free-blowing valve 5/0 %

3 Increasing HP Line Pressure to 25 bara

3.1 Waiting for HP line pressure
3.2 Increase LP steam dump setpoint to 8 bara
3.3 Checking eco damper position / side 1
3.4 Checking eco damper position / side 2
3.5 Setting furnace OFA control to auto

4 Increaseing HP Line Pressure to 30 bara

4.1 Waiting for HP line pressure
4.2 Waiting for stable 30/8 bara condition

5 Terminating Sequence

5.1 Resetting alarms ++

SEQUENCE 11 - PREPARING LP FEED HEATERS

1 Preparing LP0 Feed Water Heater

1.1 Opening steam, vent and drain valves

2 Preparing LP1/2/3 Feed Water Heaters

2.1 Opening LP1 steam, vent and drain valves
2.2 Opening LP2 steam, vent and drain valves
2.3 Opening LP3 steam, vent and drain valves

3 Preparing LP Feed Heater Safety System

3.1 Setting LP1/2 emerg. drain valves to auto

4 Terminating Sequence

4.1 Resetting alarms ++

SEQUENCE 12 - TURBINE ROLLING UP
----

1 Adjusting IP/HP Steam Pressure

1.1 Increasing steam dump setp to 10 bara
1.2 Checking HP line steam pressure (28-32)
1.3 Checking IP line steam pressure (8-11)
1.4 Checking condenser vacuum (<220 mbar)

2 Preparing HP Turbine

2.1 Opening HP turbine inlet/outlet valves
2.2 Checking turbine auxiliaries

3 Starting Cold Condenser Main Pumps

3.1 Checking main coolw pump
3.2 Checking main condensate pump
3.3 Waiting for condenser vacuum < 80 mbar

4 Increasing Turbine Speed to Low

4.1 Increasing governor setting to 10 %
4.2 Waiting for turbine speed > 1100 rpm
4.3 Waiting for vibrations to fall

5 Increasing Turbine Speed to Half

5.1 Increasing governor setting to 25 %
5.2 Waiting for turbine speed > 1400 rpm
5.3 Waiting for vibrations to fall

6 Passing Resonance Range 1700/1900 rpm

6.1 Increase governor setting to 45 %
6.2 Waiting for turbine speed > 2200 rpm
6.3 Waiting for vibrations to fall

7 Increasing Turbine Speed to Full

7.1 Increasing governor setting to 78 %
7.2 Waiting for turbine speed > 2950 rpm
7.3 Waiting for vibrations to fall

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 13 - TURBINE CONNECTION
----

1 Checking Turbine Steam Pressure/Speed

1.1 Checking turbine speed rmp (2900-3100)
1.2 Checking HP line steam pressure (28-32)
1.3 Checking IP line steam pressure (8-11)
1.4 Checking condenser vacuum (<80 mbar)

2 Synchronizing Generator

2.1 Adjusting frequency difference
2.2 Adjusting voltage difference
2.3 Connecting (waiting for correct phase)

3 Increasing Generator Load to 15 MW

3.1 Increasing governor setpoint to 87 %
3.2 Checking/closing free-blowing valve (safe)

4 Terminating Sequence

4.1 Resetting alarms ++

SEQUENCE 14 - BLOCK BINDING
----

1 Checking Turbine Power / Steam Pressures

1.1 Checking for sufficient generator power
1.2 Checking HP line steam pressure > 29 bara
1.3 Checking IP line steam pressure > 8 bara
1.4 Resetting LP bypass/dump controllers

2 Electric Block-Binding

2.1 Connecting auxil circuit breaker
2.2 Increasing governor setpoint to 90 %

3 Increasing Boiler Steam Production

3.1 Increasing firing rate to 12 t/h (20 %)
3.2 Reducing HP bypass min position to 0 %
3.3 Checking/closing free-blowing valve (safe)

4 Setting Turbine Vacuum Reduction/Breaking

4.1 Setting turbine reduction (if poor vacuum)
4.2 Setting turbine vacuum breaking (if trip)

5 Terminating Sequence

5.1 Resetting alarms ++

SEQUENCE 15 - PREPARING HP FEED HEATERS ++
--

1 Preparing HP Feed Heater Drain

1.1 Opening HP1 drain / vent valves
1.2 Opening HP2 drain / vent valves
1.3 Opening FW deaerator drain return valve
1.4 Opening LP3 drain return valve

2 Preparing HP Feed Heater Steam

2.1 Opening HP3 steam valve
2.2 Opening HP2 steam valve

3 Preparing HP Feed Heater Vent

3.1 Opening HP1/2 vent valves

4 Preparing LP Steam Generator

4.1 Lining up heating from IPC steam line
4.2 Opening make-up deaerator drain inlet valve
4.3 Opening LP generator steam outlet valve
4.4 Lining up sec. drain return system
4.5 Closing auxil sec. drain return valve

5 Preparing Steam to Cooling Tank from IPC

5.1 Lining up steam supply from IPC line

6 Preparing MD Steam Supply from IPC Line

6.1 Lining up steam from FD heating supply

7 Preparing FW Deaerator Heating

7.1 Opening steam supply from turbine ex4 line

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 16 - PRESSURE RISING TO 70 BAR CC
---

1 Preparing FW Control System

1.1 Setting master FW flow control to auto
1.2 Setting FW pump speed control to auto
1.3 Setting FW pump speed setpoint to auto

2 Preparing for Higher Boiler Load

2.1 Increasing firing rate to 15 t/h (25 %)
2.2 Checking OFA control to auto
2.3 Increasing turbine governor setp to 100 %
2.4 Activating turbine vacuum red/breaking

3 Preparing Boiler Glide Pressure Control

3.1 Checking HP bypass contr valve min pos
3.2 Setting HP bypass press glide control auto
3.3 Setting LP steam dump control to man/stby
3.4 Setting SH3 temperature target to 540 dgrC
3.5 Checking/setting FW deaerator heating ex4

4 Ignition of Burner Plane C

4.1 Opening primary air shut off dampers
4.2 Setting burner management system to auto
4.3 Waiting for all C-burners to be started

5 Rising Boiler Steam Pressure

5.1 Checking MD heating supply
5.2 Waiting for HP line pressure > 40 bara
5.3 Increasing firing rate to 21 t/h (35 %)
5.4 Waiting for HP line pressure > 60 bara
5.5 Increasing firing rate to 24 t/h (40 %)

6 Preparing for Steam Pressure 70 bara

6.1 Waiting for HP line pressure > 70 bara
6.2 Setting turbine min press control to auto

7 Waiting for Dry Steam Conditions

7.1 Waiting for boiler steam to super-heat
7.2 Waiting for separator to empty

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 17 - DISTRICT HEAT WATER SYSTEM

1 Preparing DHW Circulation

1.1 Setting multiblock mode (extern press ctr)
1.2 Setting DHW bypass controller to 100 %
1.3 Opening DHW direct heater bypass valve
1.4 Opening city grid return and supply valves
1.5 Opening expansion tank connection valves
1.6 Starting DHW pumps
1.7 Increasing DHW pump speed

2 Preparing Direct Heater 1

2.1 Opening DHW circulation valves
2.2 Preparing level control system
2.3 Preparing subcooler system
2.4 Opening steam admission valves
2.5 Waiting for direct heater to warm up
2.6 Setting inlet steam control valve to auto

3 Preparing Direct Heater 2

3.1 Opening DHW circulation valves
3.2 Preparing level control system
3.3 Preparing subcooler system
3.4 Opening steam admission valves
3.5 Waiting for direct heater to warm up
3.6 Setting inlet steam control valve to auto

4 Preparing LP Bypass Control

4.1 Setting DH1/2 level command to remote
4.2 Setting LP bypass cntr auto/dump cntr stby
4.3 Closing DHW direct heater bypass valve
4.4 Closing free-blow valve when IPH > 3.5 bara

5 Terminating Sequence

5.1 Resetting alarms ++

SEQUENCE 18 - HOT CONDENSERS

----

1 Preparing Hot Condenser 2

1.1 Starting water filling
1.2 Lining up hotwell level control system
1.3 Opening air suction (vacuum) valve
1.4 Opening air suction x-over valve from CC
1.5 Waiting for hotwell level > 0.50 m

2 Preparing Hot Condenser 1

2.1 Preparing hot condensate pumps
2.2 Opening air suction (vacuum) valve
2.3 Waiting for hotwell level > 0.30 m
2.4 Starting hot condensate pump 1
2.5 Setting hotwell level control to auto
2.6 Closing CC drain return from LP1

3 Preparing Hot Condenser Cooling

3.1 Opening DHW circulation valves
3.2 Setting DHW low-temp protection to auto
3.3 Closing HC filling valve

4 Terminating Sequence

4.1 Resetting alarms ++

```
SEQUENCE 19 - EL POWER+HOT WATER PRODUCTION
-------------------------------------------


1    Preparing for DHW Production

     1.1 Setting multi-block mode / ambient 5 dgrC
     1.2 Setting Burner Management to auto
     1.3 Increasing firing 40 % / governor to 100 %
     1.4 Starting flue gas fan 2
     1.5 Starting feed water pump 2
     1.6 Starting hot condensate pump 2
     1.7 Opening boiler economizer outlet dampers
     1.8 Checking boiler glide pressure control
     1.9 Setting FW pump control to auto+auto


2    Transfering to Back Pressure Mode

     2.1 Setting LP steam bypass control to stby
     2.2 Connecting Direct Heater 1/2 contr to TMC
     2.3 Connecting LP turbine damper contr to TMC
     2.4 Reducing steam command to LP turbine
     2.5 Checking FW deaerator heating from turb ex4


3    Initial TMC District Water Control

     3.1 Setting TMC control to auto
     3.2 Setting TMC setpoint to recommended temp
     3.3 Waiting for DHW temperature to stabilize
     3.4 Checking OFA control to auto

4    Preparing for Single-Block Operation

     4.1 Setting single-block mode
     4.2 Setting DHW pump speed control to auto
     4.3 Starting DHW pumps 2
     4.4 Waiting for DHW temperature to stabilize


5    Optimal BP Control by BLW-controlled Fire

     5.1 Aligning BLW controller
     5.2 Connecting BLW and BLM controller
     5.3 Setting BLW temp setpoint to auto select
     5.4 Waiting for TMC controller to balance


6    Preparing Cold Condenser for BP Mode

     6.1 Lining up coolw system for auto-auto
     6.2 Lining up condensate system for auto-auto


7    Terminating Sequence

     7.1 Resetting alarms ++
```

SEQUENCE 20 - FULL DHW PRODUCTION / COAL

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1 Transferring to Coal Operation on Plane D

1.1 Checking coal data (MVP111-112-113)
1.2 Starting coal mill
1.3 Waiting for coal mill in operation
1.4 Stopping oil burners
1.5 Turning off primary air heater

2 Transferring to Coal Operation on Plane C

2.1 Starting coal mill
2.2 Waiting for coal mill in operation
2.3 Stopping oil burners
2.4 Turning off primary air heater

3 Setting HFO Supply System to Back-up Mode

3.1 Starting HFO circulation pump
3.2 Setting main HFO pumps in auto

4 Preparing for Cold Weather Conditions

4.1 Setting ambient temperature to -20 dgrC
4.2 Setting Burner Management system to auto
4.3 Starting main condensate pump 2

5 Starting Sequentially New Burners Planes

5.1 Waiting for plane B burners (BLM > 43 %)
5.2 Waiting for plane A burners (BLM > 62 %)

6 Increasing Boiler Load to Max Coal Load

6.1 Waiting for DHW temperature
6.2 Waiting for TMC to balance

7 Terminating Sequence

7.1 Resetting alarms ++

SEQUENCE 21 - ACCUMULATOR LOADING

1 Preparing Accumulator Tank Systems

1.1 Setting ambient condition to 5 dgrC
1.2 Preparing accumulator hot/cold lines
1.3 Lining up exp tank emerg make-up system
1.4 Setting exp tank emerg dump control auto
1.5 Starting accumulator spray pump

2 Preparing Accumulator Pump/Turbine System

2.1 Setting accumulator to load mode
2.2 Starting accumulator (pony) motor
2.3 Resetting turbine trip
2.4 Setting high-temp protection to auto
2.5 Increasing turbine flow setting to 5 %
2.6 Setting motor speed (level) control auto

3 Increasing Accumulator Loading Rate

3.1 Increasing turbine flow setting to 30 %
3.2 Waiting for pump/turbine flow balance

4 Terminating Sequence

4.1 Resetting alarms ++

SEQUENCE 22 – ACCUMULATOR DAY/NIGHT DEMO

1 Preparing for Accu Operation (Day 1)

1.1 Setting ambient condition to -1 dgrC
1.2 Increasing accumulator flow setting to 60 %
1.3 Starting main condensate pump 2

2 Increasing Boiler Load to Maximum (Day 1)

2.1 Waiting for burners on plane B to start
2.2 Waiting for burners on plane A to start
2.3 Waiting for heat load balance

3 Recording Power Situation (End of Day 1)

3.1 Record El-power/DHW power/Accu power

4 Decreasing Boiler Load to Minimum (Night 1)

4.1 Setting night mode (moon)
4.2 Decreasing accumulator flow setting to 20 %
4.3 Changing to accumulator unload mode
4.4 Waiting for burners on plane A to stop
4.5 Increasing accumulator flow setting to 50 %
4.6 Waiting for burners on plane B to stop
4.7 Waiting for heat load balance

5 Recording Power Situation (End of Night 1)

5.1 Record El-power/DHW power/Accu power

6 Increasing Boiler Load to Maximum (Day 2)

6.1 Setting day mode (sun)
6.2 Decreasing accumulator flow setting to 20 %
6.3 Changing to accumulator load mode
6.4 Waiting for burners on plane B to start
6.5 Increasing accumulator flow setting to 60 %
6.6 Waiting for burners on plane A to start
6.7 Waiting for heat load balance

7 Recording Power Situation (End of Day 2)

7.1 Record El-power/DHW power/Accu power

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 23 - FULL EL POWER PRODUCTION CC
--

1 Preparing Boiler Flue Gas Dampers

1.1 Checking damper after economizer - side 1
1.2 Checking damper before economizer - side 1
1.3 Checking damper after economizer - side 2
1.4 Checking damper before economizer - side 2

2 Preparing the Second Flue Gas Fan

2.1 Starting flue gas fan 2

3 Preparing the Second Feed Water Pump

3.1 Starting feed water pump 2
3.2 Setting feed water pump 3 in stand-by

4 Preparing the Second Condensate Pump

4.1 Starting cold condensate pump 2
4.2 Setting cold condensate pump 3 in stand-by
4.3 Starting main condensate pump 2

5 Checking Steam Temperature Set Points

5.1 Setting SH3 target temperature to 540 dgrC
5.2 Setting RH2 set pint to 540 dgrC

6 Preparing Block Master Controllers

6.1 Aligning block el-power controller (BLE)
6.2 Connecting BLE and BLM controllers
6.3 Setting Burner Management to auto
6.4 Setting BLE power set point to 230 MW

7 Increasing Electric Power Production

7.1 Waiting for electric power > 230 MW
7.2 Adjusting plane balance for min wtr inject
7.3 Waiting for stable conditions
7.4 Turning frequency support mode on

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 24 – FROM COLD PLANT TO MAX POWER

1 Basic Preparations (Seq 1/2)

1.1 Starting sequence 1
1.2 Waiting for sequence 2 to be ready

2 Condensate Cleaning (Seq 3/4/5/25)

2.1 Waiting for sequence 3 to be ready
2.2 Waiting for sequence 4 to be ready
2.3 Waiting for sequence 5 to be ready
2.4 Waiting two minutes
2.5 Starting desox plant

3 Boiler Light-off (Seq 6/7/8)

3.1 Waiting for sequence 6 to be ready
3.2 Waiting for sequence 7 to be ready
3.3 Waiting for sequence 8 to be ready

4 Steam Plant Preparations (Seq 9/10/11)

4.1 Waiting for sequence 9 to be ready
4.2 Waiting for sequence 10 to be ready
4.3 Waiting for sequence 11 to be ready

5 Turbine Connection (Seq 12/13/14)

5.1 Waiting for sequence 12 to be ready
5.2 Waiting for sequence 13 to be ready
5.3 Waiting for sequence 14 to be ready

6 Increasing Plant Load (Seq 15/16)

6.1 Waiting for sequence 15 to be ready
6.2 Waiting for sequence 16 to be ready
6.3 Waiting for generator power > 70 MW

7 Increasing Electric Power (Seq 23)

7.1 Waiting for sequence 23 to be ready
7.2 Waiting for generator power > 200 MW
7.3 Increasing power set point to 240 MW
7.4 Waiting for generator power > 255 MW

8 Terminating Sequence

8.1 Resetting alarms ++

SEQUENCE 25 - DESOX PLANT START-UP
----

1 Filling Lime Day Silo

1.1 Opening lime silo outlet valve
1.2 Starting S801 : Lime scoop lift
1.3 Waiting for lime day silo > 25 %

2 Preparing Slake System

2.1 Preparing slake water cooler
2.2 Opening lime supply valve
2.3 Opening lime day silo outlet valve
2.4 Starting S802 : Slake tank 1
2.5 Mixing slake tank 1 (2 min)
2.6 Starting S804 : Slake suspension pump 1
2.7 Mixing slake suspension tank (2 min)
2.8 Checking slake system (S802/S804)

3 Preparing Slurry Mixing System

3.1 Opening mixer 1 recirculation valve
3.2 Opening product silo shut off valve 1
3.3 Starting S806 : Mixing tank 1
3.4 Mixing slurry in tank 1 (2 min)
3.5 Checking mixing system (S806/S807)

4 Preparing Absorber Feed System

4.1 Opening slake suspension supply valve
4.2 Starting S810 : Feeder tank/mixer 1
4.3 Mixing absorber slurry (2 min)
4.4 Starting S811 : Feeder tank pump 1
4.5 Waiting for stable conditions (2 min)
4.6 Checking feeder system (S810/S811)

5 Preparing Product Transport System

5.1 Preparing flue gas filters
5.2 Opening product silo inlet damper
5.3 Starting S816 : Filter product conveyer
5.4 Opening ash silo inlet damper
5.5 Starting S815 : Absorber product conveyer
5.6 Waiting for stable conditions (1 min)
5.7 Checking product system (S815/S816)

6 Preparing SOX Absorber System

6.1 Starting S813 : Absorber spreader
6.2 Waiting for spreader running ok
6.3 Starting S814 : Absorber slurry feed
6.4 Waiting for stable conditions (2 min)
6.5 Checking absorber system (S813/S814)
6.6 Waiting for SO2 control to normalize

7 Terminating Sequence

7.1 Resetting alarms ++

SEQUENCE 26 – DESOX PLANT SHUT-DOWN

1 Shutting Off Lime Day Silo

1.1 Closing lime silo outlet valve
1.2 Stopping S801 : Lime scoop lift
1.3 Closing lime day silo outlet valves
1.4 Stopping silo fluidized bed fans
1.5 Stopping silo filter fans

2 Stopping Slake System

2.1 Closing lime supply valve
2.2 Stopping S802 : Slake tank 1
2.3 Shutting off slake water cooler
2.4 Stopping slake tank fan
2.5 Stopping S804 : Slake suspension pump 1
2.6 Waiting for S802/S804 to finish
2.7 Stopping slake/suspension tank mixers

3 Stopping Absorber Feed System

3.1 Stopping S810 : Feeder tank/mixer 1
3.2 Stopping S811 : Feeder tank pump 1
3.3 Closing slake suspension supply valve
3.4 Closing slurry strainer inlet valves
3.5 Waiting for S810/S811 to finish
3.6 Stopping feeder tank mixer
3.7 Checking/closing all manual valves

4 Stopping Slurry Mixing System

4.1 Stopping S806 : Mixer tank 1
4.2 Stopping S807 : Mixer tank 1 pump
4.3 Waiting for S806/S807 to finish
4.4 Closing mixer 1 recirculation valve
4.5 Closing mixer tank 1 filter water spray
4.6 Stopping mixer tank 1 dust filter fan

5 Shutting Down SOX Absorber System

5.1 Stopping S814 : Absorber slurry feed
5.2 Stopping S813 : Absorber spreader
5.3 Waiting for S813/S814 to finish
5.4 Opening absorber bypass dampers
5.5 Closing absorber inlet dampers

6 Shutting Down Product Transport System

6.1 Stopping S815 : Absorber product conveyer
6.2 Waiting for S815 to finish
6.3 Closing ash silo inlet damper
6.4 Closing flue gas filter outlet valves
6.5 Stopping S816 : Filter product conveyer
6.6 Waiting for S816 to finish
6.7 Closing product silo inlet damper
6.8 Securing product transporters
6.9 Stopping silo fluidized bed fan

7 Terminating Sequence

7.1 Resetting alarms ++

6 APPENDIX C SEQUENCE 24 DEMO

Start-up from cold plant to full power. A demonstration

Sequence 24 demonstrates a “single push” start-up from cold plant to maximum electric power, 250 MW. It is an administrative sequence that starts appropriate other sequences when needed and as fast as possible. The following time table gives more details on the procedure involved. Cold condensing mode is used so there is no district heat production.

Total time required is approximately 3 hours in real time on the simulator. When running this demonstration it is recommended to speed up the simulation model execution by a factor of 5 (Set “simulation speed ratio”, X94001, to 5.0)

Sequence	Started	Finished	Sequence text
24	0:00	3:08	From Cold Plant to Max Power
01	0:00	0:09	Initial Preparations
02	0:02	0:11	Condensate Make-up System
03	0:11	0:28	Small Clean-up Loop
04	0:28	0:38	Fuel Oil Supply Heating
05	0:28	0:54	Big Clean-up Loop
25	0:31	1:25	Desox Plant
06	0:51	1:05	Boiler Ignition
07	1:05	1:47	Pressure Rising to 15 bar
08	1:07	1:24	Cold Condenser Vacuum
09	1:21	1:38	Feed Water Deaerator Heating
10	1:47	1:57	Pressure Rising to 30 bar
11	1:47	1:49	Preparing LP Feed Heaters
12	1:57	2:08	Turbine Rolling-up
13	2:08	2:11	Turbine Connection
14	2:11	2:13	Block Binding
15	2:12	2:15	Preparing HP Feed Heaters + misc
16	2:15	2:35	Pressure Rising to 70 bar
23	2:27	3:06	Full El-Power Production / CC

7 APPENDIX D TPP PROCESS COMMENTS

In the following pages, comments are made on functions and variables that may not be obvious from the information found on the model drawing pictures (MD) and associated model variable pages (MVP) and therefore need some clarification.

MD100 – Fuel Oil System

MVP0100
Heating of the HFO tank is taken from a secondary hot water supply, represented by the variable T00320, auxiliary water supply temperature. The supply pressure is fixed at 10 bar. The hot water is indirectly heated by the (external) DHW system.

MVP0110
The chemical composition of the fuel oil contained in the tank can be set from this page. From the "ingredients list" actual lower heat value and combustion air demand is computed. Final adjustment of computed heat value, theoretical air consumption and NOx/CO generation can be done at will.

MVP1002
The HFO tank must be drained regularly. The "drain index" is used to control the colour of the drain funnel: 0,1,2 = off, on+water, on+fuel oil

The nominal water content in the fuel is settable from MVP0110.X00807
Actual water content in tank outlet fuel flow is shown by MVP1002.X01036
High water level in the service tank will give extra water content in out-flowing fuel. Suction height is set at 1.0 m. Water level below 0.6m has no influence. Water level between 0.6 and 1.0m will result in gradually more water in outlet flow and correspondingly reduced heat value.

There is not modelled any tank water settling process as such.
Malfunction M1001, "tank heater leakage", will give a steady increase in tank water level. Malfunction M1004, "tank water high", will set the water level high and give a noticeable reduction in effective fuel heat value.

<u>Auto-auto standby function</u>

All major pumps have the basic "start-at-low-pressure" type standby logics. Alarm will be given at start. There is no function for automatically stopping the standby-started pump. Stopping is up to the operator to decide.
HFO pump 1 can be set in "auto-auto". In this mode the pump is started and stopped when required and no start/stop alarm is normally given. The pump should be set in

auto-auto when the coal mills are in operation. The HFO system is then kept hot by the circulation pump while the main pump is used only during burner start/stop operations.

MVP1040
The HFO pump 1 will start when some oil burners are on, will stop when no oil burners are on. Auto-auto mode requires that the HFO circulation pump is running and appropriate pump/tank valves are open.

MD120 – Secondary Steam System

MVP1204
The steam cooling tank is supplied with some steam for warm keeping, even when there is no outgoing steam. The steam cooling tank will therefore tend to gradually fill up. Necessary periodical draining is handled by the auto drain valve, which should always be kept in auto. The drain valve opens above 0.9 m and closes blow 0.7m (C01268/C01269)

MVP1205
When steam heating is from the external “auxil steam system”, be sure to keep the drain return valve to the assumed external “auxil water tank”, in auto.

MVP1223
The controller after the drain pump keeps the inspection tank level at set point. To avoid overfilling the LP steam generator tank, the drain controller is gradually choked at increasing steam generator level. Below “normal” level there is no overriding; at “high” value the control valve is completely closed.

MD140 – Burner Plane A

MVP0111
The main chemical components of the coal can be specified. The sum of the five components C,H,S,O,N should preferably add up to 100 % , to avoid confusion, but it is not strictly necessary, because the C,H,S,O,N setting is always recalculated to a 100 % basis before used in other computations.

Water and “inert” matter (ash/slag) should then be added. The water content varies much and has great impact on the amount of preheating required by primary air. Computed is lower heat value (including water/inert matter) and theoretical combustion air needed and flue gas produced. Computed is also (not shown) the important gas parameter, specific flue gas heat (kJ/kgC), used in the furnace model. The air/flue gas values are given in ncm/kg (ncm=normal cubic meter). Empirical adjustment factors are available for trimming final values.

MVP1425
The air/fuel ratio of each burner plane can be adjusted by the “air ratio adjust” factors, one for oil fuel and one for coal fuel. Adjusting these factors will lower or raise the air/fuel profile used by the Fuel Master Controller (MD180) when splitting up the general energy command into actual burner plane air, oil and coal flow set point commands.

MD170 – Burner Plane D

MVP0112/0113
A set of fuel data reflecting typical values for bio fuel like wood pellets is available. To demonstrate bio-fuel firing, select “pellets” on MVP0113. The coal silos are then filled with pellets and the coal mills are assumed rebuilt to fit the new material. To compensate for the reduced heat value, the mill and feeder equipment capacity is also increased, default setting is 140 %.
100 % represents the original coal mill capacity, 20 t/h.

MVP1709
A burner can only be started when the preset ready-conditions are satisfied. When a burner is started, the fuel oil and secondary air controllers are switched to auto. When a burner plane is off, all controllers are kept in manual.

To start a coal mill, all burners one the plane must be burning on fuel oil. Note also that the manually operated primary air fan inlet shut off damper must be open to get ready-signal. The primary air temperature/flow controller and the coal feeder speed controller are all handled by the coal mill sequence logics.

The temperature of the ring channel air can be insufficient for coal drying at start-up and low load, especially if the coal is wet. The two planes that are started first, plane C and D, are equipped with electric primary air preheaters to speed up the preheating of the coal mill. The electric heaters are manually operated only. A flow guard device turns the heater off if the primary air flow is below a low limit (3 t/h) (hidden function).

MVP1725
The temperature set point of the primary air controller is ramped up to running value from a start value, for smooth start-up performance. The mill air outlet temperature must be above 80 dgrC before the mill table starts rotating and pressure is put on the mill rollers to grind the coal to powder.

MVP1730
The primary air flow in the coal powder tubes is kept sufficiently high to have air velocity in the tubes higher than the flame combustion front speed, 10-15 m/s. This ensures that no furnace flame can burn back towards the mill. For safety the mill is tripped at low primary air flow and also at high air temperature.

The coal tubes are heavily built to avoid damage from possible coal powder back-feed explosions. The tubes therefore have a significant thermal heating-up delay. The preheating of the primary air piping system is simulated 3-4 times faster than in actual plant.

MD180 – Boiler Combustion Control

MVP1823
The energy commands are given in standard HFO flow units (t/h). All measured fuel flow signals are converted to equivalent standard HFO values (“normalized” HFO values) before used in the controller system.

Air requirements are computed (trimmed) from fuel heat value setting. To simplify preparations when changing fuel type, current heat value figures, C11844/45/46, are automatically set to the controller, unlike on the actual plant’s equipment.

The basic fuel/air control profile is defined by the master air bias/range parameters, C11847 and C11848. The adjustment span of the oxygen controller, C11846, can also be changed.

The measured oxygen content in flue gas is alarmed. Both low and high limits are dynamic and change with fuel mix and boiler load. A recommended best range for control is indicated. When automatic oxygen set point setting is used, an intermediate “best” value is selected.

MVP1830/31
To be able to keep tight trip limits, proper signal delays are necessary for avoiding too sensitive trip reactions. The trip delays are simulated as 1. order filters , with filter constants (tc) as specified.

The term “water saturation ” denotes the temperature difference between economiser boiling temperature at current outlet pressure and actual economizer water outlet temperature.

“Over Burner Air”
To reduce NOx generation, a portion if the secondary air is split off the main duct and entered a third channel just above the burner. The damper controlling this “over-burner-air”, abbreviated OBA, can fail, see malfunction M1800.

Failing OBA control can be detected by an abnormal flame display. The NOx generated from the faulty burner will also increase, resulting in an a higher overall NOx flow reading (see MD200/G02197)

MD190 – Block Master Control System

MVP1900
The control profiles for converting from power to steam flow, drawn as white boxes in the picture, are each defined by two parameters.
BLE : C01907 and C01908 , BLW : C01927 and C01928.

The working range of the BLE and BLW correction controllers are adjustable (C01906 and C01926).

MVP1920
When the BLE controller is in manual, power set point is always tracking current el-production, to keep the controller aligned. In auto the power set point is entered manually. The active set point is rate limited.

When the BLE controller is in auto, the frequency support function can be selected. The support gain, C11915, can be adjusted. Note that the support function must be moderate, for safe and stable combustion control.

For demonstrating its effect, the electric grid frequency must deviate from standard value, 50Hz. The instructor can introduce load unbalances on the external grid to create dynamic frequency changes, or the grid frequency can be adjusted manually in “grid fixed” mode, see MD380

MVP1921
When the BLW controller is in manual, the temperature set point is tracking current DHW supply temperature, as long as the TMC controller also is in manual mode.

The BLW temperature set point can be connected to “recommended line temperature”, but only if the BLW and BLM controllers both are in auto.

The active temperature set point is rate limited for safety reasons.
MVP1922
The BLM controller can only be put in auto if either the BLE or the BLW controller is connected. As long as the BLM controller is in manual, the BLE or the BLW system is tracking current steam production if set in auto mode. Connection of BLM is therefore bumpless.

The controller output is limited to max value 96 % if in auto, C11949, no limitation in manual control.

MVP1923
The optimal way of operating when producing hot water for district heating, is to adjust the firing rate so that the turbine system can operate as close to pure ”back pressure”

mode as possible. This situation produces maximum cheap electric (spin-off) power in relation to delivered city heat.

The balancing signal shown is used to gradually adjust the LP turbine / DH split controller (TMC) to neutral position. The balancing set point is set slightly towards the “direct heater dump” side (50.5%)

MVP1930

The active master energy signal is limited by the BLR system to a safe, process condition dependent maximum value. For instance, during coal firing the maximum rate is reduced from 60 t/h to 50.4 t/h (48,6 t/h if pellets). The load reduction is necessary mainly because of insufficient flue gas fan capacity and because of too short fuel resident time for complete combustion in the furnace. Violating the maximum firing rate limits may result in high CO-values and pose problems keeping the proper furnace under-pressure, especially at high ambient temperature and humidity.

Note that all limiting values are given in normalized HFO flow units.

When the BLR safety override is activated or deactivated, outgoing energy command is rate limited to give a smooth transition to the new control level.

MVP1940

Requirements for putting the Burner Management system to auto are:

- All burner supply valves (MD100) must be open.
- The primary air fan shut off dampers must be open.
- All burners must show “ready” or be in operation.
- At least one burner plane must be started.

In auto mode burner planes are started and stopped according to the FMC fuel command signal. The burner plane trigger limits can be adjusted.

If the first plane is burning on coal, new burner planes will also be started up on coal by the Burner Management system.

MVP1941

Various time blocking limits are used in the final processing of the start/stop commands to avoid burner cycling.

All burner operations are time-checked. If a preset maximum time is exceeded, burner fault will be indicated by Burner Management state diode changing from green (ready) to red (burner fault). The burner plane should then be re-operated manually for check-out. Pressing the Burner Management button to manual and then back to auto will act as an acknowledge of burner fault.

General remark.
When studying the Block Master Control System it is recommended to operate with simulation speed ratio setting *5

MD200 – Combustion Air/Flue Gas System

MVP2000
The ambient relative air humidity can be set, together with the ambient temperature. The absolute and relative air humidity at the combustion fans is computed. The combustion air is heated in the turbine hall/boiler building, but no moisture is assumed added.

MVP2005
The page gives a survey of heat releases in the furnace. Radiation is the dominating mechanism of heat transfer.

MVP2006
The composition of the gas flow is shown on this page. All main components are given in ton/h units, for easy comparison. The content of CO, NOx and SOx leaving the boiler is shown as kg/h-flows.

MVP2010
Area factors (heat transfer coefficient*area) are available for manually trimming the heat transfer to measured load dependency.

MVP2020
The final ring channel pressure set point is computed from steam production (“load”) and the output signal from the ring channel air pressure set point controller (“damp”).

MVP2021
The ring channel air pressure set point controller has as set point wanted sec. air damper opening (70 %) and as feed back high-selected sec. air damper position (=the highest of the four burner planes sec. air damper pos) .The controller’s output is then used as an adjustment signal for the final ring channel set point.

MVP2025
To reduce NOx , additional air above all burner planes is added. This “over-fire-air” reduces NOx by enabling richer fuel mix in the high-temperature combustion zone at the burners (two step combustion).

Approximately 10 % of the combustion air is added as OFA air.

MD210 – Combustion Air Preheaters

MVP2106
The condition of the air sealing between air and gas rotor departments can be checked by monitoring the oxygen content before and after the preheater.
In the simulator the leakage flow is explicitly displayed on this page.

MD240 – Boiler Water System

MVP2422
The speed of the feed water pumps are adjusted until the feed water control operates at a suitable degree of valve opening. The feed water pump speed control set point is computed from the boiler steam flow according to the parameters shown: K12538, K12539, C12538 and C12539

MVP2423
The feed water master controller adjusts the feed water flow command in order to keep a constant degree of superheating of the steam leaving the boiler. This important, but very sensitive control loop, easily tends to oscillate. To stabilize the control, three auxiliary feed forward signals are used as supplements to the steam temperature feed back:

- boiler fuel flow
- boiler water charge
- boiler water flow deviation (steam - water)

The control gains associated with these signals are shown on the page and can be adjusted.

MVP2427
At steam separator pressures above 20 bara any drain to the bottom blow tank is shut off by a safety valve. The valve is released below 12 bara.

MD250 – Boiler Steam System

MVP2500
The superheaters SH2 and SH3 are both receiving radiation heat in addition to convection heat.

MVP2502
The reheaters RH1 and RH2 are modelled as pure convection heat exchangers.

MVP2520
The steam temperature controllers all have a cascade structure: Final temperature control is by outlet temperature feed back. A corrective feed forward (cross) signal is computed from the inlet temperature (“cross temp”)

The cross temp is first processed in a derivative filter ("cross tc")

MVP2524
Both SH2 and SH3 have temperature rate control logics: Active temperature set point is reduced at low outlet steam temperature. It will be ramped up at a safe rate when steam temperature increases, to the final (target) value.

For the SH2 controller, a minimum temp set point limit and a maximum increase rate can be adjusted from the page. The target temperature is the value displayed as "set point" on the SH2 temp controller. This set point is normally kept fixed at 475 dgrC. The dynamic set point/rate limitation mechanism can not be turned off for the SH2 control.

MVP2604
Soot-blowing must be done at regular intervals. Details other than steam consumption are not modelled.

MD260 – Main Steam Lines

MVP2602
The HP safety valve has a fixed, mechanical limit of 220 bara.
The IP safety valve has one fixed, mechanical limit at 52 bara, but can in addition be opened by a remotely controlled signal when in auto. The auto open limit is computed from the HP steam pressure. The safety valve profile is designed to keep the ratio between IP and HP pressure below a safe value,
because a high IP/HP steam pressure ratio can cause HP turbine to overheat. The active open pressure limit is always displayed on the IP safety valve panel.

MVP2604
Steam leakages from the HP, IPC or IPH steam lines can be introduced as malfunctions and checked at this page.

MVP2605
To protect against condenser overheating, the steam dump is tripped at low cooling water supply pressure, high steam temperature and poor condenser vacuum. A trip is reset simply by opening the trip valve.
Note that the condenser vacuum trip function is inhibited during partial vacuum breaking (vacuum breaker trip = 6)

MVP2623
The permitted rate of pressure increase can be adjusted by the two parameters "glide time constant" and "glide margin". The glide function can not be engaged below min pressure, 22 bara.

The HP glide control is automatically turned off at turbine trip.

MVP2624
The LP bypass pressure controller will stay in auto mode only if the direct heaters are remotely controlled, see remote switch in MD610.
In manual mode the steam bypass set point is tracked by the IPH steam line pressure. If set to standby, there will be an immediate transfer from manual to auto at turbine trip and the set point will be reduced to the value given by parameter C22618 (9.50 bara).

MVP2625
In manual mode the steam dump set point is again tracked by the IPH steam line pressure. If the controller standby mode is set, there will be an automatic transfer from manual to auto control if the turbine should trip, helping to limit the steam line pressure rise following the trip incident. The dump set point will be set to C22648 (10 bara)

MVP2630
The HP turbine may overheat if its back pressure is high compared to turbine inlet pressure. The HP turbine is protected from overheating by two different actions that both tend to reduce the IP line pressure: opening of the IP turbine inlet (“intercept”) valve and opening of the IP safety valve.

Note that only a possible IP turbine valve reduction, set by manual choking, will be lifted. Throttling caused by the governor speed reduction command is not affected.

MD300 - Steam Turbine

MVP3012
Auxiliary systems are greatly simplified. Sealing steam is normally taken from the IP line. During start-up when the boiler pressure is low, steam from the (external) auxiliary steam supply can be used. No details on the sealing steam pressure control system is modelled. However, if the sealing steam supply is turned off, there will be increased air leakage to the condenser, and it will be impossible to reach full condenser vacuum.

The electric lube oil pumps are used during turbine rolling up only.
If the electric governing oil pump is not on at low turbine speed, the vacuum breaker valve on the condenser opens due to low governing oil holding pressure. If the electric lube oil pump is not running at low turbine speed, the turbine is kept in a tripped condition with closed inlet and outlet steam shut off valves.

At high turbine speed, the (hidden) attached lube oil pumps are sufficient. The electric oil pumps are stopped above 2790 rpm and restarted below 2400 rpm.

The turbine’s vibration monitoring system is in the simulator represented by one representative overall vibration signal. 40 um (micrometer) amplitude is displayed as 100 % vibration. The turbine trips at 80 %

Readings like bearing lube oil pressure, bearing temperature and axial displacement are static (settable) variables intended for the instructor to introduce turbine trips.

MVP3022
The output from the turbine min pressure controller functions as a limiting signal to the speed governor (low-selection type logic). It can not be engaged below the low limit, 60 bara. When active, it throttles the turbine steam admission valves if the inlet pressure should drop below 70 bara. This helps keeping the boiler pressure/temperature up at low turbine load, which is safe for the boiler and gives a faster response at load increase.

MVP3023
If "Turbine vacuum protection" is on, the governor command is reduced if poor vacuum (low-selection type logic). The protection characteristic is defined by the four parameters (C13057, C13058, K13057 and K13058).
The "Turbine vacuum breaking" function helps reducing the turbine speed as fast as possible to a safe level during turbine trip. This is accomplished by opening the vacuum breaker valve to increase the condenser pressure. When the turbine speed has dropped below 2200 rpm, the vacuum breaker valve will intermittently close and open to keep the condenser pressure between 200 and 230 mbar. Resetting the vacuum breaker trip also clears the breaking function and full vacuum can be obtained.

MD380 - Electric Generator System

Normally the turbine is operated with 100 % open steam admission valves, to avoid throttle losses. However, if the line frequency increases above 50 Hz, the turbine governor immediately reduces the steam throttle. Low line frequency normally will be counteracted by increasing steam production. Extra firing can automatically be ensured by the frequency support function of the Block Master Controller.

MVP3810
A dynamic, external electric grid model has been included.
The size of the grid is defined by the limits C03805, C03806. Acceptable range limits are 500-8000 MW

The final consumer load connected to the grid can be set, E03805, and the actual consumption, E03806, will be ramped up or down according to preset rates, C03807 and C03808. The power producers will respond to changes in grid frequency and voltage and hopefully, by the joint action of the External and TPP power plants, a new power balance eventually will be restored at correct frequency and voltage.

When the actual load is close to the maximum grid power limit, C03805, the TPP plant needs to take its share of the load deficiency to obtain balance. Vice versa, when the actual load is close to the minimum power limit, C03806, the TPP load must be reduced to avoid permanent over-frequency. In the intermediate range the External power producers always succeed in restoring perfect balance after a transient period ("isochronous" control action)

Remark: It is convenient to study the grid /TPP dynamics at 5x simulation speed-up setting.

MVP3811
The external grid model can be de-activated and the grid set to fixed frequency and voltage values. The frequency/voltage on the grid are then settable directly from the page (V03800, F03801) or can be adjusted from increase/decrease push buttons on the picture.
MVP3830
When the turbine trips, the main circuit breaker should normally trip due to under-current, after some delay. The main circuit breaker is deliberately not tripped directly from the turbine trip system due to safety considerations. If the turbine steam throttle valves are worn they may be leaking. Disconnecting the turbine with leaking throttle valves may cause turbine over-speeding and damage. Disconnecting the turbine by an "under- current trip" is proving that the steam throttle valves are in tact.

Comment: The trip limit C03894 has no effect and should be removed in future simulator SW releases.

MD400 - Cold Condenser System

MVP4000
The number of active cooling tubes in the condenser can be changed by the "tube number factor", C14030. Tube number factor = 2.0 means that the number of cooling tubes has been doubled (same diameter and length). Tube number factor = 0.7 means that 30 % of the cooling tubes have been plugged. The parameter can be convenient to use for studying the influence of small/large condenser on overall plant performance.

The cold condenser hotwell conductivity is monitored and alarmed, X04028. It is (slowly) influenced by the water purity in the main condensate tank. It will increase sharply if there is a cooling water leakage into the condenser. (micS/m = microSiemens/m)

MVP4004
The nominal capacity of the cooling pumps can be adjusted by the general capacity-parameter C14031. This is intended to be used together with the tube number factor, C14030, when condenser performance is studied.

MVP4030
The vacuum breaker valve is opened if some of the low pressure feed heaters LP0, LP1 or LP2 have high-high drain level. Breaking the condenser vacuum reduces the risk of

turbine damage caused by water back-flowing from over-flooding LP heaters. Note that opening the vacuum breaker valve also will trip the turbine.

Vacuum breaker trip caused by high LP heater level is indicated by trip code 1, 2 or 3. If, after a turbine trip, the vacuum breaker is opened to speed up turbine breaking, the trip code is 6 (“Partial vacuum breaking”).

MVP4040
In back pressure turbine mode, with active hot condensers, the cooling water and condensate pumps should be in standby mode. Only auxiliary pumps need to be running.

The normal (basic) standby start function is trigged by either low cooling water pressure or high condenser pressure.

In auto-auto control coolw pump 1 is started/stopped from the LP turbine damper position signal, Z13803. A hysteresis band is defined by the parameters K13803 and K13804. The band is necessary to avoid mode cycling during back pressure plant control.

MVP4041
Normal standby start of the condensate pumps is from high hotwell level detection. Auto-auto start/stop of condensate pump 1 is controlled from a modified LP turbine damper position signal: If the main circuit breaker (MCB) disconnects, the control signal will be set to 100 % and result in an immediate transition to main cooling mode. This is to secure adequate cooling water pressure for the steam dump operation, which is likely to be activated at this incident.

MD410 – Main Condensate System

MVP4100
The condensate purity, X04147, reflects the contamination (ion-content) of the water. The purity responds dynamically to the operation of the condensate cleaning plant (and also to the in-line filtering operation)

MVP4120
The tank level controller use as feed forward signal tank net inlet flow.
(sum inlet-sum outlet)

MD420 – Low Pressure Feed Heaters

MVP4202/4204

To avoid turbine trip at high-high drain level, independent emergency drain valves operate in parallel with the drain control valves. Open/close limits can be adjusted (C14247, C14248 and C24247, C24248).

MVP4210
The drain flow from one LP heater to another is significantly influenced by the relative height position of the heaters, because of the low differential pressures involved. The mounting (“geodetic”) heights are shown on the page (C14202, C14203, C24202 and C34202).

For detailed studies, the heat transfer capacity of the preheaters can be varied by changing the parameter called “area factor” (heat transfer coefficient*area)

MD430 – Feed Water Deaerator System

MVP4300
In addition to serving as a regenerative preheater and a pressure head tank to avoid cavitation in the feed water pumps, the tank is designed to remove dissolved oxygen by boil-off flashing.
The release of oxygen in feed water by heating is simulated by a simple model unit. If the vent valve to the bottom blow tank (BB) is closed and the steam heating is on, the released inert gas will gradually build up. Measured tank pressure will then be higher than the saturation pressure for the actual temperature. When the plant is shut down and the tank gets cold, the reverse process takes place; oxygen in the tank atmosphere is gradually absorbed.

MVP4310
The feed water pump assembly comprises a low pressure pump and a high pressure pump both attached to an electric motor. The high pressure pump speed is geared up by a factor of 5.3

MVP4312
The electric motor is an asynchronous (induction) motor with wound rotor and slip rings. The speed is controlled by varying the resistance in the rotor circuit. High resistance gives high slip and low speed. The external rotor resistance consists of a DHW-cooled electrolyte vessel with variable electrode submersion. The rotor losses associated with the speed control, which are substantial, are therefore not lost but converted to useful district water heat. Note that the resistance vessels, one for each motor, are modelled but not shown on any MD pictures.

MVP4320
The FW deaerator level controller uses as feed forward signal net tank outlet flow.

MVP4321

The pressure of the FW deaerator is free to drift up and down according to plant load, as long as the pressure is above a minimum limit, 2.50 bara
In order to prevent fast pressure reductions, which can lead to feed water pump cavitations and sudden loss of feed water flow in worst case, the controller works as a pressure reduction rate limiter. The rate gain setting is indirectly defined by the two parameters "glide dp" and "glide tc"

MVP4330
An optical detector is measuring the sparking intensity from the rotor slip rings. Poor brush contact will increase light sparking and eventually cause trip 6: light arc.

MVP4340
It is difficult to use the discharge pressure as signal for standby start, because the pressure varies too much. The pressure standby limit is set as an ultimate low limit only, and will normally not activating a pump start. In stead a special standby start logic unit is used to start a ready feed water pump, whenever pumps in operation are electrically stopped.

MD440 - High Pressure Feed Heaters

MVP4430/4431
HP heater 1 and 2 are protected from overfilling by tripping the heater's inlet steam valve at high drain level. HP heater trip also opens the HP heater bypass line valve. The trip levels (C14455, C24455) are both set to 2.5 m

MVP4432
If the drain level of HP heater 1 or 2 continues to rise (due to HP heater tube leakage) and finally exceeds high-high level, all three HP feed heaters are isolated by closing the inlet and outlet protection valves in the feed water line. The emergency ("FW") trip limits (C14458, C14459) are set to 3.0 m

To demonstrate trip of HP heaters, set malfunction M4412, "HP feed heater 2 tube leakage", use fault value 40 %. Drain level will gradually increase in the feed heater, steam inlet valve will trip and bypass feed water valve open. But level will continue to increase, proving a tube leakage. The HP heater train is finally isolated and leakage flow from the damaged tube stops.

MD500 – Make Up Deaerator System

MVP5000
The "water purity" variable is intended to reflect content of ions and dissolved CO2/O2. The initial "Cold Plant" condition has a rather poor water quality. Operating the make-up deaerator stripper during clean-up recirculation will gradually improve water quality.

MVP5004
An emergency discharge to Lake is activated if the MD level exceeds 1.95m The discharge valve, which also can be manually operated, is closed at 1.60 m. The discharge function is always “in auto”

MVP5020
MD level feed forward signal is computed as the net tank inlet flow (make-up water + bottom blow – transfer flow)

MVP5021
Normal MD heating set point is 75 dgrC. At plant clean-up circulation before start, the set point should be reduced to 45 dgrC for best efficiency of the ion-exchange filters in the cleaning plant (MD410)

MD600 – Hot Condenser/DHW System

MVP6022
At very low HC condenser pressure the IP turbine operates far from design expansion ratio and it tends to vibrate. To avoid excessive vibrations, the minimum temperature controller will reduce the cooling water flow and thus limit the vacuum in the condensers.

MVP6023
The return/supply pumps are operated so that the water pressure in the grid supply lines is in the normal range, 5-7 bar. A pressure sensor measures the difference between the supply and the return line pressure at a representative location in the city.

The pressure at supply pump inlet is fixed to the expansion tank pressure (MD620), while the return pump inlet pressure can be trimmed by the supply/return speed balance setting.

MVP6040
The HC pump standby start is controlled by the hotwell level in HC1, control by pressure is unreliable due to large variations in the condenser pressure.

MD610 – Direct Heater System

MVP6100
The level command to the direct heater controls the steam valve opening and the level controller set point. The steam valve, when in auto, opens at decreasing level command. The valve positioning profiles are defined by the parameters C06121/C06122 and C06141/C06142.
MVP6122

When both remote signals, the LP bypass controller (LPC) and the DHW temperature controller (TMC), are connected, the signal with the lowest level command is selected. Profiles for converting remote control (dump) signal to level set point are defined by the parameters C06162/K06162 and C06162/K06162.

MVP6123
The subcooler flow set point is increasing with drain flow, starting from a base value, C16115, and increasing according to the drain coefficient setting, C16116.

MD620 – Accumulator System

MVP6220
The feed forward signal, Z16344, the difference between turbine flow and pump flow, is an important signal for stabilizing the control loop. The pump speed control is of the same kind as used for the main feed water pumps and the DHW pumps: asynchronous AC motor, wound rotor with slip rings and variable external motor resistance (“rheostat”)

MVP6221
To prevent the water in the low pressure accumulator tank to boil, a temperature limiting control is included. It keeps the water leaving the francis turbine below 95 dgrC

MVP6222/6223
The expansion tank low/high level controllers are safety devices that should be standby, but they are normally not activated.

MVP6302
The parameters C06220-C06223 define the city heat need, as a function of ambient temperature. The parameters C06206/7 define the recommended supply line temperature profile. Recommended night reduction is given by C06208.

MD700 – DeNOx Plant Overview

General remark on the cleaning plant sequences.

MVP7901++
All cleaning plant (sub) sequences can be operated from model variable pages, and to some extent be guided manually through the process of starting or stopping.
At some situations a sequence can be caught in a state of dead-lock and there will be needed some manual “stepping support” from the operator in charge. This is done by manually increasing the step number (S07901 etc). Remember that starting steps are in the intervall1-49, stopping steps are in the interval 51-99. Step = 0 means that the sequence is in stable off or on state.

Never decrease the step number manually!

MD800 – DeSOx Plant Overview

MVP8901++
As for the deNOx plant, all cleaning plant (sub) sequences can be operated from model variable pages, and to some extent be manually overridden.

MD850 – Product System

A new product damper control system helps demonstrating the function of the deSOx – absorption process:

The original manually controlled dampers of absorber and filter discharge products have now been changed to modulating dampers under automatic control.

No exact details are given on the controller hiding behind the dotted "Damper Control" box. Briefly said, the controller is directing as much product flow to the recirculation product silo as is leaving from this silo to the mixer tanks. If the product flow from the filter assembly is insufficient, cross-over make up is taken from the absorber product line. This is the normal situation when firing with low-sulphur fuel (oil/bio). Then the feeder slurry consists mainly of re-circulated, chemically passive $CaSO_4$.

When firing with sulphur-rich fuel (coal) the absorber (SO_2 controller / MD830) asks for Ca(OH2) rich feeder slurry with low content of re-circulated $CaSO_4$. In this situation surplus filter product is cross-directed to the final product silo and is mixed with the absorber product there.

8 APPENDIX E TPP DESIGN REVIEW

A short description if main software improvements implemented during winter/spring /autumn 2008

General Comments
Improved graphics, main process lines draw broad, auxiliary lines narrow.
Various static texts added for clarification.
More process information, many extra model variable pages added.
A new (MC90-V type) footer bar included, offering feature for fast jump to recently alarmed model drawing.

In lower right corner of all model drawings a model variable page pop-up push button has been added. Similar, in the lower left corner model malfunction page pop-up push buttons are placed.

Red/green marking of indicator ranges are applied when appropriate.

MD100: Fuel Oil System
Extended pump standby start logic, giving improved HFO pump auto function at coal mill operation.
Dynamic display of none-return valves and relief valves related to pumps.

7 additional model variable page pop-up push buttons added.

MD120: Secondary Steam System
The original secondary steam system had some structural control deficiencies which have been corrected:

New automatic auxiliary steam supply control to steam cooling tank.
New automatic drain valve from steam cooling tank
New automatic control function of the LP steam generator cross-over valve.
Extended level control function for the inspection tank level control (high level override)
New cleaning steam pressure indicator

10 additional model variable page pop-up push buttons added.

MD140: Burner Plane A

The Burner Control panel and the Coal mill Control panel are now providing more information during burner operation by means of state indicators with associated dynamic text information for guidance.
The trip function of the coal mill is moved close to the coal mill graphics for clarity.
A new furnace pressure indicator, important during ignition, is added.
Graphical appearance of flames will change according to fuel type burned (oil/mix/coal)

9 additional model variable page pop-up push buttons added.

MD150: Burner Plane B See MD140
MD160: Burner Plane C See MD140
MD170: Burner Plane D See MD140

MD180: Boiler Combustion Control

New combustion control feature added: automatic generation of the oxygen control set point. The function can be selected by an "Auto" push button.
The computed set point signal is dependent on fuel type (oil/coal mix) and boiler load.

4 additional model variable page pop-up push buttons added.

MD190: Block Master Control System

The block control system is modernized and extended with new functions:

A Burner Management system is added. This system safely handles all burner and coal mill operations. The control panel has multicolor light diodes and state indicators, and dynamic text display options are included.

All master controllers (BLM, BLE, BLW and TMC) have been redesigned and trimmed for optimum dynamic performance.

The BLW and TMC controller set points can be selected to automatically adapt to ambient district temperature (recommended supply line temperature)

The alignment procedure and connection of the BLE and BLM controllers have been simplified. Now just a single "connect" push is required, the controller balancing is automatic.
The alignment and connection of the BLW and BLM controllers have been similarly simplified.
The BLE controller has been added a function for automatic grid frequency support.

Added is also indicating diodes showing accumulator operation mode (load/unload) and city grid supply mode (single block / multi block)

In order to better be able to demonstrate the overall operations of the accumulator system, a night/day selection (moon/sun mode) is made available.

Big digital MW-displays have been added, showing net electric power production and total water heat supplied to city grid.

7 additional model variable page pop-up push buttons added.

MD200: Combustion Air/Flue Gas System
Oxygen measurements after air preheaters, for air leakage check, added.
Text on fan balancing push button is changed from “auto-man” to “remote-local”

6 additional model variable page pop-up push buttons added.

MD210: Combustion Air Preheaters
Two individual shut off valves in the hot water supply to preheaters added.
Oxygen sensors after rotary air preheaters included.

5 additional model variable page pop-up push buttons added.

MD240: Boiler Water System
Some static texts added.
Master feed water controller trimmed for best performance.

4 additional model variable page pop-up push buttons included.

MD250: Boiler Steam System
The performance of the SH2 steam temperature controller is improved.
A temperature rate control logic will start water injection even before (max) temperature set point is reached. This results in a smoother control function.

3 additional model variable page pop-up push buttons included.

MD260: Main Steam Lines
A new LP steam dump system is added.
The system is intended to be used for pressure stabilizing during turbine rolling-up, in stead of and /or in addition to the present LP bypass controller.
Cooling water supply is taken from the main condensate system. The system is designed for “wet” steam operation with surplus water injected, hence there is no need for direct temperature control, other than an alarm/trip function, which is be provided.

The LP bypass controller and the new LP steam dump controller can both be set in safety stand-by mode.
6 additional model variable page pop-up push buttons included.

MD300: Steam Turbine
A facility to supply the turbine gland sealing system with external auxiliary steam has been added. This makes the preparation procedyre before rolling up more flexible.

The governor control signals to the steam control valves are indicated as dotted lines. Descriptive texts have been added.

The turbine electro-hydraulic speed governor system has been improved.
The generator power in MW is displayed on a large digital indicator, also the generator frequency in Hz

5 additional model variable page pop-up push buttons included.

MD380: Electric Generator System
New, large electric digital indicators for
1: net line power (MW)
2: generator voltage (kV)
3: generator frequency (Hz)

To ease turbine synchronizing, connection and loading after connection, a new set of turbine speed decrease/increase command push buttons have been added.

Also, decrease/increase push buttons for ramping the external grid line voltage and frequency up or down are implemented.

The external grid conditions can now also be set to respond dynamically to load changes by activating a new, separate electric grid model.

3 additional model variable page pop-up push buttons included.
MD400: Cold Condenser System
Extended pump standby start logic for the condenser cooling water system and for the cold condensate system. The new pump control offers improved flexibility and safety at back pressure operation mode, allowing for automatic change between auxiliary cooling mode and main cooling mode when required.

A steam pipe from the new LP steam dump system to the condenser is added. Included is also a condensate supply line for the steam dump cooling.

The cold condensate pumps have been equipped with gland sealing water supply valves.

The gland steam condenser fan can now be operated from a dedicated fan on/off push button.

A new hotwell water conductivity reading is available. This enables early detection of possible cold condenser cooling water leakage.

3 additional model variable page pop-up push buttons included.

MD410: Main Condensate System
Sealing water for the condensate pumps is added.
Condensate purity computations, reflecting the functioning of the cleaning plant has also been added.

4 additional model variable page pop-up push buttons included.

MD420: Low Pressure Feed Heaters
A back-up flow bypass facility is arranged, so that the LP preheaters can be bypassed and isolated during faulty conditions and for service.

In order to reduce the risk of turbine shut down caused by high-high level in the LP1 or LP2 preheaters, level-controlled on/off emergency valves with independent level detectors are included. The emergency valves are placed in parallel with the condensate control valves. Each emergency valve is equipped with an auto selection button.

5 additional model variable page pop-up push buttons included.

MD430: Feed Water Deaerator System
An additional supply valve for auxiliary steam to the make-up deaerator has been added, for greater flexibility during pressure rising periods. The feed water deaerator can now be changed over to own (IPC line) steam supply for heating as fast as possible after boiler light-off, without conflicting with the heating requirements of the make-up deaerator.

8 additional model variable page pop-up push buttons included.

MD440: High Pressure Feed Heaters
7 additional model variable page pop-up push buttons included.

MD500: Make Up Deaerator System
A small adjustment is done in the drain/vent return lines.
Purity of water in the make up deaerator is computed.

4 additional model variable page pop-up push buttons included.

MD600: Hot Condenser / DHW System
The DHW pump speed controller has been trimmed.
Some static texts have been added for clarity.

By click on the “city grid” block, a schematic city pipe line diagram will pop up. The city grid is composed of two major parts, the “near city” and the “far city”. The diagram shows line pressure and main supply and return temperatures. It also indicates the setting of the multi-block mode selection valves.

6 additional model variable page pop-up push buttons included.

MD610: Direct Heater System
The direct heater model has been adjusted.
The direct heaters have been made more robust, and the trip limits are changed correspondingly.

Static texts indicate how the steam admission valve set point and the level controller set point are jointly controlled from the DH1/2 control panel.

7 additional model variable page pop-up push buttons included.

MD620: Accumulator System
The DHW system is presented as a closed-loop system.
A pop-up feature for displaying city grid details is added in the same way as on MD600.

Dotted “valve command” signals from the accumulator control station are included, to clarify the valve changeover actions.

Some new descriptive texts are added.

5 additional model variable page pop-up push buttons included.

MD700/800: DeNOx/DeSOx Plants
Generally the cleaning plant dynamics have been speeded up.

Adjustments of the cleaning sequence parameters have been made in order to give more robustly functioning systems.

Some sequences have been simplified to reduce the risk of dead-lock situations, by adding “skip-if- not-necessary” type of logics.

All controllers have been reviewed in detail and corrected when found necessary.

9 APPENDIX F INITIAL CONDITIONS

The new series of initial conditions (1-19) are made by the assistance of the sequence system. This ensures easy and accurate reproduction of initial conditions, when needed.
Operate the simulator with speed-up ratio 5x to save time.

I001: Cold Plant	All other plant conditions are derived from this one.
I002: Small clean-up loop	Make: I001+sequence 1, 2, 3
I003: Big clean-up loop	Make: I002+sequence 4,5
I004: Fire on furnace	Make: I003+sequence 6
I005: Ready for rolling-up	Make: I004+sequence 25, 7, 8, 9, 10, 11
I006: Block connected	Make: I005+sequence 12, 13, 14
I007: CC 40 % load/oil/man	Make: I006+sequence 15, 16
I008: CC 88 % load/oil/man	Make: I010+BLM 88 % + wait
I009: CC 90 MW /oil/auto	Make: I007+BLE set point 90 MW + wait
I010: CC 230 MW /oil/auto	Make: I007+sequence 23
I011: BP 40 % load/oil/man	Make: I012+BLM 40 % + wait
I012: BP 35 % load/oil/auto	Make: I006+sequence 15, 17, 18, 19+wait
I013: BP 35 % load/coal/auto	Make: I014+ambient temp 5dgrC+wait
I014: BP 80 % load/coal/auto	Make: I012+sequence 20
I015: BP 80 % load/bio/auto	Make: I014+biofuel setting+wait
I016: Max DHW load/bio/man	Make: I015+multiblock/60% DHW pump/-25 dgrC
I017: Accu loading (day)	Make: I012+sequence 21, 22 (day pause)
I018: Accu unloading (night)	Make: I017+sequence 22 (night pause)
I019: Cold Plant/no sequences	Make: I001+MVP0102.A01000=1

10 APPENDIX G SHUTTING DOWN PLANT

In the following pages a procedure for shutting down the plant is described. The plant is operating in BP mode at full load / coal firing (I014-condition)
(The procedure can well be demonstrated at 5x simulation speed ratio)

Reduce firing.

MD190: Transfer to "Multi-Block" mode. Set the BLM controller to manual and reduce firing gradually from 80 to 15 %. Keep the TMC control in auto. See electric power being reduced and burner planes A,B and C stopping by the Burner Management system.

Steam dumping.

MD380: When the main circuit breaker trips on reverse power:
MD260: Set the HP bypass min position to 12 %
Reduce then the HP bypass control set point gradually to 30 bara
Check that the steam dumping system is working correctly. Set the LP bypass steam dump set point to 10 bara and turn off the LP steam dump controller.

Shutting down the boiler.

MD200: Stop combustion air fan 2 and flue gas fan 2.
MD190: Reduce the firing rate to 5 % and set the Burner Management to manual.
MD170: Stop burner plane D (start burners/stop mill/stop burners)
MD903: Shut down deSOx plant

Shutting down the turbine.

MD300: Stop the turbine by manual trip, observe partial vacuum breaking.
MD400: Reset partial vacuum breaking when turbine speed < 1500 rpm
MD190: Set the TMC control to man/0 %
MD300: Set turbine LP damper control to local
MD610: Set the TMC Direct Heater command selection to local
MD260: Adjust HP/LP bypass set points from 30/10 bara to 5/1 bara

Cooling down the boiler.

MD240: Observe boiler cooling down (big clean-up loop)
MD430: When boiler pressure/temperature < 2.5 bara/130 dgrC stop feed water pumps.
MD240: Set feed water flow control to manual/0 %
Drain separator manually to the bottom blow tank.

Emptying the boiler (dry conservation)

MD500: Stop make up pumps
MD410: Increase main condensate tank level setpoint from 1.50 to 1.70 m
MD430: Increase FW deaerator level setpoint from 2.50 to 2.90m
MD240: Start draining boiler to the bottom blow tank.

MD600: Stop the DHW pumps, shut off the hot condenser system.
MD120: Shut off secondary steam system
MD100: Shut off HFO heating and stop HFO circulation

MD240: When boiler pressure < 1.1 bara open separator vent
MD250: Open superheater vent/drain valves

MD240: When the boiler is empty, set the dry air reverse-ventilation system in operation for dry conservation of boiler (not show in the simulator)

Securing the turbine

MD300: Close sealing steam system and shut off the HP and LP turbines
Open drain valves and stop turning gear (after xx hours).
When the turbine has stopped, stop the electric lube oil pumps.

Securing the plant

MDxxx: Review plant condition. Shut down and secure all auxiliary systems, stop pumps, close valves etc.

Trick for resetting the process sequences:
Set MVP0102.A01000 to 1 (inhibit all sequences)
Set MVP0102.A01000 to 0

11 APPENDIX H RESTARTING AFTER A BOILER TRIP

The following describes a recovery procedure after a boiler trip.
Initial condition I010, Full electric production (CC / 230 MW / oil)

Boiler disturbance.
MD180: Trip the boiler manually

Boiler purge.
MD700: Select SCR1 , start purge sequence S701.
MD180 Wait until boiler purge ready, start boiler purge.

Boiler ignition.
MD190: Set BLM manual/5 %
MD180: Set FMC manual/0 %, set oxygen control manual/50 %, reset trip
MD200: When purge complete, stop comb. air fan 2 and flue gas fan 2.
MD170: Start all burners on plane D
MD180: Set FMC to auto, set oxygen control to auto

Preparing for turbine connection.
MD300: Observe turbine power dropping
MD380: The main circuit breaker will trip on reverse power, reset trip.
MD260: Set HP bypass min pos to 12 % after MCB has disconnected. Turn glide control off and reduce HP bypass setpoint to 30 bara . Check that the LP steam dumping is activated, setpoint 10 bara.
MD190: Increase rate of firing, BLM = 15 %

Starting SCR1/Absorber.
MD710: Restart SCR1 by starting denox sequence S702.
MD840: Restart absorber by starting sequence S814

Re-phasing of turbine.
MD300: Check steam line conditions (30/10 bara). Adjust speed governor setpoint to 78-79 % (careful !)
MD380. Adjust turbine speed/voltage. Connect turbine. Increase governor setpoint to 90 %
MD260: Reduce HP bypass min pos to 0%. Set glide control to auto. Set steam dump control manual/0% and turn stby setting on
MD380: Block bind.

Starting SCR2

MD200: Start comb. Fan 2 and flue gas fan 2

MD720: When SCR1 is in normal operation, restart SCR2 by starting sequence S703.

Increasing electric power.

MD190: Increase BLM to 25 % and turn burner management to auto.

MD300: When the HP line steam pressure is > 30 bara, increase turbine speed governor setpoint to 100 %

MD190: Align BLE control system. Set BLM controller to auto. Set BLE setpoint back to original power, 230 MW. Activate frequency support.

(Increase simulation speed ratio to 5 x)

MD300: When HP line pressure is 70 bara, set min pressure control to auto.

MD240: Check that the feed water control is functioning correctly.

MD250: Check that the steam temperature control is working correctly.

MD190: Observe burner planes being started, one by one, and electric power increasing gradually until the original power level, 230 MW, is resumed.

12 APPENDIX I DESCRIPTION OF PICTURES

12.1 Picture list

The system consists of the following pictures:

MD 010	Steam Plant Overview	MD 400	Cold Condenser System
		MD 410	Main Condensate System
MD 100	Fuel Oil System	MD 420	Low Pressure Feed Heaters
MD 120	Secondary Steam System	MD 430	Feed Water Dearator System
MD 140	Burner Plane A	MD 440	High Pressure Feed Heaters
MD 150	Burner Plane B		
MD 160	Burner Plane C	MD 500	Make Up Dearator System
MD 170	Burner Plane D		
MD 190	Block Master Control System	MD 600	Hot Condenser System
		MD 610	Direct Heater System
MD 200	Combustion Air/Flue Gas Sys	MD 620	Accumulator System
MD 210	Combustion Air Preheaters	MD 700	DeNOx Plant Overview
MD 240	Boiler Water System	MD 710	SCR Reactor 1
MD 250	Boiler Steam System		
MD 260	Main Steam Lines	MD 800	DeSOx DeSulphurization Pl.
		MD 810	Lime Silo
MD 300	Steam Turbines	MD 820	Slake System
		MD 830	Feeder System
MD 380	Electric Generator System	MD 840	Absorber
		MD 850	Product System
		MD 860	Mixing System

12.1.1 MD010 Steam Plant Overview

The picture is used to give an overview of the main steam lines.

Following subsystems are implemented:

Direct heater system	(MD610)
Cold condenser system	(MD400)
Main condensate system	(MD410)
Low pressure feed heaters	(MD420)
Feed water deaerator system	(MD430)
High pressure feed heaters	(MD440)
Boiler water system	(MD240)
Hot condenser system	(MD600)
Accumulator system	(MD620)

12.1.2 MD 100 Fuel Oil System

This picture gives an overview of the fuel oil system delivering heated fuel oil to the burners.

- The FO service tank is heated by steam, supplied from the low pressure steam generator (MD120).
- The tank is filled by means of a FO transfer pump which operates automatically with a level control system. The suction is taken from one of the bunker tanks (always assumed full).
- The fuel oil to the main burner deck A-D is supplied by a pair of FO supply pumps.
- Pressure after pumps is controlled by recirculation of oil back to the service tank. The pressure control valve is under PID control.
- The FO is heated to normal operating temperature by either one of two steam heaters, before it flows to burner deck A-D.
- There is recirculation of fuel from the burner decks to the service tank during preheating or trip.
- The temperature of the fuel oil, which is measured in the common line after the FO heaters, is controlled by a temperature controller (PID) which controls the steam flow through the heaters.

12.1.3 MD 120 Secondary Steam System

The LP steam generator produces secondary, low pressure steam to be used for the following purposes:

- main boiler atomising steam
- heating of heavy fuel to burner deck A-D
- heating of storage and service tanks
- production of cleaning steam

- The primary steam to the LP steam generator is normally supplied from the IP bleeder system.
- If the Intermediate turbine bleeder pressure is too low, steam is provided from the auxiliary steam system.
- In cases of emergency, the steam source is from the aux. steam system.
- The flow of steam to the heat exchanger in the steam generator's steam drum is automatically controlled to keep the secondary steam pressure constant.
- The condensate from the heating coil is drained to a separate primary drain tank before it is discharged to the make-up deaerator.
- The rate of primary condensate discharge is controlled so that the drain cooler always is filled with water.
- Secondary drain from miscellaneous heaters is collected in the inspection tank. This is designed for easy observation and removal of possible oil contamination.
- For production of cleaning steam and atomising steam a special steam cooling tank is provided.
- Supply to the steam cooling tank spray nozzles taken from the IP line.
- Both LP steam generator and steam cooling tank has a level control system and make-up water is taken from main condensate pumps.

12.1.4 MD 140-170 Burner Plane A-D

The picture gives an overview of the burner deck, with option of firing with coal or fuel oil. Picture MD140-MD170 have the same function and are representing burner plane A-D.

- Supply of fuel to the burner deck is from the FO system (MD100).
- The burner deck has four burners. They are operated by push button commands on the burner control panel.
- Burner 1 to 4 are normally lighted off on fuel from cold plant start-up.
- The option of firing with coal can only be performed when burners are already fired on FO.
- The burners shall always be lit off in the following sequence 1,3 and 2,4.
- The light off sequence will be indicated. Ignition is confirmed by the flame scanner signals.
- It is possible to change to coal firing, this requires that system for coal transportation system is running.
- Hot and cold air are mixed by a temp. controller, and a primary air fan supplies air to the coal grinder.
- The coal silo supplies coal to the coal feeder system. The coal feeder system supplies coal to the coal grinder.
- The coal dust is fed to the burners with conveyer air from primary air fan.
- The coal feeder system is controlled by a coal mill control panel.
- To light off a burner, press the START button and the light off sequence will be executed:
- The FO flow can be adjusted by manually controlled throttle valves.

12.1.5 MD 190 Block Master Control System

The Block Master control system consits of two major parts: One part controlling the rate of fuel input to the boiler system ane one part controlling where to discharge the blocks' waste heat.

Part one is based on one steam controller (BLM) which has its set point generated either from an electric power controller (BLE) or from a district heat water temperature controller (BLW). The output signal from the steam flow controller is an energy signal for the fuel master control system. It is checked and possibly reduced in a logic system called "block load reduction system" (BLR).

Part two consists of a single temperature controller (TMC). The inlet dampers of the LP turbines and the steam flow to direct heaters are controlled from measured district heat water temperature.

The Block Load Master Controller (BLM) corresponds with the master steam pressure controller of fixed pressure boilers. It controls the steam flow according to set point.

the Block load reduction system (BLR) limits the fuel command from the master controller if necessary.

The limiting value is displayed (G01952). If this limit is exceeded, the BLM controller is switched to Manual, the fuel signal is reduced to limit, BLR alarm will be given (AG05.X01963) and the cause of the limitation indicated by a "reduction index". (To get reduction index text, click on index display.)

An overview of load reduction causes and corresponding limits is given on MVP1901.

Note that the reduction associated with the turbine trip or main circuit breaker trip, will be overidden if the turbine is not in operation. The inhibition signal for this is taken from the HP turbine supply valve, V03001. When this valve close, BLR reduction 4 & 5 are cancelled.

An BLR action should be followed by manual firing at rates below BLR limit, until the cause of reduction is corrected.

The BLR function is always present, regardless of Manual or Auto mode. In Auto mode, the limit not to be exceeded, G011952 is automatically set according to plant state. In manual mode, the limit must be manually set by the operator at his choice.

In addition to the limiting function, the BLR controller performs rate limitations of the fuel command (up and down). If the source of a block reduction is corrected, the BLR system will slowly increase the fuel command towards the RLM controller command.

12.1.6 MD 200 Combustion Air/Flue Gas System

The drawing shows the flow of air and flue gas, from forced draft fan inlet to tube stack uptake duct.

Air is:

- entering the forced draft fans
- preheated in the air preheater
- mixed with oil and burned in the furnace space to flue gas

Flue gas is:

- radiating heat to the furnace walls and superheater
- cooled by convection heat transfer in the steam generating tube bank and the superheater
- cooled further in the feed water economiser
- cooled to final flue gas temperature in the air preheater before entering the funnel

12.1.7 MD 210 Combustion Air Preheaters

There are two sets of hot water/steam air preheaters. They are heating the combustion air for the burners.

- The hot water air preheaters are supplied with hot water from the district heater system.
- The steam air preheaters are supplied with steam from the feedwater deaerator tank.
- The hot water and steam air preheaters have a temperature controller connected.
- The primary side from the hotwater air preheaters are drained back to the district water system.
- The primary side of the steam air preheaters are drained to the make up deaerator system.

12.1.8 MD 240 Boiler Water System

This picture gives an overview of the Boiler water system.

- The feed water flow from the main feeder line is controlled by the feed water control valve. Its valve position can be set directly in LOCAL control. REMOTE control is from the boiler panel.
- The feed water is heated in a preheater before it is supplied to the economiser.
- After the economiser the feed water enters into the evaporator where steam is produced. The steam is then going to superheater 1.
- The superheated steam is then supplied to a steam/water separator which has a certain water level to isolate full steam pressure from the feed water deaerator tank.
- The steam is then led from the separator into superheater 2, from this into the desuperheater where the outlet steam temperature is regulated.
- The superheater and the steam supply lines are protected by a safety valve after the superheater.
- Valves for bottom blow off or top (surface skimming) blow off are included. The blow off goes to a bottom blow tank.
- For filling of boiler water a special line is provided called filling line.

12.1.9 MD 250 Boiler Steam System

This picture includes the high pressure steam line and the intermediate pressure steam line including the Intermediate superheater temperature controller, who mixes the steam with feedwater.

High Pressure steam line:	-	The piping from the boiler superheater 3 outlet is a separate steam line: HP steam line to HP turbine.
	-	The main steam line supplies the HP turbine.
	-	The HP turbine has a bypass control system if HP steam shall be fed to the district heater system.
Intermediate Pressure steam line:	-	The piping from HP turbine outlet is the supply for reheater 1. IP steam return from HP turbine.
	-	The temperature for the reheated IP steam supply is controlled by a separate temperature controller which mixes the steam with feedwater.
	-	The outlet from reheater 2 is the IP steam supply to IP turbine. IP steam line to IP turbine.
	-	There are bypass and drain valves for heating and drainage of steam lines before use.

12.1.10 MD 260 Main Steam Lines

This picture gives an overview of the main steam lines with their turbines.

- The piping from the main boiler outlet is branched to three separate steam lines:
  - HP steam line (HP)
  - IP steam line from HP turbine (IPC)
  - IP steam line from reheater 2 (IPH)
- The HP steam line supplies the HP turbine.
- The IP steam line from reheater 2 supplies the IP turbine.
- There are a bypass control system for the inlet to HP turbine.

12.1.11 MD 300 Steam Turbines

This picture contains all the information necessary for the steam turbine train.

- Control and shut off valves for HP and IP turbine are implemented.
- Turbine extractions are implemented.
- The three main steam lines are marked as IPH line, HP line and IPC line.
- The generator are implemented.

A quick shut down of the turbines or an aggregate switch disconnection to power production for internal use only, is supposed to occur when any of the following conditions are fulfilled:

Incident	Limit
- High steam pressure at VK41	> 2,10 bar
- High steam pressure at VK42	> 2,55 bar
- High temperature at HP turbine outlet	> 510°C

The block load reduction controller (BLR) takes care of the reduction in boiler effect.

12.1.12 MD 380 Electric Generator System

This picture includes all the necessary information about the electric generator.

<u>Control of the generator:</u>

- Control of excitation current and voltage
- Control of main circuit breakers and bus-tie breakers.

<u>Monitoring of the generator:</u>

- Monitoring of block active load (MW)
- Monitoring of block reactive load (MWAR)
- Monitoring of generator current (KA)
- Monitoring of cosφ

12.1.13 MD 400 Cold Condenser System

- Cooling water to the main condenser is supplied by two pumps that pump fresh water from a suction duct.

- The cooling water is taken from the lake, and returned to lake after the cold condenser.

- The vacuum of the main condenser is maintained by two mechanical vacuum pumps. Normally one is in operation at a time. The vacuum pump has a special system for sealing water which comprises two pumps.

- Steam inlet to the condenser is from the LP turbine (MD300).

- The condensate is collected in the hotwell below the condenser shell. Three electrically driven condensate pumps are pumping the condensate from the hotwell to the LP feed heater (MD420), through a gland condenser. Condensate pump1 & 2 has the same rate and size, but condensate pump 3 is a smaller pump.

- The water level in the condenser is controlled by recirculation of condensate back to the condenser.

- Water level control in the cold condenser is realised by controlling valves with a PID-controller at the outlet of the condenser.

12.1.14 MD 410 Main Condensate System

- The main condensate tank has connected drains from hot condenser, from direct heater 1 & 2 and from the cold condenser.
- The main condenser has a separate level control system. If the level is low, the level controller open supply from the make up deaerator tank.
- The main condensate tank has a separate vacuum pump with a sealing water system.
- There are three main condensate pumps in the system with safety valves, delivery and suction valves. The condensate pumps have a sealing water system.
- There is implemented a dump valve on the discharge from the main condensate pumps, to make dumping of condensate water possible. The delivery is to the lake.
- For the complete thermal power plant there is a common cleaning plant. This is not modelled, just indicated on the picture. It is possible to start a cleaning plant transfer pump for cleaning condensate water from the main condensate tank. It is also a valve for return of cleaned condensate water.

12.1.15 MD 420 Low Pressure Feed Heaters

There are three LP feed water heaters in this system: LP1, LP2 and LP3.

- Supply line is from main condensate tank. It is a possibility to run the condensate through a filter plant with 2 POWDEX filters. The system is used as long as the condensate has low temperature (during start up). After the temperature reaches normal level the filter efficiency is getting too low.
- There are ventilation lines between each LP feed heater which have to be opened before starting the system.
- Each LP feed heater have a separate level control system. If the level is getting too high the condensate is drained back to the cold condenser.
- For heating of the LP feed heaters Turbine extractions on IP turbine is used (MD300).
- The feedwater outlet from LP feed heater 3 is going to the feedwater deaerator tank.
- The LP3 feedheater has a safety valve installed.

12.1.16 MD 430 Feed Water Dearator System

- The feedwater deaerator tank has supply from LP feedheaters and from separator.
- There are three main feed water pumps implemented in the system with a recirculation system back to the feedwater deaerator tank. The recirculation system is pressure controlled through a pressure shock absorber.
- The feed water pump motors are water-cooled and the pump has a sealing water system.
- The delivery goes through a common feedwater line to a valve and the into the high pressure feedheaters.
- The delivery is also divided to the boiler water make up line.
- The feedwater deaerator tank has a special clean up line valve for cleaning of condensate before start up.
- For temperature control of the feedwater deaerator tank, a line from IPC is implemented with a separate temperature controller.
- For level control of the feedwater deaerator tank there is a supply line from the LP feed heaters controlled from a level controller.

12.1.17 MD 440 High Pressure Feed Heaters

- The HP feed heaters has input from the feedwater pumps. The feedwater could be made to go by-pass the HP feedheater 1-3.
- There are two outlets on the feedwater line for water injection in the Superheater 1 and 2.
- The level control for the feedheaters is connected back to the feedwater tank or to LP feedheater 3.
- HP 3 feedheater has no level control but it has connection to HP 1 feed heater which has level control.
- The HP feedheater 2 has separate level control which also drains to HP feedheater 1.
- The steam supply for heating is taken from turbine extractions on IP turbine.
- The steam is supplied to HP feed heater 3 and 2.
- There is venting valves and lines between the HP feed heaters.
- All HP feedheaters has safety valves.

12.1.18 MD 500 Make Up Dearator System

The main purpose for the make up deaerator system is to make boiler water and to clean boiler water from different drains.

- The make-up deaerator system has different inputs:
  - From miscellaneous drains and from steam air preheaters.
  - From the primary drain LP steam generator.
  - From the bottom blow tank.

- The make up of the deaerator water level is done from a make up water suction tank. This tank has connection to a nitrogen bottle. There is also a vent valve connected to this tank.

- The level control for this tank controls the delivery valve to the make up deaerator.

- The level control for the make up deaerator controls filling of freshwater to the make up suction tank.

- There are three pumps which serve as make up pumps.

- The filling of make up water is done through a dearation column which is designed with a large surface. This will make separation of water and oxygen easier. The vapour from this deaerator column is taken through a deaerator cooler for condensation of vapour.

- The deaerator cooler is connected to two vacuum pumps. The purpose of the vacuum pumps is for evacuation of air.

- The temperature control on the deaerator is controlling a steam valve for the heating steam system (MD430).

- The deaerated water supply to the system is delivered by three make up pumps.

12.1.19 MD 600 Hot Condenser System

The main purpose for this system is to heat district heater water system from the IP steam system.

- Instead of running the IP turbine at full effect we can open for turbine extractions 1 and 2, and let some of the reheated steam to heat primary water for the district water system.
- The water in the return line from the district heater system is pumped in to the system by means of two district heater supply pumps. The water goes into hot condenser 1 and afterwards to hot condenser 2.
- The condensate from hot condenser 1 and 2 are pumped out of the hot well by three hot condensate pumps.
- The level control on hot condenser 1 is controlling a delivery valve on the output of the hot condensate pumps to the condensate tank.
- The level control on hot condenser 2 is controlling a delivery valve on the outlet of the hotwell on hot condenser 2 to hot condenser 1.
- The Hot condensers have also connection to the vacuum pumps which also is used for the cold condenser system.
- The outlet from district heating water supply pumps could also be controlled direct to the direct heater by-pass valve if the temperature on district water is high enough.

12.1.20 MD 610 Direct Heater System

- The direct heater 1 and 2 are in fact another set of hot condensers.
- The direct heater system is connected to the IPH line so it is possible to use the reheated IP steam to direct heater system.
- Inlet to direct heater 1 and 2 has three valves from IPH line: One shut off valve, one steam control valve and one preheater valve which is normally open to keep a minimum temperature in the direct heater.
- Both direct heaters has drain and ventilation valves.
- The district water inlet to direct heater 2 is supplied from hot condenser 2 (MD610).
- Supply to sub-cooler 1 and 2 are taken from the outlet of the district heating water suction pumps.(MD610). The flow through the sub-coolers is very small compared to the total flow of district water. The return from the sub-coolers is connected back to the district heating water suction pumps.
- Both district heaters have a level control system which controls a regulating valve on the outlet off the sub-coolers.
- The sub-coolers main purpose is to cool down the condensate from direct heater. In some situations the condensate could be very hot and this condensate is lined back to the condensate tank which contains "cold" water at atmospheric pressure. It is not recommended to supply water with this temperature difference direct to the condensate tank.
- The capasity of the direct heaters are controlled by the condensate level in the direct heaters. For high capasity, condensate level is low and for low capasity, water level is high.

12.1.21 MD 620 Accumulator System

Main particulars
The system consists of a large hot water storage tank, an expansion tank, a water turbine, an accumulator pump, auxiliary pumps and necessary valves and pipes.

(a) Accumulator tank

Diameter:	42 m
Height:	18 m
Normal level:	16.5 m
Min charge volume:	19600 cubm
Max charge volume:	22300 cubm
Heat storage capacity:	1100 Mwh

(b) Accumulator pump

Flow:	5000 cubm at head 95 m
Motor:	1000 kW

(c) Turbine

Type: francis	
Design head:	80 m
Shaft power:	50-750 kW
Speed:	700-900 rpm

(d) Expansion tank

Height:	26 m
Normal level:	18 m
Volume:	500 cubm

(e) Make up pumps

Flow:	200cubm at head 55 m
Speed:	2900 rpm
Power:	60 kW

General description
The accumulator tank is used to store heat energy produced by the power plant. The full heat production of 4 hours can be stored for later release. Operation of the heat storage tank will depend on electric power price, weather condition and time of day. The accumulator tank enables a more safe and optimal power plant operation. Normal procedure will be to charge the accumulator at day time and thus producing much electric power at high price, and discharge the accumulator during night when electric power price is lower. Hot water demand varies from hour to hour. For instance high hot water requirement in the morning

(showers), high power requirement in the afternoon (cooking) etc. The accumulator makes is easier to meet such changing heat loads and electric power demands.

Accumulator tank
The accumulator tank is operating at atmospheric pressure. It is based on the principle that hot water is lighter than cold water. It is therefor possible to store the water in stable temperature layers with hardly any inter mixing, assuming water is supplied to the tank top, or removed from the tank bottom without turbulence.

The specific water density of 55 dgr C water is 986 kg/cubm, while it is 962 kg/cubm at 95 dgr C. This represents a weight difference of 25 kg/cubm.

The useful load volume of the tank is 22000 cubm and the total heat storage capacity amounts to 1150 MW with a temperature difference of 45 dgrC. The maximum load or unload rate is 5000 cubm/h, which corresponds to approximately 250 MW. This means that the power plant has a good momentary heat reserve in case of disturbances like turbine or boiler trip.

As the working pressure of the DHW pipe line is 80-100 mWL, 60-80 mWL pressure head is available for the water turbine installed to help driving the accumulator pump, pumping water back to the DHW pipe line from the accumulator tank.

Turbine power varies with flow and pressure. It can be as high as 750 kW. Never the less, the turbine power is not in any mode of operation sufficient for driving the accumulator pump up to balanced water flow.

The speed of the combined turbine/pump unit is boosted by an electric motor with speed control facility, to control the flows to and from the accumulator tank to desired (usually equal) values.

Flow through the turbine is manually controlled by opening or closing the inlet dampers of the turbine.

The volume difference between unloaded (cold) and loaded (hot) accumulator tank amounts to approximately 575 cubm. This corresponds to an level variation of 0.5 m in the accumulator tank.

The pump speed is controlled to keep the expantion tank level constant, and all variations in water density will be reflected in changing accumulator tank level.

Description of accumulator tank interior
In the tank bottom there is a fixed distribution system for cold water. In the tank top there is a movable float arrangement with 4 movable floats mounted on 4 arms. The arms are flexibly connected to the hot water supply pipe in the center of tank. The system is designed to discharge water with as low velocity as possible, to avoid turbulence and mixing of hot and cold water layers.

The volume above the water level is to be held free of oxygen. The air in the zone above the water is removed by a hot water spray system. A collecting arrangement for surface water is used for recirculation of spray water, which is kept at the boiling point by a steam heater. The steam to the heater is controlled according to the tank top pressure. Normal pressure is 30 mmWL above atmospheric pressure.

To active the spray system, start the spray pump. The system is not modeled in detail.

To protect the accumulator tank from excessive over or under pressure, a water seal is mounted a tank top. It opens at 65 mmWL and -40 mmWL. In addition safety valves open at 90 mmWL for extra protection (Not shown on drawing).

The water temperature distribution vertically in the tank is monitored by 20 platina resistance sensors mounted on a vertical wire going from tank top to bottom.

Turbine and pump unit
Between the turbine and the pump is a centrifugal clutch mechanism that releases the turbine from the pump shaft when the turbine shaft speed is below 200 rpm.

The turbine is a francis turbine type with spiral shaped inlet casing. Inlet dampers can be manually set for flow adjustment.

The turbine shut off valve is closed if the electric motor stops, or if any trip signal is present.

The turbine bearings are lubricated by a separate lubrication system including a LO cooler. This system is not modeled.

The accumulator pump is of the same type and capacity as the DHW supply and return pumps. The speed can be controlled by varying the rotor resistance through an electrolytic boiler rheostat, as for all major speed controlled pumps in the power plant system.

Accumulator temperature protection

A temperature control system protects the accumulator tank from being loaded by too hot water. This is done by recirculation of cold water from the accumulator pump to turbine inlet, when necessary. If loading temperature exceeds 101 dgrC for some time, turbine trip signal will be given.

If the turbine is set for accumulator tank loading, and the pump motor is started, an open pulse is given to the recirculation valve, for flushing of cold water through the turbine piping. The open pulse at start lasts for 100 sec.

Expansion tank

The pressure at the DHW supply pumps, called the "intermediate pressure", is to be controlled within the range 7.5 to 8.5 bar. The pressure is controlled by water flowing back and forth between the supply pumps inlet and the expansion tank, depending on pressure head difference.

The expansion tank has a steam cushion at top controlled by a separate steam system.
The steam system is not modeled in detail. The tank bottom pressure will be the sum of the steam pressure at top and the static liquid pressure head. Normal tank level is 18 m.

Make up/dump system

If the expansion tank level gets too low for some reason, a special dump valve opens and dumps water from the DHW system to the accumulator tank.

If the expansion tank level is too low, a make up controller opens the make up valve and water is pumped from the accumulator tank to the DHW system.

The make up pumps are automoatically started when the make up valve position is more than 25 % open.

The make up/dump system controlles the expansion tank level at times when the accumulator turbine/pump system is not in operation. Should a major leakage in the DHW net work occur, the make up pumps will start and alarm will be given if the make up flow is above a certain limit (150 t/h).

12.1.22 MD 700 DeNOx Plant Overview

The main purpose of the DeNOx plant is for removal of nitrogen oxide from the flue gas. The method is built on a selective catalytic reduction. The medium used for the reduction is ammonia gas.

- The plant comprises two SCR (selective catalytic reduction) reactors and an ash silo.
- There are different dampers which is channelling the flue gas either into or bypass the SCR-reactor.
- Before the DeNOx plant can be set into operation a special heating procedure has to be done.
- A certain fouling of the catalysators is modelled. The effect of this fouling will be an increase of the difference pressure over the SCR. A manually initiated soot blowing will clean the surfaces in the reactor.

12.1.23 MD 710 SCR Reactor 1

There are two similar reactors. The boiler has two similar flue gas outlet manifolds, one for each reactor.

Ammonia Injection

The ammonia injection system comprises a high pressure fan, a gas mixer, and 16 nozzle pipes.

The air is lead from the fan via a pipe to a mixing chamber where ammonia is injected. In the DeNOx plant simulator ammonia is supplied from a tank containing ammonia at a given pressure and temperature.

After mixing, the gas is flowing to the nozzle tubes which are inserted into the flue gas channel at the reactor inlet. Measurement of NOx in the flue gas is used as input to the controller. A sensor installed in the reactor outlet channel is used to measure content of ammonia in the flue gas, and an alarm is issued in the case of high content.

SCR Reactors

The cleaning of flue gas is based on the High Dust Principle. The flue gas passing through the reactor has a high content of foreign matter and sulphur.

The reactor is made up of three parts, namely, the inlet, the reactor chamber, and the outlet. Flue gas and ammonia/air mixture enter the inlet at the top of the construction.

The catalysts are of the plate type. The plates are covered with an active material, which constitutes the real catalyst.

Reactor product handling

Reactor product drops from the pockets through the channels and dampers down to the ejectors. From the ejectors the solids is transported to the cyclone by means of pressurised air. From the cyclone the stuff drops into the intermediate tank which has a capacity of 2 m^3. A level guard issues an alarm in the case of high level in the intermediate tank.

Further handling of the solids is not to be taken into account in the DeNOx plant simulator.

Soot Blowers

Both reactors are furnished with soot blowers, and pressurised steam is used to clean the catalysts. The soot blowers are operated manually, either from the central control room or from a local panel.

Reactor heating

When starting up from cold state or in order to keep the reactor warm, hot combustion air is drawn from the spiral channel. A circulation fan is used to force the air through the reactor.

Reactor drying

In order to keep the reactor dry, for instance during shut down, the reactor is furnished with a dryer. A fan provides circulation of air through the reactor.

12.1.24 MD 800 DeSOx DeSulphurization Plant

- The plant has two silos for storage of lime, one main silo and one lime day silo.
- The lime is transported down to a weight system and a conveyer belt to feed a continuos and correct amount of lime to the slake system. From here the lime is led into the slake tanks.
- The overflow from the slake tanks are piped to the slake suspension tank where even more water are added to make the suspension pumpable. The slake suspension is pumped to a slake feeder tank through a strainer.
- The absorber has two inlets for flue gas, one for 40% (bottom inlet) and one for 60% of the flue gas (on top of the absorber).
- Ash from the absorber is taken out of the bottom of the absorber and out to a powder pump.
- There is an electro filter at the end of the system to remove combustion recidues and ash.

12.1.25 MD 810 Lime Silo

The main purpose of this picture is to give an overview of the lime filling system.

- Lime is filled by truck into the main lime silo, full capacity is $500m^3$
- The lime day silo is filled by a conveyer belt and a scoop lift system. Full capacity is $20m^3$.
- The conveyer belt is fluidized with air to transport the lime in a sufficient way.
- The operation of the conveyer belt and scoop lift is operated by level switches for high and low level installed in the lime day silo.
- Both silos have an air fan in the bottom of the well to ensure proper delivery.

12.1.26 MD 820 Slake System

The main purpose of this picture is to get an overview of the slake system.

- There are two slake tanks in the system, one in operation and one in reserve.
- Lime from the lime day silo is taken into the slake tank via a transport system.
- Lime is mixed with water to make a slake suspension. The mixing water is taken from the district water system.
- The flow of mixing water and lime is controlled by a controller sensing SOx content in the flue gas.
- The slake suspension tank has a mixer system where the slake is mixed with more water to make the slake pumpable.
- There are two pumps supplying slake suspension to the feeder tank. These pumps has water supply for washing after they have been stopped and for sealing during operation.

12.1.27 MD 830 Feeder System

The slake suspension is pumped from the slake suspension tank into the feeder tank.

The feeder tank is also supplied from mixer tank 1 and 2. The purpose is to mix product from the electric filter with slake suspension.

The slake suspension is supplied to a spreader tank which supplies the electrically driven rotating spreader.

The overflow of this tank is returned to the feeder tank.

The delivery out of the feeder tank is controlled by the level in the feeder tank, and the level is controlled by the filling from the slake suspension tanks. The setpoint is taken from the power used by the spreader.

12.1.28 MD 840 Absorber

The picture shows schematically the absorber, electric filter, and flue gas channels with dampers and fans.

When the SO_2 absorber (slake and product slurry) is spreaded into the hot flue gas with the rotating spreader a reaction will be established. The reaction in the absorber is carried out in two ways. The absorbent will partly react with the flue gas content of sulphur dioxide and chlorides and the water content of the absorbent will be evaporated.

The evaporation process is total so the remainings is a dry powder which is separated in the el-filter after the absorber. Some of the recidues is also falling down into the bottom of the absorber.

- The dew point sensor is located in the chimney close to the SO_2 sensor. Actually there are two sensors.

- At start up, during heavy changes of load, and during abnormal operations, safety precautions require a flue gas set point with a higher margin to the dew point.

- The spreaders power is proportional to the flow of feeder slurry. Therefore the motor power is used to control the flow. The power is given as function of feeder flow as shown in the diagram.

- The temperature is measured both before and after the absorber. Sensors are installed in the flue gas channel at the fans outlet.

- The spreader tank is filled with a mixture of product slurry and lime suspension.

- The absorber has two inlets for flue gas, one for 40% (bottom inlet) and one for 60% of the flue gas (on top of the absorber). In the middle the spreader is placed which is feeded with slake from the spreader tank. The spreader is rotating with high speed to mix flue gas with product slurry.

- There in only one outlet for flue gas.

- The Flue gas enters a diffuser in lower and upper section which makes the flue gas rotate and spreads out so the mixing effect between flue gas and product slurry is maximum.

- There is also a valve to operate the absorber in by-pass.

12.1.29 MD 850 Product System

- The recidues from the absorber is taken to an ash silo. This delivers ash for production of a product called cefill.
- The recidues from the el-filter is transported with a powder pump to a product silo for recirculation.
- The product slurry system has two parallel lines, where one is in reserve.

12.1.30 MD 860 Mixing System

The slurry is composed of water, desulphurization product from the absorber, and product from the electric filter.

There are two independent processing lines. One line may be in operation while the other is in a state of preparation. As soon as a mixing tank contains slurry, the slurry is pumped via the pipes to the shut off valve in front of the feeder tank. A density meter is installed at the discharge side of the slurry pump. The measurement is used to compute content of pulp in the slurry and is input to controllers DIC810 and DIC814.

The flow of product slurry is measured at the inlet of the feeder tank. Measurements of flow and level are combined, and the result is used as set point value for flow controller. The set point must exceed a certain threshold before the controller starts to open the water valve at the mixing tank. The water flow measurement is combined with a factor from the density controller, and the result is used as control signal for frequency transformer controller. This controller controls the cell feeder at the product silo outlet.

13 APPENDIX J DESCRIPTION OF SYMBOLS

13.1 Symbol list

1. Vessel with Level Indicator
2. General Tank with Level Indicator
3. Condencer / Heat Exchanger
4. Direct Heater
5. Heat Exchanger
6. General Preheater
7. Rotating Regenerative Preheater
8. Steam / Water Separator
9. Steam Turbine - single
10. Steam Turbine - double
11. Strainer
12. General Filter
13. Filter
14. Flue Gas Filter
15. Flame symbol
16. Cole Grinder
17. Cole Feeder
18. Product Silo
19. Function Generator
20. Electric Circuit Breaker
21. Electric Circuit Breaker
22. Transformer
23. Mixer
24. Cell Feeder
25. Ejector
26. Steam Trap
27. Silencer
28. Hopper
29. Pump
30. Solenoid Damper
31. Control Damper
32. Manual Damper
33. Unspecified Valve
34. Non Return Valve
35. Manual Valve
36. Manual Non Return Valve
37. Control Valve
38. Solenoid Valve
39. Solenoid Non Return Valve
40. Relief Valve
41. Safety Valve

13.2 Symbol description

13.2.1 no. 1. Vessel with Level Indicator

This is a tank used for liquid with an indicator who indicates the amount of liquid in the tank.

13.2.2 no. 2. General Tank with Level Indicator

This is a tank used for liquid with an indicator who indicates the amount of liquid in the tank.

13.2.3 no. 3. Condencer

This symbol is a condencer. It is supplied with steam and cold water. The cold water is separated from the steam with a special pipe system. When the hot steam flows into the condencer and hits the pipes where cold water is flowing the steam will condensate.
The condensate will drip down into the hotwell which is the collector of the condensed steam.

13.2.4 no. 4. Direct heater

This heater is used as a direct heater. Steam is used as the heating medium and it will transport heat to water which flows in a internal pipe system.
The steam will then condensate, and the Condensate level in the direct heater is level controlled to control the efficiency of the direct heater.
High level - low efficiency
Low level - High efficiency

13.2.5 no. 5. Heat Exchanger

This is a heat exchanger where both primary side and secondary side can be any kind of liquid. The prim. and sec. side is separated by means of a pipe system.

13.2.6 no. 6. General Preheater

The preheater is used for preheating of liquid or air. The heating medium on the primary side is normally water or steam.

13.2.7 no. 7. Rotating Regenerative Preheater

The rotating regenerative air preheater is using exhaust gas for heating the surface of a rotating heat register, this will pass through the air inlet channel for combustion air and will then transport the heat to the cold inlet air. This unit is also called Ljungströms air preheater.

13.2.8 no. 8. Steam/Water Separator

The Steam Separator is used for separating water from the steam.

13.2.9 no. 9. Steam Turbine - single

This is the symbol for a single steam turbine. The steam turbine is used for power production, and is connected to an electric generator.
In this simulator used as the High pressure steam turbine in the turbine train.

13.2.10 no. 10. Steam Turbine - double

This is the symbol for a double steam turbine. The steam turbines are used for power production, and are connected to an electric generator.
In this simulator used for the Intermediate and Low pressure turbine on the turbine train.

13.2.11 no. 11. Strainer

This is a symbol for a strainer. It is used for separating larger pieces from process flow.

13.2.12 no. 12. General Filter

This is the symbol for a general filter.

13.2.13 no. 13. Filter

This is a filter symbol.

13.2.14 no. 14. Flue Gas Filter

This is an electric filter used for separating the remainings after the reaction in the absorber.

13.2.15 no. 15. Flame symbol

The Flame symbol is used for indicating that the burners are lightened.

13.2.16 no. 16. Coal Grinder

The Cole Grinder is used for crushing the coal into dust. The Cole dust is fed to the burners with conveyer air from primary air fan.

13.2.17 no. 17. Coal Feeder

The coal feeder system supplies coal to the coal grinder. The system is controlled by a coal mill control panel.

13.2.18 no. 18. Product Silo

The product silo contains the recidues from the El. filter. The recidues which are in form of dry powder will be taken from the product silo for recirculation.

13.2.19 no. 19. Function Generator

This is the symbol for a Function Generator. The symbol indicates that this is a linear generator; the signal on the outlet of the function generator is proposional with the signal set into the generator.

13.2.20 no. 20. Electric Circuit Breaker

The main electric circuit breakers can be turned into two positions:
on or off.

13.2.21 no. 21. Electric Circuit Breaker

The main electric circuit breakers can be turned into two positions:
on or off.

13.2.22 no. 22. Transformer

The transformers transform electric voltage into wanted voltage level e.g. from 17,6 kV into 220 kV.

13.2.23 no. 23. Mixer

The mixer is used to mix e.g. lime with water to make a slake suspension.

13.2.24 no. 24. Cell Feeder

The Cell Feeder delivers the correct amount of product needed in the absorption process. The Cell Feeder is controlled by a controller who combines the water flow measurement and signals from the density controller to indicate the correct amount of product needed in the absorption process.

13.2.25 no. 25. Ejector

This is the symbol for and ejector The drive medium is often steam or water and it can be used for transport of any liquid or slurry.

13.2.26 no. 26. Steam Trap

This is the symbol for a Steam Trap. The trap is used for separating water from the steam, and it opens when the water level has reached a certain level.

13.2.27 no. 27. Silencer

This symbol is for the silencer. The silencer is placed together with safety valves for steam to reduce the noise when a safety valve opens.

13.2.28 no. 28. Hopper

The hopper is a device for loosing up a medium as lime for instance. It is designed with a table which is vibrating. It is often placed together with a conveyer belt.

13.2.29 no. 29. Pump

This is the symbol of a pump. The arrow indicates the flow direction of the liquid

13.2.30 no. 30. Solenoid Damper

This is the symbol of a Solenoid damper. This damper is controlled open/ closed by an electromagnet.

13.2.31 no. 31. Control Damper

This is the symbol for the Control damper. The damper is connected to a controller who controls the opening.

13.2.32 no. 32. Manual Damper

This is the symbol for a Manual damper. The opening or closing of this damper are done manually.

13.2.33 no. 33. Unspecified Valve

This is a symbol for an unspecified valve. This symbol just indicates that there is a valve present, but not what kind.

13.2.34 no. 34 Non Return Valve

This is a symbol for a Non-return Valve. The flow trough this valve is one way directioned. The white arrow indicates the flow direction.

13.2.35 no. 35. Manual Valve

This is the symbol for a Manual valve. There is no controllers connected for opening or closing this valve.

13.2.36 no. 36. Manual Non Return Valve

This is the symbol for a Manual Non-return valve. There is no controllers connected for opening or closing this valve, and the flow is one way. The flow direction is indicated by the white arrow in the symbol.

13.2.37 no. 37. Control Valve

This is the symbol for the Control valve. The valve is connected to a controller who controls the opening of the valve.

13.2.38 no. 38. Solenoid Valve

This is a symbol for the Solenoid valve. This valve is an electromagnetic valve and are controlled open/closed by electricity.

13.2.39 no. 39. Solenoid Non Return Valve

This is a symbol for the Solenoid Non-return valve. This valve is an electromagnetic valve and are controlled open/closed by electricity. The flow is one way, and the flow direction is indicated by the white arrow in the symbol.

13.2.40 no. 40. Relief Valve

This is the symbol for a Relief Valve. The valve is normally in closed position, but opens if the pressure increases a certain level.

13.2.41 no. 41. Safety Valve

This is a symbol for a Safety Valve. If the pressure exceeds a certain level the valve blow and prevent accidents or damage on equipment.