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Preliminary Plant Operation Manual

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Chapter 2 Process Description

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REVISION INDEX

REV. / PAGE	Z01	Z02	Z03	Z04	REV. / PAGE	Z01	Z02	Z03	Z04	REV. / PAGE	Z01	Z02	Z03	Z04
1														
2														
3														
4														
5														
6	X													
7														
8	X													
9														
10														
11														
12														
13	X													
14	X													
15	X													
16	X													
17	X													
18	X													
19	X													
20	X													
21	X													
22	X													
23														
24	X													
25														
26														
27														
28														

LIST OF CONTENTS

1. General

The methanol plant is designed for production of 5000 MTPD grade AA Methanol.
This process description refers to the following Lean Gas - SOR process flow diagrams:

- Description
- Process Flow Diagram for Natural Gas Station
- Desulphurization and Reforming
- Process Gas Cooling
- Methanol Synthesis Loop
- Process Flow Diagram for Methanol Tank
- Distillation – part 1
- Distillation – part 2
- Process Flow Diagram for Closed Drain Drum
- Saturator
- Steam Balance

The main processes steps are:

- Desulphurisation
- Saturation of natural gas with process condensate
- Adiabatic prereforming
- Tubular reforming
- Auto thermal reforming
- Reformed gas cooling train
- Methanol synthesis
- Methanol Tank
- Methanol distillation
- Steam System
- Flare system
- Pipe rack and pipe net system

2. Unit 1000, Desulphurisation

The natural gas feed is filterred, meterred and regulatred in the Gas Station X 1001. In the Natural Gas K.O. Drum, D 1001, possible condensate is separated out and sent to the Liquid Off stream Tank, TK 5003. From the outlet of D 1001 the natural gas are split into a fuel stream and a process feed stream.

The natural gas feed is preheated to 250℃ in the 1st Natural Gas Feed Preheat Coil, E 2006, in the reformer waste heat section.

Then recycle hydrogen is added to the natural gas feed, it serves as hydrogen source for the hydrogenation of organic sulphur in the hydrogenator, R 1001. During normal operation the recycle hydrogen is a small part of the purge gas from the methanol synthesis loop.

After addition of recycle hydrogen gas the mixture is preheated to 380℃ in the 2nd Natural Gas Feed Preheat Coil, E 2004, in the reformer waste heat section.

2.1. Scope of process

The catalysts in the reforming section are extremely sensitive to sulphur compounds since these will cause deactivation or poisoning.

The desulphurization section contains three reactors, first a reactor loaded with Nickel-molybdenum-oxide hydrogenation catalyst (TK-261) followed by two reactors containing zincoxide sulphur absorption (HTZ-51).

2.2. Gas station

The natural gas feed supplied from OSBL enters the gas station, where it goes through three sections: filtering, flow metering and pressure regulating. Firstly, the natural gas is routed to the dry gas cartridge filters. In the second stage, gas flow rate is measured by the ultrasonic type gas flow meters. Finally, the metered gas is routed to the pressure regulating section. The natural gas pressure is reduced through the regulators. The natural gas after regulating in pressure regulators leaves the gas station and is sent to the Natural Gas K.O. Drum, D 1001.

2.3. Hydrogenation

The first catalyst in the desulphurization section is a Nickel-molybdenum hydrogenation catalyst in a single bed placed in the reactor, R 1001. The Topsøe catalyst TK-261 is delivered as 2.5 mm quadralobes. It catalyses the following reactions.

$$RSH + H_2 \Rightarrow RH + H_2S$$
$$R_1SSR_2 + 3H_2 \Rightarrow R_1H + R_2H + 2H_2S$$
$$R_1SR_2 + 2H_2 \Rightarrow R_1H + R_2H + H_2S$$
$$(CH)_4S + 4H_2 \Rightarrow C_4H_{10} + H_2S$$
$$COS + H_2 \Rightarrow CO + H_2S$$

where R is a radical of hydrocarbon.

If CO and CO2 are present in the hydrogenation gas, the following reactions may take place:

$$CO_2 + H_2 \Leftrightarrow CO + H_2O$$

$$CO_2 + H_2S \Leftrightarrow COS + H_2O$$

The optimum temperature range is between 350°C and 400°C (660–750°F) for natural gas. For heavier feedstocks it is recommended keeping the temperature at a maximum of 380°C. The lowest operating temperature is around 300°C (570°F). At temperatures above 400℃ coke could be formed on the surface of the catalyst and thus decrease the activity.

The hydrogenation catalyst must not get into contact with hydrocarbons which have not been mixed with hydrogen. The result will be poor conversion of organic sulphur compounds, giving an increased sulphur slip to the prereformer.

2.4. Absorption of sulphur

The two reactors, R 1002 1/2, located in series are identical, R 1002 2 acting as guard vessel in case of breakthrough from R 1002 1 or for the short time R 1002 1 is taken out of service for replacing the catalyst.

The Topsøe HTZ-51 catalyst consists of activated zinc oxide. The zinc oxide is delivered as 4 mm diameter extrusions. The bulk density is around 1.3 kg/l. The zinc oxide reacts with H_2S according to the following equation:

$$H_2S + ZnO \Leftrightarrow ZnS + H_2O$$

3. Unit 6000, Saturation Unit.

3.1. General

From the Sulphur Absorbers, the feed gas is led to the saturator unit where the process gas is saturated with water.

The purpose of the saturator unit is to utilise the steam generated in the methanol reactor (MP steam). The MP steam could otherwise not be used as process steam as the pressure of MP steam is lower than the pressure of the natural gas.

Simultaneously the waste water problem is solved, as process condensate and distillation water is fed to the saturators.

The saturator unit consists of:

a) E 6001, Saturator Feed/effluent Exchanger. The feed/effluent exchanger provides heat for superheating of the saturated natural gas to 262°C, by cooling the feed gas with the effluent gas to 265°C.

b) T 6001 1/2, Saturator. In the saturator the process water is evaporated into the natural gas.

c) D 6001, Feed Gas Scrubber Separator. Surplus of process water and saturated natural gas is separated. The surplus Na^+ from distillation is washed out of the gas stream by process condensate.

d) P 6001 A/B, Saturator Circulation Pump. Process water from D 6001 is returned to the saturators.

e) P 6002 A/B/C, Steam Condensate pump. Steam condensate from T 6001 1/2 is returned to the MP Steam Drum, D 3003.

f) D 6002, Saturator Blow Down drum.

g) E 6003, Saturator Blow Down Cooler.

h) E 6004, Wash Water Preheater.

i) X 6001 A/B & X 6002 A/B, Particle Filters.

3.2. T 6001 1/2, Saturator.

- The process gas enters through a gas distributor at the top of the saturator.
- The process water enters through a ring distributor which is located around the inner tube wall; the ring distributor is perforated in the bottom. From the ring distributor the liquid is lead to the top of the tube sheet.
- Each tube in saturators is equipped with an 'insert-type distributor' These are basically an extension of the tubes above the tube sheet. The extended tubes have perpendicular holes in two elevations, the process water enters through these holes, and the perpendicular shape ensures easy formation of a water film on the inside of the saturator tubes. The process gas enters the saturator tubes through the top of the extended tubes.
- The Saturator is a falling film type with gas and water in concurrent flow on the tube side.
- The necessary heat input for the evaporation is obtained by condensing steam on the shell side. The steam is imported from the methanol synthesis section.

The gas leaves the saturators at approximately 226ºC/42.8 bar g.

The water used for saturation of the natural gas feed gas is a mixture of process condensate from the condensate separators, D 2002, D 2003, D2004 and D 2005, and the excess water from the distillation section. It is also possible to use BFW and/or excess condensate from TK 7002.

Process condensate from the cooling train downstream the reformer is send through Particle Filter, X 6001 A/B and X 6002 A/B before entering the saturators. In the filter catalyst dust and possible refractory dust, which potentially could block the holes in the saturator tubes, is removed.

Before being introduced as wash water to the Feed Gas Scrubber Separator, D 6001 the process condensate is heated slightly above the saturation temperature in the Wash Water Preheater, E 6004.

A surplus of water is circulated through the saturators by means of the Saturator Circulation Pump, P 6001 A/B to ensure a water film in all tubes.

3.3. Blow down from saturators

Continous blow down:

Continuous blow down is withdrawn from the upper tube sheets of the saturators. The blow down is cooled in the Process Condensate Preheater, E 6002 and then passed on to the Saturator Blow Down Drum, D 6002.

<u>Excess condensate:</u>

In case of an upset situation where the saturator cannot evaporate all the in coming process condensate, excess water is withdrawn from D 6001, and send to D 6002.

Part of the excess condensate will flash as D 6002 is operating at ambient pressure.

Process condensate/blow down from D 6002:

- Is pumped by the Excess Process Condensate Pump, P 7003 A/B.
- Then it is cooled in the Saturator Blow Down Cooler, E 6003
- Then the continuous blow down is sent to BL for further treatment and the excess condensate is sent to the Process Condensate Tank, TK 7002.

3.3.1. Excess process condensate.

If the plant is operating at a higher S/C ratio than foreseen due to an upset situation, the saturator may not be able to utilize all process condensate; in such a situation process condensate can be exported to TK 7002. The process condensate may then, when the operation is stable, be returned to the saturator by the 'Excess Condensate Pump', P 7004 A/B. It is possible to return maximum 5000 kg/h of process condensate.

The process steam is provided partly by saturation and partly by addition of direct steam.

The excess condensate return flow must be kept low enough, to ensure that the direct steam flow is high enough for the flow control to function stable, and thereby keep the S/C ratio stable.

3.3.2. S/C ratio adjustment

The hydrocarbon feed coming from the saturator system is mixed with direct process steam to achieve a steam to carbon ratio of 1.8 at the inlet of the prereformer.
Definition of steam to carbon ratio: n moles H2O per mole C (C from hydrocarbons only) at the inlet of the prereformer.

3.3.3. Prereformer feed preheater.

The natural gas/steam mixture is further preheated to approximately 496ºC in the Prereformer Feed Preheater coil, E 2002, before entering the Prereformer, R 2003. The inlet temperature is controlled by adding water to the gas upstream the pre-reformer feed preheater.

4. Unit 2000, Reforming

4.1. Adiabatic Prereforming

In the Prereformer containing the reforming catalyst, Topsøe AR-401, the natural gas/steam mixture is converted into a mixture of H2, CO, CO2, H2O and CH4 by catalytic steam reforming according to the following reactions:

(1) $C_nH_m + n\,H_2O \rightarrow (n + ½m)\,H_2 + n\,CO$

(2) $CO + 3\,H_2 \leftrightarrow CH_4 + H_2O$

(3) $CO + H_2O \leftrightarrow CO_2 + H_2$

Almost all higher hydrocarbons are completely converted, irreversibly, by the first reaction, while the other two reactions are nearly equilibrated.

The main purpose of the Prereformer is to reform all higher hydrocarbons completely simultaneously with methane reforming.

In addition, incorporation of a Prereformer has several advantages:

1) Considerable energy savings are obtained because heat recovered in the convection section of the primary reformer can be utilised for additional preheating of feed to the primary reformer radiant section.

2) Prolonging life of primary reformer catalyst due to prereformed catalyst will act also as guard. This is especially relevant when the reformer operates at low exit temperature

4.2. Primary Reforming

The prereformed gas/steam mixture leaving the Prereformer is heated to approximately 638ºC in the Reformer Feed Preheater Coil, E 2001, in the waste heat section of the reformer before it enters the Primary Reformer, H 2001.

The tubular Primary Reformer consists of two radiant chambers with six sections each, connected to a common flue gas waste heat section. The radiant sections each contains 26 vertically mounted high alloy Cr Ni Nb Ti steel tubes filled with the catalyst R-67-7H. The tubes are mounted in a single row along the centre line of the radiant chamber.

The process feed is distributed to the top of the tubes from a header through “hairpins".

In the catalyst tubes the natural gas/steam mixture is converted into a mixture of H2, CO, CO2, H2O, and CH4 by catalytic steam reforming according to the following reactions:

(1) $C_nH_m + n\,H_2O \rightarrow (n + ½m)\,H_2 + n\,CO$

(2) $CO + 3\,H_2 \leftrightarrow CH_4 + H_2O$

(3) $CO + H_2O \leftrightarrow CO_2 + H_2$

The heat required for the endothermic reforming reactions is supplied by heating the tubes by a number of radiant wall burners. The burners are located on either sidewall of each radiant chamber and arranged in horizontal rows at different elevations to provide easy control of a uniform temperature profile along the length of the catalyst tubes. In this manner, the optimal utilisation of the expensive high alloy tubes is obtained.

The burners are forced draught type burners. Combustion air is delivered by the Combustion Air Blower, ‘F 2002’. The air is preheated to approximately 165ºC in E 2007

The flue gas leaves the top of the radiant chambers and enters the waste heat section at a temperature of approximately 1095°C.

Purge gas from the methanol loop and natural gas are used as fuel.

In the flue gas waste heat section, the sensible heat of the flue gas is utilised for:
E 2001 Preheating of reformer feed.
E 2002 Preheating of prereformer feed.
E 2004 Preheating of natural Gas Feed.
E 2006 Preheating of natural Gas Feed
E 2007 Preheating of combustion air.

At the outlet the flue gas temperature has been reduced to approximately 150°C, ensuring that the surface temperature of the Combustion Air preheater, E 2007, is always above the Sulphuric acid dew point.

An induced draught Flue Gas Fan, F 2001, installed downstream of the waste heat section, transfers the flue gas to the Stack, S 2001.

F 2001 and F 2002 is driven by steam turbines, however both blowers are installed with stand by electrical motors.

The reformed gas leaves the primary reformer at approximately 739ºC / 31.4 bar g.

4.3. Secondary Reforming

The Secondary Reformer, R 2004 is a refractory lined vessel containing a burner mixer (CTS burner) and the reforming catalyst, type RKA and RKS-2.

Process gas from H 2001 is mixed with oxygen in the CTS burner.

To ensure safety the oxygen is mixed with steam before entering R 2004. The maximum oxygen content is 92 vol%.

Safety also requires the oxygen to be free from particles, therefore both the oxygen and the steam is filtered.

The oxygen is filtered in the Oxygen Filter, ‘X 2001 A/B’ and preheated in the Oxygen Preheater, ‘E 2008’ to 230 °C.

The burner protection steam is filtered in the Steam Filter, ‘X 2002 A/B’.

The chemical reactions taking place are a combination of combustion and steam reforming reactions dividing the reactor space into three reaction zones:

Reactor Equipment Reaction Zones

CTS Burner	Mixing
Combustion chamber	Combustion zone and thermal zone
Catalyst bed Catalytic	zones

The CTS burner is the key element of the auto thermal reforming technology. The CTS burner provides the mixing of the feed streams in a turbulent diffusion flame.
The CTS burner is characterised by its capability of operating at very high flame temperatures without burner wear problems.

The combustion zone is the turbulent diffusion flame where the hydrocarbons and the oxygen are gradually mixed and combusted. Normally, the principle of “mixed-is-burnt” can be assumed, because the exothermic combustion reactions consuming oxygen are very fast reactions.

The combustion of methane takes place through numerous radical reactions, but in a simplified model it can be considered as one molecular reaction, i.e. the highly exothermic combustion of CH4 to CO and H2O. Excess methane will be present at the combustion zone exit after all oxygen has been converted.

Combustion zone

(1) $CH_4 + 1½\, O_2 \rightarrow CO + 2\, H_2O$

Thermal and catalytic zones

(2) $CH_4 + H_2O \rightarrow CO + 3\, H_2$

(3) $CO + H_2O \leftrightarrow CO_2 + H_2$

The thermal zone is the part of the combustion chamber where further conversion of the hydrocarbons proceeds by homogeneous gas phase reactions. The main reactions are methane reforming (2) and water shift reaction (3).

The combustion chamber is followed by a fixed catalyst bed, the catalytic zone, in which the final hydrocarbon conversion takes place through heterogeneous catalytic reactions. At the exit of the catalytic zone, the synthesis gas will be in equilibrium with respect to the methane reforming (2) and shift reaction (3).

The reformed gas leaves the secondary reformer at approximately 1020ºC / 27.1 bar g.

Methane Content of the synthesis gas

Methane acts as an inert in the methanol synthesis loop and will lower the partial pressure of the active reactants. It is therefore important to keep the methane content of the synthesis gas low.
The methane content depends by the following parameters:

- operating pressure
- reforming temperature
- steam/carbon ratio in the primary reformer
- oxygen/carbon ratio in the secondary reformer

The methane slip of R 2004 is approximately 0.65 dry mole%.

4.4. Reformed Gas Cooling Train

The reformed gas from the Secondary Reformer is cooled in three steps.

The heat from the reformed gas is used to generate HHP steam which is used as power supply for steam turbines.

The hot process gas at around 1020°C from the secondary reformer R 2004 is symmetrically split into two streams which flow to two parallel trains:

- Waste Heat Boiler E 2020 1/2 where the process gas is cooled to around 544°C
- Steam Super heater E 2021 1/2, where the process gas is cooled to around 409°C

The two process gas streams from outlet of E 2021 1/2 are joined and the combined stream is further cooled in the steam super heater E 2021 3 to 360°C and in the BFW preheater E 2022 1/2/3 to around 165°C.

After cooling in the BFW preheaters the heat of the process gas is utilised in the distillation sections, in the column reboilers E 5023 and E 5024 1/2.

The reformed gas is then cooled to about 132°C in the DMW Preheater, E 2025 and the DMW is heated from 35°C to 72°C.

Further cooling takes place in the Air Cooler, AE 2026 and the Water Cooler, E 2027.

Process condensate is separated from the synthesis gas in a series of process condensate separators, D 2002, D 2003, D 2004 and D 2005, before the synthesis gas is sent to the Methanol loop. Process condensate is sent to saturator unit by the condensate pumps P 2001 A/B, P 2002 A/B and P 2003 A/B.

Process condensate from P 2003 A/B is used for cooling of blow down from the saturator, before being passed on to the saturator.

The reformed gas leaves the cooling train at approximately 48ºC / 24 bar g

5. Unit 3000, Methanol Synthesis Loop

The synthesis gas is compressed in the Synthesis Gas Compressor, C 3001. The compressed synthesis gas is mixed with the recycle gas from the Recirculator, C 3002.

During SOR, when the methanol catalyst is new, the loop pressure is 80 bar g, as the catalyst is aging the pressure is increased to 90 bar g.

The gas mixture is then preheated to in the Feed/Effluent Exchanger, E 3001 1/2/3 before entering the Methanol Reactor, R 3001 1/2/3.

During SOR, when the methanol catalyst is new, reactor inlet temperature is 210 ºC, as the catalyst is aging the pressure is increased to 230 ºC.

In the reactor, hydrogen, carbon monoxide and carbon dioxide are converted into methanol according to the following reaction schemes:

(1) $CO_2 + 3\,H_2 \leftrightarrow CH_3OH + H_2O$

(2) $CO + H_2O \leftrightarrow CO_2 + H_2$

(3) $CO2 + H2 \leftrightarrow CO + H2O$

In addition, some side reactions take place to a very limited extent whereby traces of oxygenates, boiling both lower than and higher than methanol, and paraffin's are formed.

Based on the above reactions the stoichiometric ratio often referred to as the module M can be calculated:

$$\text{Module M} = \frac{H_2 - CO_2}{CO + CO_2}$$

The module of the synthesis gas entering the loop must always be above the stoichiometric value 2.0, design value is between 2.05 and 2.15.

If the module becomes to high the requirement for purge will increase and if the module gets to low the by product formation will increase

High CO/CO2 will increases reaction rate

If CO2 is below 1-2% the reaction rate will decrease for reaction kinetic reasons The reactor is a boiling water reactor, i.e. the methanol synthesis catalyst, MK-151, is loaded into several tubes, all surrounded on the shell side by boiling water, which efficiently removes the heat of reaction from the methanol synthesis.

A layer of MK-151 is loaded on top of the tube sheet acting as an adiabatic pre-converter thus reducing the required catalyst volumes loaded in the catalyst tubes.

The temperature of the shell side is easily controlled by adjusting the pressure of the boiler water/steam mixture. Steam from the reactor is utilised in the Saturator, T 6001 and/or in the LP steam header.

During SOR, when the methanol catalyst is new, the steam temperature is 240 ºC, as the catalyst is aging it is increased to 252 ºC.

The synthesis gas exit the reactor is cooled in the Feed/Effluent Exchanger, E 3001 1/2/3, and further cooled to 48ºC and condensed in the Loop Air Cooler, AE 3002 1/2/3, and in the Loop water Cooler, E 3003 1/2/3.

The crude methanol is separated from the recycle gas in the HP Separator, D 3001, and sent to the LP Separator, D 3002.

Due to the size of the equipment part of the methanol loop has been made of three parallel trains.

The make-up gas contains a small quantity of inert gases, Ar, N2 and CH4. In order to prevent these gases from accumulating in the synthesis loop, a certain amount of gas is purged from the loop. The purge is withdrawn downstream the HP Separator, D 3001, where the inert gas concentration is highest.

After withdrawal of purge gas, the synthesis gas from D 3001 is recirculated to E 3001 by the Recirculator, C 3002.

The crude methanol, which is partly degasified in the LP Separator, D 3002 at 4.0 bar g, is sent to the Raw Methanol Buffer Tank, TK 5001.

Purge gas from HP Separator and flash gas from LP Separator and OH gas from the Stabilizer column is sent to the primary reformer H 2001 and used as fuel.

6. Unit 4000, Methanol Tank

The function of Methanol Tank TK 4001 1/2 in the Methanol Tank Unit (Unit 4000) is to store methanol product from the Methanol Distillation Section (Unit 5000).

During normal case, the methanol product from T 5002 and T 5003 is cooled, polished and sent to Methanol Product Buffer Tank TK 5002 1/2. Methanol product in TK 5002 1/2 is then pump to the tank farm outside the battery limit by Methanol Product Pump P 5008 A/B/C.

When the tank farm outside the battery limit is not available to receive methanol at some abnormal case for a short time, Methanol Product Buffer Tank TK 5002 1/2 would reach its maximum storage without sending out the methanol in it and the whole plant would have to shut down. In order to solve this problem, Methanol Tank TK 4001 1/2 is set as an alternative storage tank for the methanol product, which makes the storage time much longer. Methanol product in Methanol Product Buffer Tank TK 5002 1/2 can be sent to Methanol Tank TK 4001 1/2 via Methanol Product Pump P 5008 A/B/C. When the time of this abnormal case is shorter than the storage time of TK 5002 1/2 together with TK4001 1/2, the shutdown of the plant can be avoided.

When the abnormal case above is over, methanol in Methanol Tank TK 4001 1/2 should be sent to the tank farm outside the battery limit via Methanol Transfer Pump P 4001A/B.

Furthermore, methanol in Methanol Tank TK 4001 1/2 is also able to be transferred to Product Buffer Tank TK 5002 1/2 through a bypass in Unit 5000. Methanol in TK 4001 1/2 and TK 5002 1/2 can be transferred to each other, which makes the operation more flexible.

The methanol drain in startup or shutdown cases is routed to Methanol Tank Unit Closed Drain Drum D 4001, and sent to Raw Methanol Buffer Tank TK 5001 via Methanol Tank Unit Closed Drain Pump P 4002.

Note: T 5002, T 5003, TK 5002 1/2, P 5008 A/B/C and TK 5001 are all equipment of Unit 5000.

7. Unit 5000, Methanol Distillation Section

The crude methanol contains water and traces of reaction by-products, i.e. ethanol, higher alcohols, dimethyl ether, acetone and methyl formate. The upgrading of the crude methanol takes place in a 3-

column distillation system. The organic impurities are concentrated in a gaseous and a liquid waste stream.

7.1. Raw Methanol Tank

The crude methanol produced in the methanol synthesis loop enters the distillation section via the Raw Methanol Buffer Tank, TK 5001.

Off-spec. methanol can be recycled to the raw methanol tank and reprocessed in the distillation unit.

7.2. Vent Wash Column.

On top of TK 5001 a small Vent Wash Column, T 5004 is located.

Dissolved gases from the raw methanol will flash in T 5001 due to the low operating pressure.

The dissolved gasses from the raw methanol as well as vent gas from all the other storage tanks TK 5002 1/2 and TK 5003 are washed with excess water from the ‘MP Methanol Column’ in T 5004. Thereby methanol loss is minimized.

The vent gas from T 5004 is sent to the combustion air blower and forth to the reformer burners thereby any exhorts to surroundings are prevented.

7.3. Stabiliser Column

The main purpose of the stabiliser column is to remove the light compounds from the raw methanol. Apart from acetone and TMA, none of the light compounds are difficult to remove. TMA and acetone will leave the system via the OH gas line together with the remaining light gaseous components.

The Raw Methanol Pump, P 5001 A/B/C, feeds the raw methanol to the feed tray of the Stabilizer Column, T 5001. In T 5001 the various volatile compounds and dissolved gases are stripped off.

<u>Stabilizer column OH system:</u>
Main part of the condensable vapours in the OH stream is condensed in the Stabilizer Column OH Condenser, AE 5004.

Off-gas and OH condensate is separated in the ‘Stabiliser Column OH Accumulator’, D 5001.

By cooling the off-gas further in the ‘OH Gas Condenser’, E 5010, the methanol loss is limited. Gaseous impurities as well as light components such as acetone are removed via the OH gas stream.

The condensate from E 5010 is returned to D 5001 by gravity.

The liquid accumulated in D 5001 returned to the column as reflux by the Stabilizer Column Reflux Pump, P 5003 A/B. The overhead gas from T 5001 is condensed in the Stabilizer Column

The OH gas is used as fuel in the Primary reformer H 2001.

Stabilizer reboiler system:

The heat required for the distillation process in T 5001 is supplied by process gas in the Stabilizer Column Reboiler, E 5024 1/2.

An additional steam fired reboiler is available for start up or stand alone operation.

Steam condensate from the 'Stabilizer Column Reboiler', E 5001, is collected in the 'Steam Condensate K.O.drum', D 5009, before it is send to the Dearator by the 'Steam Condensate Pump', P 5011 A/B.

If the distillation unit is operating in stand alone mode, the steam condensate may be cooled in the 'Excess steam Condensate Cooler', E 7003 1, before it is send to the DMW Tank, TK 7001 1/2.

The bottom product, stabilized methanol, from T 5001, contains mainly methanol and water and small amounts of ethanol and other higher alcohols. The stabilized methanol is pumped by the Stabilizer Methanol Pump, 5002 A/B, to the LP Methanol Column, T 5002.

7.4. LP Methanol Column

Part of the methanol product is withdrawn from the overhead system of the LP Methanol Column, T 5002.

LP column reboilers:

The heat required for the distillation process in T 5002 is supplied by condensation of overhead vapour from T 5003 in the LP Column Reboiler, E 5002 1/2/3/4. The methanol OH vapour from T 5003 is condensed at 101ºC and the BP in the LP column is 86 ºC, thus providing sufficient margin for the reboilers.

LP column OH system:

The OH vapour from T 5002 is condensed in the 'LP Column OH Condenser', AE 5005, the condensate is collected in the 'LP Column OH Accumulator', D 5002. The liquid methanol is partly returned to the column as reflux and partly withdrawn as product. The methanol product is cooled in the 'Methanol Product Cooler No 1', E 5008, before it is sent to the product polisher.

A mixture of methanol, water and heavy by-products is removed at the bottom and sent to the MP Methanol Column, T 5003 by the MP Column Feed Pump, P 5005 A/B.

7.5. MP Methanol Column

The feed to MP methanol column T 5003 will contain the same by-products and impurities as were contained in the original inlet stream to the LP methanol column. The only difference is that it is partly depleted for methanol.

The OH vapour from T 5003 consisting of pure methanol is condensed on the tube side of the LP column reboiler E 5002 1/2/3/4, utilising the heat of condensation of the methanol OH vapours as reboiler heat for the LP methanol column.

The condensate flows by gravity and is accumulated in the 'MP column OH accumulator', D 5003.

The liquid accumulated in D 5003 is returned to the column as reflux by the MP column reflux pump, P 5006 A/B.

Three liquid product streams leave the MP Methanol Column, T 5003:

- Methanol product from the overhead system.
- Liquid off stream, i.e. Ethanol and higher alcohols, drawn off above the bottom tray. And it is atomized via FZ-6058 into the natural gas before it is send to the saturation unit. The flow is indicated by FI-6057 (P07).
- Excess water drawn off at the bottom.

Excess water

The excess water consists primarily of water with a small content, in ppm level, of methanol. Besides methanol, it may contain a small quantity of organic compounds and surplus morpholine or Na+ originating from neutralisation of raw methanol.

The 'MP Column Recycle Pump', P 5007 A/B is recycling excess water from the T 5003 sump to the T 5003 reboilers, thereby ensuring sufficient liquid to maintain the level in the reboilers.

A small stream of excess water is withdrawn from the exit of P 5007 A/B, the water is cooled in the 'Wash Water Air Cooler', AE 5006 to 65ºC and in the 'Wash Water Cooler', E 5007, to 48ºC before it is used as wash water in the 'Vent wash Column', T 5004.

The main part of the excess water is recycled to the process via the 'Excess Water Pump', P 5010 A/B and the Saturator, T 6001.

Liquid off stream:

The stream of higher alcohols withdrawn from T 5003 is cooled in the 'Liquid Off-stream Cooler', E 5011, before being stored in the 'Liquid off stream Tank', TK 5003. From the tank the liquid is pumped by the Liquid off stream pump, P 5009 A/B and subsequently added to the natural feed gas upstream the saturator.

If NaOH solution is used for neutralisation of the raw methanol, the liquid off stream must be send to BL, because Na+ is a poison to the prereformer catalyst.

OH system:

The MP Methanol Column is operated at elevated pressure so that the heat of condensation of the overhead vapours can be used for reboiling in the LP Methanol Column, which is operated at low pressure.

Reboilers:

The heat input required for the MP Methanol Column, T 5003, is supplied by condensing LP steam in the MP Column Reboiler No. 1, E 5003 1/2 and from cooling of process gas in the MP Column Reboiler No 2, E 5023.

Under normal operation steam condensate from E 5003 1/2 is returned to the deaerator. If the distillation unit is operating in stand alone mode, the steam condensate from E 5003 1/2 may be cooled in the 'Excess steam Condensate Cooler', E 7003 2, before it is send to the DMW Tank, TK 7001 1/2.

7.6. Ion Exchange unit (optional).

If NaOH solution is used for neutralization of the raw methanol the Na+ must be removed from the distillation excess water before it can be recycled to the pre-reformer because Na+ is a poison to the catalyst.

Excess water from T 5003 is

- Cooled to 62ºC in the 'Feed/Effluent Excanger', E 5014.
- Further cooled to 43ºC in the 'Excess Water Cooler', E 5015.
- Na+ is removed in the 'Ion Exchange Unit', X 5004.
- The water is collected in the 'Excess Water Drum', D 5010, by natural gravity.
- The pressure is increased by the 'Excess Water Pump', P 5010 A/B ALT.
- The purified excess water is heated to 130 ºC in the feed/effluent exchanger before it is send to the saturator

If morpholine is used for neutralization of the raw methanol the 'Ion Exchange Unit', X 5004, is NOT required.

7.7. Methanol Product

The methanol product from T 5002 and T 5003 is cooled in the Methanol Product Coolers, E 5008 and E 5012, and polished in the Product Polishing Unit, X 5001 A/B, before being sent to Methanol Product Buffer Tank TK 5002 1/2.

The product polisher contains a bed of amberlyst 15, wet used for removing the remaining TMA. From the tank Methanol is pump to battery limit by Methanol Product Pump, P 5008 A/B/C.

8. Unit 7000, Steam System

8.1. DMW storage

Demineralised water from the BL is stored in the 'Demineralised Water Tanks'. TK 7001 1/2. The 'Demineralised Water Pumps', P 7002 A/B sends DMW from storage tanks to the 'DMW Preheater', E 2025 where the DMW is heated from 35ºC to 72ºC. From E 2025 the DMW is sent to the 'Deaerator', D 7001.

8.2. BFW preparation.

In D 7001 oxygen is stripped from the DMW by steam. A continuous purge of steam is vented from D 7001.

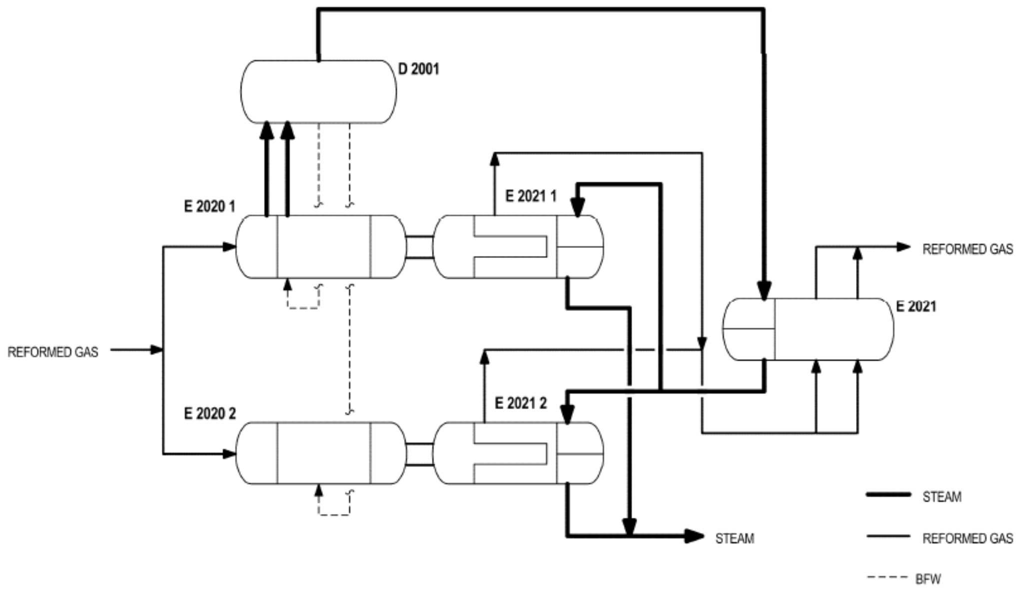
Steam condensate from the plant is returned to D 7001, to be reused as BFW but steam condensate does not need to be deaerated.

Steam condensate from turbine condensers is send to Unit 7200, Polishing Unit to avoid impurities in steam system.

BFW from the Deaerator is pumped by BFW pump, P 7001 A/B/C, BFW from P 7001 A/B/C is then distributed to the steam drums, D 2001 and D 3003.

8.3. HHP Steam generation

HHP steam is generated in the two parallel waste heat boilers, E 2020 1/2, at approx 102 bar g. The steam is superheated to 338ºC in the steam super heater E 2021 3 and then further to 460ºC in E 2021 1/2.



8.4. HHP steam header.

HHP steam is used in the turbine driver for the Synthesis Gas Compressor, C 3001 and the Recirculator, C 3002. Excess steam is quenched to 410ºC, depressurized to 43 bar g and exported.

8.5. HP steam header

Superheated HP steam at 345ºC and 44 bar g is extracted from the Steam Turbine FT 3001-1. HP is used in:

- Turbine FT 7001 A/B for driving the BFW Pump P 7001 A/B
- Turbine FT 2001 for driving the Flue Gas Blower
- Turbine FT 2002 for driving the Combustion Air Blower

- Turbine FT 0501 1/2 for driving the cooling water pumps
- Process steam to achieve a steam to carbon ratio of 1.8
- Burner protection steam for R 2004
- Heating of process oxygen in the Oxygen Preheater E 2008

8.6. MP steam header

Saturated MP steam is generated in the Methanol Reactor at approx. 34-41 bar g. The header pressure is determined of the age of the methanol synthesis catalyst. MP steam is used as heat input to the Saturator. HP steam may be quenched down to MP steam if required. Surplus MP steam is quenched down to LP steam.

8.7. LP steam header

LP Steam at 180 ºC and 7.0 bar g extracted from the Turbines; FT 3001, FT 2001, FT 2002 , FT 7001 and FT 0501 1/2 is used in

- E 5001, Stabilizer Column Steam Reboiler.
- E 5003 1/2, MP Column Reboiler No 1.
- Heat input for the Deaerator.

9. Unit 8500, Flare System

The flare system is to be designed for collecting all combustible gases and liquids which are discharged in case of emergencies, equipment malfunctions, etc.

Released to flare may be expected during plant start-up, plant shut-down or during an upset when the plant is not in balance or when part of the plant is shut down or tripped.

In case the methanol synthesis is not able to consume the gas available, it will be flared up stream that section.

In case of a trip of either the complete plant or plant section, some release to flare will occur due to depressurisation of some sections.

In case of fire, release to flare may occur due to manual activation of trip, due to manually controlled depressurisation or due to release through safety valves .

Release through the safety valves may also occur as a result of the other contingencies considered for the safety valves, for instance blocked outlet, gas break-through, etc.

9.1. Design Condition

9.1.1. Plant start-up and shut-down

When the reforming section is started up or shut down, the desulphurisation section and reforming section may operate at different capacities. This will result in flaring of excess natural gas from the vent valve, PV-1045 (1000-PID-003), downstream of the desulphurisation section or PV-2073 (2000-PID-003),downstream to the saturator.

Throughout the start-up sequence of the reforming unit and until the reformed gas can be sent to the methanol synthesis, reformed gas will be flared from the vent valve, PV-2481 (2000-PID-016), downstream of Final Separator, D 2005.

During start-up of the methanol synthesis, the purge gas from the synthesis section will be sent to flare via, PV-2536B (2000-PID-17), until stable operation has been obtained and the gas can be sent to the fuel gas header.

The plant sections may be shut-down in the opposite sequence of the start-up resulting in the feed gas to the plant section being temporarily flared.

9.1.2. Plant Trip

If the plant trips the reforming section and the methanol synthesis will be depressurized automatically by discharging the gas to the flare. The other sections will remain under pressure until it is decided to depressurise these sections.

In case of trip of the methanol synthesis section, the reforming section will continue operation and the excess reformed gas will be released via vent valve, PV-2481 (2000-PID-016), to flare.

9.1.3. PSV contingencies

In case of fire, release to the flare system through safety valves will occur only if the equipment heated by the fire is isolated and the temperature increase causes the system pressure to increase to the relief pressure of the safety valves. It would be expected that the plant is tripped and the system pressure decreased through the vent valves discharging to the flare system.

9.2. Location layout description

The flare system at MKP Methanol Project Plant consist one flare, which will collect emergency and continuous release. The Tie-In point of this plant to offsite is at northeast of this unit. The mentioned flare header with all utility lines/cables will locate at west side of road I2 and after passing the utility corridor and main road, goes to the flares area. The stack of MKP Methanol Project will be located at north of IGAT.

10. Unit 0500, Cooling Water Unit

The open type cooling water system is applied for the MKP Methanol project, that include the counter flow mechanical draft type cooling tower, cooling water pumps, side filter, inhibitor and dispersant dosing facility. The normal cooling water demand is 11694m^3/h and the max demand is 13477m^3/h.

Meteorological parameters for cooling tower design follows the air conditioning design meteorological data:

- Dry bulb temperature 48℃
- Wet bulb temperature 33℃
- Barometric pressure 990~1100 bar
- The cooling water system operating data as follow:
- The normal cooling water demand is 11694m^3/h
- The maximum cooling water demand is 13477m^3/h

Technological parameters for cooling water system as follows:

- *Cooling water supply pressure*(B.L. of Process Unit) *4.5Barg*
- *Cooling water return pressure*(B.L. of Process Unit) *2.5Barg*
- Cooling water supply temperature 38℃
- Cooling water return temperature 48℃
- Concentration ratio 4
- Makeup water normal consumption 246m^3/h
- Makeup water max consumption 283m^3/h
- Normal blow down 37m^3/h
- Max blow down 43m^3/h

The heated circulating water returns into the cooling tower by residual pressure, and goes through the packing then into the water pond (PD 0501) after heat exchange with air. The cooling water is delivered to the user by the cooling water supply pumps(P0501 1/2, P0502 A/B). Screen will be installed on the suction pit and conical strainer will be installed in suction pipe of cooling water pump. The makeup water source of the cooling water system is the pretreated water. The blow down is pumped to the clean salty water piping system and finally discharged to the outside of the plant

Two rows of side filters are applied for cooling water system and each row consists of 8 sets of filters. When the pressure difference of filter arrives at 0.5bar, the automatic valve on the outlet will be closed. At the same time, the 3-way valve of the first filter will shift to the backwash channel. The backwash water will be drained to Clean Salty Water Pond PD 0502 from the outlet of 3-way valve. After the backwash procedure, 3-way valve will shift the inlet direction. The backwash for 8 sets of filters will be finished one by one, and then the valve on the outlet will be open.

Chemical dosing facility is applied for the cooling water system, that intends to prevent scaling, corrosion and deposit. And the sodium hypochlorite is added intermittently for control of biological growth.

The chemical dosing system includes NaClO solution, inhibiter solution, antiscale solution and H_2SO_4 dosing system.

Main equipment technological parameters as follows:

Cooling tower(T0501A/B/C/D), four cells, three run and one standby, the capacity of each cell: Q=4500m3/h. The clapboard material is reinforced concrete and the maintenance structure is FRP. The size of each tower will be 17000x17000mm.

Fan, four sets, three run and one standby, design parameters of each fan: D=9.75m, P=200kW. Three are running and one is standby.

Cooling water pump(P0501 1/2), two sets, two run, steam turbine driven, design parameters of each pump: Q＝4500m^3/h, H＝55m.

Cooling water pump(P0502A/B), two sets, one run and one standby, electric driven, design parameters of each pump: Q＝4500m^3/h, H＝55m, P＝1120kW.

Side filter, two groups, the filter capacity is 320m^3/h.

More details please refer to P&ID for Cooling Water Unit (MKP-11-AS-0500-PR-PID-001~006) and Equipment Layout of Cooling Water Station (MKP-11-AS-0500-PI-LYT-013).

11. Unit 7200, Polishing Unit (Unit No. 7200)

Process condensate water is polished and pumped to DMW user after mixed with DMW from DAMAVAND Petrochemical Company. Process condensate water polishing capacity is 94 m^3/h~103 m^3/h and DMW capacity from DAMAVAND Petrochemical Company is 119 m^3/h. The DMW feeding capacity from polishing unit is 211m^3/h~220 m^3/h.

11.1. Process Description

According to the condensate quality analysis, the scheme of cartridge filter + heat exchanger + ion exchanger will be adopted for the project, the simple process is as following:

The condensate water @52℃ will firstly be filtrated by cartridge filter X 7201 A/B. When the DPI of filter arrived at 2bar, it should alarm and operator will change filtration elements. The condensate will be cooled down to 40℃ through heater exchanger by cooling water. After storaged in intermediate tank, the condensate water will be pumped to mixed-ion exchanger. Qualified DMW will be storaged in 2 sets of Demin Water Tank and then pumped to user through demin water pumps.

Demineralized water from DAMAVAND Petrochemical Company complied with the requirement of TOPSOE, it will be fed into demin water tank and then be pumped to user mixed with treated condensate water.

11.2. Pre-treated section

One cartridge filter is installed to remove FexOy. The filter capacity is 105m3/h and composed of SS304 shell and 6”x60” PP filter element. 6μm precision filter element will be adopted for cartridge filter. There are two pressure gauge installed between inlet and outlet. Once pressure difference reaches 2 bar, the filter element will be changed.

Then the condensate water will be cooled down by plate heat exchangers. Two sets of plate heat exchanger are designed, one run and one standby. The outlet of condensate wat*er will* be 40℃.

11.3. After-treatment Section

After cooled down, the condensate water will be stored in intermediate water tank and pumped to mixed-ion exchangers.

There are two mixed-ion exchangers, one operation and one standby at 100% capacity. Residual cation and anion can be almost simultaneously exchanged with the cation and anion resin to obtain a qualified demineralization water.

Set flow gauge on mixed-ion exchanger inlet pipe, set pressure difference gauge at inlet and outlet pipe, set SiO_2 gauge at outlet pipe, when the pressure difference between inlet and outlet increases to the set point or the conductivity reaches the set point, the mixed-ion exchanger will be started to regeneration. Resin trap will be installed in the discharege pipe of mixed-ion exchanger to prevent the resin leakage.The in-place regeneration is used for the mixed-ion exchanger, 3% HCl solution and 3% NaOH solution will be utilized as regeneration chemical agents. When the mixed-ion exchanger resin invalid, backwash the resin to make it expansion, the anion resin will lie in the upper layer and the cation resin in the lower layer in the mixed-ion exchanger because of the different resin density. The NaOH solution is fed into the mixed-ion exchanger from the top and the HCl solution from the bottom, the cation and anion resin will be respectively regeneration at the same time. Then the cation and anion resin will be washed with demin water and the regeneration and washing wastewater will be discharged via the middle pipe outlet of mixed-ion exchanger. After the regeneration, the cation and anion resin are mixed with compressed air for next operation. These two mixed-ion exchanger will not be regeneration at the same time.

The product water from mixed-ion exchanger flows into the demineralization water tanks for storage. The effective volume is 2x3500m^3. There are two demineralization water pumps with capacity 265m3/h@H85m. Set the pH gauge, conductivity gauge, SiO_2 gauge, flow gauge, pressure gauge in the demineralization water pipe.

11.4. Acid and Alkali Regeneration Section

The regeneration acid and alkali adopt 30% concentration HCl and NaOH, which are carried by the tanker to the polishing unit and unloaded to the acid and alkali metering box by transfer pump. The metering box liquid level is interlocked with the transfer pump. On-off valve is set on outlet of metering tank, the outlet is connected with ejector, the inlet of ejector is connected with regeneration pump discharge pipe. Alkali or acid is sucked via pressure water and concentration of 3% solution is prepared. 3% alkali or acid solution will be ejected to mixed-ion exchanger. Concentration meter is set on ejector outlet to on-line monitor the concentration of regeneration solution. Start or stop the regeneration pump and open or close the outlet valve of metering tank are controlled by the mixed-ion exchanger operation sequence program. Volatile acid should be collected and treated in acid mist eliminator.

11.5. Wastewater Collection Section

The mixed-ion exchanger regeneration wastewater, acid and alkali dike drain, discharge of acid mist absorber will be discharged into neutralization water basin by trench.

There are two neutralization water discharge pumps, one operation one standby. Set the backflow pipe at the outlet pipe of pump and lead compressed air to basin, that can fully mixed the wastewater with dosing acid and alkali.

pH gauge is set in the pump outlet pipe and the dosing is calculated quantity according to pH value. The valves can be controlled manually according to the remote signals to adjust the doses. When pH reaches to the range 6.5~9, open the discharge valve of the neutralization water pump and close the backflow valve, then the wastewater will be discharged to the wastewater underground piping system. The water level is set to be interlocked with the pumps. The neutralization water pump stops when the water level reaches to the set low value.

12. Unit 9400, Water Supply & Drainage for Whole Plant

12.1. Potentially Oily Contaminated water (POC)

The POC network collects surface water run-off from areas that are at risk of hydrocarbon contamination as a result of spillage or malfunction. Normally contamination would be light to nil and can be handled in a light treatment to produce re-usable water.

The sources of POC waters are mainly those listed hereafter and results from rain fall water and wash water for:

Paved process areas

Road trucks or tankers loading and unloading areas

Off-spec steam condensates, with limited oily or salty contamination.

POC storm basins will be settled which based on the recovery of the first 25mm of rain water in polluted area by rain ditch. The excess rain water is considered as clean water and shall be overflow to external rain ditch and then this water discharged directly to sea. Two pumps will be set at each storm basin, one run, one standby, which pump the polluted rain water to outside treatment facilities after the rain stop.

12.2. Continuously Oily Contaminated water and process effluents (COC)

These effluents are those which are continuously contaminated and need a complete OSBL treatment before rejection. Main sources are:
Miscellaneous process effluents and drains.
Process steam blow down effluents in Plant,
Oily water from hydrocarbons storage tanks de-watering,
Water from flares seals drums.
COC will be collected and pump to DAMAVAND Petrochemical Company by pipe rack.

13. Unit 8000, Pipe rack and pipe net system

Plot shows that the plant is divided into many areas as listed in Table.1. In plant, pipe rack and pipe net connect the different unit and deliver process stream and utility stream.

Table.1

AREA NO.	UNIT NO.	UNIT
2000	2000(include 1000\2000\6000\7000)	Reformer
3001,3002	3000	Methanol synthesis
4000	4000	Methanol tanks
5001,5002,5003	5000	Distillation Unit
7200	7200	Polishing unit
8000	8000	Pipe rack and pipe net
8500	8500	Flare
0201	0201	MCC substation
0202	0202	Control room
0203	0203	Lab
0500	0500	Cooling water Unit

There are two main process pipe nets in the plant:
One is from west to east between 3001/3002/5001 area and 2000/5003 area
Another is from south to north between 3001 area and 3002 area

Furthermore, there are two Tie-In points in plant. One is at the southeast of this plant, which is not only the entrance of utilities and natural gas but also the export of methanol production; Another Tie-In point is Flare line which will collect emergency and continuous release, and the Tie-In point of this plant to offsite is at northeast of the plant.

References	Topsøe drawing number
Process description	4338815
Process flow diagrams	
End of run (EOR) Lean gas with feed gas scrubber	
DESULPHURIZATION AND REFORMING	1423711
PROCESS GAS COOLING	1423712
METHANOL SYNTHESIS LOOP	1423713
DISTILLATION - PART 1	1423714
DISTILLATION - PART 2	1423715
SATURATOR	1423716
STEAM BALANCE	1423717
BLOCK DIAGRAM	1423718
Start of run (SOR) Lean gas with feed gas scrubber	
DESULPHURIZATION AND REFORMING	1423743
PROCESS GAS COOLING	1423744
METHANOL SYNTHESIS LOOP	1423745
DISTILLATION - PART 1	1423746
DISTILLATION - PART 2	1423747
SATURATOR	1423748
STEAM BALANCE	1423749
BLOCK DIAGRAM	1423750
End of run (EOR) Rich gas with feed gas scrubber	
DESULPHURIZATION AND REFORMING	1423775
PROCESS GAS COOLING	1423776
METHANOL SYNTHESIS LOOP	1423777
DISTILLATION - PART 1	1423778
DISTILLATION - PART 2	1423779
SATURATOR	1423780
STEAM BALANCE	1423781
BLOCK DIAGRAM	1423782
Start of run (SOR) Rich gas with feed gas scrubber	
DESULPHURIZATION AND REFORMING	1423807
PROCESS GAS COOLING	1423808
METHANOL SYNTHESIS LOOP	1423809
DISTILLATION - PART 1	1423810
DISTILLATION - PART 2	1423811
SATURATOR	1423812
STEAM BALANCE	1423813
BLOCK DIAGRAM	1423814