LABORATORY MANUALS

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Z01	30.04.2020	As built	Yi Hui	Wu Jinling	Qiu Yuxin	
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1. General information

In the following a brief description of the analytical methods is given:

Ref. 1 Annual Book of ASTM Standards, latest edition

Ref. 2 Betz Handbook of Industrial Water Conditioning, 9th Edition, 1991,

Betz Laboratories Inc., Trevose, PA 19053, USA

Ref. 3 Standard Methods for the Examination of Water and Waste Water,

American Public Health Association, Washington D.C., USA

Ref. 4 NIOSH Manual of Analytical Methods,

U.S. Department of Health, Education, and Welfare, Cincinnati, Ohio, USA

The ASTM methods are generally recommended when applicable since they are more widely recognised.

2. Analytical methods

2.1. ASTM D888

Standard method for determination of dissolved oxygen in water.

2.2. ASTM D1067

Standard Test Methods for Acidity or Alkalinity of Water

2.3. ASTM D1070

Standard Test Methods for Relative Density of Gaseous Fuels.

The specific gravity of gases can be determined by analysis as described in this standard method.

2.4. ASTM D1126

Standard Test Method for Hardness in Water

2.5. ASTM D1252

Standard Test Methods for Chemical Oxygen Demand (Dichromate Oxygen Demand) of Water

2.6. ASTM D1253

Standard Test Method for Residual Chlorine in Water

2.7. ASTM D1293

Standard Test Methods for pH of Water

2.8. ASTM D1296

Standard Test Method for Odor of Volatile Solvents and Diluents

2.9. ASTM D1353

Standard Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products

2.10. ASTM D1385

Standard method for hydrazine in water.

2.11. ASTM D1613

Standard Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer, and Related Products

2.12. ASTM D1614

Standard Test Method for Alkalinity in Acetone

2.13. ASTM D1945

Standard method for analysis of natural gas by gas chromatography.

2.14. ASTM D1946

Standard method for analysis of reformed gas by gas chromatography.

2.15. ASTM D2036

Standard method for analysis of cyanide in water by ion selective electrode.

2.16. ASTM D3561

Standard method for determination of sodium and potassium content in water by means of atomic absorption spectrophotometer.

2.17. ASTM D3588

The heating value and the specific gravity can be calculated on the basis of the composition, using physical constants of hydrocarbons, as described in this standard method.

2.18. ASTM D3695

Standard Test Method for Volatile Alcohols in Water by Direct Aqueous-Injection Gas Chromatography

2.19. ASTM D3921

Standard Test Method for Oil and Grease and Petroleum Hydrocarbons in Water

2.20. ASTM D4327

Test method for anions in water by ion chromatography..

2.21. ASTM D5453

Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence

2.22. ASTM D5504

Standard Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence

2.23. ASTM D5907

Standard Test Methods for Filterable Matter (Total Dissolved Solids) and Nonfilterable Matter (Total Suspended Solids) in Water

2.24. ASTM D6228

Standard Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Flame Photometric Detection

2.25. ASTM D7315

Standard Test Method for Determination of Turbidity Above 1 Turbidity Unit (TU) in Static Mode

2.26. ASTM E200

Standard Practice for Preparation, Standardization, and Storage of Standard and Reagent Solutions for Chemical Analysis

2.27. ASTM E203

Test method for water using Karl Fischer reagent.

2.28. ASTM E346

Standard method for analysis of methanol.

2.29. ASTM E2313

Standard Test Method for Aldehydes in Mono-, Di-, and Triethylene Glycol (using Spectrophotometry)

2.30. O-M-232

Federal Specification Methanol (Methyl Alcohol)

2.31. ISO 7393-2

Water quality -- Determination of free chlorine and total chlorine -- Part 2: Colorimetric method using N,N-diethyl-1,4-phenylenediamine, for routine control purposes

2.32. Note 1:

The composition of various process gases is determined by means of a gas chromatography or by the classical Orsat method. For flue gas analyses, the Orsat method is suitable. Small quantities of CO, CO_2, NH_3 and H_2S can be determined by means of the so-called "sniffer", a handy laboratory apparatus that is available from several suppliers, for instance:

- DRAEGER WERK

Moislinger Allee 53-55

D-23558 Lübeck

Germany

- MINE SAFETY APPLIANCES COMPANY INC.

MSA Building

P.O. Box 426

Pittsburg, PA 15230

USA

Composition of reformed, shifted and washed process gas is determined by gas chromatography, as described in ASTM designation D 1946.

Traces of CO and CO_2 in gases, Topsøe AM-1233.

2.33. Note 2:

Hydrochloric Acid is determined by titration with standard sodium hydroxide using phenolphthalein indicator solution.

2.26.1 The standard sodium hydroxide （1mol/L）is prepared according to ASTM E200

2.26.2 Phenolphthalein Indicator Solution (10 g/L)—Dissolve 1 g of phenolphthalein in 100 mL of ethanol (95 %).

2.26.3 Procedure: add 2 drops of phenolphthalein indicator solution to the specimen and titrate with standard NaOH solution to a pink color or accord to the indication of titrator.

2.26.4 Calculate the concentration of the HCl solution, as follows:

$$C1 = \frac{C2 * V2}{V1}$$

where:

C1 = molar concentration of HCl solution, mol/L

C2 = molar concentration of NaOH solution, mol/L

V1 = volume of HCl solution, mL

V2 = volume of NaOH solution consumed, mL

2.34. Note 3:

Sodium hydroxide is determined by titration with standard hydrochloric acid using methyl red indicator solution.

2.27.1 The standard hydrochloric acid solution （1mol/L）is prepared according to ASTM E200.

2.27.2 Methyl Red Indicator Solution (1 g/L)—Dissolve 1 g of methyl red in 1 L of ethanol (95 %).

2.27.3 Procedure: add 2~3 drops of methyl red indicator solution to the specimen and titrate with standard HCl solution to a red color

2.26.4 Calculate the concentration of the HCl solution, as follows:

$$C1 = \frac{C2 * V2}{V1}$$

where:

C1 = molar concentration of NaOH solution, mol/L

C2 = molar concentration of HCl solution, mol/L

V1 = volume of NaOH solution, mL

V2 = volume of HCl solution consumed, mL

2.35. Topsøe Analytical Method No. 1021

Copper in the range of 0.002 to 0.2 mg Cu/l can be determined by a colorimetric test as copper ions react with sodium diethyl dithio carbamate under the formation of a yellow complex. As ferric ions in the sample interfere with the test, these ions are fixed by addition of citric acid. The intensity of the colour formed is measured by means of a photometer. (Enclosed in the appendix).

One method for determination of iron is based on the development of an orange-red complex from the reaction of ferrous iron with phenanthroline. The intensity of the colour produced is measured by means of a filter photometer or a spectrophotometer (Atomic Absorption Spectroscopy, AAS). Similar methods can be applied also for the determination of chromium and nickel. For this reference is made to instructions by the supplier of AAS equipment. (Enclosed in the appendix).

2.36. Topsøe Analytical Method No. 1026

This test is based on the development of an orange-red complex from the reaction of ferrous iron with phenanthroline. A filter photometer or a spectrophotometer is used at a wave length of 510 nm and a minimum light path of 10 mm. The values of iron in parts per million are read directly from calibration curves.

2.37. Topsøe Analytical Method No. 1077

Soluble silica is determined by the formation of the yellow silica-molybdate complex, followed by reduction to the molybdate blue colour. The blue colour produced is proportional to the silica content and is measured by means of a filter photometer. (Enclosed in the appendix).

2.38. Topsøe Analytical Method No. 1131

Determination of methanol in gases by means of gas chromatography. (Enclosed in the appendix).

2.39. Topsøe Analytical Method No. 1132

Determination of hydrocarbons C1-C9 in gases by means of gas chromatography. (Enclosed in the appendix).

2.40. Topsøe Analytical Method No. 1133

Determination of methanol in water by means of gas chromatography. (Enclosed in the appendix).

2.41. Topsøe Analytical Method No. 1158

Determination of trace amounts of hydrocarbons in methanol by means of gas chromatography. (Enclosed in the appendix).

2.42. Topsøe Analytical Method No. 1160

The steam-to-carbon ratio inlet the steam reformer can be calculated on the basis of the dry gas composition and the shift and reforming equilibrium data.
The calculation method is described in this Topsøe method attached in the appendix.

2.43. Topsøe Analytical Method No. 1191

The conductivity of water and condensate is measured by means of a conductivity meter.(Enclosed in the appendix).

2.44. Topsøe Analytical Method No. 1246

Determination of methane sulphonate, CH3SO3 -, fluoride, F-, acetate, CH3COO-, formate, HCOO- in liquid or solid samples. The method can also be used for other weak ions. It is based on

ion chromatography separation of anions in basic borate solution and detection by conductivity.

2.45. Topsøe Analytical Method No. 1303

Determination of impurities in methanol by means of gas chromatography. (Enclosed in the appendix).

2.46. Topsøe Analytical Method No. 1304

Determination of methylamine, dimethylamine and trimethylamine in methanol by means of gas chromatography. (Enclosed in the appendix).

2.47. Topsøe Analytical Method No. 1434

Determination of formate, formamide, acetate and fluoride by ion chromatography

2.48. SP-693-EN

Determination of Dimethylether (DME) and Methanol in Gases (LP 1131)

3. Appendix

1. 2000/E List of analytical methods

2. 1021/E Determination of Copper in Water

3. 1026/E Determination of Iron in Water

4. 1077/E Determination of Soluble Silica in Water

5. 1132 Determination of Hydrocarbons C1-C9 in Gases

6. 1158 Determination of Trace Amounts of Hydrocarbons in Methanol

7. 1160/E Determination and calculation of the steam to carbon ratio for reformer feed gas

8. 1191/E Conductance (specific) of boiler water and steam condensate

9. 1434/E Determination of formate, formamide, acetate and fluoride by ion chromatography

10. 1304 Determination of Impurities in Methanol by Ion Chromatography

11. SP-693-EN Determination of Dimethylether (DME) and Methanol in Gases (LP 1131)

Preliminary Plant Operation Manual

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Chapter 1 Introduction

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Reference documents:

Below we have listed reference documents, which are issued as part of the project. These have been referred to in the manual. However the manual will not include these documents again. Appendices listed in the individual chapters will however be included in the manual.

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51	Process specification for H 2001 Primary reformer	4338806	4
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1 Introduction

This methanol plant is designed based on Haldor Topsøe A/S (HTAS) technology.

The production of methanol is based on natural gas; operation with both lean and rich natural gas is foreseen.

The capacity of the plant is 5,000 MTPD of methanol.

The following units are included in the 'methanol plant':

- Unit 1000: Desulphurization of natural gas.
- Unit 2000: Reforming section.
- Unit 3000: Methanol synthesis
- Unit 4000: Methanol Tank
- Unit 5000: Distillation section.
- Unit 6000: Saturation section.
- Unit 7000: Utilities.
- Unit 8000: Pipe rack and pipe net
- Unit 8500: Flare

- Unit 7200: Polish Unit
- Unit 0500: Cooling Water Unit
- Unit 9400: Water Supply and Drainage for the Whole Plant
- Unit 0300: Foam Station

This manual includes descriptions, instructions and guidelines for start-up, operation and shut-down of the plant.

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Chapter 2 Process Description

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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:

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

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.

Excess condensate:

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) $C_nH_m + n\,H_2O \rightarrow (n + \frac{1}{2}m)\,H_2 + n\,CO$

(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) $C_nH_m + n\,H_2O \rightarrow (n + \frac{1}{2}m)\,H_2 + n\,CO$

(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.

Stabilizer column OH system:

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.

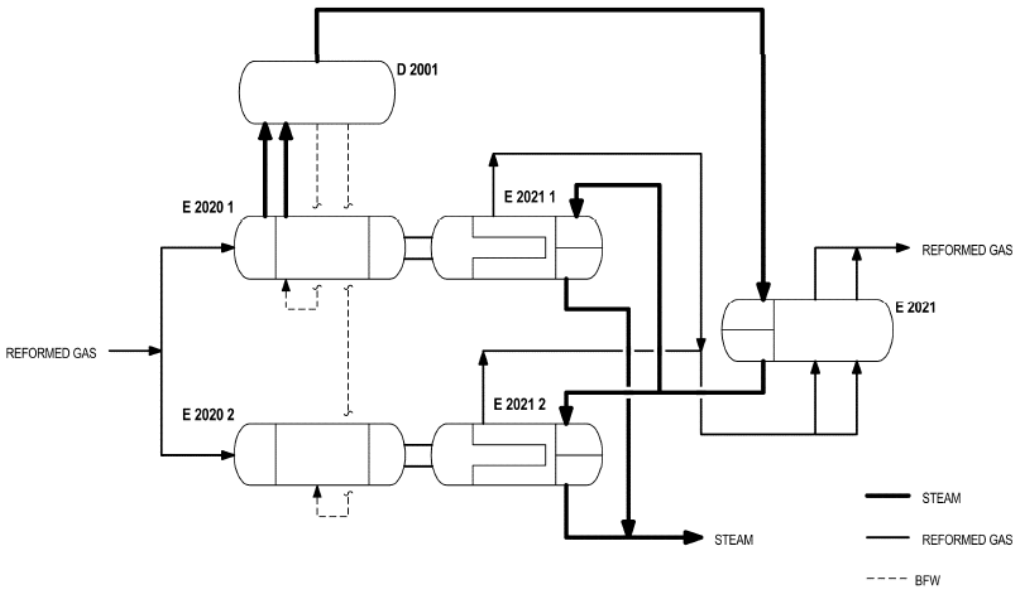
Steam condensate from the plant is returned to D 7001, to be reused as BFW but steam condensate does not need to be deaerated.

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

Preliminary Plant Operation Manual

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Chapter 3 Description of Process Control

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REVISION INDEX

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8	X				41	X								
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References

- Piping and instrument diagrams
- Utility diagrams
- Description of load and temperature Management (Topsoe Doc no.J66750)

3 Description of process control

3.1 General

This chapter contains a description of the normal operation of various equipment and instruments within the methanol plant. For a detailed description of turbines, compressors and pumps reference is to be made to the operating manuals prepared by the suppliers.

The information presented below gives some of the main functions of various instruments installed in the plant. The purpose of the text is to give the reader an overview of the normal operation, control and design philosophy of the plant in conjunction with the process flow sheet, process description and piping and instrument diagrams.

In addition, the unit is designed with a Load and Temperature Management (LTM) system, which allows capacity control with change of only one parameter – plant capacity by HIC-6067 – and it is described in Description of load and temperature management .

3.2 Desulfurization and reforming section

3.2.1 Natural gas feed from BL

Natural gas for the plant arrives at battery limit at a pressure of 54.1 to 62 barg. PT-8308 (8000-PID-001) shows the pressure of the natural gas at BL, PT-8308 is equipped with both low and high alarm.

Natural gas first flow into gas station, to be filtered, metered and regulated. The natural gas is metered by ultrasonic type flow meter FT-1915/1925, and regulated by self-operated type regulator PCV-1916/1926. Natural gas flows out gas station at a constant pressure of 52 barg. The self-operated slam shut-off valve USV-1915/1925/1935 in gas station could be shut-off at high high pressure and low low pressure case.

The pressure controller PIC-1006 (1000-PID-002 / P01) is located downstream the Natural Gas K.O. Drum, D 1001; it maintains a constant pressure of 50 barg of the natural gas into the desulfurization unit.

3.2.2 Preheating of natural gas

The natural gas/hydrogen mixture is preheated to

- 250°C in the 1st Natural Gas Preheat coil, E 2006, temperature is shown by TI-2149 (2000-PID-006 / P12).
- 380°C in the 2nd Natural Gas Preheat coil, E 2004, temperature is shown by TIC-2220 (2000-PID-007/P13).

The coils are located in the flue gas waste heat section of the Primary Reformer, H 2001.

The temperature out of E 2004 is controlled by TIC-2220 via a by-pass over E 2006.
High temperature alarms are foreseen on both TI-2148 and TIC-2220.

TIC-2220 is also foreseen to have a low temperature alarm, to ensure that the temperature is high enough to convert organic sulfur into H_2S in the Hydrogenator, R 1001.

3.2.3 Recycle hydrogen header

(2000-PID-019 / U17)

Methanol loop purge gas:
Methanol loop purge gas is used as recycle hydrogen during normal operation. The pressure in the hydrogen header is maintained by PIC-2608. Flow is indicated by FI-2607.

Recycle of reformed gas:
When the methanol loop is not in operation reformed gas from D 2005 is used as recycle hydrogen. The recycle hydrogen is pressurized in the Hydrogen Recycle Compressor, C 2002, before it is passed to the hydrogen header.

3.2.4 Addition of recycle hydrogen

(2000-PID-006 / P12)
Recycle hydrogen is added to natural gas at the inlet E 2004 to provide hydrogen for the hydrogenation of organic sulfur in the hydrogenator.

- FI-2151 shows the natural gas feed flow from D 1001.
- FIC-2150 controls the flow of recycle hydrogen from hydrogen header.
- The H2/NG ratio is set by the operator via HIC-2151
- FY-2151 calculates the required hydrogen recycle gas flow by multiplying the requested H2/NG ratio with the NG flow. The calculated hydrogen recycle gas flow is given to FIC-2150 as the set point.
- FFY-2152 calculates the actual H2/NG ratio and FFI-2152 displays the value.

FIC-2150 is equipped with both low alarm and deviation low alarm, which will warn the operator if the hydrogen recycle flow becomes too low, these alarms are to prevent the prereformer catalyst from being poisoned by sulfur.

3.2.5 Desulfurization section

(1000-PID-003 / P04)
In the Hydrogenator, R 1001, organic sulfur compounds are converted into H_2S which is then absorbed on the downstream Sulfur Absorbers, R 1002 1/2.

Online total sulfur analyzer AI-1045 is located downstream R 1002 2 and it is equipped with high alarm.

The vent valve PV-1045 located downstream the Sulfur Absorber, R 1002 2, is used during start-up of the desulfurization unit. By venting the natural gas until the desulfurization section is properly operating, slippage of sulfur to downstream piping and equipment is prevented. PIC-1045 is used for pressure control in the desulfurization section during start up.

In case trip of interlock IS-1: trip of primary reformer, FV-6070 (6000-PID-003, P07) closes and the natural gas flow through the saturator unit is stopped.

When FV-6070 is closed, pressure will increase and PIC-1045 will open the vent valve PV-1045. Operator must maintain natural gas flow through the natural gas preheat coils, E 2004 and E 2006 as long as required to protect the coils against elevated temperatures.

3.2.6 Liquid off-stream injection.

(6000-PID-003 / P07)
Liquid off stream (higher alcohols plus water) from the methanol distillation unit is sprayed into the natural gas line between R 1002 2 and E 6001 by the spray nozzle FZ-6058. The length of straight pipe required downstream the injection point must be specified by the spray nozzle vendor in order to have proper mixing of fluids. The liquid off stream flow is shown by FI-6057 A/B/C.

The liquid off-stream to natural gas plus recycle hydrogen ratio is calculated in FFY-6059 and shown in FFI-6059 which has a high ratio alarm to alert the operator. The reason for the alarm is that the liquid off stream contains higher alcohols, which will react to form solid carbon in the reformer if the concentration of higher alcohols in the feed gas is too high.

Sodium hydroxide solution is used for neutralization of raw methanol. The feed gas outlet the saturator is scrubbed in the Feed Gas Scrubber Separator D 6001.Thereby sodium, which acts as a poison to the reformer catalyst, is eliminated.

3.3 Plant capacity

The capacity of the front end is set by FIC-6070 (6000-PID-003 / P07) located upstream the injection of liquid off stream from the distillation unit.
FIC-6070 is provided with a low flow alarm
When the LTM is enabled, capacity is set by HIC-6067

3.4 Saturator unit

(6000-PID-001~004 / P05~08)

3.4.1 Process water

The various sources in the plant from where the process water can be sent to the saturators are

a) Process condensate from the process condensate pumps P 2001 A/B, P2002 A/B and P 2003 A/B

b) Excess water from the distillation section
c) Excess condensate from Process Condensate Buffer Tank, TK 7002
d) BFW from Header.

Process condensate

Process condensate from the process gas cooling train is sent to the saturators through the particle filters, X 6001 A/B and X 6002 A/B. The filters can be cleaned during normal operation as two parallel filters are foreseen for each.

Pressure drop across the filter X 6001 A/B in operation is shown on PDI-6028 (6000-PID-002 / P06); a high alarm is foreseen to warn the operator that the filter needs to be cleaned.

Pressure drop across the filter X 6002 A/B in operation is shown on PDI-6057 (6000-PID-003 / P07); a high alarm is foreseen to warn the operator that the filter needs to be cleaned

Excess water from distillation

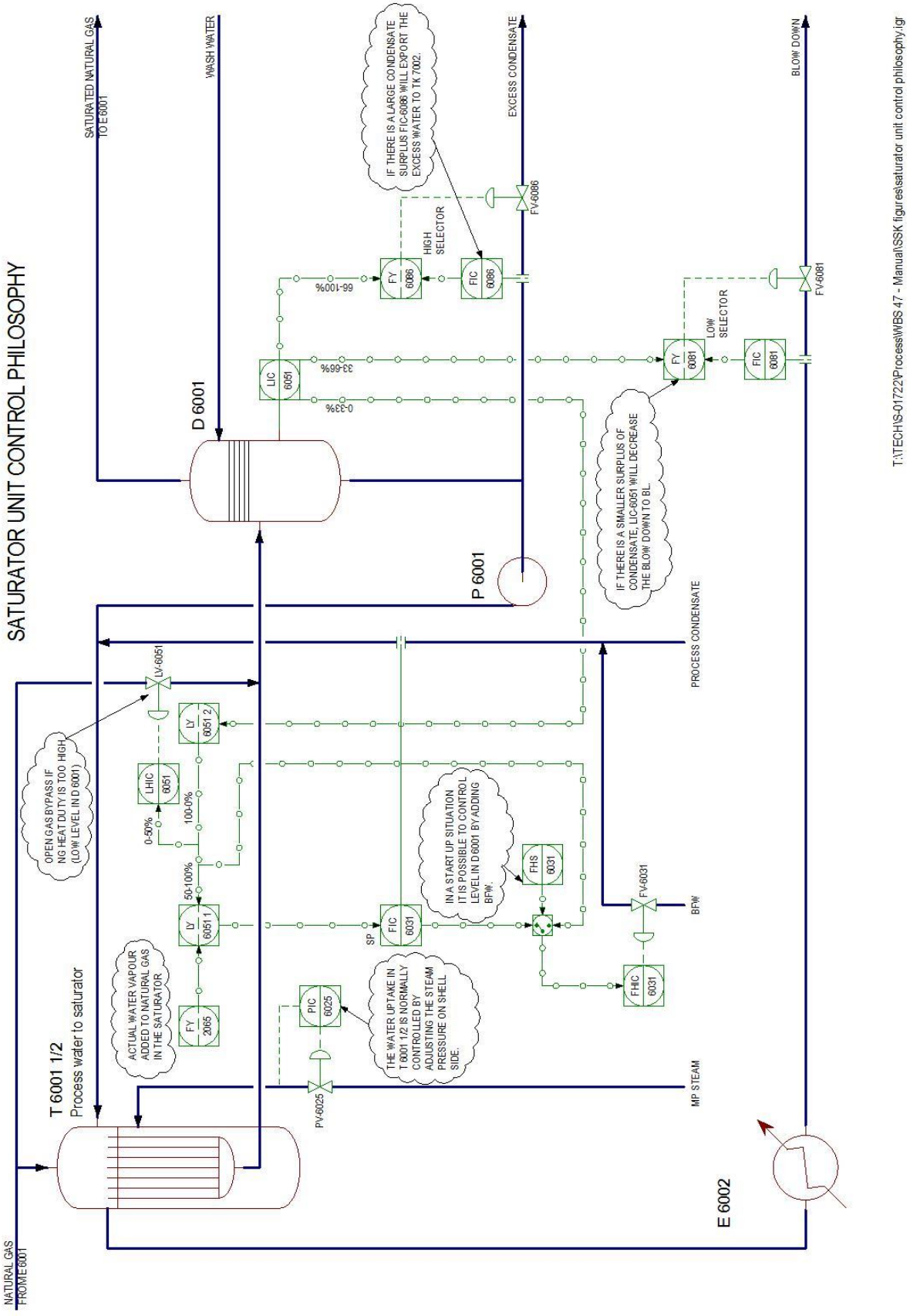
Excess water from distillation is sent to saturators by P 5010 A/B (5000-PID-013 / P41). The contents of alkali in excess water is removed in Feed Gas Scrubber Separator D 6001 (6000-PID-003 / P07).

BFW from Header

In case process condensate and excess water from distillation is not sufficient - for example at start-up – boiler feed water from HP BFW Pump P-7001 A/B may be used as make-up by means of FHIC-6031 (6000-PID-002 / P06). However, the use of **BFW must be strictly limited** as its contents of alkali have a negative effect on the activity of the reforming catalyst.

Process water recirculation

A continuous flow of process water is recycled by the saturator recirculation pump P 6001 A/B. The recirculation flow is measured by FI-6068 installed on the discharge of P 6001 A/B


SATURATOR UNIT CONTROL PHILOSOPHY
SATURATED NATURAL GAS TO E 6001
WASH WATER
IF THERE IS A LARGE CONDENSATE SURPLUS FIC-6086 WILL EXPORT THE EXCESS WATER TO TK 7002.
EXCESS CONDENSATE
BLOW DOWN
FV-6086
HIGH SELECTOR
FY 6086
FIC 6086
66-100%
LOW SELECTOR
FY 6081
FIC 6081
FV-6081
LIC 6051
33-66%
0-33%
D 6001
P 6001
IF THERE IS A SMALLER SURPLUS OF CONDENSATE, LIC-6051 WILL DECREASE THE BLOW DOWN TO BL.
PROCESS CONDENSATE
LV-6051
LY 6051 2
OPEN GAS BYPASS IF NG HEAT DUTY IS TOO HIGH (LOW LEVEL IN D 6001)
LHIC 6051
0-50%
100-0%
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LY 6051 1
IN A START UP SITUATION IT IS POSSIBLE TO CONTROL LEVEL IN D 6001 BY ADDING BFW.
FHS 6031
FV-6031
BFW
SP
FIC 6031
FHIC 6031
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THE WATER UPTAKE IN T 6001 1/2 IS NORMALLY CONTROLLED BY ADJUSTING THE STEAM PRESSURE ON SHELL SIDE.
PV-6025
MP STEAM
T 6001 1/2
Process water to saturator
E 6002
NATURAL GAS FROM E 6001
T:\TECH\S-01722\Process\WBS 47 - Manual\SSK figures\saturator unit control philosophy.igr

3.4.2 Capacity control of saturator

The saturator must handle all process condensate and excess water from the distillation.
The capacity of the saturator unit is controlled by adjusting the steam pressure on the shell side of the saturators.

The level in Feed Gas Scrubber Separator, D 6001 is used as an indication for capacity of the saturators.

- If the level is decreasing, the heat input is too high.
- If the level is increasing, the heat input is too low.
- If heat input has reached its maximum and the level is still increasing, the continuous blow down can be increased.
- If both heat input and continuous blow down has reached its maximum, the control will allow excess condensate to be extracted.

If the capacity of the saturators suddenly drops, the holes in the 'insert-type distributor' in the top of the saturators T6001 1/2 (6000-PID-002 / P06) are possibly blocked and must be cleaned. Blocking of the holes is also indicated by high level in LI-6033 1/2 that are equipped with high alarm. The top of the tube sheets must be inspected during shut downs to check for deposits. Low level alarms on LI-6033 1 and 2 as well as LI-6034 1 and 2 is foreseen to inform the operator against lack of feed water to the top of the saturators. Low low level interlock on LI-6033 1 and 2 as well as LI-6034 1 and 2 is foreseen to prevent the process gas in the top of T 6001 1/2 escaping into the Saturator Blow Down Drum D 6002 (6000-PID-004 / P08)

3.4.3 Level control of feed gas scrubber separator D 6001

This equipment has two functions: the first function to separate the gas from surplus process water, second is to wash the natural gas free from sodium hydroxide from the distillation water.

The process water used for washing the natural gas is lead through the particle filters X 6002 A/B and then heated-up in the wash water preheater, E 6004, to avoid cooling the natural gas when the water enters the feed gas scrubber separator.

The wash water flow is controlled by FIC-6059. As first priority, the controller will use process condensate from the process condensate pumps P2002 A/B, by opening FV-6059 1. If there is low level in D 2004, LIC-2441 will turn down the flow of process condensate. This is done by the low selector, FY-6059. If the process condensate flow is too low, FIC-6059 will add BFW by opening of FV-6059 2. The wash water flow is equipped with low alarm to ensure that Na^+ is properly washed out of the natural gas.

The level in the feed gas scrubber separator D 6001 is controlled by LIC-6051 A/B/C (6000-PID-003 / P07). LIC-6051 A/B/C is equipped with both low and high alarm. See figure for "Saturator unit control philosophy".

The signal from the level controller LIC-6051 is split into 3 parts and described below:

Output signal 0 to 33% from LIC-6051

- The level signal is sent to LY-6051 2 where the 0-33% is converted to a 100-0% signal
- The level signal 0-50% is sent to LV-6051 and 50-100%to LY-6051/1 (6000-PID-002 / P06)
- LY-6051/1 also receives a feedforward input from FY-2065 (2000-PID-003 / P09). The flow calculator FY-2065 gives information of the water vapor that has been added to the natural gas in the saturators.
- Based on these two inputs, LY-6051 1 calculates the set point of FIC-6031 (6000-PID-002 / P06)

The BFW flow addition can be used during start up or in upset situations. The BFW control can be operated either direct via D 6001 level controller (LIC-6051) or via FIC-6031. How to operate BFW addition is selected via FHS-6031.When operating the BFW addition via FIC-6031 it will help to keep the control stable because the BFW addition control is ‘fast’ where as the level control is ‘slow’.

During normal operation FHIC-6031 must be in manual and BFW flow control valve FV-6031 must remain closed. Steam pressure PIC-6025 should be adjusted so that the process gas bypass valve LV-6051 is kept closed during normal operation.

Output signal 33 to 66% from LIC-6051

- Is used to adjust the continuous blow down from top of the tube sheet in the saturators
- Is sent to FY-6081 (6000-PID-004 / P08). FY-6081 selects the higher output from
  - Output from LIC-6051 and
  - Output from FIC-6081 (6000-PID-004 / P08), which controls continuous blow down from the tube side of the saturators

Normal flow of FIC-6081 is approximately 6000 kg/h

Output signal 66 to 100% from LIC-6051

- Is used to adjust the extraction of excess condensate from D 6001
- Is sent to FY-6086 (6000-PID-004 / P08). FY-6086 selects the higher output from
  - Output from LIC-6051 and
  - Output from FIC-6086 (6000-PID-004 / P08), which controls extraction of excess condensate.

During normal operation FV-6086 is foreseen to remain closed; Max flow of FIC 6086 is 54000 kg/h.

3.4.4 Saturator blow down drum

The level in the saturator blow down D 6002 is controlled by LIC-6082 (6000-PID-004 / P08).

Output: 0 to 50% from LIC-6082

Continuous blow down to BL:

D 6002 level controller LIC-6082 (6000-PID-004 / P08) and continuous blow down flow controller FIC-6082 (6000-PID-004 / P08) signals are sent to the low selector FY-6082.

FY-6082 prevents D 6002 from running dry.

Output from 50 to 100% from LIC-6082

If the level is increasing even if maximum continuous blow down is withdrawn, excess condensate is sent the Process Condensate Buffer Tank, TK 7002 via LV-6082.

LIC-6082 is foreseen with both high and low alarm.

3.4.5 Level control of T 6001 1/2

Steam condensed on the shell side of T 6001 1/2 is returned to the MP steam drum, D 3003 by the steam condensate return pump, P 6002 A/B/C. In case of high level in D 3003, the steam condensate is sent to the deaerator, D 7001.

The two saturators are 'communicating vessels' and the elevation of each saturator is the same. Therefore only level control on T 6001 1 is required. The Level in T 6001 1 is controlled by LIC-6021 (6000-PID-002 / P06) which operates LV-6021A and LV-6021B on split range. LIC-6021 is foreseen with both high and low alarm.

Output signal 0 to 50% from LIC-6021 is sent to the low selector LY-6021 (6000-PID-001 / P05) which normally sends the steam condensate to MP steam drum D 3003. LY-6021 also receives signal from D 3003 level controller, LIC-3042 (3000-PID-002 / P23). The low selector LY-6021 ensures that the make-up water to D 3003 is first satisfied by steam condensate from the saturators via LV-6021A. The low selector aims make use all of the steam condensate from saturators and minimize BFW make up to D 3003. The low selector also protects D 3003 from over filling.

Output signal 50 to 100% from LIC-6021 operates LHIC-6021 that sends steam condensate to deaerator D 7001 by means of LV-6021 B.

3.5 Steam to carbon ratio

In order for the reforming reaction to take place steam is added to the natural gas feed. The plant is designed to operate at a constant steam/carbon ratio of 1.8.

Steam to carbon ratio is defined in 'Process description'.

3.5.1 Calculation of S/C and total required steam in process gas feed

HSIC1004 (1000-PID-002 / P01) is the ESD input station for the carbon number of the hydrocarbon feed this is normally left in remote set point, so the carbon number is calculated based on a 2oo3 specific gravity measurement ASY-1001 2

The set point for the steam to carbon ratio is set in FHIC-2070 and the required steam and required direct HP steam is calculated in FY-2070 3 and FY-2070 2 giving the SP to FIC-2072. The controller has a deviation alarm and there is a low steam to carbon ratio trip to protect the reformer section.

The calculation of the steam to carbon ratio is executed in FFY-2069 and is based on either a manual input of the carbon number for natural gas in HIC-1005 or a calculated value based on a 2oo3 measurement of specific gravity AI-1001 1, for liquid off stream in HIC-6057and recycle hydrogen in HIC-2077.

The carbon numbers are based on regular laboratory analysis; the carbon number is calculated based on mole percentage of all C_nH_m in the feed and excludes CO_2 and includes half of CO. An indication of the carbon number of natural gas is given by AI-1001, analyzer of specific gravity. The output from AI-1001 must be supervised carefully.

The steam flow is obtained by adding steam from the following sources:

- Water vapor added to the process gas in the saturator, FY-2065
- Direct process steam from MP steam header, FY-2072
- MP attemperation water injection as quench , FY-2233 1

FIC-6070 is the flow of natural gas and recycles hydrogen upstream the saturator, FI-6057 is the flow of liquid off stream from distillation unit.

FIC-2061 is the flow of natural gas, recycle hydrogen, liquid off-stream and added steam downstream the saturator.

The added amount of steam in the saturator is calculated in FY-2065. The steam amount and the total carbon calculated in FY-2069 3 are input to FFY-2069, where the actual steam to carbon ratio is calculated. The actual steam to carbon ratio is indicated by FFI-2069 equipped with low alarm.

The required direct steam flow is calculated in FY-2070 2 and the output goes to the flow controller for the direct steam FIC-2072.

3.6 Plant capacity control

The capacity of the front end until the LTM is enabled is set by flow controller FIC-6070 (6000-PID-003 / P07) located upstream the saturator feed/effluent exchanger E 6001. FIC-6070 is provided with a low flow alarm. Too low feed flow shall initiate an IS-1 and I-20 trip.

There is a second flow controller FIC-2061 (2000-PID-004 / P10) installed downstream the saturator which gets the set point from PIC-2073 (2000-PID-003 / P09). This flow controller dampens any fluctuations in the saturator and thus maintains steady conditions for the downstream reforming section.
FIC-2061 is provided with a low flow alarm

The smaller flow control valve FV-2091(2000-PID-004 / P10) installed in parallel to FV-2061 shall be used during start up in order to slowly introduce feed to the reformers. FV-2091 has its own flow controller FIC-2091.

3.7 Reforming section

3.7.1 Prereformer, R 2003

The process gas is heated in the pre-reformer feed preheat coil E 2002 to approx. 496ºC during normal operation. The temperature controller TIC-2253 (2000-PID-008 / P14) is provided with both high and low alarm.

- Higher inlet temperatures may result in carbon formation.
- A low operating temperature will decrease the rate of reaction and may lead to slip of higher hydrocarbons.

3.7.2 Prereformer inlet temperature control

The inlet temperature to the prereformer can be controlled by manual adjustment of the firing in the top of the primary reformer H 2001, thereby adjusting the duty in the pre-reformer feed preheat coil E 2002.

The prereformer inlet temperature can, if necessary, be controlled by quenching the process stream with process condensate or alternatively with BFW at the inlet of the Prereformer Feed Preheat Coil, E 2002.

TIC-2253 (2000-PID-008/P14) located downstream E 2002 gives a remote set point to TIC-2232(2000-PID-007/P13) located upstream E 2002. TIC-2232 controls process gas temperature at the inlet of E 2002 by giving set point to quench flow controller FIC-2233.

Quenching with BFW must be minimized, as its contents of alkali have a negative effect on the activity of the reforming catalyst

FIC-2233 operates the process condensate valve FV-2233 1 and the BFW valve FV-2233 2 on split control.

As long as there is enough liquid in the Final Separator D 2005 the quench flow will be process condensate from D 2005. The low selector FY-2233 2 ensures that D 2005 is not emptied. When the level in D 2005 is low, then any quench requirement would be satisfied by BFW injection through FV-2233 2.

The prereformer temperature profile has to be indicated on the DCS screen.

The pressure drop across the prereformer is indicated by PDI-2252 (2000-PID-008/P14). PDI-2252 is equipped with a high alarm indicating possible carbon formation or crushing of catalyst.

3.7.3 Reformer feed preheating

The process gas from the prereformer is heated to approx. 638ºC in the Reformer Feed Preheat Coil, E 2001, located in the top of the flue gas waste heat section.
TI-2234 (2000-PID-007 / P13) is located at the outlet of E 2001; and is provided with high temperature alarm.

The temperature outlet of E 2001 or inlet of Steam Reformer, H 2001, may be controlled by adjusting the firing in the top of the reformer furnace.

3.7.4 Primary reformer

(2000-PID-009 / P15)
The stream outlet of E 2001 is split into two parallel headers feeding each of the radiant chambers of Primary Reformer H 2001. From the reformer headers, the feed passes through the inlet hair pins to the catalyst tubes inside of the radiant chambers. In the catalyst tubes the hydrocarbon feed is converted into a mixture of H_2, CO, CO_2 and CH_4 by the endothermic reforming reactions and the shift reaction. The heat for the conversion is supplied by the burners located on the side walls of the radiant chambers.

The reformer effluent leaves the tubes at a temperature of around 740°C. The temperature in the outlet collectors is measured by TI-2303/TI-2304 and is provided with high temperature alarm.

The gas is sent through a refractory lined transfer line to the Secondary Reformer, R 2004. The temperature in the transfer line is measured by TIC-2305, a high temperature alarm is provided. Too high primary reformer outlet temperature initiates IS-1 trip by TSAH-2305.

The pressure inlet/outlet the catalyst tubes are measured by PI-2282 / PI-2307 respectively. The differential pressure across the tubes is measured by PDI-2283. Both PI-2282 and PDI-2283 are provided with high alarms.

The steam reformers are induced-draught box heaters containing totally 312 catalyst tubes, which are installed in two separate radiant chambers. The two chambers are connected to a common flue gas duct.

The chambers are provided with totally 576 forced draught radiant wall burners fed with a mixture of natural gas fuel and purge gas from the synthesis loop. The burners are mounted equidistantly in 6 horizontal rows on the two walls of each chamber. This arrangement and the large number of burners provide an easy control of the desired temperature profile along the height of the reformer tubes and a uniform heat distribution through-out the length of the combustion chambers.

Part of the fired heat released from the burners is transferred to the reformer tubes by radiation from the walls and by convection with the flue gas, while the remaining part (except for heat losses) leaves the combustion chambers with the flue gas.

3.7.5 Secondary reformer, R 2004

The secondary reformer outlet temperature should be kept at about 1020°C, which corresponds to a methane slip of around 0.65 dry mole%. The methane content in the effluent gas from the secondary reformer is closely related to this outlet temperature.

The secondary reformer outlet temperature is determined by the temperature of the process gas from the primary reformer and the flow of oxygen. The secondary reformer outlet temperature is not automatically controlled but instead manual controlled by adjusting the oxygen flow.

3.7.6 Oxygen flow control

(2000-PID-001/P02)
When entering the unit the oxygen is filtered in the Oxygen Filters, X 2001 A/B. Two oxygen filters are operating in parallel. Both filters to be pressurized simultaneously during start up. Once pressurized, one block inlet filter may be closed. It is not allowed to clean/maintain filters during operation.

The filters are equipped with pressure differential measurements PDI-2004 with high alarms, indicating the requirement for change of filter.

The process oxygen flow for R 2004 is normally controlled by FIC-2007, which is foreseen with a low flow and a flow deviation alarm. Because of limited range ability of FIC-2007, the oxygen flow is during start-up controlled by FIC-2009. The oxygen flow to secondary reformer is indicated by FY-2007. In case of too low flow, FSAL-2007 initiates an IS-2 trip.

The set point to FIC-2007 is calculated in FY-2007 2, the feedforward flow of oxygen calculated in FY-2007 1 is multiplied by a feedback signal, the output from TIC-2334 (signal between 0.7 and 1.01) to avoid high outlet temperature from the secondary reformer. The output from FY-2007 1 is the product of the carbon flow FY-2069 3 and the required oxygen to carbon ratio set in HIC-2005.

The actual oxygen to carbon ratio is calculated continuously in FFY-2020 and indicated by FFI-2020 with a high alarm. The actual oxygen to carbon ratio is equal to the flow of oxygen (O_2) divided by carbon in the feed.

When FIC-2007 is in remote set point then in case of a high secondary reformer outlet temperature or rapidly rising outlet temperature the LTM system will automatically initiate an oxygen cutback of 10%. It is also possible for the operator to initiate oxygen cutbacks of 2% using HS-2004.

FFSY-2008 is connected to the ESD and indicates the actual oxygen to carbon ratio. Too high oxygen to carbon ratio initiates an IS-2 trip by FFSAH-2008.

The oxygen from BL can be isolated by closing HV-2003 & HV-2004. If the downstream oxygen line has been depressurized IS-23 ensures a slow pressurization through HV-2004 before allowing the opening of HV-2003.

3.7.7 Oxygen temperature control

The oxygen is preheated to about 230°C in the Oxygen Preheater, E 2008 by HP steam.

The temperature of HP steam from the header is reduced by quenching BFW into the steam. The steam temperature is controlled by TIC-7071 (7000-PID-010/U07). TIC-7071 is provided with both high and low alarm. Too high steam temperature initiates an IS-2 trip by TSAH-7071.

It must be ensured that the oxygen temperature downstream E 2008 is high enough to avoid condensation of steam by cold oxygen. Oxygen temperature downstream E 2008 is indicated by TI-2047 (2000-PID-002/P03). TI-2047 is provided with a low alarm. Too low oxygen temperature initiates an IS-2 trip by TSAL-2047.

3.7.8 Steam addition to oxygen

The preheated oxygen is mixed with HP steam to protect the piping and the CTS burner against the reactivity of the oxygen. The oxygen content should be max. 92 vol. % at the burner inlet.

The steam is sent through the filters X-2002 A/B. Two filters are operating in parallel allowing maintenance during operation. The filters are equipped with pressure differential measurements and high alarms indicating requirement for cleaning the filters.

The HP steam flow is controlled by FIC-2040 (2000-PID-002/P03). If the flow becomes too low, FSAL-2040 will activate the IS-2 trip. Furthermore, to prevent oxygen from entering the steam system, PDI-2036 is provided across the steam valves FV-2040, USV-2038 and USV-2039.Too low differential pressure across these valves initiates an IS-21 trip by PDSAL-2036.

The actual oxygen to steam ratio is indicated by FFI-2042.

3.7.9 Monitoring of secondary reformer

(2000-PID-010/ P16A)
The process gas at around 740°C from the primary reformer and the oxygen-steam mixture are admitted to the secondary reformer through the burner.

The process gas is equilibrated with respect to the shift and methane reforming reactions in R 2004.

The secondary reformer is equipped with several temperature indicators and other instruments as shown below, in order to monitor the reforming reactions.

- Burner tip temperature is monitored by TI-2329 equipped with a high alarm. If the burner tip temperature goes too high, TSAH-2329 initiates an IS-2 trip.

- Burner chamber temperature is monitored by TI-2325 equipped with high and low alarm. TSAH-2325 initiates an IS-2 trip.
- Temperature in the catalyst bed is monitored by TI-2334 equipped with high and low alarm. If the temperature goes too high, TSAH-2334 initiates an IS-2 trip.
- Temperature outlet the secondary reformer or waste heat boiler inlet temperature is monitored by TI-2333 equipped with high alarm. If the temperature goes too high, TSAH-2333 initiates an IS-2 trip.
- Shell temperature of the Secondary Reformer is monitored by TI-2326, TI-2327, TI-2328 equipped with high alarm and is located on the top conical part of the secondary reformer vessel. The shell temperature is also monitored by TI-2330, TI-2331, TI-2332 equipped with high alarm and located below the catalyst bed.
- Skin Temperature of the Secondary Reformer is also monitored by heat sensitive painting. The skin temperature must be supervised to avoid operation at excessive shell temperatures, in case the lining of the vessel does not work satisfactorily
- Pressure drop across the Secondary Reformer monitored by PDI-2323 equipped with high alarm.

3.7.10 Fuel system control

(1000-PID-002/ P01 & 2000-PID-017/ U01)
Adjustment of reformer firing.
The reformer firing can be controlled by manually adjusting the set point for QIC-2535. The total fired duty is then set independently of the conditions on the process side. Great care should therefore be taken when adjusting the firing: When increasing the load of the plant, the process side should always be increased first and subsequently the firing is adjusted and vice versa when decreasing the plant load. This precaution should prevent over-firing in the reformer furnace. Alarm and trip devices are present which should help to control any adverse situations.

When QIC-2535 is in remote set point the required duty for the actual operating capacity is calculated and is fed to the controller as a feedforward signal. The specific heat used in the calculation is entered in HIC-2541. The feedback correction is provided by the reformer outlet temperature controller TIC-2305 giving a set point to the flue gas temperature controller TIC-2221 A the output of which adjusts the duty calculated by the feedforward control. An overriding controller in the flue gas TIC-2221 B connected to the low selectors FY-2531 5 & FY-2536 4 on the outputs going to the fuel valves and limits the fuel flow in case of high flue gas temperature.

Duty control for primary reformer:
The duty of fuels burners in the primary reformer is controlled by duty controller QIC-2535.

The lower heating values (LHV) for natural gas and for purge gas are entered manually into HIC-2532 and HIC 2537 respectively. Online LHV analyzers AI-2531 and AI-2532 are installed for natural gas and purge gas respectively.

The total calorific value or duty of the natural gas (QY-2535 2) is calculated by multiplying the natural gas flow (FIC-2531) by the LHV specified (HIC-2532).

In the same way, the total calorific value or duty of the purge gas (QY-2535 ~~3~~ 1) is calculated by multiplying the purge gas flow (FIC-2536) by the LHV specified (HIC-2537).

The duty of natural gas and the duty of purge gas are added in QY-2535 3. The process value from QY-2535 3 is sent to the duty controller QIC-2535. QIC-2535 operates the purge gas flow controller FIC-2536 and the natural gas flow controller FIC-2531 on a preferential firing basis first using available purge gas.

In case the desired set-point duty is higher than the actual duty, QIC-2535 will first try to increase purge gas flow to the burners and when the duty is still not matched, it will then increase the natural gas flow.

In case the synthesis loop is tripped, the purge gas flow will be replaced by natural gas.

Control of purge gas fuel

During normal operation all purge gas from the synthesis loop and OH gas from the distillation is used as fuel gas for the reformer. Maximum allowable PG firing is set in HIC-2542.

The pressure in the purge gas line is maintained by PIC-2536 A and PIC-2536 B.
If the pressure of the purge gas gets too high, PIC-2536 B will open PV-2536 B and sent excess purge gas to the flare header. PIC-2536 A prevents low pressure by sending a minimum signal to the flow controller.

The purge gas flow to fuel system is controlled by FIC-2536.Signals from FIC-2536 and PIC-2536 A are sent to the minimum selector FY-2536 1. The minimum selector FY-2536 1 output is connected to FY-2536 4 which gives output to FV-2536 A.

Control of natural gas fuel

Natural gas used as fuel gas is depressurized across the pressure control valve PV-1011 (1000-PID-002/P01). Pressure controller PIC-1011 is equipped with high and low alarm.

The fuel gas pressure to the burners is controlled by PIC-2554 (2000-PID-017 / U01). The signals from the pressure controller PIC-2554 and natural gas flow controller FIC-2531 are sent to the high selector FY-2531 3 output is connected to the low selector FY-2531 5 which also has input from the overfiring override controller TIC-2221 B, which operates natural gas fuel flow valves FV-2531 1 and FV-2531 2 in split control.

- 0-50% signal from FY-2531 5 is sent to flow control valve FV-2531 1
- 50-100% signal is sent to flow control valve FV-2531 2.

FV-2531 1 is smaller than FV-2531 2 and covers operating at low capacity.

The natural gas flow is measured by FIC-2531 that receives the process value through a high selector FY-2531 1, from either FT-2531 1 or FT-2531 2. The two flow transmitters ensure the precision of the flow measurement throughout the entire range of natural gas flow.

The natural gas fuel flow should always at least correspond to 10% of the total duty in order to have some flexibility on the control of the firing. This is ensured by high selector FY-2531 2 which ensures that a certain minimum flow of natural gas is always, the min flow is inserted via HIC-2534.

The natural gas flow to burners is controlled through a high selector FY-2531 3 which receives signals from FIC-2531 and PIC-2554. The pressure controller PIC-2554 must always have a set point above the minimum firing pressure provided by burner vendor.

In case the fuel pressure at the burners is lower than normal, FY-2531 3 will operate the natural gas fuel valves FV-2531 1/2 on pressure control. If on the other hand, the flow of natural gas fuel is lower than the set point of FIC-2531, and then FY-2531 3 will operate the natural gas fuel valves FY-2531 1/2 on flow control.

Control of natural gas fuel during Start-up

During start-up the reformer will be fired with natural gas fuel only. The initial fuel flow is controlled by PIC-2554, since the flow is too small to be measured by the flow meter, FT-2531 1. When the reformer firing has been increased and a reliable output from the flow measurement has been received, control can be shifted to normal operation.

Low fuel pressure

When the fuel pressure is decreasing the follow actions will take place:

- There will be an alarm at low fuel pressure by PIC-2554
- At low fuel pressure PSAL-2554 will initiate purge gas fuel trip IS-14
- At too low pressure PSAL-2556 will initiate a reformer trip IS-1

The trip value for PSAL-2554 (linked to purge gas trip) is slightly higher compared to the trip value for PSAL-2556 (linked to reformer trip). This is to avoid unnecessary trip of the reformer when the pressure in the purge gas line goes too low.

3.7.11 Control of combustion air to primary reformer

(2000-PID-005 / P11,2000-PID-017 / U01)

The primary reformer is designed to operate at an excess air ratio of 10%, which corresponds to an oxygen content in the flue gas as indicated by AI-2223 1 (2000-PID-007 / P13) of about 2 mole% on a dry basis (corresponding to about 1.5 mole% on wet basis).

Combustion air is supplied for the primary reformer by the combustion air blower F 2002. The combustion air is preheated in E 2007 located in the waste heat section of the primary reformer.

Air bypass across E 2007 is provided in order to control that the temperature of the flue gas, shown by TI-2155, is above the sulfur dew point. TI-2155 is equipped with low alarm. Thereby corrosion of E 2007 can be avoided.

Combustion air to fuel ratio is inserted manual in

- HIC-2533 for natural gas
- HIC-2538 for purge gas

The air required for natural gas FY-2531 4 is calculated by multiplying the natural gas flow (FIC-2531) by the value set in (HIC-2533).

In the same way, the air required for purge gas FY-2536 2 is calculated by multiplying the natural gas flow (FIC-2536) by the value set in (HIC-2538).

A combined feedforward and feedback strategy is applied for control of the flow of combustion air. The feedforward calculation uses the stoichiometric air demand required for combustion of natural gas and purge gas which is added in FY-2111 1 and the excess air factor as well as a lead function to avoid firing with a deficit of air at load increase. Feedback correction is done by the excess air controller AIC-2225 controlling oxygen content in the flue gas from the radiant section. It is possible to adjust the excess air factor using HIC-2226.

The pressure downstream E 2007 is controlled by PIC-2163 (2000-PID-006 / P12).

The flow is controlled through the high selector FY-2111 by either FIC-2111 or PIC-2163 by adjusting the inlet guide vanes of the blower.

In case the combustion air pressure gets too low, PSAL-2163 will activate the IS-1 trip.

It is possible to optimize the steam consumption of FT 2002 by adjusting the speed controller SC-2119 manual through HIC-2119.

3.7.12 Vent gas from tanks

All the vent gases from the storage tanks are mixed with the combustion air to prevent air pollution. All the emissions from the tanks are burned in the primary reformer.

If the combustion is tripped (I-61) the vent gasses are isolated from the combustion air blower and are vented to the atmosphere.

3.7.13 Flue gas flow control

(2000-PID-006 / P12, 2000-PID-007 / P13 & 2000-PID-009 / P15)
The flue gas leaves the two radiant chambers of the steam reformer at a temperature of about 1090°C. The temperature in the chambers is measured by TI-2295 and TI-2297 (2000-PID-009 / P15).

Both TI-2295 and TI-2297 are provided with a deviation high alarm to warn the operators of upset situations.

The temperature of the mixed flue gas from the 2 chambers is measured by TI-2221 (2000-PID-007 / P13), which is provided with a high alarm. When the temperature goes too high, TSAH-2221 initiates trip of IS-1.

The flue gas blower F 2001, transfers the flue gas to the stack S 2001. The induced draught blower establishes a pressure slightly below the atmospheric pressure inside the radiant chambers in order to safe-guard against leakages of hot flue gas to the surroundings.

Pressure control in waste heat section

The draught in the reformer chambers is controlled by PIC-2224 (2000-PID-007/P13) by adjusting the guide vanes of F 2001. PIC-2224 is placed at the cross over between the radiant section and the waste heat section of the primary reformer. PIC-2224 is equipped with low and high alarms.

Trip actions

Low and high pressure switches, PSAL-2224 and PSAH-2224, respectively, are installed in case of too much draught or in case of lack of draught in the furnace. Both switches activate a trip of the reformer, IS-1.

Personnel protection

In case of too high pressure in the reformer furnace box PAHH-2224 will initiate trip of I-15. As a consequence, it will start the reformer hazard flashers warning the personnel and open the reformer furnace box false dampers HV-2225 1/2 (2000-PID-007/P13).

A sampling point AP-2160 installed at the discharge of the flue gas blower can be used in order to determine leak, if any, through the "false air" dampener to the waste heat section.

3.7.14 Reformed gas and HHP steam temperature control

(2000-PID-011 / P16B)

The temperature of the superheated HHP steam is controlled by TIC-2360 by adjusting the position of the hot bypass dampers TV 2360 12/22. Thereby the duty can be changed between steam production and steam superheating. THIC-2360 11/21 can be used for adjustment to keep the hot bypass dampers in their control range. The dampers are located inside the Waste Heat Boilers E 2020 1 and 2

The piping around the boilers are made symmetrical to ensure an even flow distribution, however the dampers might introduce a small maldistribution. Therefore it is possible manually introduce a differentiated signal to the dampers of each boiler through THIC-2360 1&2.

TSAH-2335 and TSAH-2336 will cause a reformer trip if the temperatures between the waste heat boilers and the steam super heaters are too hot, thereby protecting the steam super heater against elevated temperatures.

3.7.15 Reformed gas cooling train

(2000-PID-014~016/P19~21)

1st Separator, D 2002

The process fluid from E 2022 3 is a two phase fluid, it is routed to D 2002 where the process condensate is separated from the process gas.

Level in D 2002 is controlled by LIC-2403. Process Condensate Pump no. 1, P-2001 A/B sends the condensate to the saturator unit.

Level controller LIC-2403 (2000-PID-014 / P19) is equipped with high and low alarm. Too low level in D 2002 initiates an IS-33 trip by LSAL-2404.

MP Column reboiler, E 5023

E 5023*:* Reformed gas from D-2002 is cooled to about 159°C in the MP Column Reboiler, E 5023. The reboiler duty can be adjusted by means of process gas bypass controlled by TIC-5277 (5000 -PID-010/P38).

2nd Separator D 2003

The two phase process fluid from E 5023 is routed to D 2003 where the process condensate is separated from the process gas. The process condensate is sent to 3rd separator, D 2004. Level in D 2003 is controlled by LIC-2419 (2000-PID-014/P19) and is provided by low and high alarm.

Stabilizer column reboiler, E 5024 1/2

Reformed gas from D 2003 is cooled to about 138°C in E 5024 1/2. The reboiler duty can be adjusted by means of process gas bypass controlled by TIC-5064 (5000-PID-002/P30).

3rd Separator, D 2004

The two phase process fluid from E 5024 1/2 is routed to D 2004 where the process condensate is separated from the process gas.

Level in D 2004 is controlled by LIC-2441(2000-PID-015 / P20). Process Condensate Pump no. 2, P-2002 A/B sends the condensate to the saturator unit.

Level controller LIC-2441 is equipped with high and low alarm.

DMW Preheater, E 2025

The outlet temperature of the DMW is controlled via a bypass line on the process gas side.

A 'High Selector' TY-2457 is used to prevent the deaerator pressure from increasing. TY 2457 receives input from TIC-2457 (DMW temperature) and PIC-7094 (7000-PID-012/U09) (deaerator pressure).

Air cooler AE 2026 and water cooler E 2027

The process gas from E 2025 is cooled to about 65°C in air cooler AE 2026 and further cooled to 48°C in water cooler E 2027.

Final separator, D 2005

The two phase process fluid from E 2027 is routed to D 2005 where the process condensate is separated from the process gas.

Level in D 2005 is controlled by LIC-2474(2000-PID-016 / P21). Process Condensate Pump no. 3, P-2003 A/B sends the condensate to the process condensate preheater, E 6002.

Level controller LIC-2474 is equipped with high and low alarm. Too high level initiates a partial trip of the synthesis gas compressor (IS-40).

The flow of the synthesis gas is measured by FI-2476 equipped with high flow alarm. The methane content of the synthesis gas is analyzed by online analyzer AI-2479.

3.7.16 Pressure control of the reforming section

The suction pressure of the synthesis gas compressor is controlled by PIC-3007 by adjusting the operation of the compressor.

If the synthesis gas compressor is out of operation PIC-2481 (2000-PID-016 / P21) located on vapor outlet line of the final separator D 2005 takes over pressure control of the reforming unit. PIC-2481 controls the pressure by sending excess gas to flare.

If it is required to operate the front end but not to heat up the distillation unit is possible to utilize the vent located before the distillation reboilers and to use PIC-2406 (2000-PID-014 / P19) for pressure control. During normal operation the set point of PIC-2406 set higher than the set point of PIC-2481 in order to avoid venting of process gas from the first separator.

PIC-2481 must have a set point slightly higher than the normal operating pressure in order to minimize flaring of gas.

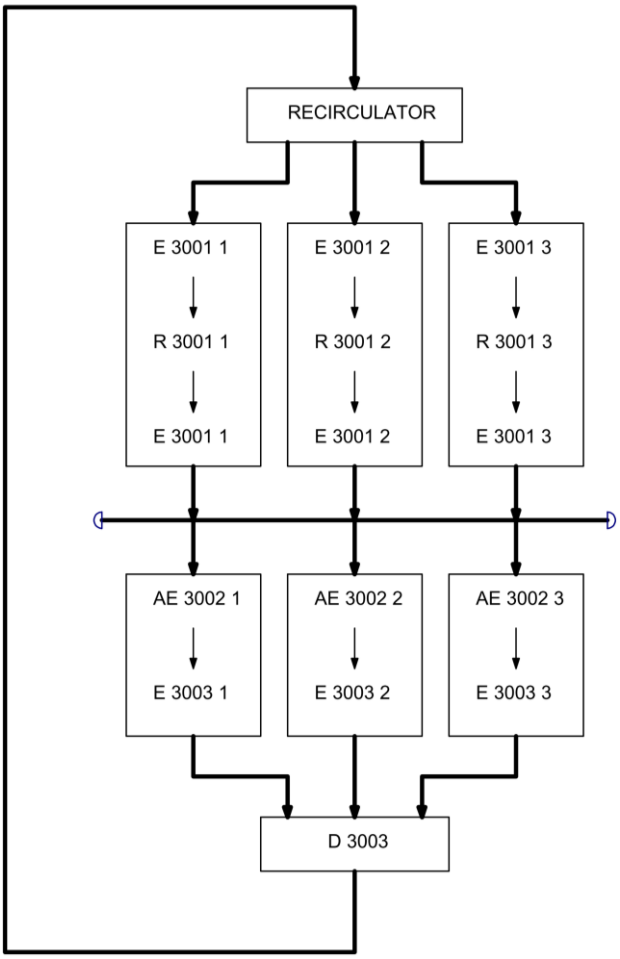
PIC-2481 together with FO-2483 is also used for depressurizing the reformer unit in case of an IS-1 trip.

Methane content of the synthesis gas

Online methane analyzer AI-2479 (2000-PID-016 / P21) installed on final separator vapor outlet line provides the methane content and is equipped with high alarm.

3.8 Methanol synthesis loop

Part of the methanol loop is made of three parallel trains due to the large flows.



The main parameters in the loop are:

- Loop pressure
- Steam drum pressure, which defines catalyst temperature
- Recirculation flow rate
- Module at reactor inlet

Each of these parameters, which are described below, will have an impact on the conversion in the methanol reactors.

3.8.1 Module for methanol synthesis

The synthesis gas used for methanol synthesis is characterized by the stoichiometric ratio the module M, please refer to process description for definition.

Online analyzers AI-3001 for H_2, AI-3002 for CO and AI-3003 for CO_2 (3000-PID-001/P22) are installed on vapor line of D 2005. These analyzers are provided with automatic manifold that enables operator to measure the module M either for synthesis gas from D 2005 or for gas at methanol reactor inlet.

AFY-3004 1&2 calculates the module M based on the input received from these three online analyzers. AFI-3001 1 indicates the module M inlet the synthesis section and is equipped with low alarm. AFI-3001 2 indicates the module M inlet the methanol reactors and is equipped with low alarm.

The module is adjusted by the primary reformer outlet temperature and the oxygen flow to the secondary reformer. However, it is important to keep the steam to carbon ratio of 1.8 and secondary reformer outlet temperature steady at 1020 °C, (in order to have methane slip of 0.65 dry mole %).

When the module M is higher than required

- lower the primary reformer outlet temperature by adjusting the fuel firing
- increase the oxygen flow to the secondary reformer.

And vice versa when the module M is lower than required.

3.8.2 Capacity control

The capacity of the methanol synthesis section is controlled by capacity of reforming section but in case the capacity of methanol synthesis must be reduced without reducing the capacity of the reforming section, the steam governor should be put in manual and given a set point as required. Excess synthesis gas will then be vented to flare by PV-2481 (2000-PID-016/P21). Alternatively PIC-2481 could be set on manual and opened gradually while keeping the steam governor on auto.

3.8.3 Pressure control of methanol synthesis loop

With fresh catalyst a loop pressure of around 76.2 bar is foreseen. As the catalyst ages the pressure should be increased towards 84.1 bar in order to maintain a high conversion.

The pressure in the synthesis loop is controlled by purging part of the gas from D 3001. The purge gas is used as fuel in the tubular steam reformer

Purge gas to ejector, J 3001

The purge gas sent to the Ejector, J 3001, is controlled by FIC-3171 (3000-PID-006/P27).
J 3001 is used for increasing the pressure of the OH gas from the Stabilizer Column, in order to use the OH gas as fuel for the steam reformer burners.

The remaining part of the purge gas is controlled by FIC-3169, which gets its set point from the pressure controller PIC-3166 A.

In case of a methanol synthesis trip (IS-3) FV-3171 and FV-3169 is closed in order to maintain the pressure in the loop for easy re-start of the plant, FV-3169 is ramped down to prevent a IS-1 trip caused by low pressure in the reformer fuel header.

Emergency depressurization
An emergency depressurization valve, PV-3166 (3000-PID-006/P27), is located on vapor outlet line of D 3001. This valve opens when IS-41 trip is manually initiated by the operator in case of an emergency such as a fire or a bad leak in the unit. The pressure control valve is designed to depressurize the synthesis loop from normal operating pressure in D 3001 down to 50% of design pressure in 15 minutes.

3.8.4 Methanol reactor

The pressure drop across the methanol reactors is measured by PDI- 3112, PDI-3115 and PDI-3117 (3000-PID-004/P25) and is equipped with high pressure alarms.

Control of temperature in catalyst bed
R 3001 1/2/3 is tubular reactors with methanol synthesis catalyst loaded on the tube side.
R 3001 1/2/3 shell side is connected by risers and down-comers to the MP steam drum, D 3003.
Cooling of the reactor tubes is provided by boiling water on the shell side.

The methanol synthesis reaction is exothermic, so there will be temperature rise in the reactors. By controlling the pressure of steam produced in the methanol reactors, PIC-3042 (3000-PID-002/P23), the reaction temperature can be controlled and optimized.

3.8.5 Recycle flow

The recycle flow in the synthesis loop is controlled by the control valve located upstream the suction of the re-circulator C 3002. The control valve is included in compressor vendor's scope.

With fresh catalyst it may not be advantageous to allow full recycle as the additional conversion is limited and the heat of reaction will be transferred to the air and water coolers rather than being recovered as MP steam from D 3003. As the catalyst ages, the recirculation can be increased to ensure that the conversion stays high.

3.8.6 Raw methanol

Level control of the HP separator, D 3001
The level in D 3001 is controlled by LIC-3161 (3000-PID-006/P27) which operates the valves, LV 3161 A/B. Only one valve will be in operation at the time. Two valves are installed in parallel due to the wear and tear resulting from the large depressurization as well as possible deposits of wax.

LIC-3161 is provided with both low and high alarms. LSAH-3161 will be activated in case of too high level causing a trip of the methanol synthesis IS-3, in order to prevent liquid from over

flowing to the reformer burners and to the Re-circulator. In case of a too low level, LALL-3161 will be activated causing the level control valves LV-3161 A/B and the solenoid valve USV-3172 to close in order to prevent gas break through to the LP Separator, D 3002.

Pressure control of LP separator, D 3002

Most of the gas dissolved in the raw methanol is flashed off in D 3002, where the pressure is controlled by PIC-3194. The flash gas is used as fuel in the Steam Reformer, H 2001.
PIC-3194 is equipped with low and high alarms.

Level control of LP separator, D 3002

The level in D 3002 is controlled by LIC-3192 which is equipped with low and high alarms.
If the level in D 3002 becomes too low (LSAL-3192) or the level in the 'Raw Methanol Buffer Tank', TK-5001 becomes too high (LSAH-5002), the flow of raw methanol to TK 5001 (LV-3192) will be closed automatically by the interlock IS-43 and IS-44, respectively.

If the level in D 3002 becomes too high, the flow of raw methanol from D 3001 to D 3002 (LV-2721 A/B and USV-3172) will be closed by IS-42 in order to prevent liquid reaching the reformer burners.

3.8.7 MP steam generation

MP steam is generated in the three parallel methanol reactors, R 3001 1/2/3. Boiler feed water for the reactors are supplied by natural circulation from D 3001.

Saturated MP steam is routed to the MP steam header.

Pressure control

The pressure of the steam generated in D 3003 is set by the reaction temperature required in the methanol reactors R 3001 1/2/3.

The pressure in D 3003 is controlled by PIC-3042 (3000-PID-002/P23).

All steam condensate from the saturator is returned to D 3001 via P 6002A/B, make-up water is supplied from HP BFW header.

Level control

The level in D 3003 can be controlled by either single or three element control as decided by the operator via input to FHS-3041 (3000-PID-002/P23).

- Single element control: The BFW flow is controlled directly by the steam drum level controller, LIC-3042.
- Three element control: The flow is controlled by FIC-3041, based on input from level in steam drum LIC-3042; steam flow, FI-3050 and boiler feed water flow, FT-3041.

3.9 Methanol distillation

Capacity:
The capacity of the distillation unit is determined by the requested product withdrawal.
The product withdrawal is set indirectly by manual setting the OH reflux flow - MeOH product flow ratio via HIC-5337 for T 5002 and HIC-5336 for T 5003 (5000-PID-012/P40).

Reboiler duty:
The controller FIC-5301 (5000-PID-011/P39) of steam flow to the 'MP Column Reboiler no 1', E 5003 1/2 receives a set point from FY-5301 based on the actual methanol production in the synthesis loop, FI-3198.

If additional heat input to the stabilizer column is required, E 5001 must be taken into operation manually.

Control principle of distillation unit:
The feed flow to the distillation unit is adjusted by the column level controllers that are set to maintain a stable level in the columns as described below:

Raw MeOH -> T 5001-> T 5002-> T 5003

Methanol/water flow from T 5002 to T 5003 is controlled by TIC 5266, 67 or 68 (5000-PID-010/P38), because the temperature profile of the column ensures methanol content of excess water.

Methanol flow controller from T 5001 to T 5002 receives a set point calculated based on

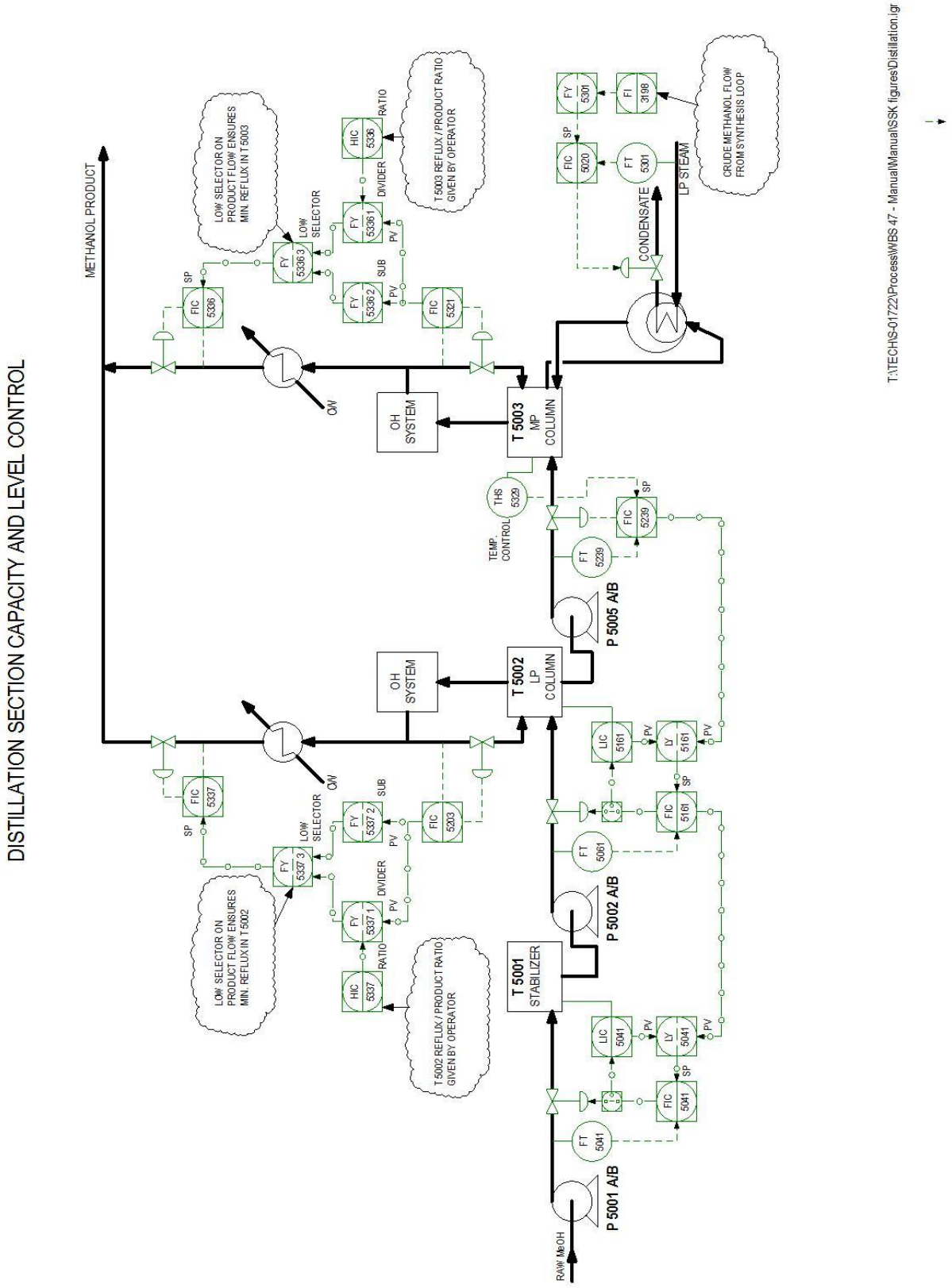
- Level of T 5002 and
- Flow of methanol/water flow from T 5002 to T 5003

Methanol flow controller from TK 5001 to T 5001 receives a set point calculated based on

- Level of T 5001 and
- Flow of methanol/water flow from T 5001 to T 5002

See figure for "Distillation section capacity and level control"

DISTILLATION SECTION CAPACITY AND LEVEL CONTROL



3.9.1 Stabilizer column, T 5001

(5000-PID-002/P30, 5000-PID-003/P31, 5000-PID-004/P32 & 5000-PID-005/P33)

Feed and level control

The raw methanol from P 50001 A/B, is introduced to tray no. 20 of the stabilizer column T 5001. The capacity of the distillation section is controlled by the feed flow controller, FIC 5041. The selector switch FSH-5041 (5000-PID-002/P30) gives the possibility of feed control by either single element control or three element control.

- In the single element control, the flow is controlled directly by the stabilizer column level controller, LICA-5041.
- In the three element control, the flow is controlled by FIC-5041 which receives a set point from LY 5041. LY 5041 calculate the set point based on level in T 5001 and methanol/water flow from T 5001 to T 5002 (FIC-5161).

The three element control is normally preferred. T 5001 level controller LIC-5041 is equipped with both high and low alarm. In case of too low level LSAL-5042 will initiate trip IS-54 and stop stabilizer methanol pump P 5002 A/B.

OH pressure control

The normal operating pressure in the column is about 0.7 bar g. Pressure controller PIC-5091 located upstream the stabilizer column OH condenser, AE 5004, controls the pressure of the column.

PIC-5091operates PV-5091A and PV-5091B on split control.

At normal operation PV-5091B sends the off-gas to the reformer fuel header via ejector, J 3001. If the pressure gets to low, PIC-5091 can add nitrogen via PV-5091 A.

If the synthesis loop and/or J 3001 are out of operation, PIC-5109 automatically takes over and sends the off-gas to the flare via PV-5109. The set point of PIC-5109 should be higher than the set point of PIC-5091.

Reflux flow control

The reflux is flow controlled by FICA-5093 which gets set point from D 5001 level controller FICA-5093.

Liquid off-stream from stabilizer

Acetone is foreseen to be removed via the OH gas stream.
If, however, the removal of acetone appears to be insufficient, a small stream of liquid from the discharge of the reflux pump P 5003 A/B may be withdrawn. FIC 5107 is used for flow control. This liquid off steam stream is cooled in the liquid off-stream cooler, E 5011, before going to the liquid off-stream tank, T 5003. In case of too high level in T 5003, IS-51 is initiated and FV-5107 is closed.

Stabilizer column reboilers

Below tray no 1 is the chimney tray from which all liquid is withdrawn and flows by gravity to reboilers.

All the liquid are passed through the start-up heater for stabilizer column, E 5001, and then it is sent to the stabilizer column reboilers, E 5024 1/2. The liquid passes through E 5001 even if E 5001 is not in operation.

These reboilers are of the kettle type and the top of their tube bundles are at same elevation. Sufficient liquid level is ensured by a weir in E 5024 2. Level in E 5024 2 is indicated by LI-5065 equipped with a low alarm.

E 5024 1/2 is heated by the synthesis gas from D 2003 in the reforming section. The duty of E 5024 1/2 is controlled by TIC-5064, via a bypass of process gas.

If additional duty for the reboilers is required then E 5001 is put in operation.

E 5001 is foreseen to be in operation either during start up or if the front end is not operating.
E 5001 is heated by low pressure steam and the pressure of steam is controlled by PIC-5069. The steam condensate is collected in steam condensate pot, D 5009.

Level of D 5009 is controlled by LIC-5070, equipped with high and low alarms.

If the level of D 5001 becomes too low LALL-5071, will initiate trip IS-55 and stop P 5011 A/B.
In case of trip of distillation section IS-4, the steam valve PV-5069 will close.

The sump at the bottom of the stabilizer column provides space for the total hold-up on the trays, which will be dumped in case of shut-down.

3.9.2 LP methanol column, T 5002

(5000-PID-006/P34, 5000-PID-007/P35, 5000-PID-008/P36, 5000-PID-009/P37 & 5000-PID-012/P40)

Feed and level control

The raw methanol from P 5002 A/B, is introduced to tray no. 5 of the LP Methanol Column T 5002.

The capacity of the distillation section is controlled by the feed flow controller, FIC 5161. The selector switch FSH-5161 (5000-PID-006/P34) gives the possibility of feed control by either single element control or three element control.

- In the single element control, the flow is controlled directly by the stabilizer column level controller, LIC-5161.

- In the three element control, the flow is controlled by FIC-5161 which receives a set point from LY 5161. LY 5161 calculate the set point based on level in T 5002 and methanol/water flow from T 5002 to T 5003 (FIC-5239).

OH pressure control

The normal operating pressure in the OH accumulator is only slightly above atmospheric pressure. Pressure controller PIC-5207 located on the LP column OH accumulator, D 5002, controls the pressure of the column.

PIC-5207operates PV-5207A and PV-5207B on split control.
At high pressure PV-5207B sends the vapor to safe location.
At low pressure nitrogen is added via PV-5207 A.

Reflux flow control

The reflux is flow controlled by FIC-5203 which gets set point from D 5002 level controller LIC-5203.

LP column reflux pump P 5004 A/B pumps most of the accumulated liquid in D 5002 as reflux to the column under level control and part of it is sent as methanol product.

Methanol product draw-off

About 60 wt% of the total product grade AA methanol is drawn from discharge of P 5004 A/B.

The ratio between reflux flow and product draw off is entered manual into HIC-5337.

The methanol product flow is controlled by FIC-5337 (5000-PID-012/P40).

The lowest value of FY-5337 1 and FY-5337 2, selected by FY-5337 3, is used as set point for FIC-5337.

- FY-5337 1: The product draw-off is calculated by the 'ratio of reflux flow and product draw-off' set on HIC-5337.
- FY-5337 2: Limits the product withdrawal in case the reflux flow falls below a minimum preset value.

LP methanol column reboilers

Below tray no 1 is a chimney tray from which all liquid is withdrawn and flows by gravity to the column reboilers E 5002 1/2/3/4. These reboilers are of the kettle type and the top of their tube bundles are at same elevation. Sufficient liquid level in all reboilers are ensured by a weir in E 5002 4.

Level in E 5002 4 is indicated by LI-5182 equipped with a low alarm.

The column T 5002 is provided with several temperature measuring points giving a good picture of the temperature profile. The column is further provided with several sample points. The concentration profile is strongly interrelated with the temperature profile.

The sump in T 5002 provides space for the total hold-up on the trays, which will be dumped in case of shut-down. All the ethanol, water and remaining methanol is pumped by the MP column feed pump P 5005 A/B, to the MP methanol column T 5003 for further treatment.

3.9.3 MP methanol column, T 5003

(5000-PID-009/P37, 5000-PID-010/P38, 5000-PID-011/39 & 5000-PID-012/P40)

Feed flow control

The feed to T 5003 is introduced on tray no 42 and the flow is controlled by FIC-5239 (5000-PID-009/P37).
The flow controller FIC-5239 receives set point from the temperature selector switch FHS-5239.

The selector FHS-5239 is switched on with any one of the following temperature controllers in the column

- TICA -5268 controls the temperature in tray no 10
- TICA -5267 controls the temperature in tray no 14
- TICA -5266 controls the temperature in tray no 18

The temperature controller must be selected based on the actual temperature profile in the column; a temperature controller operating on the steep part of the curve must be selected.
The remote set point should only be in operation when the column is operating at stable conditions.

Column T 5003 is provided with several temperature measuring points giving a good picture of the temperature profile.

The MP methanol column OH system

If the level in D 5003 is too low, LSAL-5322 will stop the pumps.

The reflux is controlled by FICA -5321 operating in cascade with the level controller of D 5003, LICA -5321.

During start-up, venting from D 5003 via HIC-5338 (5000-PID-012/P40) is required in order to purge inert gases from the system. No venting will be required during normal operation.

Reflux flow control

The reflux is flow controlled by FICA-5321 which gets set point from D 5003 level controller LICA-5321.

HP column reflux pump P 5006 A/B pumps most of the accumulated liquid in D 5003 as reflux to the column under level control and part of it is sent as methanol product.

Methanol product draw-off

About 40 wt% of the total product grade AA methanol is drawn from discharge of P 5006 A/B.

The ratio between reflux flow and product draw off is entered manual into HIC-5336.

The methanol product flow is controlled by FIC-5336 (5000-PID-012/P40).

The lowest value of FY-5336 1 and FY-5336 2, selected by FY-5336 3, is used as set point for FIC-5336.

- FY-5336 1: The product draw-off is calculated by the 'ratio of reflux flow and product draw-off' set on HIC-5336.
- FY-5336 2: Limits the product withdrawal in case the reflux flow falls below a minimum preset value.

Liquid off-stream draw-off

Higher alcohols must be withdrawn from tray no. 10, 14 or 18. The tray with the highest concentration of higher alcohols, based on analysis, must be selected.

Liquid off stream flows from the selected tray to the liquid off-stream cooler, E 5011, before being transferred to the liquid off-stream tank, TK 5003. The flow is controlled by FIC-5441, the set point of which is decided on the basis of regular analyses.

MP methanol column reboilers

Below tray no 1 is a chimney tray from where the liquid is withdrawn and flows by gravity to the column reboilers E 5023 and E 5003 1/2.

These reboilers are of the kettle type and the top of their tube bundles are all at same elevation. Sufficient liquid level in all reboilers are ensured by a weir in E 5003 2.

Level in E 5003 2 is indicated by LI-5278 equipped with a low alarm.

Reboiler E 5023 is heated by synthesis gas from D 2002 in the reforming section.
E 5023 is controlled by TIC-5277, via a bypass of process gas.

The remaining heat input to the column is provided by reboilers E 5003 1/2, which are heated by LP steam. FIC-5301 controls the heat duty of E 5003 1/2 by adjusting the condensate flow through control valve FV-5301, thereby flooding part of the tubes. The part of tubes flooded is indicated by LI-5308 and LI-5310 respectively.

The reboiler duty controller FIC-5301 gets a remote set point from FY-5301. FY-5301 calculates the set point based on raw methanol production in synthesis loop indicated by FI-3198 (3000-PID-007/P28).

Excess water

The bottom product 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 Na^+ originating from neutralization of raw methanol. The methanol content in the bottom can be controlled by adjusting the set point of temperature controller selected by FHS-5239. Thus, fluctuations in this temperature will cause corresponding fluctuations in the methanol content of the bottom product, which represents a loss of methanol. The top product quality is less sensitive to the temperature.

A minor part of the excess waters is used as wash water in the vent wash column. The flow of the wash water to T 5004 is controlled by FICA-5020.

Recyle of excess process water

The excess water is recycled to the saturator T 6001 1/2 via the excess water pump P 5010 A/B under flow control FIC-5367 which receives set point from T 5003 level controller LIC-5270.

The sump in T 5003 provides space for the total hold-up on the trays, which will be dumped in case of shut-down.

3.10 Product polisher unit

(5000-PID-014/P42)

The methanol product from distillation columns T 5002 and T 5003 is mixed and cooled to 48°C in the product coolers E 5008 and E 5012 respectively.

The product methanol is sent through the product polisher unit, X 5001 A/B, for removal of amines before being transferred to methanol storage. The purity and amine content of the product methanol is regularly analyzed at AP-5382 and AP-5383.

DMW is used to wash the catalyst before being unloaded and sent for regeneration. The DMW flow is controlled by FIC-5383 (5000-PID-014/P42).

Each product polisher unit is designed for 100% plant capacity making it possible to change one vessel while operating with the other at full capacity.

Downstream the product polisher unit strainers prevent resin from being transported to the storage tank. PDI-5385 high alarm indicates problems with resin loss from vessel.

3.11 Methanol product storage

(5000-PID-015/P43 & 5000-PID-016/P44)

The methanol product from the distillation columns T 5002 and T 5003 is measured by coriolis flow meter or mass flow meters FT-5337 and FT-5336 (5000-PID-012/P40). The sums of these tow flows is the total methanol production and is shown by FI-5338 (5000-PID-012/P40).

The methanol from the polisher unit is sent to methanol product buffer tank TK 5002 1/2. One tank is used at a time and when the methanol quality is confirmed by analysis the methanol is sent to methanol product tank outside battery limit.

The flow of methanol as final product is measured by coriolis flow meter FT-5421 (5000-PID-016/P44).

If the methanol is off-spec, it is sent to raw methanol buffer tank TK 5001 to be re-processed in the distillation section.

The product buffer tanks are provided with nitrogen blanketing. The pressure in the tanks is kept slightly above atmosphere, 0.001 to 0.01 bar g, in order to send the vapors from the tanks to vent wash column T 5004.

TK 5002 1: (5000-PID-015/P43)
PCV-5395 regulates the nitrogen blanketing pressure. Pressure indicator PI-5398 is equipped with high and low alarm. The tank is also provided with level transmitters LI-5396, which is equipped with high and low alarm.

Similarly instrumentation is provided for the second tank TK 5002 2.

3.12 Emergency hydrogen for trip of reformer

Hydrogen produced by cracking methanol in the pre-reformer is used for start-up and shut down. The ‘Methanol S.U. Pump’, P 5012 A/B, must always be in operation, recycling methanol to the storage tank, ready for injecting methanol into the process steam. Methanol injection is controlled by FIC-5407 (5000-PID-015/P43). FIC-5407 operates two control valves FV-5407 A/B, A is recycling methanol to the storage tank, B is injecting methanol into the process steam.

3.13 Liquid off-stream storage

(5000-PID-017/P45)
In order to prevent ingress of air a small overpressure in the tank is maintained automatically by nitrogen via PCV-5445. Pressure indicator PI-5448 is equipped with high and low alarm. The tank is equipped with a breather valve PVRV-5451.

The liquid off-stream can be injected directly into the natural gas feed to reforming section via the ‘Liquid Off stream Pump’, P 5009 A/B, The liquid off stream flow is shown by FI-6057 (6000-PID-003/P07).

3.14 BFW and steam generation

3.14.1 DMW preheater

The DMW temperature from the outlet of the 'DMW Preheater', E 2025, is controlled via a bypass on the process gas side (TIC-2457).

The process value from TIC-2457 is sent to the high selector TY-2457, which also receives input from the deaerator pressure controller PIC-7094. The high selector ensures that the DMW temperature always is at least 10°C lower than the dearated BFW temperature (TI-7097).

3.14.2 Deaerator

DMW from storage tank flow control:

The DMW flow to the deaerator D 7001 is controlled by FIC-7091 which receives a remote set point from the deaerator level controller LIC-7091. The selector switch LHS-7091 allows operator to select control FV-7091 either on level control alone or on combined level / flow control.
During start up the water flow to D 7001 is controlled by LIC-7091 only.

The DMW is deaerated with steam over a packed bed in the dome of the deaerator; the amount of steam vented to the atmosphere is fixed by the restriction orifice, FO-7096.

Pressure control of D 7001:

The operating pressure in the deaerator is controlled at around 1.0 bar g by pressure controller PIC-7094.

- 0-50% signal from PIC-7094 is used to adjust LP steam addition.
- 50-100% signal from PIC-7094 is used to adjust bypass of DMW preheater.

When the pressure in D 7001 is lower than normal, PIC-7094 would first increase the stripping steam by opening valve PV-7094 and if the normal pressure is still not obtained, the DMW temperature is increased by closing bypass valve TV-2457. The reverse action takes place when the pressure is higher than normal. PIC-7094 is equipped with high and low alarm.

If too much steam condensate is added to the deaerator compared to BFW withdrawl, PIC-7094 will not be able to control the pressure, and then PIC-7101 takes over. The set point of PIC-7101 is kept slightly higher than the set point of PIC-7094. PIC-7101 will relieve the excess steam to safe location via vent valve PV-7101.

3.14.3 Boiler feed water

BFW pH control

The pH of the BFW from D 7001 should be controlled within the range 9.0 to 10 by injection ammonia directly into the BFW. The pH is measured continuously by the online pH analyser AIC-7099 installed at the suction of P 7001 A/B/C.

HHP BFW header

Deaerated water from D 7001 is send to the HHP BFW header by 'BFW Pump', P 7001 A/B/C.

BFW from HHP BFW header is used for:

- HHP steam generation in E 2020 1/2.
- Quench of HHP steam down to HP steam.
- Quench of HHP steam down to export steam.

HP BFW header

A smaller part of the BFW is extracted for P 7001 at approx. 55 bar g and send to HP BFW header.

The HP BFW header pressure is controlled by PIC-7141. PIC-7141 gives a remote set point to FIC-7141, that allows BFW to be passed from HHP to HP BFW header via FV-7141.
BFW from HP BFW header is used for:

- HP steam generation in R 3001 1/2/3.
- Quench of process gas for control of pre-reformer inlet temperature.
- Additional water source for saturator.
- Quench of HP steam for use in oxygen preheater.
- Quench of HP steam down to MP steam
- Quench of HP steam down to LP steam
- Quench of import steam down to HP steam
- *Quench LP steam to E 5003*
- *Quench LP steam to E 5001*

BFW preheater

The BFW from the pumps is pre-heated the BFW pre-heater E 2022 1/2/3. BFW temperature outlet of pre-heaters should be maintained below its boiling temperature to ensure that vaporization does not occur in the BFW pre-heater. During normal operation the pre-heated BFW temperature is around 276°C. TI-2371 (2000-PID-013 / P18) located at outlet of the pre-heater is equipped with high temperature alarm gets activated when the BFW temperature is 10°C below its boiling temperature.

3.14.4 HHP Steam drum

The liquid level in D 2001 is controlled by LIC-2373 by adjusting the BFW flow from HHP BFW header. LIC-2373 is equipped with high and low alarm. BFW flow is controlled by FIC-2417 equipped with high and low alarm. The selector switch FHS-2417 makes it possible to control the flow of BFW make-up by simple level control, or if a faster-acting control is desired, the flow of saturated steam can be used as feed forward input.

Single element control

The flow is controlled directly by the steam drum level controller, LIC-2372. For start-up and operation at low capacities it is possible to select the smaller BFW valve LV-2372 via LHIC-2372.

Three element control

The BFW flow is controlled by FIC-2417, based on input from level in steam drum, LIC-2372, steam flow, FI-2372 and boiler feed water flow, FT-2417. In the 3-element control, the steam generated in D-2001 indicated by FI-2372 and level controller LIC-2372 resets the BFW flow through FIC-2417.

During normal operation, the pressure drop across FV-2417 and LV-2372 is controlled by PDIC-2417, which in provides a remote set point to the governor of the boiler feed water pump turbine. A low pressure drop is beneficial for the energy consumption.

3.14.5 HHP steam generation

HHP steam is generated in the two parallel waste heat boilers, E 2020 1/2. Boiler feed water for the waste heat boilers are supplied by natural circulation from D 2001.

The HHP steam is superheated in the steam super heater E 2021 1/2/3 before entering the HHP steam header.

Temperature control
TIC-2360 controls the HHP steam temperature by adjusting the flow of reformed gas through the internal by pass pipe of the waste heat boilers.

E 2020 1/2 is equipped with a damper controlling the flow through the internal by pass (damper 2) as well as a damper controlling the flow through the tube bundle (damper 1). The signal from TIC-2360 is send to TY 2360 1 and TY 2360 2, it is however possible for the operator manual to specify a small deviation via THIC-2360 1 or 2.

Pressure control
The pressure in the steam drum D 2001 is maintained at 102 bar g by PIC-2363 (2000-PID-012 / P17).

3.14.6 MP steam generation

MP steam is generated in the three parallel methanol reactors, R 3001 1/2/3. Boiler feed water for the reactors are supplied by natural circulation from D 3001.

Saturated MP steam is routed to the MP steam header.

Pressure control
The pressure of the steam generated in D 3003 is set by the reaction temperature required in the methanol reactors R 3001 1/2/3.

The pressure in D 3003 is controlled by PIC-3042 (3000-PID-002/P23).

All steam condensate from the saturator is returned to D 3003 via P 6002A/B/C, make-up water is supplied from HP BFW header.

Level control

The level in D 3003 can be controlled by either single or three element control as decided by the operator via input to FHS-3041 (3000-PID-002/P23).

- Single element control: The BFW flow is controlled directly by the steam drum level controller, LIC-3042.
- Three element control: The flow is controlled by FIC-3041, based on input from level in steam drum LIC-3042; steam flow, FI-3050 and boiler feed water flow, FT-3041.

3.14.7 Blow down system

(7000-PID-026/U16)

In order to maintain the quality of boiler water, primarily with respect to the content of salts, the steam drums, water heat boiler and the methanol reactors are provided with a blow-down system.

A continuous blow-down flow is withdrawn from each steam drum and an intermittent blow down flow is withdrawn from the water heat boilers as well as from the reactors.

Continuous blow down drum, D 7002

Blow-down from D 2001 and D 3003 are sent to D 7002 where blow down flashes at LP header pressure, the saturated LP steam is sent to the LP steam header. The condensate is routed to the 'Intermittent Blow Down Drum no 1', D 7003. D 7002 level is controlled by LIC-7251.

Intermittent blow down drum No 1, D 7003

D 7003 receives condensate from D 7002 and intermittent blow-down from the waste heat boilers.

D 7003 operates at atmospheric pressure and steam is vented to safe location. The level in D 7003 is determined by elevation of drain pipe.

Blow down cooler for D 7003, E 7001

The condensate from D 7003 is cooled in E 7001 before being sent to BL.

Intermittent blow down drum No 2, D 7003

Intermittent blow-down from the methanol reactors R 3001 1/2/3 is received in D 7004, which operates at atmospheric pressure and any steam generated is vented to safe location. The level in D 7004 is determined by elevation of liquid seal.

The condensate is left to cool in the drum, and when TG-7258 shows it is safe, the manual valve is opened and the water is drained.

3.15 Steam headers

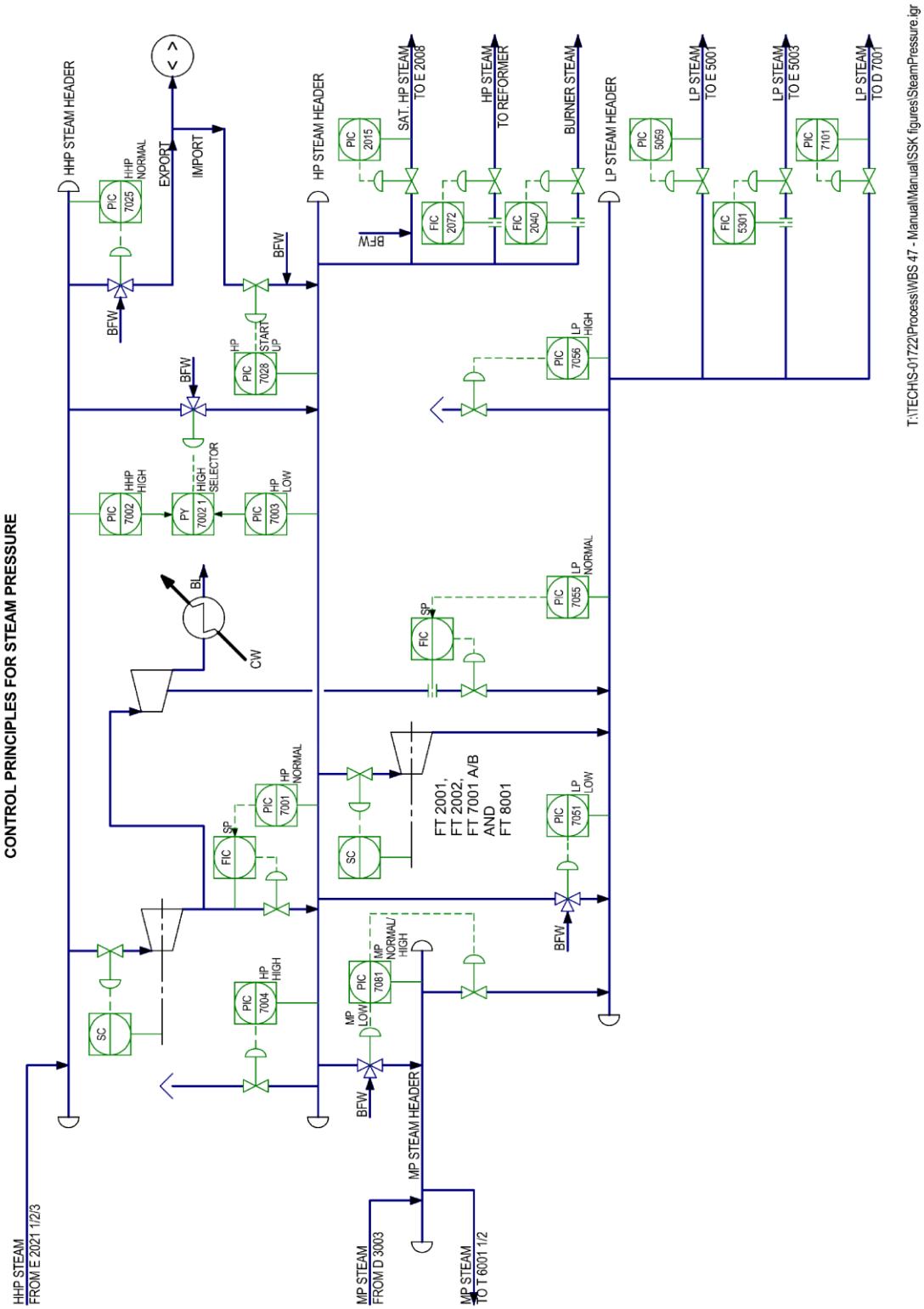
The plant is following steam headers are foreseen:

- HHP Steam Header 454°C @ 98 bar g
- HP Steam Header 345°C @ 44 bar g

- MP Steam Header, saturated steam at 32~40 bar g
- LP Steam Header 210°C @ 7 bar g

Quench stations provide flexible operation of steam system also in upset situations.

See figure for “Control principles for steam pressure”.


CONTROL PRINCIPLES FOR STEAM PRESSURE
HHP STEAM HEADER
HP STEAM HEADER
LP STEAM HEADER
MP STEAM HEADER
EXPORT
IMPORT
BFW
SAT. HP STEAM TO E 2008
HP STEAM TO REFORMER
BURNER STEAM
LP STEAM TO E 5001
LP STEAM TO E 5003
LP STEAM TO D 7001
HHP NORMAL
HHP HIGH
HP START UP
HP NORMAL
HP HIGH
HP LOW
LP HIGH
LP NORMAL
LP LOW
MP NORMAL/ HIGH
MP LOW
HIGH SELECTOR
FT 2001, FT 2002, FT 7001 A/B AND FT 8001
CW
HHP STEAM FROM E 2021 1/2/3
MP STEAM FROM D 3003
MP STEAM TO T 6001 1/2
T:\TECH\S-01722\Process\WBS 47 - Manual\Manual\SSK figures\SteamPressure.igr

3.15.1 HHP Steam header

Pressure control:

Controller	Case	BFW quench	Mean of control
PIC-7025 (7000-PID-007/U04)	Normal operation	TIC-7026 / TIC-7027	Export of HP steam
PIC-7002 (7000-PID-006/U03)	High pressure	TIC-7002 / TIC-7003 / TIC-7004	Let down to HP steam

3.15.2 HP Steam header

Pressure control:

Controller	Case	BFW quench	Mean of control
PIC-7003 (7000-PID-006/U03)	Low pressure	TIC-7002 / TIC-7003 / TIC-7004	Let down HHP steam
PIC-3094 (3000-PID-012 GE)	Normal operation	No	FT 3001 Extraction
PIC-7004 (7000-PID-006/U03)	High pressure	No	Vent to atmosphere
PIC-7028 (7000-PID-007/ U04)	Start Up	TIC-7025	Import steam

3.15.3 MP steam header

Pressure control:

Controller	Case	BFW quench	Mean of control
PIC-7031 (7000-PID-008/ U05)	Low pressure	TIC-7033 / TIC-7032	Let down HP steam
PIC-7031 (7000-PID-007/ U04)	Normal operation & high pressure	No	Let down to LP steam

3.15.4 LP steam header

Pressure control:

Controller	Case	BFW quench	Mean of control
PIC-7051 (7000-PID-007/U04)	Low pressure	TIC-7033 / TIC-7032	Let down HP steam
PIC-3597 (7000-PID-007/U04)	Normal operation	No	FT-3001 Extraction
PIC-7056 (7000-PID-007/U04)	High pressure	No	Vent to atmosphere

3.16 Methanol Tanks Unit

(4000-PID-001 & 4000-PID-002)

The methanol produced in this plant meet the requirement of grade AA. The specification of methanol product is shown in the following table.

Items	Specification
Acetone and aldehydes, wt, percent max	0.003
Acetone wt percent max:	0.002
Ethanol, wt percent:	Less than 0.0008
Acidity (as acetic acid), wt percent max.	0.003
Appearance and hydrocarbons	Free of opalescence suspended matter and sediment (clear – colourless)
Carbonizable substances colour	Not darker than colour standard no.30 of ASTM, D1209, platinum – cobalt scale
Colour	Not darker than colour standard no.5 of ASTM-D1209, platinum-cobalt scale
Distillation range	Not more than 1℃ and shall include 64.6 ℃ + 0.10 ℃ at 760 mmHg
Specific gravity, max	0.7928 at 20 ℃/20 ℃
Percent methanol by weight, minimum	99.85
Non-volatile content, mg / 1000 ml max	8
Odour	Characteristics non-residual
Permanganate fading time	No discharge of colour in 50 minutes
Water content, wt percent max	0.10
Alkalinity (as ammonia)	0.003 wt% max
Iron (ppm)	Lees than 0.03
Chloride (ppm)	Less than 0.1
TMA (ppb)	Less than 20

Usually, the methanol product is stored in TK 5002 1/2. The methanol product (at most three days output methanol product for each tank) could be stored in tank TK 4001 1/2 if needed, and

the methanol product is measured by orifice plate flowmeter FT-4024 (4000-PID-002). The sum of the flow is shown by FIQ-4024.

One tank is used at a time and when the methanol quality is confirmed by analysis method the methanol is sent to methanol product tank outside battery limit by P 4001 A/B. The transfer of methanol product will last for 8 hours each day. The flow of methanol as final product sent to methanol product tank outside battery limit is measured by coriolis flow meter FT-5421 (5000-PID-016/P44).

If the methanol is off-spec, it is sent to raw methanol buffer tank TK 5001 to be re-processed in the distillation section.

The methanol tanks TK 4001 1/2 are provided with nitrogen blanketing. The pressure in the tanks is kept around atmosphere, -0.0025 to 0.015 bar g.

TK 4001 1:
PCV-4025 regulates the nitrogen blanketing pressure. Pressure indicator PI-4005 is equipped with high and low alarm. The tank is also provided with level transmitter LI-4009, which is equipped with high and low alarm. Furthermore, the level transmitter LST-4007 is connected to the interlock system.

TK 4001 2:
Similarly instrumentation is provided for the second tank TK 4001 2.

All the drains in methanol tank unit are routed to an underground closed drain drum D 4001 (4000-PID-001). The drum D 4001 is provided with nitrogen blanketing. PCV-4026 regulates the nitrogen blanketing pressure.The pressure in the drum is kept around atmosphere, -0.0025 to 0.015 bar g. The drum is also provided with level transmitter LI-4030. The drains in D 4001 will be sent to raw methanol buffer tank TK 5001 by P 4002 when the level is high.

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Chapter 4 Preliminary Procedures and Precommissioning

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4 Preliminary procedures and precommissioning

4.1 General procedure

The preliminary procedures described below should be carried out after the plant has been erected. In addition to these procedures, all instructions in the vendor manuals must be followed.

4.1.1 Check of piping and arrangement

Check to make sure that the piping and the arrangement of equipment, valves and instruments is in accordance with relevant documentation such as P&I diagrams, plot plan, piping arrangement drawings, specifications, etc.

Special attention must be paid to internals such as grids, trays and thermowells.

4.1.2 Pressure testing

All pressure piping and equipment should be pressure tested with water.

Instrument air piping should be pressure tested pneumatically by means of instrument air with proper sealing of the area in question.

However, equipment and vessels have already been pressure tested in the workshops, and they are therefore only subject to testing after erection when specifically requested by authorities, or when practical in connection with testing of pipes.

Pressure testing must take place before insulation. Safety valves, control valves, and measuring orifices should be removed or blocked off.

All pressure parts of the tubular reformer have been pressure tested in workshops (reformer to outlet hairpins, hot collectors). After erection, the weldings should be tested for tightness only in order to prevent any contact between refractory-lined manifold and water.

4.1.3 Cleaning of equipment and pipes

Measuring orifices and flow meters should not be installed until the pipes have been cleaned. Control valves and safety valves must either be removed or blocked off during the cleaning operation, and all connections to instruments must be disconnected. All connections to pumps and compressors are to be blocked off or disconnected. Filter internals are to be removed as well.

Process pipes are blown out with steam, air or water at reasonably high velocities corresponding to a ρV2 at least equal to the value for normal operating conditions.

Instrument pipes are cleaned by blowing with instrument air.

The following piping requires special attention during cleaning:

- Oxygen piping: The oxygen piping is to be delivered with cleanliness “for oxygen service”. If the cleanliness is not at the required level, a specialist company should be requested to perform an oxygen cleaning procedure. In any case cleaning by steam blowing should be carried out before oxygen is admitted to the system. Please note that the steam used for the blowing must be particle-free.

- Steam piping feeding steam to oxygen system: steam piping downstream of filters shall be cleaned according to the same specification as for oxygen piping. For steam piping upstream the filters see under steam system below.

- Piping upstream from the primary reformer. Sand and other impurities left over from cleaning could be blown into the reformer and cause obstructions in the reformer hair-pins, or could be a source of silica, which is a catalyst poison.

- Refractory-lined equipment cannot be blown with steam because it would cause condensation in the refractory. For this reason, these pipes should be cleaned manually by use of brushes and vacuum cleaning.

- Fuel gas piping. Blocking of burner nozzles should be avoided.

- Steam system. The boilers, superheaters and connecting piping must be cleaned thoroughly to remove all rust and foreign material as described below. Care must be taken not to introduce catalyst poisons into the system with the cleaning chemicals.

- Coils in reformer waste heat section. Header end caps to be welded after completion of blowing.

- Compressor and pump suction piping. Suppliers' recommendations should be followed closely.

After cleaning, all intermediate connections and blinds are to be removed and normal connections established. Dirt filters, strainers, etc. are to be installed where necessary (suction of pumps).

Finally, the insides of reactors, towers and separators should be checked and all foreign material which could otherwise plug drains and bottom outlets must be removed. If scale and rust are still present, the citric acid rinsing procedure - or any other proper method - should be repeated. It is necessary to check to make sure that no water remains in the piping and equipment.

Please note that catalysts are sensitive to chlorine and sulphur, so solvents and other products containing such compounds should not be used for cleaning.

4.1.4 Cleaning of steam generating system

Manuals describing detailed procedures for cleaning of waste heat boilers, steam superheaters and tubular reactors will be delivered separately.

It is important to clean the steam generating system, because even small quantities of oil and grease may produce a film on the heating surfaces and this reduces the heat transfer considerably. This may result in equipment damage due to excessive temperatures. Furthermore, solid particles such as rust and scale may wear equipment, block valves and cause other damage.

4.1.4.1 Cleaning of BFW system

BFW preheaters should be cleaned prior to installation of the packing and the liquid distributor in the deaerator and before demineralized water is introduced into the steam drum.

Degreasing is performed by circulating a hot caustic demineralized water solution, which has been adjusted to a pH of about 11 with trisodium phosphate.

Establish circulation through all the BFW preheaters and continue for at least 4-6 hours. The circulating solution should be kept at a temperature of about 80ºC.

The BFW preparation system can now be chemically cleaned by circulating a hot ammoniated citric acid solution, the so-called "pickling" procedure.

Finally, the BFW preparation system should be passivated. This could be done, for example, by circulating an anhydrous ammonia/sodium nitrite solution.

4.1.5 Check of instruments

Before and during start-up, the control instruments and analysers should be adjusted and checked according to suppliers' instructions.

The set point for all alarms and trip devices must be adjusted and the functionality of the trip system itself must be checked.

4.1.6 Precommissioning

All instruments and valves have to be adjusted and calibrated in accordance with the specifications.

All connections, cables, process pipes and signal tubes have to be checked. Cables by a visual check and an electrical insulation test. Pipes and tubes by means of a soap water test.

4.1.7 Commissioning

After precommissioning, connect power and air supply to the plant, then test loop by loop according to the following procedure:

1) Disconnect process connection.
2) Establish a simulating process signal.
3) Check the functioning of each instrument in the loop at 0-10-20-30-40-50-60-70-80-90-100% of the process signal.
4) Check the air failure action of the control valve and the burn-out feature of the thermocouple. Test the function of each loop and all of its individual components, in particular the correct direction of control valve movement (direct / reverse action).
5) Establish a test certificate for each loop.
6) Check each safety interlock trip groups thoroughly, i.e. the individual active alarms and the related safety actions.

4.1.8 Check of electrical installations

Before power is applied to any part of the electrical installations, it is necessary to ensure that the points listed below have been checked and fulfilled:

1) Visual check to make sure that all electrical equipment has been erected in accordance with good electrical installation practice.
2) Check that all cables are properly supported and protected.
3) Check of all terminal and junction boxes to ensure that all conductors are marked and in place, in particular the protective conductors. Check also the seals on covers and cable glands.
4) Check and adjustment of all equipment in accordance with the manufacturers' instructions and specifications.
5) Test of earthing system to determine the continuity of connections and the value of resistance to earth.
6) Test of insulation of electrical equipment and cables using a megohmmeter and/or in accordance with the manufacturers' instructions, e.g. breakdown test on oil from power transformers.
7) Check of power and control circuit for correct connection by means of test lamp or buzzer.
8) Test of protective relays by fault simulation and by current injection techniques.
9) Check of fuse ratings.
10) Check of proper co-ordination between various protective devices.

4.1.9 Check of valves

All valves should be inspected to ensure that they have been properly packed and that they can operate easily. The valves should be left in closed position.

The set pressures for the safety valves are checked by means of a hydraulic test stand in the workshop before installation of the valves.

The set pressure as determined by a hydraulic test is slightly different from the one existing when the safety valve is working at the specified temperature. Therefore, it is recommended to check, after mounting, the set pressure of the safety valves on the steam boiler by means of steam at the specified temperature. This is done by slowly raising the pressure in the boiler until reaching the set pressure of the safety valves, at which pressure the safety valves should open.

Dampers should be checked for free operation before and after heating-up.

4.1.10 Check of rotating equipment

All rotating equipment should be checked according to suppliers' instructions. The following points should in particular be covered:

- Alignment of shaft
- Direction of rotation
- Proper alignment of piping and casing
- Lubrication and cooling system
- Running-in of spare equipment during operation
- Proper connection of cables
- Vibration testing

4.1.11 Check of laboratory

Before the initial start-up, a check must be made that the analytical laboratory is ready, i.e. that all equipment, chemicals and analytical manuals are available, and that the laboratory is sufficiently staffed with experienced laboratory workers.

4.2 Drying of furnaces and refractory lining

The refractory linings on the inside of the process equipment and piping are located as follows:

1) Bottom heads of the steam reformer outlet collectors.
2) Transfer line and the branches running from the steam reformer outlet collectors to the waste heat boiler (E 2020).
3) Inlet chamber of the waste heat boiler.
4) Secondary reformer

The procedures followed when drying out the inner refractory linings must be in accordance with the recommendations of the manufacturers and suppliers of the refractory bricks, cements, etc. In particular, the development of temperatures as a function of time, temperature increases or decreases per hour, duration of time periods and temperature levels (if temperatures are to be kept constant for a certain period of time), and means of temperature control at the various lining locations should be discussed with the relevant manufacturers and suppliers.

The necessary heat for drying out the primary reformer is supplied by the installed burners. The outlet collectors and downstream refractory sections are dried out by use of portable fired heaters being installed in the manholes.

The drying out of secondary reformer must be done in accordance with separate manual.

This drying out process is the first time the system is heated, so monitor carefully for thermal expansion of equipment and piping by observing marks made when the system was cold. Make sure that all parts are free to move so that excessive stress is avoided.

Heating above design temperatures must be avoided; special attention should be paid to the coils in the waste heat section with stagnant conditions on the process side.

The shell temperature of the refractory-lined manifold, the secondary reformer and the inlet section of the process boiler must be closely monitored.

External surfaces should be provided with temporary insulation to ensure proper dry-out of the outermost refractory layers.

After drying out the refractory, cool the unit down for inspection. Stop firing in the re-former when convenient, following the temperature gradients specified by the supplier of the refractory lining.

If inspection reveals that repair of the refractory is necessary, it must be done in accordance with vendor instructions.

4.3 Catalyst loading

4.3.1 Instructions for handling, storage and loading of catalysts

4.3.1.1 General precautions

It should be pointed out that catalyst containers must always be handled carefully and the containers must never be rolled, because this could cause breakage of the catalyst particles.

Furthermore, the catalyst must not be exposed to moisture, and it is to be stored in tightly closed containers.

During loading operation, the catalyst is to be protected against rain.

Dust and broken particles are to be removed in accordance with the procedure for the catalyst in question.

As soon as possible after catalyst loading, close the reactor to protect the catalyst against moisture, dirt and foreign matter.

Keep a 1 kg sample of each catalyst after loading.

Whenever the catalyst loading process is interrupted for an extended period of time - e.g. overnight or during a period of rain - any reactor entrances, hoppers and catalyst exposed to weather conditions should be covered with a tarpaulin.

4.3.1.2 Safety precautions

Because dust is formed during handling of the catalyst, the personnel involved should wear dust masks. It is recommended that personnel working inside the reactors during loading should wear air masks with a fresh-air supply from the outside.

During loading, there must also be a supply of fresh air to the inside of the reactor - e.g. by means of a venturi blower with its intake connected to a dumping chute - which creates a flow of fresh air downwards. The capacity of the venturi blower should be in the order of 25 m^3/min.

Personnel entering the reactors should be equipped with life-lines and safety belts. Personnel inside the reactors should also be provided with some means of communication with personnel outside.

Finally, all local safety regulations must be observed.

4.3.1.3 Handling and storage

Topsøe catalysts are supplied either in steel drums containing approximately 120-130 kg of catalyst or in big bags containing approximately 1000 kg of catalyst.

The catalyst should be stored indoors in a dry and well-ventilated room.

The catalyst should not be stored directly on the ground, but should be placed on logs or pallets.

Drums and big bags can be stacked, but only in stacks of two.

4.3.2 Screening of catalyst

It is normally only necessary to screen the catalyst taken from the bottom of the drums, if the drums have been subjected to rough handling during transport. A screen with openings of 1 mm is suitable for use. The screening operation must be carried out with care: to minimize attrition of catalyst, avoid vigorous shaking of sieve. The sieve can conveniently be tilted at an angle, which permits the catalyst to be moved easily, e.g. by raking.

4.3.3 General equipment for catalyst loading

Below is a non-exhaustive list of general equipment needed for catalyst loading:

1) Screen wire mesh, 1 mm and 2 mm
2) Lifting rig for lifting of catalyst drums
3) Screwdriver for opening the catalyst drums
4) Adjustable wrench
5) Twenty-litre polyethylene buckets
6) Tackle and 50 m rope
7) Dust masks
8) Scales max. 30 kg
9) Electric torch and a 10 m line
10) Hopper with a flexible polyethylene hose
11) "Snow shoes" or walking planks to be worn by the operator distributing the catalyst, etc. during loading.
12) Funnel fittings

For information on more specialised equipment, please see the catalyst loading/unloading manuals in the Appendices.

4.3.4 Hydrogenator reactor, R 1001

Please see the following documents:

- Catalyst specification
- Specification of reactor filling materials
- Process specification for R 1001 Hydrogenator
- Manual for Topsøe hydrodesulphurization catalyst for purification of steam reformer feed type, TK-261

Cover the ellipsoidal head at the bottom of the reactor with a double layer of stainless steel wire mesh (10 x 10 mm and wire diameter 2 mm). Cover the mesh with a layer of 1" ceramic balls up to 860 mm below the tangent line. The pipe for unloading of catalyst should be filled with 1” ceramic balls as well. Cover the layer of balls with a stainless steel wire mesh (3 x 3 mm and wire diameter 1 mm). The wire mesh should be of ample size so that an upward bent edge of 50 mm can be made to prevent catalyst particles from passing. Then load the TK-261 catalyst on top of the wire mesh. For more detailed information, please see the reactor specification sheet for the hydrogenator reactor.

The catalyst is to be loaded in rather thin (200-300 mm) horizontal layers in order to avoid segregation and channelling.

The catalyst can be loaded either by buckets or by loading chute. Be particularly careful to spread each layer of catalyst all the way out to the side walls. Before loading, remove dust and crushed particles from the catalyst by screening and air blowing.

Guide the loading equipment to ensure that the catalyst is not poured in a heap.

Continue loading until the correct height has been reached. Put a 100 mm layer of 1" ceramic balls on top of the catalyst bed.

4.3.5 Sulphur absorber, R 1002 1/2

Please see the following documents:

- Catalyst specification
- Specification of reactor filling materials
- Process specification for R 1002 1/2 Sulphur absorber
- Manual for Topsøe activated zinc oxide catalyst type HTZ-51

Cover the ellipsoidal head at the bottom of the reactor with a double layer of stainless steel wire mesh (10 x 10 mm and wire diameter 2 mm). Cover the mesh with a layer of 1" ceramic balls up to 770 mm below the tangent line. The pipe for unloading of catalyst should be filled with 1” ceramic balls as well. Cover the layer of balls with a stainless steel wire mesh (3 x 3 mm and wire diameter 1 mm). The wire mesh should be of ample size so that an upward bent edge of 50 mm can be made to prevent catalyst particles from passing. Then load the HTZ-51 catalyst on top of the wire mesh. For more detailed information, please see the reactor specification sheet for the sulphur absorber.

The catalyst is to be loaded in rather thin (200-300 mm) horizontal layers in order to avoid segregation and channelling.

The catalyst can be loaded either by buckets or by loading chute. Be particularly careful to spread each layer of catalyst all the way out to the side walls. Before loading, remove dust and crushed particles from the catalyst by screening and air blowing.

Guide the loading equipment to ensure that the catalyst is not poured in a heap.

Continue loading until the correct height has been reached. Put a 100 mm layer of 1" ceramic balls on top of the catalyst bed.

4.3.6 Prereformer, R 2003

Please see the following documents:

- Catalyst specification
- Specification of reactor filling materials
- Process specification for R 2003 Prereformer
- Manual for Topsøe prereforming catalysts AR-401

Cover the ellipsoidal head at the bottom of the reactor with a double layer of stainless steel wire mesh (10 x 10 mm and wire diameter 2 mm). Cover the mesh with a layer of 1" alumina balls up to 790 mm below the tangent line. The pipe for unloading of catalyst should be filled with 1” alumina balls as well. Cover the layer of balls with a stainless steel wire mesh (3 x 3 mm and wire diameter 1 mm). The wire mesh should be of ample size so that an upward bent edge of 50 mm can be made to prevent catalyst particles from passing. Then load the AR-401 catalyst on top of the wire mesh. For more detailed information, please see the reactor specification sheet for the prereformer.

The catalyst is to be loaded in rather thin (200-300 mm) horizontal layers in order to avoid segregation and channelling.

The catalyst can be loaded either by buckets or by loading chute. Be particularly careful to spread each layer of catalyst all the way out to the side walls. Before loading, remove dust and crushed particles from the catalyst by screening and air blowing.

Guide the loading equipment to ensure that the catalyst is not poured in a heap.

Continue loading until the correct height has been reached. Put a 100 mm layer of ½" alumina balls on top of the catalyst bed and a 100 mm layer of 1” alumina balls on top of the ½” alumina ball layer.

4.3.7 Primary reformer, H 2001

Please see the following documents:

- Catalyst specification
- Process specification for H 2001 Primary reformer
- Manual for Loading and Unloading of Catalyst in a Tubular Reformer
- Manual for Topsøe Steam Reforming Catalysts R-67-7H

An amount of R-67-7H corresponding to a height of 12.4 m is to be loaded in the bottom of each reformer tube.

When the catalyst has been loaded and the pressure drops adjusted as described in the above-mentioned manual for loading and unloading of catalyst, the hairpins and distributors can be connected to the catalyst tubes, after having been carefully cleaned. Once the connections have been established, blow nitrogen or dry air through all catalyst tubes in order to remove dust created during the filling.

4.3.8 Secondary reformer, R 2004

Please see the following documents:

- Catalyst specification
- Specification of reactor filling materials
- Process specification for R 2004 Secondary reformer
- Secondary reformer general assembly drawing
- Manual for RKS-2/RKS-7H - Topsøe Secondary Reforming Catalyst

In the bottom part of the secondary reformer around the ceramic mushroom at the outlet nozzle, alumina balls are loaded as per the methanol reactor assembly drawing.

Different layers of catalyst are loaded. Catalyst layer (from bottom) are:

1st layer: RKS-2-7H to a height of 1240 mm on top of alumina balls layer.
2nd layer: RKS-2 rings to a height of 620 mm on top of RKS-2-7H layer.
3rd layer: RKA-02 to a height of 300 mm on top of RKS-2 layer.

The catalyst is finally covered by a 150 mm layer of tiles. The purpose of the tiles is to protect the catalyst from turbulence and secure a uniform flow and gas distribution during operation.

4.3.9 Methanol reactor, R 3001 1/2/3

Please see the following documents:

- Catalyst specification
- Specification of reactor filling materials
- Process specification for R 3001 1/2/3 Methanol reactor
- Methanol reactor general assembly drawing
- Manual for Topsøe Methanol Synthesis Catalyst, Type MK-151, in Boiling Water Cooled Converters

The support cone in the bottom head is covered by two layers of stainless steel wire mesh (10 x 10 mm and wire diameter 2 mm).

Three sizes of alumina balls are installed as support for the catalyst in the bottom head.

- 2" alumina balls are loaded from the bottom to the top of the support cone.
- On top of this a uniform layer of 300 mm 1" alumina balls are loaded
- On top of this a uniform layer of 100 mm ½" alumina balls are loaded

Loading of the above mentioned balls is done by the following procedure:

The top of the support cone is equipped with hinges to allow loading of support balls through the top of the support cone.

The lower 2” support layer can be completely loaded through the top of the support cone.

As much as possible of the next two layers are loaded from the top of the support cone.

The remaining part must be loaded through the top tube sheet, finalizing the respective layers of 300 and 100 mm. This must be done carefully so that the balls do not bridge in the tubes.

The methanol catalyst is to be loaded from the top tube sheet. A hopper containing the catalyst should be placed above the converter and connected to a flexible hose. The flexible hose should be able to reach all areas on the top tube sheet in the reactor. It is essential that the hose has a reasonable slope from the hopper outlet to the feeding point in the reactor in order to ensure that the catalyst will flow through the hose at a satisfactory pace.

During the loading, a person should be present inside the converter to distribute the catalyst carefully. The hose should be kept in a constantly horizontal movement in order to secure a uniform and high loading density in the tubes. Tubes loaded with catalyst should be levelled off by sweeping excess catalyst into neighbouring tubes.

After catalyst loading, the top cover of the methanol reactor is reinstalled as soon as possible, and the reactor is purged with nitrogen.

Careful loading of the methanol catalyst into the reactor tubes is important to achieve the highest possible loading density. The consequence of poor loading is poor performance of the reactor.

4.4 Tightness test and purging

4.4.1 Tightness test

When all the catalysts have been loaded, blow nitrogen or air through the vessels and process piping to remove catalyst dust deposits formed during loading.

After this blowing procedure and after all flanges, valves and orifices have been remounted, pressurise the various units in the plant with air or nitrogen. All connections should be tested with soapy water. Flanged connections can be tested by sealing them with tape, puncturing the tape in one place and then testing the puncture with soapy water.

4.4.2 Purging

After satisfactory tightness test, the equipment must be purged with nitrogen in order to reduce the oxygen content. To avoid an explosive mixture of oxygen and synthesis gas, oxygen content after purging should be below 2%.

However, before start up, the units must be purged until

Unit	Oxygen	Hydrocarbons
HDS+saturator	<2%	
Reforming unit	<0.2%	<0.1%
Methanol synthesis loop	<0.1%	
Distillation unit	<2%	

A continuous flow can be used, but to avoid the formation of air pockets in equipment and catalysts, it is preferable to pressurise and depressurise the equipment several times. To ensure that all parts of equipment, instrumentation, bypass lines, drains and vents are purged, open the valves for 2-4 minutes during the depressurising process. Repeat this procedure 2-3 times until the oxygen content falls below 2%. Once a section has been purged, isolate it until start-up and keep it at a pressure level slightly above atmospheric.

To reduce the consumption of nitrogen, steam ejectors could be installed to suck out most of the oxygen from the system before it is pressurised with nitrogen.

Just before start-up, check the various sections in the plant again and repeat the purging process if the oxygen content is found to be above the specified limit.

4.4.3 Commissioning of burner tightness test system

During commissioning, the acceptance values for the burner tightness test system must be determined by testing.

Please refer to ‘Description of burner tightness test and furnace purge system and leak test procedure’, for description of the test.

4.5 Appendices

- Manual for Topsoe hydrogenation catalyst TK-261
- Manual for Topsoe zinc oxide absorbents – HTZ series
- Manual for Topsoe prereforming catalyst AR-401
- Manual for Topsoe steam reforming catalyst R-67-7H and R-67R-7H
- Manual for Topsoe autothermal and oxygen-fired secondary reforming catalysts RKA-02, RKS-2, RKS-2-7H
- Manual for Topsoe methanol synthesis catalyst - MK-151 FENCE in boiling water cooled converters
- Loading and unloading of catalyst in tubular reformer

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5 Start-up procedures

5.1 General remarks

Before initiating start-up operation, the utilities should be available:
Instrument air, cooling water, nitrogen, demineralised water, natural fuel gas, HP (start-up) steam, hydrogen and power supply. It should further be checked that the laboratory is ready and that the following units are operational:

- Interlock trip system
- Emergency power system
- Fire water system and fire alarms
- Telephone and intercommunication systems

It is assumed that all preparatory procedures described in Chapter 4 (Preliminary Procedures and Precommissioning) have been completed.

During start-up, surface temperatures of brick lined equipment and pipes as well as thermal expansions of essential equipment and pipes should be checked periodically.

All recommendations given by equipment suppliers (particularly of valves, refractory, burners, boilers and rotating equipment) should be incorporated in the start-up instructions.

As a general remark with respect to the interlock trip system, a number of the inactivation locks will have to be activated during the initial phases of the start-up in order to allow resetting of the respective trip groups.

As soon as the actual situation allows, i.e. when the respective operating parameters approach normal values, the corresponding switches should be reactivated to ensure optimal safety of the plant unit in operation.

The distillation section provides cooling to the reformer section; during start-up the interaction between front end and distillation must be taken into consideration.

5.2 Summary of start-up sequence

5.2.1 Start-up sequence for front end and distillation unit

1. Fill Deaerator D 7001 with DMW water.

2. Fill the HHP steam drum D 2001 with BFW and preheat the waste heat boiler E 2020 with HP steam.

3. The reforming section is pressurised to 5 bar g with nitrogen.

4. Fill the stabilizer and concentration columns until normal level. Start the air cooled overhead condensers. The distillation section is now able to cool the steam/process gas effluent from the reformer

5. Establish a once-through natural gas flow through the desulphurization section, which is vented downstream the sulphur absorber R 1002 1/2 through PV-1045. Thereby the HDS (1000 unit) is heated simultaneously to the reformer.

6. A circulation flow is created through the BFW preheaters by opening HV-2371 thereby boiling in BFW preheaters can be avoided, when heating the reformer.

7. Start the flue gas blower, F 2001, carry out the burner tightness test according to appendix 1, ignite the primary reformer burners and heat up the reforming section in circulating nitrogen.

8. Introduce steam into the reformer, and vent the steam downstream the final separator, D 2005. Nitrogen recycle is cut off.

9. Simultaneously to steam introduce methanol upstream the prereformer to produce hydrogen for reduction of reforming catalyst and for hydrogenation of organic sulphur components present in the natural gas.

10. Start the hydrogen recycle compressor in order to return hydrogen to the desulphurization section for desulphurization of the natural gas. The natural gas is vented downstream the desulphurisation section.

11. When analysis shows that the desulphurisation section operates satisfactorily, the natural gas is sent through the saturator in order to heat up the saturator system. The natural gas is then introduced to the reformer. The operation of the front end is slowly adjusted to normal operation.

    The unit is designed with a Load and Temperature Management (LTM) system, which allows capacity control with change of only one parameter – plant capacity by HIC-6067 – and it is described in Description of load and temperature management.

12. The distillation section must be started in parallel with the front end. Bring the pressure of the distillation section to its normal operating values, and adjust the temperature profile in the concentration columns. When the product quality is in order, the reflux ratio can be decreased gradually and the product withdrawal from the concentration columns can be started.

5.2.2 Summary of start-up sequence of synthesis loop

1. Purge the methanol synthesis section with nitrogen and establish nitrogen circulation in the loop via the recirculator, C 3002.

2. Fill the steam drum, D 3003, and the shell side of the methanol reactors with boiler feed water.

3. Reduction of methanol catalyst:
   The methanol reactor is heated up by admitting steam through the start-up ejector to the reactor shell side.

   The catalyst reduction is performed by admitting synthesis gas to the circulating nitrogen. The system is purged with nitrogen and sealed when the catalyst reduction is finished. The reduction must be performed as per 'Manual for Topsøe Methanol Synthesis Catalyst MK-151 in Boiling Water Cooled Converters'

4. The synthesis loop is heated to 200°C in circulating nitrogen.

5. The circulating nitrogen is stopped and synthesis gas is slowly admitted to the methanol synthesis section.

6. The methanol reaction is started by increasing the CO and CO_2 content of the synthesis gas.

7. The steam to the start-up ejector is gradually reduced as the methanol production increases.

5.3 Preparing the boiler water and steam system

5.3.1 Deaerator (7000-PID-012/U09)

The deaerator, D 7001, is filled with demineralised water to normal level. Initially the level controller LICA-7091(7000-PID-012/U09) is put into operation. When a DMW flow is established, the cascade from the level controller LICA-7091 to FIC-7091 is put into operation.

Initially, LP steam is introduced into the sparger in the bottom of the deaerator in order to heat up the water in the drum.

When the pressure reaches normal operating pressure, the steam flow through the bottom sparger is reduced to a minimum and the steam is sent through the sparger in the deaerator dome.

During normal operation, the pressure in the deaerator is controlled by PHIC-7094 (7000-PID-012/U09). PHIC-7094 is adjusting the LP steam flow added to the deaerator.

- If PV-7094 is fully closed and the operating pressure still is too high, then the temperature of the DMW into the deaerator is decreased by opening the bypass around E 2025 further.

- If the pressure in the deaerator is too high even if the LP steam addition is reduced to zero and bypass of E 2025 is maximum open, then the steam is vented through PV-7101 (7000-PID-012/U09), controlled by PIC-7101.

Chemical dosing to the deaerator is established.

- The oxygen scavenger is added to the boiler feed water from the oxygen scavenger dosing unit, in order to obtain a concentration of 0.9 wt ppm of carbohydrazide in the boiler feed water.
- Amine is added to the boiler feed water from the ammonia dosing unit X 7002 in order to obtain a pH of 9-10 in the BFW.

5.3.2 HP, MP and LP steam header

When HP import steam is available, the HP, MP and LP steam headers can be brought to normal operating pressures.

The import HP steam available is superheated, therefore it is important to ensure that the various quench stations are ready to be put into service before the steam headers are commissioned.

Import steam to HP steam header (7000-PID-007/U04):
Import HP steam from BL is admitted to the methanol plant through PV-7028. The import steam temperature is controlled by TIA-7025 via injection of BFW quench through TV-7025 A/B. The temperature of steam should not exceed 380°C, as the steam turbines operating on HP steam are designed for this maximum temperature.

The MP and LP steam header is pressurised and prepared for steam consumers through the quench stations.

5.3.3 Steam drum (2000-PID-013/P18)

After boiling-out or chemical cleaning of the waste heat boilers in accordance with the procedure given by the suppliers, the HHP steam drum and boilers are left filled with water, with the isolating valves on the steam outlet closed and with the vent valve open. Just before the boilers E 2020 1/2 are taken into operation, the water level HHP steam drum is decreased to low level using the blow down valve.

Check to make sure that the block valves around the control valves in the line from the BFW pumps P 7001 A/B/C to the HHP steam drum D 2001 are all open.

Start the motor-driven BFW pump or, if HP steam is available, the turbine-driven pump. The BFW flow to HHP steam drum, D 2001, is established and the level in D 2001 is adjusted to minimum level.

A continuous blow down is established by opening HV-2385 (7000-PID-026/U16).

Adequate flow through HV-2371 must be maintained to have a continuous flow through the BFW preheaters to protect them from boiling when process gas is introduced.

The level in the steam drum must be watched carefully and kept at minimum level. If it starts to increase, the blow-down valve must be opened further.

5.4 Start-up of front end, initial procedures

It must be ensured that all branch lines to the main process piping are closed, preferably by double block and bleed, in order to prevent process gas leakages into various systems or other media from entering the process gas.

The desulphurisation unit is isolated from the saturator by

- Closing the manual valves (1000-PID-003/P04) located between R 1002 2 and E 6001.

The saturator is isolated from the reforming section by

- Closing FV-2061,FV-2091, USV-2092 and USV-2093 (2000-PID-004/P10)
- Opening the bleed valve USV-2094 to the atmosphere.

The process oxygen is isolated by

- Closing valves: USV-2048 and USV-2045
- Opening the bleed valve USV-2049 to the atmosphere

In order to prevent any accidental leakage of hydrogen containing gas to the primary reformer:

- Close FV-2079 (2000-PID-004/P10) and corresponding block valves in the line for addition of recycle hydrogen.
- Close FV-2150 (2000-PID-006/P12) and corresponding block valves in the line for addition of recycle hydrogen

Start-up methanol line PMP-20-161 (2000-PID-003/P09) must be isolated from the reformer by double block and bleed.

The process steam line is isolated by closing MV-2098 (2000-PID-004/P10), FV-2072 (2000-PID-003/P09), manual valves and opening HV-2097.

Process water lines are isolated by closing FV-2233 1/2 (2000-PID-007/P13) and corresponding manual valves.

The protection steam to the secondary reformer burner is isolated by closing FV-2040 (2000-PID-002/P03), manual valves and opening HV-2031.

The NG feed line is isolated by closing double block valves and open bleed valves at BL.

5.5 Protection of coils in flue gas section during start-up

- The reforming section will be heated up in a recycling atmosphere of nitrogen.

- The desulphurisation unit will be heated up in once through natural gas.
- The saturator will be heated up in once through natural gas as soon as the desulphurisation unit is operating properly. This is to avoid pollution of saturator and piping with sulphur.

At this stage, the waste heat boiler, E 2020 1/2, must be ready for operation as described in the separate manual. One of the BFW pumps is in operation with open minimum flow device.

During the entire period of start-up it is important that the temperatures around the BFW preheaters are monitored, and the recirculation flow through HV-2371 is maintained to prevent boiling in BFW preheaters.

Likewise, steps must be taken to protect some of the heat exchanger coils in the waste heat recovery section by keeping a sufficient cooling flow to prevent temperatures higher than design.

WHS coils:
During start-up, temperatures in the reformer waste heat section must be supervised and it must be prevented to exceed any design temperatures.

The scheme below shows the design tube skin temperatures of various coils in the waste heat section:

Item no.	**Design tube skin temperature, °C**
E 2001	705
E 2002	610 / 530
E 2004	440
E 2006	350
E 2007	210

The design temperatures for the inlet and outlet manifolds of various coils are:

Item no.	**Inlet/outlet, °C**
E 2001	500 / 675
E 2002	300 / 550
E 2004	375 / 410
E 2006	85 / 375
E 2007	280

During start-up, the coils will be protected as follows:

E 2001 and E 2002
During the various phases of the start-up, this coil will be supplied with a flow of recirculating nitrogen, pure steam and finally by a natural gas/steam mixture, which will ensure sufficient protection against overheating. However, if too many burners in the upper row of the reforming sections are in service at low reformer load, the maximum allowable outlet temperature may be exceeded and this must be avoided.

It is also possible to open false air dampers, HIC-2225, located at the top of the waste heat section. However; the false air dampers should be closed during normal operation.

E 2004 and E 2006
These coils will be protected by the natural gas flow needed for heating of the desulphurisation section.

E 2007
The plate heat exchanger is protected by establishing combustion air flow through this coil.

5.6 Establish nitrogen circuit around reformer unit.

The reforming section is completely isolated and connected to the nitrogen start-up circuit as described above.

a) The reforming section is completely isolated as described above.

b) Ensure that the BFW preheaters, waste heat boilers and HHP steam drum is taken into service as described above

c) The distillation section columns are purged and the reboilers are filled with liquid as described below.

d) Open the process gas bypasses across reboilers in the distillation section, TV-5064 and TV-5277. The butterfly valves at the inlet of the reboilers are throttled to minimum stop.

e) The process gas bypass TIC-2335/2336 in the waste heat boilers E 2020 1/2 should be approximately 50% open to reduce condensation, since the process gas will be relatively cold until the secondary reformer has been heated up and the primary reformer firing has increased.

f) Line up the nitrogen start-up circuit to the reforming section as follows:
C 2001 Start-up nitrogen compressor
→ E 2002 Prereformer feed preheat coil
→ R 2003 Prereformer
→ E 2001 Reformer feed preheat coil
→ H 2001 Primary reformer
→ R 2004 Secondary reformer

→ E 2020 1/2 waste heat boiler
→ E 2021 1/2 steam superheater
→ E 2021 3 steam superheater
→ E 2022 1/2/3 BFW preheater
→ D 2002 1st separator
→ E 5023 MP column reboiler no. 2
→ D 2003 2nd separator
→ E 5024 1/2 stabilizer column reboiler
→ D 2004 3rd separator
→ E 2025 DMW preheater
→ AE 2026 Air cooler
→ E 2027 Water cooler
→ D 2005, Final separator
Back to C 2001

All block valves in the lines branched from the above circulation loop have been closed.

g) In order to protect the reboilers, E 5023 and E 5024 1/2, from running dry on the shell side, the distillation section is filled with import methanol or demineralised water and the columns are pressurised to normal operating pressure with nitrogen.

h) Pressurise the reforming section and the nitrogen start-up system to 6 bar g by admitting nitrogen through 4”-N-20-112-B24-N (2000-PID-004/P10).

i) The air cooler AE 2026 and water cooler E 2027 are taken into operation.

j) The start-up nitrogen compressor C 2001 is started in accordance with supplier's instructions. The nitrogen flowrate in outlet of the compressor is normally controlled by FIC-2575 via bypass or spill-back valve FV-2575. However when the compressor is initially started, FIC-2575 is kept on manual. The compressor is first run on total recycle by opening the bypass or spill-back valve FV-2575.

k) Before proceeding to the next step, the operator should wait about 10 minutes to check that the temperatures of the compressor bearings, oil system, etc. do not increase excessively, in which case the compressor would have to be stopped and checked.

l) In order to start circulation of nitrogen, the bypass valve FV-2575 is closed stepwise, each time watching the outlet pressure of the compressor as well as the discharge temperature. When the bypass is completely closed and pressures and temperatures are stabilised, the operator can proceed to the next step. Check the pressure regularly and purge or admit more nitrogen if required.

m) With 7.5 bar g as suction pressure and with a differential pressure of 2 bars, C 2001 can give a nitrogen flow of approximately 31200 Nm^3/hr. The flow of nitrogen going into the reformer system can be verified by reading FIA-2582 (2000-PID-018/U02) located downstream C 2001.

5.7 Start flue gas fan and the combustion air blower

The flue gas fan, F 2001, and the combustion air blower, F 2002, are taken into operation.

Open all peepholes and the two false air dampers at the top of the radiant section. Individual burner air dampers may be set at 25% opening.

Switch the flue gas controller, PICA-2224 (2000-PID-007/P13), and the combustion air controller, PICA-2163 (2000-PID-006/P12) to manual.

Start the flue gas fan and the combustion air blower according to vendor instructions.

Continuously check the draught in the reforming section. The draught must never exceed -30 mm WG (PICA-2224), as the furnace walls may otherwise be damaged.

Gradually adjust the draught in the top of the radiant chambers to -5 mm WG by increasing the PICA-2224 output. Also adjust the combustion air pressure to approx. 50 mm WG (PICA-2163).

At an early stage, it should be possible to switch the pressure controllers, PICA-2224 and PICA-2163, into automatic mode. This will ensure a good and stable performance of the blowers.

During the subsequent operation, where more and more burners are ignited, it will be necessary to close the false air dampers using HIC-2225 (2000-PID-007/P13) to allow proper control of the pressure in the reformer

5.8 Furnace purge and fuel header leak test

Check that all burner fuel isolation valves are closed and that all block valves on the individual burners are closed.

The leak test is performed as per ‘Description of burner tightness test and furnace purge system and Leak Test Procedure’.

When the headers have been depressurised and the furnace purge is completed, the double block valves in the main fuel header (USV-2541, USV-2542) may be opened and bleed valve (USV-2543) is closed (2000-PID-017/U01).

5.9 Ignition primary reformer burners

The furnace must be purged and the burner tightness test must be completed successfully before the burners may be ignited.

A natural gas flow through the HDS unit has been established to protect coils in the waste heat section from over heating, Natural gas is vented through PV-1045. HDS and saturation units are isolated.

Switch the main fuel header pressure controller, PICA-2554 (2000-PID-017/U01), and the duty controller, QICA-2535 (2000-PID-017/U01) on manual with an output of 0%.

The fuel headers are pressurized and purged through the vent at the top of the reforming section. Keep the vents slightly open, adjust the PICA-2554 output to obtain the minimum burner operating pressure (to be defined during workshop test) and switch the controller to automatic mode. Later, when a number of burners has been ignited and the fuel gas flow is sufficient to enable proper control the vent should be closed.

The burners are lit one by one, starting at row one (bottom row) with uneven numbered burners. Establish a small flow of combustion air by slightly opening the combustion air damper, open the fuel block valve, and ignite the burner. The combustion air damper is adjusted to give the correct flame conditions.

A correct flame is blue with yellow tip. If the flame is yellow, the combustion is incomplete and more combustion air is required. A large amount of excess air will give a blue and very clear flame without a yellow tip.

All instructions given by the supplier of the burners must be followed. The flame must always burn along the reformer wall. The flame must never touch the reformer tubes; otherwise it will damage the tubes. Burners, which cannot be adjusted to give the normal flat flame must be removed and checked in the workshop. The reformer must never operate on reducing flue gas as this will damage the reformer tubes.

During start-up operations, i.e. when operating on natural gas feed at low capacity, the burners should operate with a larger than normal amount of excess combustion air, judged from the colour of the flames which should be clear blue without yellow tips. This is necessary to achieve the required flue gas flow. Also, less adjustment (manual) of the air flow will be required when the load and fuel gas flow is increased. The excess air ratio is ensured by watching online analyser AIA-2224 (2000-PID-007/P13). When more combustion air is required, the set point of FICA-2111 (2000-PID-005/P11) is increased.

It is important to fire symmetrically in both chambers and on both sides of the furnace. In order to have a uniform heat release and even temperature distribution in the furnace chambers it is essential to have as many burners as possible in operation at lower capacity rather than a few burners at higher capacity.

The firing in the reformer is now increased by igniting more and more burners. Initially, 3 burners in each reformer chamber, i.e. 6 burners in total, in row one (bottom row, uneven numbered), are ignited. The heating rate should not exceed 30°C/h, measured in flue gas leaving the reformer furnace (TIA-2295 and TIA-2297, equipped with high rate of change alarm TDAH-2295 and TDAH-2297 (2000-PID-009/P15)). Additional burners are ignited 3 at a time, one on each wall in each reformer chamber, until every uneven numbered burner in the bottom row has been ignited. Then the even numbered burners in row number two are ignited, 3 at a time, until every second burner in the second row has been ignited. The rows three to five should be ignited following the same procedure.

Heating of reformer unit:

The heating in circulating nitrogen is continued until the following conditions have been reached.

Temperature outlet pre-reformer, TIA-2268	400°C
Temperature outlet primary reformer, TICA-2305	550-650°C

Further, it is to be checked that the firing in the primary reformer is symmetrical by observing the temperatures of the individual outlets collectors, indicated by TIA-2303 and TIA-2304 (2000-PID-009/P15). In case of mal-distribution, the firing pattern is to be corrected accordingly.

5.10 Control of heat distribution in the primary reformer

The heat distribution between the radiant and waste heat sections in the primary reformer should be controlled during the heating-up process to avoid exceeding the design temperatures of the coils in the waste heat section.

The heat distribution can be controlled by changing one or more of the following operating parameters:

- the firing profile in the radiant section
- the false air flow into the waste heat section
- the excess combustion air to the radiant section

While maintaining a constant heat input, the heat distribution between the radiant and waste heat sections and the temperature profile in the reformer tubes can be changed by altering the firing profile. By moving the firing downwards in the radiant zone, the heat distribution is shifted from the waste heat section to the radiant section.

By admitting false air into the waste heat section, the heat distribution within the waste heat section will be affected, moving the heat input towards the cold end of the section.

By increasing the combustion air to the burners, heat is moved from the bottom to the top of the reformer tubes and the heat input is shifted towards the waste heat section.

5.11 Introduction of steam into the reformer

When to add steam:

At which stage of the start-up steam is introduced into the reformer depends on whether hydrogen is available or not.

If hydrogen is available; the HDS and saturator is taken into operation using import hydrogen. Steam is added to the reformer simultaneously with the process gas.

If hydrogen is not available; hydrogen is produced by cracking methanol in the prereformer so consequently steam/methanol must be introduced to the reformer prior to start-up of the HDS section.

Preparations for steam addition:

Before introducing steam into the reformer, condensate if any in the steam line should be drained. The steam line is heated by venting steam through HV-2097 (2000-PID-004/P10). All possible bleeder valves situated at low points in the steam lines should be kept wide open in order to prevent condensate entering the reformer.

When the steam from the high vent appears dry, close the vent and open the isolation valve *MV*-2098 (2000-PID-004/P10).

Introduction of steam:

A steam flow of around 68 ton/h, indicated by FIC-2072, shall be established gradually over approximately 5-10 minutes, simultaneously to increasing steam flow nitrogen flow is decreased; finally the nitrogen blower is shut down.

Shut-down of start-up blower:

At all times sufficient flow through the reformer tubes must be ensured.

The isolation valves upstream and downstream the nitrogen blower are closed, the spectacle on the nitrogen line are closed. Finally the nitrogen blower is depressurised and purged with nitrogen due to the entrainment of process gas in the system.

The pressure in the reformer has until now been floating with nitrogen header pressure. When steam is introduced the pressure control of the reforming section must be switched over to pressure controller PICA-2481.

At all times sufficient steam flow through the reformer tubes must be ensured. The pressure in the reforming section is kept as low as possible during steaming to prevent condensation.

Introduction of hydrogen:

In order to prevent oxidation of the pre-reformer and primary reformer catalyst, it is important to introduce hydrogen into the reformer section simultaneously with introduction of steam.

Hydrogen has two possible sources:

- Hydrogen produced by cracking methanol in the prereformer.
- Synthesis gas stored in methanol loop (subsequent start-ups).

Cracking of methanol:

In order for the cracking to take place, the prereformer outlet temperature must be minimum 400ºC. The steam/methanol mixture must have a steam-to-methanol molar ratio of 25.
5,000 kg/h methanol corresponds to 68 ton/h of steam.

The methanol start-up pump P 5012 is made ready for start before steam is introduced into the reforming section.

The methanol flow is controlled by adjusting the stroke of the methanol start-up pump P 5012. Flow indicator FIC-5407 (5000-PID-015/P43) measures the methanol flow and the methanol flow must be increased in parallel to the steam flow to keep the steam-to-hydrogen ratio stable.

Operation of reformer at steam introduction:

As soon as the steam plus methanol is admitted to the reforming section, the plant operator must be ready to increase the firing of the two upper rows in H 2001 in order to compensate for the heat absorbed by cracking of methanol. The inlet temperature for the performer should be maintained at about 450°C. Due to reforming reaction, the pressure in the reforming section, indicated by PIC-2481, will rise. The pressure in the section is initially maintained around 6 bar g (similar to pressure maintained during nitrogen circulation) by venting excess gas via PV-2481 (2000-PID-016/P21).

CTS Burner protection steam:

When the temperature outlet the primary reformer reaches 200°C, a flow of protection steam is introduced to the burner of the secondary reformer, through FV-2040 (2000-PID-002/P03). The purpose is to avoid overheating of the burner prior to later introduction of process oxygen when ignition of the secondary reformer takes place. The steam pipe should be drained for condensate before admitting steam to the secondary reformer. The steam flow must be approximately 4600 kg/hr. The steam flow can be adjusted via FIC-2040. TIA-2329 indicates the temperature of the burner tip which should never be allowed to exceed 700°C.

Process condensate handling:

The steam will be condensed in the downstream coolers and collected as condensate in the process condensate separators. During the initial phase of start-up the condensate will be polluted with scales, catalyst dust, etc. and will have to be dumped through drain connections provided in these separators.

Hydrogen recycle compressor:

When pressure in the reformer unit is stable, PICA-2481 is put on auto with a set point slightly higher, approximately 7 bar g in order to start the recycle hydrogen compressor C 2002.

5.12 Steam generation

When steam production begins, the generated steam is initially vented through the local vent on the steam drum to remove air. Close the vent and allow the steam pressure to increase to 5 bar g; then depressurize by opening the vent. Repeat this procedure three times. Continue to vent the steam at the local vent until the temperature, TIA-2352, downstream of the steam super heaters is 50ºC above the dew point of the steam, to avoid condensation.

When all air has been removed and temperatures are adequate steam is vented through PV-2361 (2000-PID-012/P17).

Protection of steam drum

During initial start-up, and if the boiler has been exposed to air, the steam drum pressure should if possible be kept at approximately 65 kg/cm^2 g for a period of time (say 48 hours) in order to obtain formation of a dense layer of magnetite in the steam drum. After this the pressure may be increased further.

Boiler heat flux

Furthermore, boiler supplier recommendations must be taken into consideration. As a rule of thumb, the pressure in the steam drum should be minimum 100 bar g multiplied by the load factor to avoid excessive heat flux in the boiler.

Blow down

The continuous blow-down must be fully open during the initial start-up, until the boiler water appears clean. Intermittent blow-down from E 2020 1/2 should initially be opened frequently, as a guideline for approximately 4 seconds every second hour.

Chemical dosing

Oxygen scavenger and ammonia water should continuously be added to the boiler feed water to keep the pH 9 - 10 and the O_2 content below 10 ppb. Phosphate must be added immediately upstream of the steam drum.

5.13 Start-up of HDS unit

When the temperature of flue gas inlet of E 2004 has reached approximately 200°C, a small flow of natural gas is established through the desulphurisation section by operating the vent PV-1045.

The natural gas flow through the desulphurisation section, measured by FI-2151, is passed through E 2006, E 2004, R 1001, R 1002 1/2 and vented through PV-1045.

Initially, the bypass valve TV-2220 over the 1st natural gas pre-heater, E 2006, is closed. Ensure that adequate flow is established through the vent valve PV-1045 (1000-PID-003/P04) in order to protect coils from overheating.

Allowable heating rate:

The catalyst beds in the desulphurisation section are heated up at a maximum rate of 50°C per hour. The heating rate is controlled by adjusting the flow of natural gas and also by adjusting the bypass valve TV-2220. It should be checked that the flue gas stack temperature does not drop below 150°C.

During the initial heating phase, the pressure in the desulphurisation section is kept low approximately 7 bar g to prevent condensation.

Addition of hydrogen:
Due to the risk of carbon formation in the hydrogenation reactor when operating without hydrogen, the temperature should not exceed 250°C before recycle hydrogen is added to the natural gas.

The recycle hydrogen compressor C 2002 is prepared to receive gas from the final separator D 2005. When all nitrogen has been vented and a significant concentration of hydrogen is achieved at the analysis point downstream the final separator, AP-2480 (2000-PID-016/P21), recycling of hydrogen to the desulphurization unit can be started.

The recycle hydrogen compressor should be started up as per the start-up procedure recommended by the compressor vendor and wait for 10-15 minutes, to ascertain that the compressor is functioning without problems. The compressor discharge gas is injected as recycle hydrogen to the desulphurisation section at the inlet of E 2004 via the flow controller FICA-2150 (2000-PID-006/P12).

Operating parameters for start-up of HDS unit:
Pressure approximately 15 bar g.
Natural gas flow: 20-30% of normal operation.
The hydrogen/natural gas flow ratio must be as for normal operation.

Verification of successful start of HDS unit:
After verifying by analysis that the total sulphur content in the exit gas from R 1002 1/2 is less than 0.05 vol. ppm (AI-1045), natural gas can be used for heating of the saturator section and it may be introduced with the steam to the reformer as described below.

5.14 Start-up of the saturator section

5.14.1 Water circulation in saturator

The saturator section and the reforming section are kept separated by double block and bleed as described above.

While the desulphurisation section is being heated up, circulation of water in the saturators is started as follows:

a) Ensure that the saturator blow down system – E 6002, D 6002, P 7003 A/B/C and E 6003, is ready to be taken into service. E 6002 is bypassed during the initial phase and later taken into service only when the condensate from the reformer unit is clear from scales and catalyst dust.

b) Boiler feed water is introduced through FV-6031 (6000-PID-002/P06) at the top of T 6001 1/2. The water will flow through the tube side of T 6001 1/2 and gets collected in feed gas separator D 6001. D 6001 is filled to normal level indicated by LIC-6051.

c) Establish a flow of wash water in D 6001 by introducing boiler feed water through FV-059 2 (6000-PID-003/P07) at the top of D 6001.

d) The section is slowly pressurised to approximately 8 barg by opening the 1” manual bypass valve provided across the isolation block valve downstream R 1002 2. The saturator system thus being pressurised consists of E 6001, T 6001 1/2 tube side and D 6001.

e) Continuous blow down is established through FV-6081 and FV-6086 to ensure a blow down rate of about 6200 kg/hr. When the blow down fills up saturator blow down drum D 6002 to normal level, the excess process condensate pump P 7003 A/B/C is started to send the condensate to outside unit BL via FV-6082. When the flow and level in D 6002 is steady, LHIC-6082 is put on auto.

f) The position of BFW make-up valve FV-6031 is adjusted to maintain a fairly constant level in D 6001, indicated in LHIC-6051

g) The saturator circulation pump, P 6001 A or B, is started and water circulation through the saturators is established. The water circulation rate is indicated by FIA-6068, equipped with low alarm.

5.14.2 Heating of the saturator unit

The saturator is heated up by natural gas from the desulphurisation unit by the following steps:

a) The control valve FV-6070 (6000-PID-003/P07) is opened slowly until the flow is 20% (32,200 Nm^3/h) of normal flow.

b) The natural gas passes through the saturator unit and is vented through PV-2073 (2000-PID-003/P09) to the flare.

c) When pressure is stable PICA-2073 is put on auto with a set point around 8 bar g. The set point for PICA-1045 is set higher than PICA-2073, so that it remains closed during the next steps of the start-up.

d) Steam from the MP steam header is slowly admitted at low pressure through PV-6025 (6000-PID-002/P06) to the shell side of T 6001 1/2. The purpose is to arrive at an operating pressure of approximately 8 bar g on the shell side of T 6001 1/2 at a heating-up rate not exceeding 50°C/hr. Open the block valve to admit MP steam to the shell side of the wash water preheater E 6004.

e) Condensed steam will accumulate in the bottom of T 6001 1/2, indicated by LICA-6021. At the beginning, it is recommended that the condensate be dumped to sewer through drain connections. As soon as the quality of condensate is acceptable, the condensate can initially be sent to the deaerator via LV-6021B (6000-PID-001/P05). Later, when the synthesis loop has been started, the steam condensate return pumps P 6002 C which is used for startup phase specially is started in order to send the steam condensate to the MP steam drum through LV-6021 A.

f) The temperature difference between the shell side steam condensate, TI-6001 (6000-PID-001/P05), and saturated gas exit D 6001, TI-6054 (6000-PID-003/P07), has to be less than 25°C at all times. This can be done by adjusting the steam pressure and/or the water circulation rate. Otherwise there is risk of 'break down' of water film on the inner walls of the tubes in the saturators.

g) The pressure of the shell side steam is gradually increased in order to increase the temperature in the saturators.

In order to keep a liquid circulation in the saturator, it is required that the temperature in the gas is below the dew point at the given pressure.

Depending on the process gas pressure in the saturator indicated by PICA-2073, the saturators should not be heated above the temperatures recommended below.

Process gas pressure PIC-2073 Bar g	Saturated gas max. temperature, TI-6054 °C
5	145
8	160
10	170
15	185
20	200
25	210
30	220
40	235
50	250

h) BFW is used as water supply for circulation water and wash water in the initial phase, but as soon as process condensate from the separators is available, it should be used because BFW has a higher level of impurities that will poison the prereformer catalyst.

i) Pressure on the shell/tube side is increased to approximately 20 bar g in parallel. The temperature outlet saturator tube side is increased to approximately 190ºC.

5.15 Process gas to reforming section

Operating parameters prior to introduction of process gas to reformer:

Pressure outlet saturator	PICA-2073 (2000-PID-004/P10)	20 bar g
Temperature outlet saturator	TI-6054 (6000-PID-003/P07)	190ºC
Natural gas feed flow (20%)	FICA-6070 (6000-PID-003/P07)	32,200 Nm^3/h
Saturated steam flow	FY-2065 (2000-PID-003/P09)	50,000 Nm^3/h
Steam to reformer	FIC-2072 (2000-PID-003/P09)	68,000 kg/h
Pressure in reformer unit	PIC-2482 (2000-PID-016/P21)	7 bar g

Check that the saturated natural gas control valves, FV-2061 and FV-2091, are in manual and closed. Open the block valves around these control valves. Reset the block and bleed valves USV-2092, USV-2093 and USV-2094 locally.

Establish a natural gas flow of approximately 4,000 Nm^3/h (FICA-6070) by gradually opening FV-2091 (2000-PID-004/P10). Increase the reformer firing (primarily in the top of the furnace) to maintain:

- Temperature outlet pre-reformer, TIA-2268: 400°C
- Temperature outlet primary reformer, TICA-2305 650-700°C

Gradually increase the natural gas feed flow to 13,500 Nm^3/h to obtain an S/C-ratio of 8. Simultaneously, the firing of the primary reformer is increased in order to maintain the temperatures.

The start-up methanol injection is continued until sufficient hydrogen is produced in the reformers by reforming natural gas.

5.15.1 Increasing load to 40%

Plant load should be increased in steps of about 5%. Flows should be increased in the following order:

1. Increase process steam flow
2. Increase natural gas flow
3. Increase primary reformer firing
4. Increase process oxygen flow (when the secondary reformer has been taken in line).

Load decrease is performed in the reverse sequence.

While increasing load, operating pressures are also increased towards the normal operating values; in the desulphurization/saturation section at controller PICA-2073 and in the reforming section at PICA-2481.

The load on the primary reformer is now increased to approximately 40%, aiming at the following key parameters, corresponding to a steam/carbon ratio of about 1.8.

Direct steam flow to pre-reformer:	13,000 Nm^3/h
Process water evaporated in T 6001 1/2:	100,000 Nm^3/h
Burner protection steam:	4,600 kg/h

Natural gas flow to primary reformer:	65,000 Nm^3/h
Recycle hydrogen gas flow to HDS unit:	1,900 Nm^3/h (as 73 mole% H_2)
Temperature inlet primary reformer:	650ºC
Temperature outlet primary reformer:	738ºC
Pressure downstream D 2005:	24 bar g

The steam to carbon ratio must never go below the plant design value of 1.8.

5.16 Ignition of secondary reformer

When the plant is operating at 40% load as described above, the secondary reformer can be ignited.

The oxygen supplier from outside BL must be ready to supply oxygen at adequate pressure. The burner tip temperature should be below 400 °C.

Drain all low points before introducing oxygen.

Before IS-2 can be reset and oxygen can be allowed to enter the secondary reformer the following conditions, I-20 reset permissive group, must be full filled:

- IS-1 is not tripped
- Oxygen control feed valve, FV-2007, is closed.
- Small oxygen control feed valve, FV-2009, is closed.
- Block valve in oxygen line upstream oxygen preheater, USV-2010, is closed.
- Block valve, USV-2021, in steam line to E 2008 is closed.
- Burner protection steam flow in operation block valve, USV-2038, is open.
- Oxygen vent line is open (i.e. PDV-2051 and USV-2051 are open).
- Double block and bleed from oxygen supply to secondary reformer is blocked, USV-2045 and USV-2048 are closed in and USV-2049 is open.
- The following trip functions must be active when taking the secondary reformer into operation:
  a) Low natural gas feed flow – trip; FSAL-6070 not inactivated
  b) Low total steam to reformer- trip; FSAL-2062 not inactivated
  c) Low steam-to-carbon ratio – trip; FFSAL-2064 not inactivated
- The vent located between saturator and reformer must be closed; PV-2073 is closed.
- Double block and bleed between saturator and pre-reformer is open; USV-2092 / USV-2093 is open in and USV-2094 is closed.
- Temperature in combustion chamber (TIA-2325) must be above 600°C to ensure ignition.
- USV-2039 must be open and USV-2041 closed.

Furthermore,

- Block valves in oxygen line upstream oxygen filter, HV-2003 / HV-2004, are closed.
- IS-23 and IS-21 shall be reset.

E 2008 is preheated slowly by introducing steam through PV-2015.

IS-2 trip due to low temperature of oxygen TSAL-2047 must be inactivated during heating of E 2008. Low flow FSAL-2007 shall also be inactivated.

The steam used in the oxygen preheater must be quenched to avoid exceeding the design temperature of 310ºC.

The oxygen system upstream the control valve is pressurized by opening HV-2004. When PI-2001 reaches the high value then IS-23 (permissive) allows the main valve HV-2003 to open.

Piping and equipment is heated by venting oxygen through PDV-2051.

- Reset PUSY-2051 and USV-2051
- Put PDIC-2051 in auto mode, set point 2 bar.
- Reset/open USV-2010
- Establish flow through FIC-2009

Both oxygen filters must be pressurized simultaneously at start-up. The manual valve upstream one filter is open during start-up. In case the first (A) filter gets blocked by dirt, then the valve upstream the second (B) filter can be opened.

Safety system only allows use of PDIC-2051 when

- USY-2045 A/B, USY-2048 A/B and USY-2049 A/B have not been reset
- USY-2051 has been reset.

If these conditions are not obliged to PDIC-2051 is forced in manual mode with 0% output.
Before oxygen can be allowed to enter the secondary reformer – opening of the double block and bleed – the following conditions must be fulfilled:

- Pressure of oxygen must be between 1 and 3 bar higher than the pressure in the secondary reformer, i.e. PDAH-2051 and PDAL-2051 must not be active.
- Oxygen pre-heater and piping are sufficiently heated, TSAL-2047 is not inactivated.

A small flow of oxygen is established through the smaller valve FV-2009, about 3000 Nm^3/hr, indicated by FIC-2009. The oxygen is added to the steam flowing through FV-2040, by reset of double block and bleed, USV-2045/2048/2049 and closing PDV-2051.

The temperature exit the secondary reformer is observed carefully (TIAC-2334/TIA-2333). An increase in temperature shows that ignition has taken place, but if no increase in temperature has been observed after 5 minutes, the oxygen flow is stopped.

When ignition has been verified by an increase in temperature outlet the secondary reformer, the oxygen flow is slowly increased to obtain the correct composition of the process gas leaving the reforming section. During this operation the temperatures outlet the secondary reformer should not be allowed to increase by more than 30-50 °C/h.

When the oxygen flow to the secondary reformer is higher than the minimum range of the bigger valve FV-2007, this should be taken into operation and FV-2009 is gradually closed.

The pressure drop across the secondary reformer (PDIA-2323) must not exceed 0.75 bar, because the gas then may run between R 2004 shell and refractory, which will damage shell and refractory.

The desulphurisation, saturation and reforming section are now in operation at reduced capacity. Hydrogen for reduction/start-up of the synthesis catalyst will thus be available.

5.17 Synthesis section

5.17.1 General

The synthesis gas section can be started as soon as sufficient steam is available for the steam turbine, FT 3001.

It is assumed that:

- Synthesis loop has been purged with nitrogen
- Fans for loop air cooler AE 3002 1/2/3 are running.
- Cooling water is established to loop water cooler, E 3003 1/2/3.

5.17.2 Heating of methanol reactor

The loop steam drum, D 3003, and the steam/water side of the methanol reactors, R 3001 1/2/3, are filled with BFW through FV-3041 (3000-PID-002/P23), to the minimum level in D 3003.

The methanol reactors, R 3001 1/2/3, are provided with start-up ejectors, J 3002 1/2/3, for heating. Steam from the HP steam export/import header is admitted to the start-up ejectors. This will create a circulation in reactors from the bottom, through the ejector and to the top of the reactors.

Natural circulation of water in the steam drum will start through the down comers to the methanol reactor and back to the steam drum via the risers, due to density differences between water in reactor and water in the steam drum.

The steam drum pressure is initially kept at 15 bar g in order to ensure that the steam introduced to the ejector is condensed in the ejector itself so that overheating or steam hammering in the system is avoided. As the system is heated up the pressure in the steam drum should be increased accordingly. In the beginning, the steam will condense and heat up the steam drum. In case the pressure in the steam drum is too high, the ejector will not function properly. Otherwise, if the pressure is too low, it is not possible to heat up the system to the temperature required.

Slowly open the manual valve inlet the ejector. Heat up the system to a temperature of 170 to 180°C as measured on TG-3051. The temperature rise of water inlet/outlet the ejector should not exceed 40°C/h. This is measured by the local temperature indicators TG-3086, TG-3089 and TG-3092.

The heating up period is estimated to 10 to 35 hours from ambient temperature.

During the heating up, the level in D 3003 is maintained by using the blow-down valve, HV-3054. In case the capacity is not sufficient the intermittent blow-down valves HV-3087, HV-3090 and HV-3093 (7000-PID-026), may also be used. If the pressure rises above 16 bar a, the vent on the steam drum should be opened to purge out nitrogen from the system.

5.17.3 Activation of catalyst in methanol reactor

Please refer to the 'Manual for MK-151 Topsoe methanol catalyst in boiling water cooled converters' attached in Chapter 4.

In case of new catalyst, the catalyst must be reduced with hydrogen/nitrogen in a closed circuit using the recirculator, C 3002. In case hydrogen in not available from outside battery limits, synthesis gas from the front-end may be used.

The synthesis gas compressor, C 3001, and the recirculator, C 3002, are pressurised with nitrogen to a pressure of about 5 bar g.

The synthesis gas compressor/recirculator is started according to instructions given by the vendor.

The synthesis gas compressor, C 3001, is isolated from the methanol loop and must operate with nitrogen in total recycle mode during the catalyst reduction stage.

A nitrogen recycle flow of about 110,000 Nm^3/h through the recirculator should be established.

The HP separator, D 3001, is drained for water, if any, and the block valves at the liquid outlets are closed.

Before the methanol reactor reaches a temperature of 120°C, the synthesis gas flow-meter FG-3010 must be checked and calibrated.

Based on the characteristics of the synthesis gas flow meter and the recycle rate in the reduction loop, it is calculated which synthesis gas flow will result in 0.5 vol% hydrogen at the inlet of the reactor. The calculated synthesis gas flow is established for one minute while circulating the nitrogen. Towards the end of the one minute period a sample of gas from C 3002 (AP-3022) is collected and immediately afterwards the recycle hydrogen flow is interrupted. The results of the analysis are to be used as a guideline when correcting the recycle gas flow meter in case of deviations from the targeted 0.5 vol% hydrogen.

It is recommended to use a temporary portable online analyser (0-4 vol% hydrogen) in addition to laboratory analysis of gas samples.

When the outlet temperature from the methanol reactors is stabilised at 170°C (TIA-3073, TIA-3077, TIA-3081), the synthesis gas flow corresponding to a hydrogen concentration of 0.5 vol% is established. When the consumption of the initially added hydrogen has been positively confirmed, the inlet hydrogen concentration can be increased in steps of 0.5 vol% hydrogen until 2.0 vol% has been reached at the reactor inlet. The 2.0 vol % and 170°C must not be exceeded at this stage, since this could initiate an uncontrolled exothermic reduction of catalyst.

The water bath in the reactor will act as a heat sink and, consequently, temperature rise due to the heat evolved from the reduction may not be visible. In order to check that the added hydrogen is consumed, it is very important immediately to start analysing the hydrogen at both the inlet and the exit of the reactor at least every half-hour.

When consumption of hydrogen is observed, the HP separator, D 3001, must be drained regularly for removal of the water formed. The temperature in the methanol reactors should be maintained at 170°C. If no consumption can be observed, the hydrogen supply must be interrupted and the cause of lack of hydrogen consumption must be found. This is necessary in order to prevent hydrogen accumulation in the nitrogen circulation loop.

Simultaneously with the hydrogen analyses the carbon dioxide concentration inlet R 3001 1/2/3 should be checked. At the relatively low catalyst temperatures there is a risk that carbon dioxide can react with the zinc oxide in the catalyst under formation of zinc carbonate, which may weaken the catalyst. This can be avoided if the partial pressure of carbon dioxide is kept below 2.1 bar a.

In case the above carbon dioxide analysis indicates that the carbon dioxide level is approaching the maximum allowable, the loop purge through PV-3166 should be established to reduce the carbon dioxide build-up. This means that additional nitrogen must be added in order to maintain the pressure. The following describes the sources of carbon dioxide:

a) Carbon dioxide already in the reducing hydrogen/synthesis gas.
b) Possible carbon monoxide in the reducing hydrogen gas, which will be converted to carbon dioxide.
c) The catalysts contain carbonates, which will release carbon dioxide during the reduction.

The conditions established should be maintained, since the reduction front will move down through the catalyst tubes in R 3001 1/2/3.

When the reduction zone approaches the bottom of the catalyst, hydrogen break-through can soon be expected, which will result in hydrogen build-up in the loop and possibly in excessive catalyst temperatures locally. This is counteracted by slowly increasing the catalyst temperature towards 230°C in methanol reactors, at a rate of 10-15°C per hour. In case this is not sufficient and the hydrogen concentration at the inlet of the reactors starts exceeding 2.0 vol%, the reducing hydrogen flow must be decreased in order to maintain the hydrogen concentration below 2.0 vol%.

When the catalyst temperature has stabilised at 230°C, the hydrogen concentration at the inlet to the reactors can slowly be increased to 4 vol%.

Recirculation is continued at the above conditions with a catalyst temperature of 230°C and a hydrogen concentration of 4 vol% at the inlet to reactors, until the hydrogen consumption has ceased, which is indicated by a difference of less than 0.2 mole % between the hydrogen concentration inlet and exit R 3001 1/2/3.

When this stage has been reached and maintained for 2 hours, the reduction is considered to be completed. Recirculation is stopped and the system is purged with nitrogen and sealed off until start-up.

5.17.4 Start-up of Methanol Loop

At this stage the temperature on the water side of the methanol reactor is 200 to 230°C and the reduction of the synthesis catalyst is finalised.

Pressurising

The synthesis gas compressor, C 3001, is lined out to receive synthesis gas from the front end. The synthesis gas should contain enough hydrogen to have a module of minimum 2.05. The methanol loop is slowly pressurised by the synthesis gas compressor.

Recirculation

The recirculation in the loop has to be established at a low rate.

Reactor inlet temperature

The inlet temperature to the methanol reactors, TIA-3113/3116/3118, is observed. When the temperature increases to above 190°C the circulation can be increased. After this point the temperature inlet the reactor is not allowed to drop below 190°C, because it might cause formation of wax. If the temperature drops, the recirculation flow has to be lowered.

Purge from loop

Once the loop is pressurised it will be necessary to start the purge in order to start reaction in the methanol reactors. Initially the purge gas is sent to flare, the controller, PIC-3166 B, is given a set point corresponding to the actual pressure.

The flow of synthesis gas is gradually increased while also increasing the recirculation rate.

Initial production

The initial 50-100 m^3 methanol/water produced should be sent to the methanol drain system or to a trailer, since this will contain amines, which may not be removed completely in the distillation section. Later, the methanol/water can be sent to the raw methanol tank buffer, TK 5001. The level controller in HP separator, D 3001, LICA-3161, and D 3002, LICA-3192, are to be taken into operation when the production has started. The pressure controller in D 3002, PICA-3194, is to be taken into operation when the pressure has increased to normal operating pressure.

Shut down of start- up ejectors

When exothermic reaction starts in the methanol reactors, the steam production will begin. Gradually reduce the steam injection to the start-up ejectors, J 3002 1/2/3. Make sure that the BFW to the MP steam drum, D 3003, is established and be aware of the level in the drum. Once a positive BFW flow to the steam drum (FIC-3041) has been confirmed, the steam to the ejectors can be shut off and the ejectors are isolated. The pressure in the steam drum is controlled at about 33.7 bar g at SOR via PIC-3042, by sending the steam to the MP header.

Carefully, observe all parameters in the synthesis loop and adjust, if necessary.

Gradually, increase the recirculation and the pressure in the synthesis loop until normal operating values are obtained.

After stabilising the conditions in the synthesis loop, the purge gas should be used as fuel in the primary reformer via FV-3169 as described above.

Finally, PIC-3166 B is put in auto with a set point 2 bar above the set point of PIC-3166 A in order to keep it closed during normal operation, but ready to take action in case of upsets.

Module

It is recommended to supervise:

- Module for the synthesis gas feed, calculated by on-line analyser AFI-3004-1.
- Module for the reactor inlet calculated by on-line analyser AFI-3004-2.

A module of minimum 2.05 of synthesis gas feed is minimum required also during start-up.

5.17.5 Distillation Off-gas

The off-gas from the distillation section can be added to the reformer fuel system after starting the ejector, J 3001.

Purge gas is slowly sent through J 3001 by means of PIC-5091. The off gas valve, PV-5091 B, will automatically start to close in order to maintain the pressure in the stabilizer column system.

This will not affect the firing in the primary reformer, because the OH gas flow is small.

5.18 Taking purge gas as fuel in the reformer burners

When the operation of the plant is in stable operation, part of the natural gas fuel can gradually be substituted by purge gas from the methanol loop.

The following procedure for introduction of purge gas as fuel must be followed.

1. Check that the purge gas controller FICA-2536 is on manual with zero output.
2. The reformer duty controller, QICA-2535, should be in operation (automatic mode), controlling the flow of natural gas fuel.
3. Enter the correct heating value for the purge gas on HIC-2537.
4. Enter the air/purge gas ration on HIC-2538.
5. Drain all low points for condensate before introducing the purge gas.
6. The block valves in the purge gas fuel line are opened.
7. The purge gas header is pressurised to a pressure slightly above the fuel header pressure. The purge gas pressure is measured by PIC-2536A.
8. Purge gas is introduced by slowly increasing the set point of FICA-2536. The natural gas flow is decreased automatically. The purge gas flow is slowly ramped up.

During the whole exercise, the performance of the burners must be observed carefully in the field.

5.19 Distillation section

5.19.1 Initial conditions

The first step of the start-up of the distillation unit takes place before the start-up of the re-forming section. This is necessary because the reformer effluent will pass the tube sides of E 5023 and E 5024 1/2. Consequently, the distillation section should be ready when steam is allowed to the reformer.

Film boiling:

In this context it should be pointed out that there is a risk of film boiling, if the temperature difference between hot fluid and cold fluid in the column reboilers is above 30 to 40°C. Film boiling causes a serious drop of the heat transfer coefficient. The process gas bypass valve TV-5064 (across E 5024 1/2) and TV-5277 (across E 5023) can be used in order to avoid film boiling. Moreover, the reboiler of the LP methanol column is the overhead condenser of the MP methanol column; therefore it might be useful to adjust the pressures in the methanol columns to avoid film boiling.

5.19.2 Preparing distillation section for start-up of front-end

Methanol/water is pumped from raw methanol tank, TK 5001, by P 5001 A/B to stabiliser column, T 5001, until the level has been established in reboilers, E 5001, E 5024 1/2 as well as in the bottom of T 5001. The level in the reboilers can be monitored via LIA-5065 and also by their respective local level gauges.

When normal level is established in T 5001, P 5002 A/B is started and methanol/water is further transferred to the LP methanol column, T 5002, to establish level in LP column reboilers, E 5002 1/2/3/4. The level in these reboilers is monitored via LIA-5182 and also by level gauges installed on each shell.

Demineralised water is transferred to the sump of T 5003 via the utility connection. From the sump, the water is transferred to reboilers, E 5003 1/2 and E 5023, by P 5007 A/B. the reboilers are filled with water to minimise the risk of film boiling. The level in these reboilers is monitored via LI-5278 and also by level gauges installed on each shell.

The MP column OH accumulator, D 5003, must be filled with methanol.

The overhead condensers, AE 5004 and AE 5005, must be started. Cooling water is circulated in all coolers.

The reflux pumps must be started as soon as the level in the OH accumulators has increased.

The distillation unit is now ready for start-up of the front end.

5.19.3 Heat-up of distillation columns, going to full reflux stage

Heating of T 5001:

The stabiliser column reboiler, E 5024 1/2, will be heated by the process gas from the front end, and if required the stabiliser column steam reboiler, E 5001, can be started.

The heat-up will be indicated by a pressure increase in the column, as seen on PIC-5091. The pressure in the column is controlled by venting the gas to flare via PV-5109. The magnitude of the pressure increase will depend on the heat load on E 5024 1/2 and E 5001.

Consequently, either the process gas bypass across E 5024 1/2 can be used or the steam rate to E 5001 should be limited to secure that the pressure levels do not exceed the design pressure of T 5001, which is 3.5 barg.

When the nitrogen has been replaced by steam/methanol, the upper part of the column is heated and methanol/water starts condensing in the stabilizer column OH condenser, AE 5004.

The methanol condensed in AE 5004 will start to accumulate at a lower rate in the stabilizer column OH accumulator, D 5001. When the level increases above the normal level, the stabilizer column reflux pump, P 5003 A/B, is started and the level and flow cascade controllers, LIC-5093 and FIC-5093, are put in automatic mode. The liquid off-stream controller FIC-5107 is normally set at zero flow.

The column is now operating at full reflux. However, the column will not be functioning properly until the vapour flow is sufficient to secure proper operation of the trays, which requires that the total reboiler load has reached 40% of design load.

Liquid will be building up on the trays during start-up, therefore the level in the reboilers, must be adjusted by adding methanol/water from the raw methanol buffer tank, TK 5001.

Heating of T 5003:

The MP column reboiler, E 5023, will be heated by process gas from the front-end. The heat available from the front-end process gas may not be sufficient and the MP column steam reboiler, E 5003, can be slowly started.

It should be marked that the control of the steam/condensate flow through E 5003 cannot function properly before the tubes are more or less filled with condensate. This fill up lasts a long time. In order to get a smooth start-up, FV-5301 should be closed initially. Only when there is condensate filled in the tubes, indicated by LI-5310 and LI-5308, FV-5301 can be opened very cautiously.

When the boiling in the reboilers begins, the nitrogen present in the column is vented to the flare through the manual valve, HV-5338. The valve will be closed during the initial heating but will be opened when the pressure starts to increase.

The water vapour will replace the nitrogen and heat up the equipment.

The pressure in T 5003 is monitored on PI-5252/54/56/58/60

The temperatures in the column are monitored by TIA-5261/62/63/64/67/69 and TICA-5265/67/68.

Liquid will be building up on the trays during start-up, therefore the level in the reboilers must be adjusted by adding methanol from the raw methanol buffer tank TK 5001, through T 5001 and T 5002.

When the pressure in the T 5003 system has increased sufficiently:

- The overhead vapour will condense in the LP column reboiler, E 5002 1/2/3/4.
- The level in the MP column OH accumulator, D 5003, will increase
- The MP column reflux pump, P 5006 A/B, is started as soon as the level in D 5003 is above normal level.

- The level and flow cascade controllers, LICA-5321 and FICA-5321, are put in automatic mode.
- HIC-5336 is set to give full reflux to T 5003, i.e. FV-5336 closed.

Heating of T 5002:
When condensation in E 5002 1/2/3/4 begins, T 5002 will be heated up.

Initiation of the heat up will be indicated by a pressure increase in T 5002, as is seen on PICA-5207. Initially, the vent valve PV-5207 B is opened.

When most of the nitrogen has been replaced with methanol vapour, PICA-5207, is set on auto, which keeps the pressure close to the atmospheric pressure.

Temperature increase is monitored on TI-5177.

Pressure increase is monitored on, PICA-5207.

When the pressure in the LP methanol column system has increased sufficiently:
- The overhead vapor will condense in the overhead condenser, AE 5005.
- The level in the LP column OH accumulator, D 5002, will increase.
- The LP column reflux pump, P 5004 A/B, is started as soon as the level in D 5002 is above normal level.
- The level and flow cascade controllers, LICA-5203 and FICA-5203, are set in automatic mode.
- HIC-5337 is set to give full reflux to T 5002, i.e. FV-3401 is kept closed.

When all process parameters have been stabilized, the distillation section has been brought in operation at full reflux, meaning that no feed is added and no product is drawn out.

5.19.4 Distillation section: Going from full reflux stage to normal operation

The distillation section must be operated with a reboiler duty at minimum 40% capacity.

MP Methanol column:
The temperatures monitored by TICA-5266/67/68 must be 25 to 35°C below the bottom temperature (TI-5273).

Temperature (TICA-5266/67/68) too low:
- The water concentration in the bottom of the column is too low.
- A small OH product flow is directed to the tank, TK 5001, as controlled by FICA-5336 set on manual.
- Level in T 5003 is maintained by adding methanol from TK 5001 through T 5001 and T 5003
- The water will accumulate in the bottom trays of T 5002 and T 5003.

Temperature (TICA-5266/67/68) too high:

- The water concentration in the bottom of the column is too high.
- No product withdrawal
- Raw methanol is sent to T 5003 from TK 5001 through T 5001 and T 5002 until the temperature as measured is correct
- Level in T 5003 is maintained by sending excess water to the saturator via P 5010 A/B.

The product quality is verified by lab analyses, AP-5326 (5000-PID-012/P40), while adjusting the temperature.

When the product quality is achieved:

- A small product flow, controlled by FICA-5336 set on manual, is withdrawn from the top of T 5003 via D 5003.
- A raw methanol feed flow is added to T 5003 from TK 5001 through T 5001 and T 5002.
- Temperature (TICA-5266/67/68) is kept stable.

LP Methanol column:

The product quality is analyzed, AP-5218 (5000-PID-008/P36) and when the product quality is achieved:

- A small product flow, controlled by FIC-5337 set on manual, is withdrawn from T 5002.
- The level in the column is controlled by adding methanol from TK 5001 through T 5001.

Stabilizer column:

- The level in the column is controlled by adding methanol from TK 5001

The capacity and reflux ratio can gradually be modified until normal operating conditions have been reached.

The controllers for reflux ratio and level in the columns are set in automatic mode.

Only when T 5001, T 5002 and T 5003 are operating stable at the requested capacity, TICA-5266/67/68 can be switched to auto.

Liquid off stream from T 5003:

Samples are taken from AP-5266/67/68 and analyzed in order to determine the optimal tray from where to withdraw the higher alcohols. The optimal point of draw-off will be the point where the concentration of impurities is at maximum.

The withdrawal of higher alcohols, controlled by FICA-5441 is initiated. The liquid off stream is sent to the liquid off stream tank TK 5003.

The liquid off stream pump, P 5009 A/B, is started as soon as the level in TK 5003 is above normal level. Open block valves downstream the liquid off stream pump to admit the liquid off stream to the reforming section. Verify that conditions of reforming section remain stable upon introduction of liquid off stream.

5.20 Restart after IS-1 trip

In case the reformer has tripped and the reason for the trip has been identified, it is possible to perform a hot start-up without establishing nitrogen circulation. A hot start-up is possible up to 2-4 hours after a trip depending on the temperature in the pre-reformer.

If the duration of the shut-down has been too long, the reforming unit must be purged with nitrogen until the content of hydrocarbons are below 0.1 mole %. Nitrogen circulation is established as described above.

5.21 Hot restart of reforming unit

5.21.1 General

The main principles of the restart are described below. Fast and precise actions by the operators are required due to the great difference in plant behaviour under these conditions compared to normal start-up conditions.

The potential risk for mal-operation during hot restart of the reformer is significantly higher than for normal operation. Mal-operation may result in overheating and failure of the reformer tubes or coils in the recovery section or damage of prereformer catalyst. It is of the uttermost importance to follow correct procedures and perform regular visual checks on the furnace. The normal instrumentation may not be relied upon during transient operation such as start-up.

Therefore, the following description of a restart without N_2 circulation is meant to be used only by experienced panel/field operators.

A survey of all design temperatures for manifolds and coils in the waste heat section and reformer tubes must be available. Trend curves showing prereformer and/or reformer temperatures, flows and pressures should be easily available from DCS screens so that the operator can observe changes in various parameters.

5.21.2 Hot restart procedure

When IS-1 is activated, the feed and recycle H_2 flow to the HDS section will stop.

An outline procedure for the hot start-up is as follows:

1) Check the availability of import steam and hydrogen.

2) Purge the reformer unit for additional 9 minutes with steam and hydrogen vented through PV-2481.

   Steam: 68 ton/h – hydrogen: 4,300 Nm^3/h hydrogen (as 100% H_2).

   The pressure controller of the vent valve should be on auto with a set point of 4 bar g.

The steam/hydrogen flow is shut off.

3) Check that the pre-reformer catalyst temperature is above the condensation temperature. It is important to avoid condensation of steam on the catalyst. At 4 bar g condensation occurs at 143ºC.

4) After a stop of the reformer, close all fuel valves at individual burners. The air damper at each individual burner may be set at e.g. 50% opening in order to reduce air from the non-lit burners. Perform furnace purge and leak test after starting the flue gas fan and combustion air blower. Close the false air dampers on top of the waste heat section and adjust the draft to normal.

5) Reduce combustion air flow to a minimum (say 1/3 of normal flow) in order to avoid cooling and preserve heat in the furnace. Excess air for burners should be minimum 10%.

6) Establish a small gas flow in the HDS section by venting the gas downstream the HDS section in order to reheat the gas piping and to be able to read representative temperatures outlet the coils in the waste heat section.

7) Establish steam and hydrogen flow through the start-up vent upstream the reformer. The flow of steam and hydrogen should correspond to the purge flows. The steam should be superheated (dry) before introduction to the reforming section.

8) Open the reformer nitrogen purge line at feed-steam mix point to the maximum possible and ensure that the downstream vent opening provides sufficient flow for reheating of piping and further that it is possible to read representative temperatures outlet each coil at the top of the waste heat section. The pressure controller of the vent valve should be on auto with a set point of 4 bar g.

9) Ignite alternate burners starting with the second top row and then move to the first and third rows from the top. The fuel pressure must be kept constant and should correspond to a heat release as close as possible to minimum heat release for the burner. The ignition of burners should continue until the flue gas temperature starts to increase. The temperature may initially increase by 80-100ºC per hour, but must be lowered to 30-50ºC per hour when the temperature reaches the same level as before start of flue gas fan and combustion air blower. Firing should be increased by ignition of burners in downward direction and not by increasing fuel pressure. This should be done in order to avoid local overheating of tubes.

10) Introduce steam and hydrogen when the flue gas temperature exit the radiant chamber is in the range from 450-550ºC.

11) In case the temperature increases above 600ºC, the upper two coils and manifolds may be damaged. Burners may be switched from top rows toward lower/bottom rows if the inlet temperature to the pre-reformer/reformer rises too quickly. Pre-reformer bed and reformer exit temperatures should be carefully observed.

12) Interrupt the nitrogen flow through the purge line and ensure that the set point of the downstream vent pressure controller is at 2-4 bar g and in auto mode after steam/H_2 introduction.

13) Continue ignition of burners in a symmetrical way until feed is ready for introduction to the reformer.

14) The reformer temperatures should be: Prereformer inlet >300ºC, reformer inlet >400ºC and reformer exit >500ºC.

15) Additional ignition of burners at the top of the furnace should be done in order to prevent a decrease in prereformer temperatures when feed is introduced and reforming reaction takes place.

16) When the temperatures in the HDS section start to rise, the gas flow may be increased in order to shorten the heating period of the HDS section. If the temperature in the hydrogenator is above 320ºC, the gas may be considered sulphur-free and used for feed-in without awaiting a sulphur sample.

17) Ensure frequent visual inspection of the furnace by field operator/shift engineer through-out the restart in order to check tube skin temperature for local overheating and to check burner performance. Hottest tube(s) should be measured by means of an IR pyrometer at least every ½ hour. From the beginning of the restart the coils in the waste heat section should always be protected with sufficient flow before the flue gas temperature reaches the design value of the respective coils.

18) The reformer furnace has a large heat capacity, which is mainly due to the amount of refractory inside furnace (approx. 75% of the total heat capacity). Owing to the heat loss and heat capacity of the cold collector it should be kept in mind that the temperature exit reformer tubes may be considerably higher than indicated on the TI exit cold collector and the difference is much dependent on the flow in the cold collector and the rate of change in firing.

19) A change in firing will be observed from the flue gas temperature only after 1-2 minutes whereas the temperature indication exit cold collector will show up much later, say after more than 10 minutes. Owing to the large endothermic reforming reaction, feed and steam flows are powerful process parameters for control of heat removal in the furnace and should be used for controlling temperatures quickly if they increase too fast. The reforming reaction starts at approx. 350ºC for the tubular reformer catalyst and at approx. 300ºC for the pre-reformer catalyst.

20) Increase the system pressure slowly to approximately 10 bar g and stabilise.

21) Continue with the normal start-up procedure. The process feed has to be introduced shortly (say within 10 minutes) after introduction of steam and hydrogen. However, it is important that the prereformer catalyst temperatures are above 430°C before process feed is introduced. If these conditions cannot be met, the hot restart must be interrupted and the normal start-up procedure is followed.

5.22 Cold restart

If the duration of the shut-down has been long, nitrogen circulation is established and the normal start-up procedure described above is followed.

Before starting the nitrogen circulation, it is very important that the total content of CH_4, CO_2 and CO is below 0.1% to avoid carbon lay-down on the reforming catalyst.

5.23 Methanol Tanks Unit

The inspection of the methanol transfer pump (P 4001 A/B) and methanol unit closed drain pump (P 4002) should be confirmed before the start up of methanol tanks unit. All the instrument should be adjusted and accepted. Electricity for methanol tank should be runnable. All the untilities as well as auxiliary device should be ready for start up. All the equipment and pipe in methanol tanks unit are already cleaned for start up.

Before filling the tanks, make sure the tanks (TK 4001 1/2) are ready for start up. If the level in methanol tanks is ready for filling, open the valve on the inlet pipe of tanks manually, and choose one of the tanks (TK 4001 1/2) with low methanol level to filling.

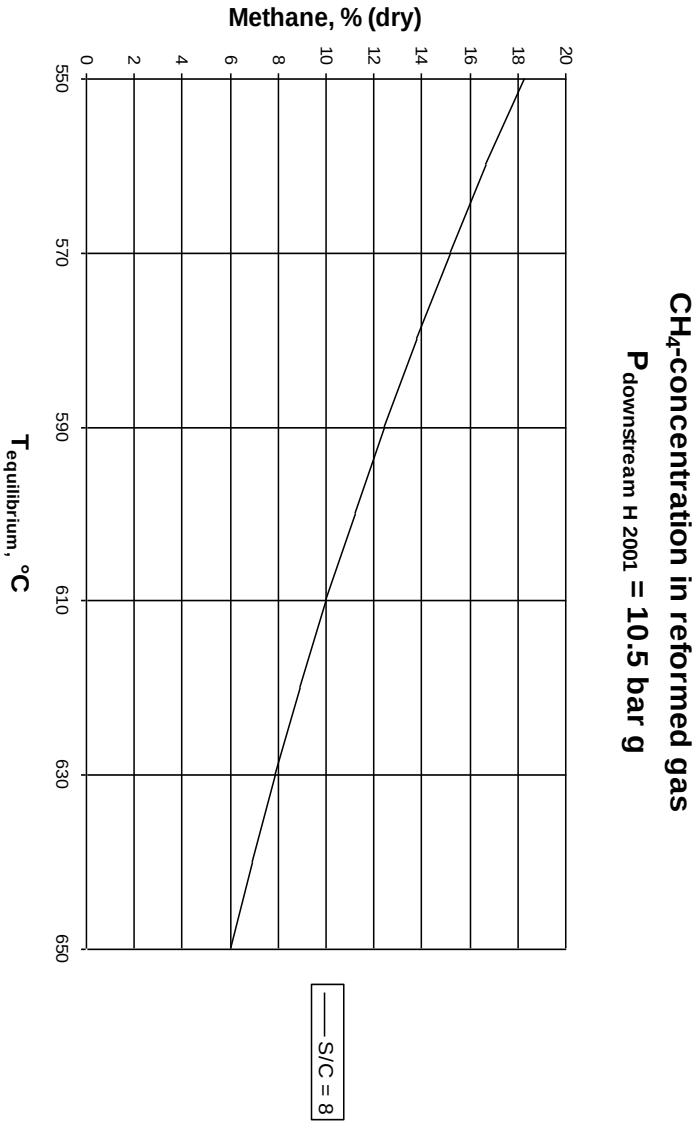
Open the on-off valve (USV-4014/4016) on outlet pipe of methanol tank after the inspection. The qualified methanol product will be tranfered to the green tank farm area outside battery limit by methanol transfer pump (P 4001 A/B).

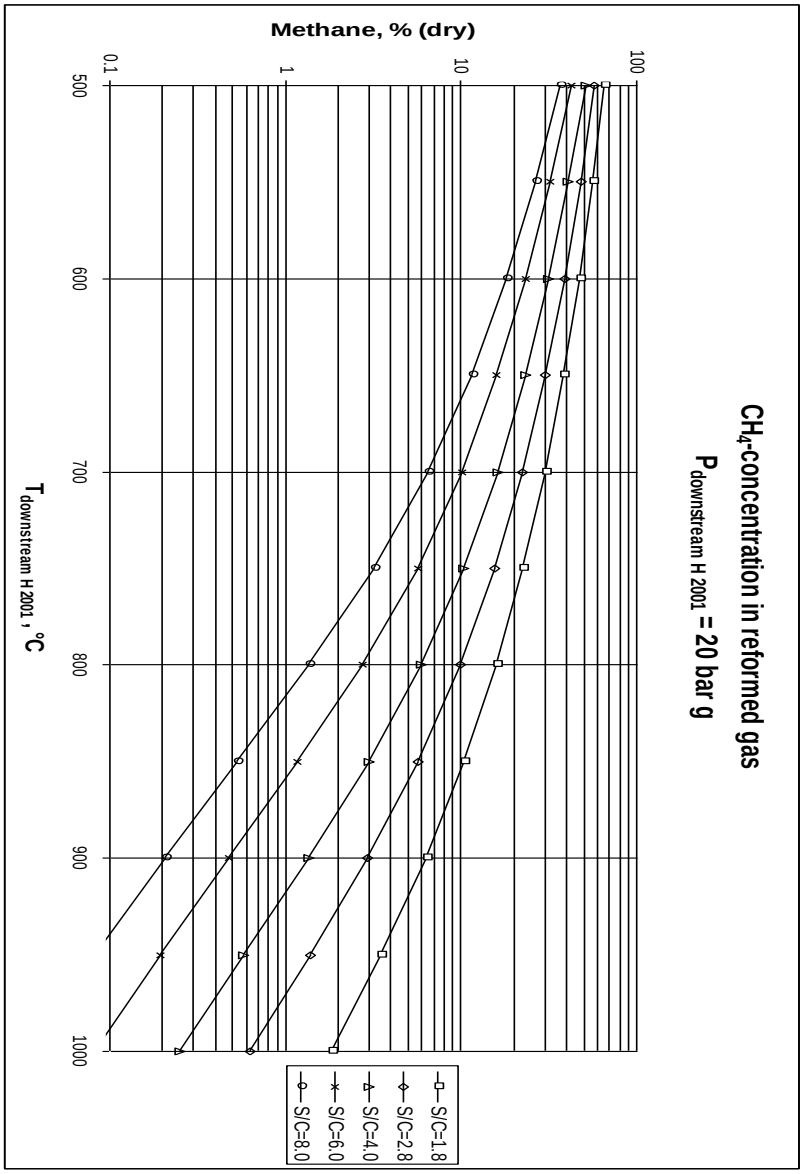
Open the valve on inlet pipe of methanol tanks unit closed drain drum (D 4001), and transfer the drain to methanol tanks (TK 4001 1/2). When the level in D 4001 is at high high level, close the valve on outlet pipe of D 4001 to stop the filling.

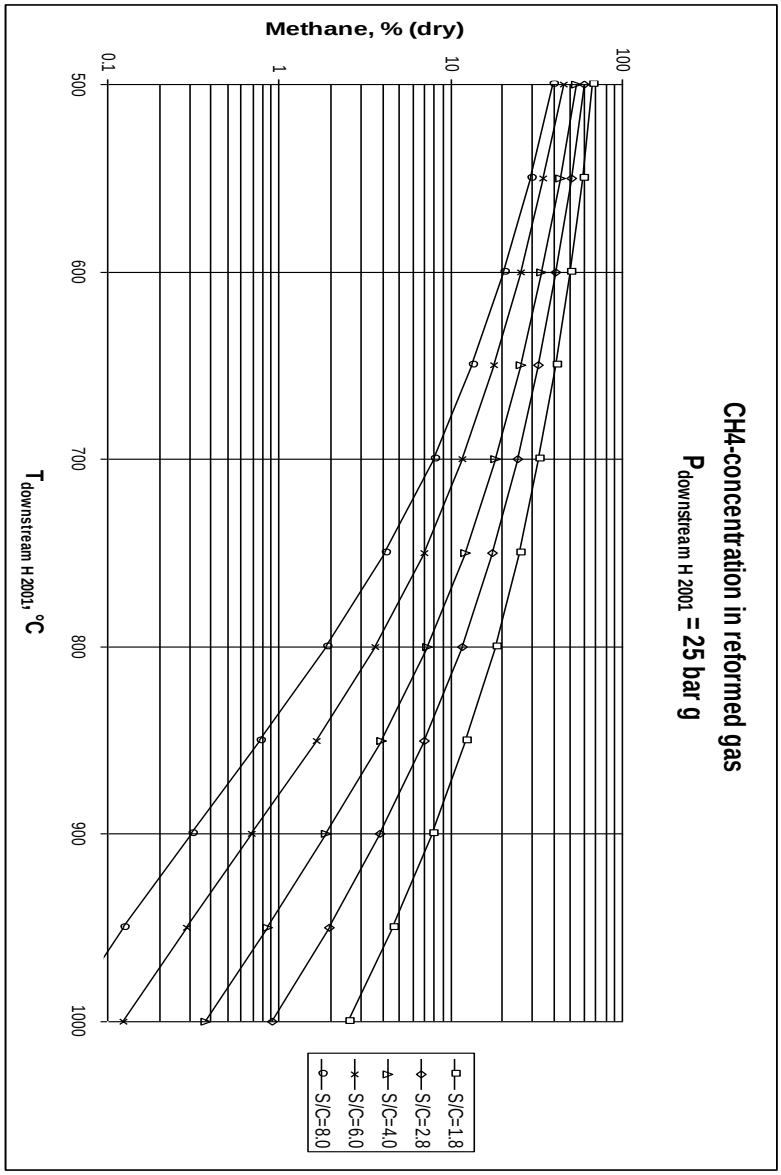
5.24 Appendix

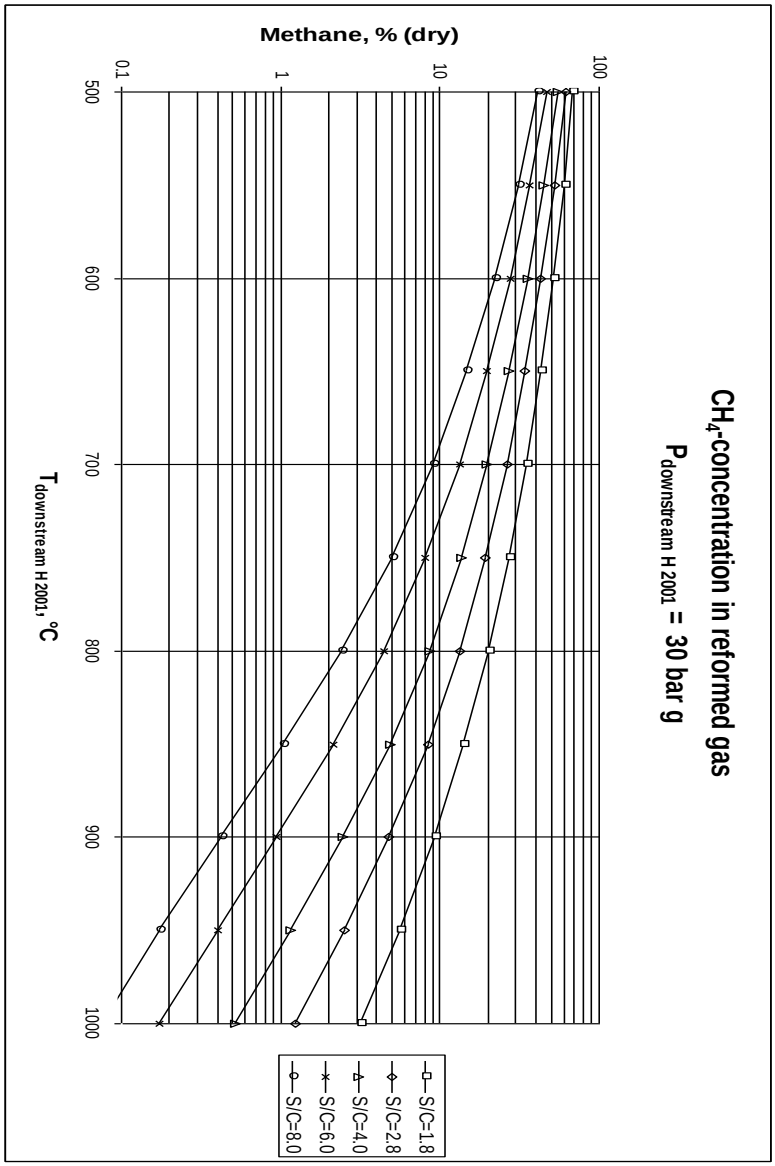
Appendix 1

Methane slip curves




Methane, % (dry)
0.1
1
10
100
500
600
700
800
900
1000
T downstream H 2001 , °C
CH4-concentration in reformed gas
P downstream H 2001 = 20 bar g
S/C=8.0
S/C=6.0
S/C=4.0
S/C=2.8
S/C=1.8


Methane, % (dry)
0.1
1
10
100
500
600
700
800
900
1000
T downstream H 2001, °C
CH4-concentration in reformed gas
P downstream H 2001 = 25 bar g
S/C=8.0
S/C=6.0
S/C=4.0
S/C=2.8
S/C=1.8


Methane, % (dry)
0.1
1
10
100
500
600
700
800
900
1000
T downstream H2001, °C
CH4-concentration in reformed gas
P downstream H 2001 = 30 bar g
S/C=8.0
S/C=6.0
S/C=4.0
S/C=2.8
S/C=1.8

Preliminary Plant Operation Manual

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Chapter 6 Normal Operation

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6 Normal operation

6.1 General remarks

6.1.1 Operating conditions

The operation of the plant is mainly supervised by the operators in the control room. They follow the indications of the various instruments, and they adjust the operating conditions in order to obtain a satisfactory operation at the desired capacity. Furthermore, they will react when an alarm is activated due to irregularities. In some cases they can re-establish the normal conditions adjusting the controllers in the control room, whereas in other cases they can give instructions to an operator regarding operations to be carried out locally in the plant.

Other operators are occupied in regular turns in the plant, especially in the reforming section in order to supervise the firing of the reformer, the temperature of the tubes in the reformer, to supervise temperatures of coils, to check against hot spots in secondary reformer, to record readings of local instruments and to notice any irregularities such as leakages or abnormal noise.

6.1.2 Rotating machines

The turbines and the compressors are supervised according to suppliers' operating manuals by an operator. The operator should regularly check the bearing temperatures, lubrication and vibrations, and notice if a stand-by machine is in operation. Furthermore, he should check the set-points of the various controllers in order to be sure that they are not displaced by vibrations.

Other machines in particular pumps and blowers are supervised by the operators during their regular turns, and the same activities as mentioned above should be checked at these machines.

6.1.3 Instruments

Control valves, instruments and on-line analysers should be carefully maintained in accordance with suppliers' recommendations.

6.1.4 Electrical installations

The electrical equipment should be checked and fundamental faults, if any, on relay systems should be corrected immediately.

6.1.5 Vent systems

In order to avoid explosive gases in the vent system, it is suggested that the various vents should be purged with nitrogen from time to time, say once a day. The vent system is regularly checked, e.g. stethoscope checking for leakages above an acceptable amount.

6.1.6 Water coolers

This only applies when using water coolers instead of a cooling tower.

The water coolers in the methanol plant are operated in parallel, which means that with only few coolers in service the cooling water flow through these coolers will increase to a value which may cause vibration of the tube bundle. To avoid this, the cooling water flow through each cooler should not exceed the design value.

6.2 Gas preparation

6.2.1 Hydrogenator, R 1001

The temperature at the inlet of the hydrogenator, R 1001, should be kept at about 380°C, which is controlled by TIC-2220 by means of a bypass around E 2006.

A flow of recycle gas from the synthesis loop is added to the natural gas to provide hydrogen for hydrogenation. At normal operating conditions the flow (FIC-2150) is 4562 Nm^3/h (for lean gas with feed gas scrubber case), corresponding to about 2.0% hydrogen in the feed gas to the reforming section.

If for some reason the recycle gas to the hydrogenation catalyst is interrupted, we recommend stopping the hydrocarbon flow to the hydrogenator. Otherwise, the result will be a gradual carbon lay-down and deactivation of the catalyst.

If the sulphur content in the feed drops to a low level (below 1 ppm) for a prolonged period of time, sulphur will be stripped off the catalyst. It is essential to keep the catalyst in the sulphided state, if at a later stage; the hydrogenator has to handle a feedstock with high concentrations of organic sulphur. Also the affinity to methanation reaction is higher for desulphurised catalyst, and it may be necessary to stop the recycle gas flow and reduce the temperature (as described above).

The performance of the hydrogenator catalyst can be checked by analysis for organic sulphur components downstream R 1001 (AP-1036).

6.2.2 Sulphur absorber R 1002 1/2

The two absorbers must be operated in series during normal operation. When sulphur is leaking through the lower bed in the first vessel, it is taken out of service and the spent catalyst is replaced.

In order to detect a breakthrough of sulphur in the first absorption vessel, analyses should be made regularly between the absorbers according to the specified frequency.

The sulphur content in the gas from the first sulphur absorber, R 1002 1, should be checked regularly by analysis at AP-1039.

The sulphur content in the gas from the second sulphur absorber, R 1002 2, can be checked by analysis at AP-1044. Whenever gas with any significant sulphur content flows to the second sulphur absorber, a record must be kept of the total amount of sulphur in order to evaluate the time for catalyst replacement.

The lifetime of the catalysts in the reforming section depends very much on the sulphur content of the process gas entering this section. The total content of sulphur in the gas from the second sulphur absorber must never exceed 0.05 ppm vol.

If inefficient sulphur absorption is detected, the reason could be that the absorption mass is fully loaded with sulphur or that the hydrocarbon contains water vapour, which gives an unfavourable equilibrium for the reaction:

$$ZnO + H_2S \rightleftarrows ZnS + H_2O$$

In case the sulphur absorption mass the first sulphur absorber has been fully loaded with sulphur, it must be replaced. Reference is made to the loading procedure described in 'Preliminary procedures and precommisioning'.

6.2.3 Replacement of catalyst in R 1002 1

The ZnO catalyst in the first sulphur absorber, R 1002 1, should be replaced as soon as sulphur break-through is detected by analysis at AP-1039. The catalyst replacement can take place while the plant is running. The manual bypass over R 1002 1 is opened and the reactor is blocked in.

The pressure is slowly released and the vessel is purged with nitrogen. When the vessel has cooled down, the spent catalyst is replaced. When ready for operation, the system is purged with nitrogen or natural gas, tested for tightness, pressurized and put into operation.

6.3 Saturation section

The water uptake in the saturator is determined by the pressure of the steam on the shell side. The steam pressure is, however, limited by the demands from the methanol reactors.

If the automatic control system exports condensate to the process condensate tank, the operators should find the cause for the problem and act to bring the water in and out of the unit in balance.

It is possible to reprocess up to 5000 kg/h of condensate from the buffer tank when operating at 100% capacity.

It is possible to use BFW as water supply for the saturator, this should, however, be avoided as much as possible, because BFW contains traces of alkali metal salts that are harmful to the pre-reformer catalyst on a long term basis.

Liquid off stream from the distillation is recycled to the inlet of the saturator feed/effluent exchanger

6.4 Reforming section

6.4.1 Capacity control

The saturated process gas is mixed with process steam in order to obtain the specified steam-to-carbon ratio of 1.8. The steam-to-carbon ratio must not drop below 1.8, because a too low steam/carbon ratio will cause carbon formation on the catalyst.

After the initial start-up it is recommended that a capacity of about 40% should be maintained for some time, in order to make the necessary adjustments. In particular, the firing of the primary reformer should be adjusted and the burners and the flame appearance should be checked. Furthermore, various controllers should be adjusted, tuned, and switched over to automatic control as soon as possible.

Once operation is stable, the load of the reformer can be increased gradually. An increase in production should take place stepwise in increments of maximum 5% of the design capacity. After each step, the operator should wait until the operating conditions have stabilized before taking the next step, i.e. at least 15 minutes.

The reforming capacity is increased shown in the following sequence:

In each step:

1) The steam-to-carbon ratio via the controller FHIC-2070 is slightly increased.
2) Natural gas flow is increased slightly. The steam-to-carbon ratio controller ensures that the steam flow will increase automatically following the natural gas flow.

In every second step:

3) Steam/carbon ratio is decreased to the normal value of 1.8
4) Firing is increased correspondingly.
5) Oxygen flow is increased correspondingly.

When operations 3 and 4 are carried out, they should be delayed a few minutes after operations 1 and 2.

The capacity of the reforming section is reduced by the same steps as indicated above, but in reverse order.

Catalyst temperature variations during capacity changes should be avoided to the extent possible.

6.4.2 Prereformer

During normal operation, the prereformer inlet temperature will be 496°C (TIC-2253 provided with high and low alarm). The adiabatic prereformer outlet temperature is measured by TI-2268. For normal operation an outlet temperature of about 441°C is expected. At a too low operating temperature the rate of reaction decreases.

The hydrogen present in the natural gas from the desulphurisation section will prevent oxidation of the pre-reforming catalyst.

The inlet temperature can be controlled by manual adjustment of the firing in the top of the primary reformer H 2001, thereby adjusting the duty in the pre-reformer feed preheat coil E 2002. The prereformer inlet temperature can, if necessary, be controlled by TIC-2253 by quenching the process gas with process condensate and/or BFW.

During normal operation, quenching should be with process condensate via FV-2233 1. Only during start-up and occasionally when process condensate is not available, BFW via FV-2233 2 may be applied. This is because BFW contains traces of alkali metal salts that are harmful to the prereformer catalyst on a long term basis.

The prereformer reactor is provided with 6 pairs of internal temperature indicators, by which the catalyst bed temperature profiles can be monitored.

By monitoring the progress of the temperature profile through the reactor and by using the analysis point placed in the catalyst bed of R 2003 (AP-2266), it is possible to estimate the extent of catalyst de-activation, thereby predicting the time of break-through of higher hydrocarbons to the tubular reformer. Thereby a shutdown for replacement of the AR-401 catalyst charge should be planned.

The performance of the prereformer, R 2003, is indirectly reflected by the temperature decrease across the reactor, which is normally about 55°C for lean natural gas.

The temperature decrease will depend very much on the steam/carbon ratio and to some extent on the inlet temperature. Thus at an elevated steam/carbon ratio, the temperature decrease is lower.

The deactivation of the catalyst bed is normally due to ingress of sulphur in ppb level from the desulphurization section, ingress of other poisons as alkali and ordinary ageing of the catalyst.

Any sudden increase in the deactivation rate of the prereforming catalyst could indicate an increased amount of sulphur leaking through the sulphur absorber. Means to rectify this must be initiated immediately. The last appendix to this chapter (Z90 plot Natural Gas) describes our procedure for monitoring the deactivation rate of the prereforming catalyst in a natural gas based plant. It is recommended to record the prereformer temperature profile on a regular basis - say once a week at similar operating conditions.

Regular samples of the prereformer effluent should be taken (AP-2266) to ensure that sufficient reforming takes place.

The pressure drop across the prereformer is indicated by PDI-2252. If the pressure drop starts to increase (at constant plant load), this may be an indication of carbon lay-down or disintegration of the catalyst. Immediate action should be taken to rectify the situation.

6.4.3 Firing and burner control in primary reformer, H 2001

The total firing in the primary reformer should be controlled by the methane percentage leaving the secondary reformer, indicated on online analyser AI-2479 (2000-PID-016/P21).

The firing of the primary reformer should secondarily be adjusted to obtain the desired reformer outlet temperature (normally 739 °C). However, the temperature in the hot collector at the outlet of the primary reformer must never exceed the design temperature of 800°C (TI-2303/2304).

The oxygen flow to the secondary reformer is controlled to obtain module values as specified below:

Case	Module of synthesis gas	Module at reactor inlet
EOR, lean gas	2.15	4.40
SOR, lean gas	2.15	4.83
EOR, rich gas	2.05	3.18
SOR, rich gas	2.05	3.41

The steam flow added to the oxygen, controlled by FIC-2040, should not be changed when capacity of the plant is changed. It is preferred to keep maximum flow at all capacities.

An optical pyrometer should be used to monitor the outer skin temperature of the reformer tubes; log sheets should also be kept. The tubes are designed for a lifetime of 100,000 hours at a tube wall temperature of 850°C and a pressure of 35.8 bar g. Running the tubes at higher temperatures and/or pressures will reduce their lifetimes. Variation in skin temperature from tube to tube may be due to sulphur poisoning of the catalyst, carbon formation, variations in the firing along a horizontal burner row, or uneven flow distribution drop in the individual tubes. The last may be due to improper loading of the catalyst or carbon formation.

The burners should be closely monitored, and any irregularities in the flame pattern should be corrected to avoid uneven heating of the tubes and obtain a good thermal efficiency.

Correct adjustment of the draught resulting in correct pressure (not less than 5 mm WG vacuum in top of the furnace chambers) is decisive for the thermal efficiency, and is controlled by PIC-2224.

The oxygen content in the flue gas should be kept at about 1.6 % vol. (AI-2224). If it is higher, it will indicate too much combustion air or leakage into the furnace. While combustion air is adjusted, the flame pattern of the individual burners should be monitored closely. The oxygen is adjusted indirectly by adjusting air to fuel ratio on HIC-2533 and HIC-2538.

If the oxygen content drops too much, a reducing or sooting flue gas will be formed. This must be avoided since the reformer tubes can pick up carbon under certain conditions. Also, the protective layer of chromium oxide on the outer surface of the tubes may be removed, which could result in corrosion of the tube material.

During normal operating conditions, the fuel gas to the steam reformer is a mixed feed gas consisting of natural gas, and purge gas (containing purge gas from the synthesis loop and off-gas from the distillation section). In case the synthesis section is down, natural gas will be used instead of purge gas. During this period off-gas from the distillation section will be routed to the flare system. During start-up or during upsets, the burners will operate on natural gas only.

When purge gas is available for the burners, the flow of natural gas is automatically reduced as described in Chapter 3 in order to keep a constant temperature level outlet the primary reformer.

6.4.4 Measurement of reformer tube skin temperatures

The skin temperature of reformer tubes is conventionally measured using an infrared pyrometer. Recommended types of pyrometers are the Minolta Cyclops 52, with a spectral response centred at a wave length of 0.98 μm and the Minolta Cyclops 339, with a spectral response centred at a wave length of 3.9 μm. Radiation at these wave lengths is virtually unaffected by absorption in the reformer flue gas (primarily caused by the content of water and carbon dioxide).

The radiation from the reformer tube surface is composed of two elements:

1. Radiation emitted by the tube itself
2. Radiation originating from the wall of the reformer furnace, and reflected by the tube wall.

The temperature indicated on the pyrometer should consequently be corrected in order to establish the correct tube skin temperature.

The temperature measurement is performed in three steps:

1. The apparent tube skin temperature is measured
2. The furnace wall temperature is measured (from the opposing wall)
3. The appropriate correction is calculated and applied.

NOTE: The operating instructions for the pyrometer should be read carefully before taking the instrument into service, in order to ensure long and trouble-free use. The power should be shut off whenever the instrument is not being used – even for a few minutes – in order to preserve the battery. The instrument comes calibrated from the supplier and should not need further calibration.

<u>Procedure:</u>

Tube wall temperature measurements should be taken with the plant operating under stable load conditions. The measurements should preferably be made through the sidewall peepholes in the reformer casing. Supplementary measurements may be made through the end wall peepholes. The maximum tube wall temperatures are normally found close to the bottom of the tubes. With variations in the firing profile, the maximum may be closer to the lowest or second lowest row of burners.

The distance setting on the pyrometer lens is at the appropriate distance (approx. 1.7 m equivalent to 0.5 × 2.07 + 0.31 – 0.5 × 0.152 + approx. 0.4 m), where 2.07 m is the internal width of the furnace chamber, 0.31 m the thickness of the furnace wall, 0.152 m the normal outside diameter of the reformer tube, and 0.4 m the approximate distance from the outer wall of the reformer to the pyrometer.

When the pyrometer has been prepared and is pointing in the appropriate direction, the peephole door is opened and the measuring button on the pyrometer is activated. The temperature is stored on the display, and the door may be closed. The measurement should not take more than 2 to 3 seconds, as the reformer tube will otherwise be cooled by air rushing in through the peephole.

Immediately after, measurement of the furnace wall temperature is made through the peephole on the opposite side of the reforming chamber. The distance setting on the pyrometer lens should be at about 2.8 m.

The true tube wall temperature, T_t, can then be calculated, using the formula:

$$\frac{1}{\exp(14388/(\lambda \cdot Tm))-1} = \frac{Et}{\exp(14388/(\lambda \cdot Tt))-1} + \frac{F(1-Et)}{\exp(14388/(\lambda \cdot Tw))-1}$$

where:

Tm = Instrument reading on the tube wall, oK
Tw = Instrument reading on the furnace wall, K
Tt = True tube wall temperature, K
Et = Emissivity of the tube wall, typically 80-90 %
F = View factor = 1
λ = Wave length of camera, µm

All temperatures are in Kelvin. All measurements with the emissivity on the instrument set at 1.

<u>Frequently asked questions:</u>

1. Why should an emissivity of 1 be used, when the emissivity of reformer tube material is generally recognised to be about 80-90%?

The emissivity is taken into account in the correction calculation formula. It is not relevant for a correct measurement of the radiation from the reformer tube, because the radiation includes both radiation due to the reformer tube surface temperature and reflected radiation originating from the furnace wall.

2. What is the effect of operating the reformer tubes at a higher temperature than the design operating temperature?

Basically, each degree increase in temperature decreases tube life expectancy by 3.76%. This means that if the design tube life expectancy is 100,000 hours, an over-temperature of 1°C will reduce life expectancy to 96,240 hours, and an over-temperature of 60°C will reduce life expectancy to 10,000 hours. The real danger does not rest with a general over-temperature within the limitations outlined above, but is caused by local overheating, for example if the burners are “torching”.

6.4.5 Methane content, reformer outlet

The methane content outlet the primary reformer depends on pressure, temperature, steam to carbon ratio, and approach to the theoretical equilibrium. On the other hand, the approach depends on the capacity and the catalyst activity. In order to get an idea of the catalyst activity, the actual methane content in the reformer effluent is compared with the theoretical methane content at the same operating conditions. Therefore, curves showing methane leakage as a function of steam to carbon ratio and temperature at different pressures are enclosed in the appendices to this chapter. The methane content is analysed at AP-2306 exit the primary reformer according to the analytical manual. The methane content in the process gas at the outlet of the primary reformer will normally be about 29 dry mole%

To achieve a minimum of methane leakage, all tubes should have the same outlet temperature.

As the catalyst ages, the approach to equilibrium of the effluent gas will tend to increase, causing an increase in methane leakage.

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 in the process gas at the outlet of the secondary reformer will normally be about 0.65 dry mole%. The methane content shown on analyser AI-2479 is representative for the methane content exit the secondary reformer, since the process condensate in-between only contains a limited amount of dissolved gases.
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

Please refer to 'methane slip curves'.

6.5 Process gas heat recovery

The process gas leaving the reforming section is first cooled in waste heat boiler E 2020 1/2 by producing HHP steam. From E 2020 1/2 the gas is cooled in steam super heater E 2021 1/2/3. The temperature of the superheated steam is controlled at TIC-2360 by dampers for the process gas side inside the waste heat boiler.

The operating temperature between E 2020 1/2 and E 2021 1/2 should be kept at 544°C or below, higher temperatures over a longer period could cause corrosion in waste heat boilers.

From E 2021, the gas is cooled in the BFW preheater, E 2022 1/2/3. The temperature of the process gas at the outlet of E 2022 is about 165°C depending on BFW flow, temperature and fouling in the heat exchangers.

The condensed water is removed from the gas in D 2002, before the gas is cooled further to about 159°C in the MP column reboiler E 5023. The condensed water is removed in a separator D 2003.

The gas is cooled to about 138°C in the stabiliser column reboiler E 5024 1/2 depending on flow, etc. and on fouling in the heat exchangers. The condensed water is removed in the separator, D 2004, and the gas is cooled further in the DMW preheater, E 2025, air cooler, AE 2026, and in the water cooler, E 2027, and finally the condensed water is separated from the gas in D 2005.

The gas stream is sent to the synthesis gas compressor. The flow and the methane contents are monitored in FI-2476 and AI-2479, respectively.

If more heat is required in the stabilizer column, part of the process gas can be bypassed across E 5023 via TV-5277. In case there is not enough heat in the process gas to produce the required vapour for the distillation, it is possible start the column steam reboiler, E 5001.

6.6 Secondary reformer

Oxygen filters:

It is not allowed to take an oxygen filter out of operation for cleaning or similar during plant operation. The two oxygen filters are both pressurised during start-up and operation. If filter A is blocked the manual valve upstream filter B is opened and the manual valve upstream filter A is kept open. If filter B is also blocked it is required to shut down the oxygen addition to the secondary reformer.

Pressure drop across catalyst bed:

The pressure drop across the secondary reformer catalyst bed, measured by PDI-2323, should be monitored closely. The typical value for the pressure drop across the catalyst bed is 0.12 bar

during normal operation. In general, if an increase is detected, the top layer of catalyst should be inspected for ruby formation at the first coming shut-down. In case of signs of ruby formation, the relevant part of the top layer should be replaced before restarting the secondary reformer.
The pressure drop must NEVER exceed 0.75 bar, if the pressure drop is higher than 0.75 bar capacity of the plant must be reduced. If the pressure drop exceeds 0.75 bar, there is a risk that the refractory lining will be damaged.

Shell temperature:

Because of the high temperatures reached during combustion, the internal surface of the secondary reformer is refractory-lined. The skin temperature should be 160°C (design maximum: 300°C). Defects in the refractory lining may result in temperatures above the design temperature, with possible damage to the reformer shell as a result. The secondary reformer is coated with a heat-sensitive paint which changes colour irreversibly to serve as a warning, and the colour change itself indicating the approximate temperature range the paint has been exposed to. Supervision of the thermo indicative paint must be included in the routines for every shift.
In case any hot spots are developed we recommend a plant shut-down for inspection of the Secondary Reformer.

6.7 Synthesis loop

Capacity control:

The capacity of front end and methanol synthesis is adjusted by the feed controller in the reformer section FIC-6070 (*6000-PID-003*/P07).

The steam governor valve of the turbine for the synthesis gas compressor, C 3001, will be operating in cascade (vendor scope) with a pressure controller, PIC-*3701* (vendor scope), on the suction side of the compressor, by adjusting the speed of C 3001. Thereby the make-up gas flow is increased/decreased automatically when the load of the reforming section is changed.

Module:

An important parameter when operating the synthesis loop is the module of make-up gas and of the synthesis gas at reactor inlet. Please refer to the 'Process Description' for definition.

Both modules should be compared regularly.

Please refer to 'The Firing and Burner Control in Primary Reformer, H 2001', for normal operating values of the module

In case the operation conditions for the loop changes, the optimum modules may differ from the above values, as the module depends indirectly on temperature, pressure, recirculation rate and purge rate.

In case the gas becomes under-stoichiometric (module below approx. 2.0) the methanol production decreases. Simultaneously, the carbon monoxide concentration in the inlet gas to the reactor increases and the by-product formation increases.

In case the module of the gas becomes high, the methanol production decreases and more gas have to be purged from the Synthesis Loop in order to keep down the pressure and compensate for the higher module. Excess H_2 content in the loop will act as additional inert with increased pressure and loss of reactants to flare through PV-3166 (3000-PID-006/P27) as a result (overall loss of carbon efficiency).

Inlet temperature:

The catalyst should be operated at a temperature as low as possible while still obtaining the required conversion because by-product formation is increased by higher temperatures.
However, a minimum temperature of 200°C is recommended and the catalyst should never be exposed to synthesis gas below 190°C.

Loop pressure:

The pressure in the synthesis loop is maintained by purging gas through FV-3169. The controller FIC-3169 gets its set point from the master controller PIC-3166 A. The loop pressure is increased as methanol catalyst is aging.

Recirculation flow rate:

The recirculation flow is determined by the speed of the compressor. However, in case a lower flow is required (e.g. in SOR) the valve located on the suction side of the compressor may be throttled. In general, higher recirculation flow means higher production and lower by-products formation due to a less reactive gas. On the other hand, high recirculation increases the wear on the catalyst therefore the recirculation rate should be optimised depending on the catalyst activity.

Steam pressure in D 3003:

As a last means to maintain the methanol production with old catalyst, the pressure and thereby the temperature of the steam side of the methanol reactors and of the catalyst can be increased. However, this will increase the deactivation rate for the catalyst further.

Pressure of D 3002:

From the HP separator D 3001, raw methanol is sent to the LP separator D 3002, which operates at about 4 bar g. By this depressurisation, dissolved gases in the raw methanol and some methanol and water are released.

The pressure in D 3002 is maintained by PIC-3194, which controls the gas flow from the separator. A low pressure means that more gas is released, but it also means that more methanol is lost. A high pressure means that there is too much dissolved gas in the raw methanol from D 3001.

The gas from D 3002 is used as fuel in the primary reformer, and the liquid is sent to the raw methanol tank TK 5001.

6.7.1 Removal of wax in loop water cooler

Due to the nature of the synthesis gas and process conditions involved in methanol synthesis, small amount of wax (or paraffin) is formed as a by-product. The wax tends to deposit or precipitate on the cold parts of the loop water cooler E 3003 1/2/3 and subsequently effects the efficiency of the water cooler.

The design of the three water coolers E 3003 1/2/3 installed in parallel allows cleaning of the process gas side online.
One exchanger at a time is cleaned, by increasing the shell side inlet temperature to above the wax melting; thereby the wax is melted and sent to the D 3001.

One exchanger at a time is put into ‘wax melting’ mode by:

- First fully shutting off the cooling water flow and drain the cooling water side of the exchanger.
- Increase the shell inlet temperature to about 80-90°C by adjusting the fans in the corresponding upstream air cooler.
- When one exchanger is in special mode, the other exchangers shall be on normal operation with 70-80% of total duty.

During plant turnarounds or planned shutdowns, it is also possible to remove the tube bundles and clean the exchangers mechanically.

6.8 Distillation unit

The operation of the front end and of the distillation is close connected because, the heat for the reboilers E *5023* and E *5024 1/2* are surplus heat from the reforming unit cooling train.

If the front end is operating at reduced capacity and the distillation capacity at the same time is to be maintained, the heat input is increased by adding LP steam to the stabiliser column steam reboiler, E 5001.

Distillation unit operating 'stand-alone':
The 'Stabilizer column steam reboiler', E 5001, also provides the possibility to operate the distillation unit at 50% capacity even if the front end and synthesis loop are tripped.
Steam for the reboilers must be imported; steam condensate may then be cooled in E 7003 1/2 and send to the 'Demineralized Water Tank' TK 7001 1/2.

The capacity of the distillation unit is adjusted by adjusting the product flow from

- LP Column via FV-5337 (5000-PID-012/P40)
- MP Column via FV-5336 (5000-PID-012/P40)

The control system will automatically withdraw raw methanol from TK 5001 as required to meet the product requirement

The level in the raw methanol tank must always leave room for liquid accumulated in the distillation unit in case it has to be emptied in an emergency.

Apart from occasional adjustments of the capacity, it may be necessary to adjust the operating conditions primarily based on the results of the analyses of the final product as well as various waste product streams.

Remarks on the operation of the individual sections in the distillation section are given below.

6.8.1 Raw methanol tank

During normal operation the raw methanol from the LP Separator D 3002 is fed to the raw methanol tank TK 5001. The level of the tank is indicated by LI-5001 (equipped with high and low level alarms). Furthermore, the level transmitter LST-5002 is connected to the interlock system.

The operators must continuously ensure that the raw methanol tank has a sufficient capacity otherwise a full shut down of the loop will be necessary.

Adjustment of pH:

In order to protect the storage tank as well as downstream equipment, NaOH-solution flow must be added continuously to the raw methanol upstream TK 5001.
Thereby the small quantities of organic acids present in the raw methanol are neutralised.

The NaOH-solution flow must be adjusted so that the pH value of the bottom product in the stabilizer column, T 5003, is about 10. Be aware that any effect of changing the flow has a long delay. If pH is measured in the raw methanol the effect of CO_2 will cause addition of excess NaOH-solution.

If pH-adjustment has not been performed properly, less TMA will be stripped in the stabilizer column, and the TMA that has to be removed in the product polisher will increase.

The pH has to be controlled at the bottom product in the Stabilizer column, AP-5044 (5000-PID-002/P30).

6.8.2 Stabilizer column

The main purpose of the stabilizer column is to remove the light compounds from the raw methanol. Apart from acetone and TMA[1], none of the light compounds will be difficult to remove. TMA and acetone will leave the system via the OH gas line together with the remaining light gaseous components. The OH gas line is provided with the analytical point AP-5112 (5000-PID-004/P32).

Even though acetone is difficult to remove, the enrichment of the stripped acetone taking place above the feed tray should cause no problem, and the acetone is expected to be removed together with the remaining light compounds in the OH gas stream. Nevertheless, if removal of acetone at this point appears difficult, a small liquid stream can be drawn off from the reflux via FIC-5107 to the liquid off-stream tank, TK 5003.

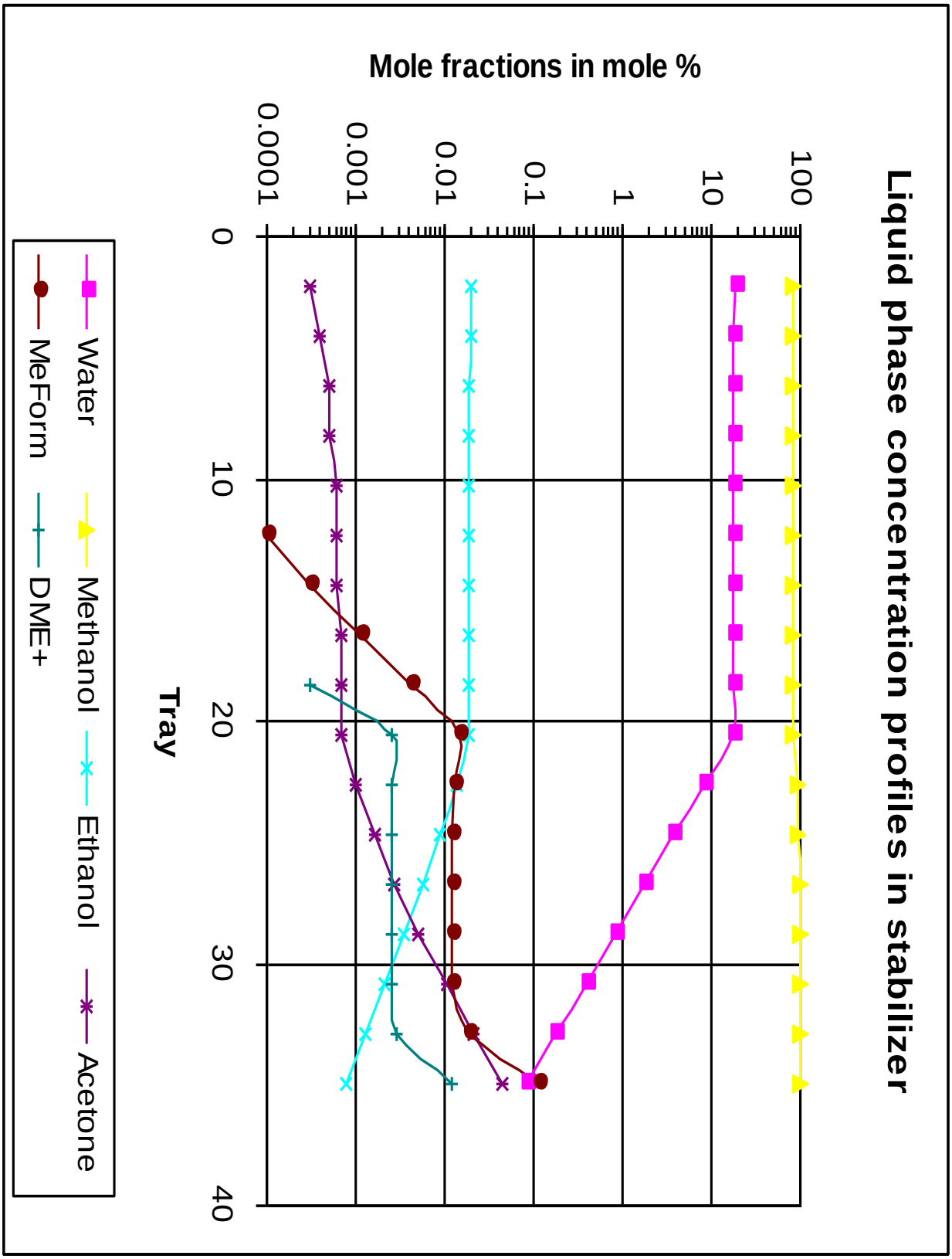
The heat to the system is supplied by the stabilizer column reboiler, E 5024 1/2, heated by the reformed gas. The heat to E 5024 1/2 from the reformed gas can be controlled by TIC-5064 (5000-PID-002/P30) via the by-pass around E 5024 1/2, and by TIC-5277 (5000-PID-010/P38) via the by-pass around the MP column reboiler, E 5023.

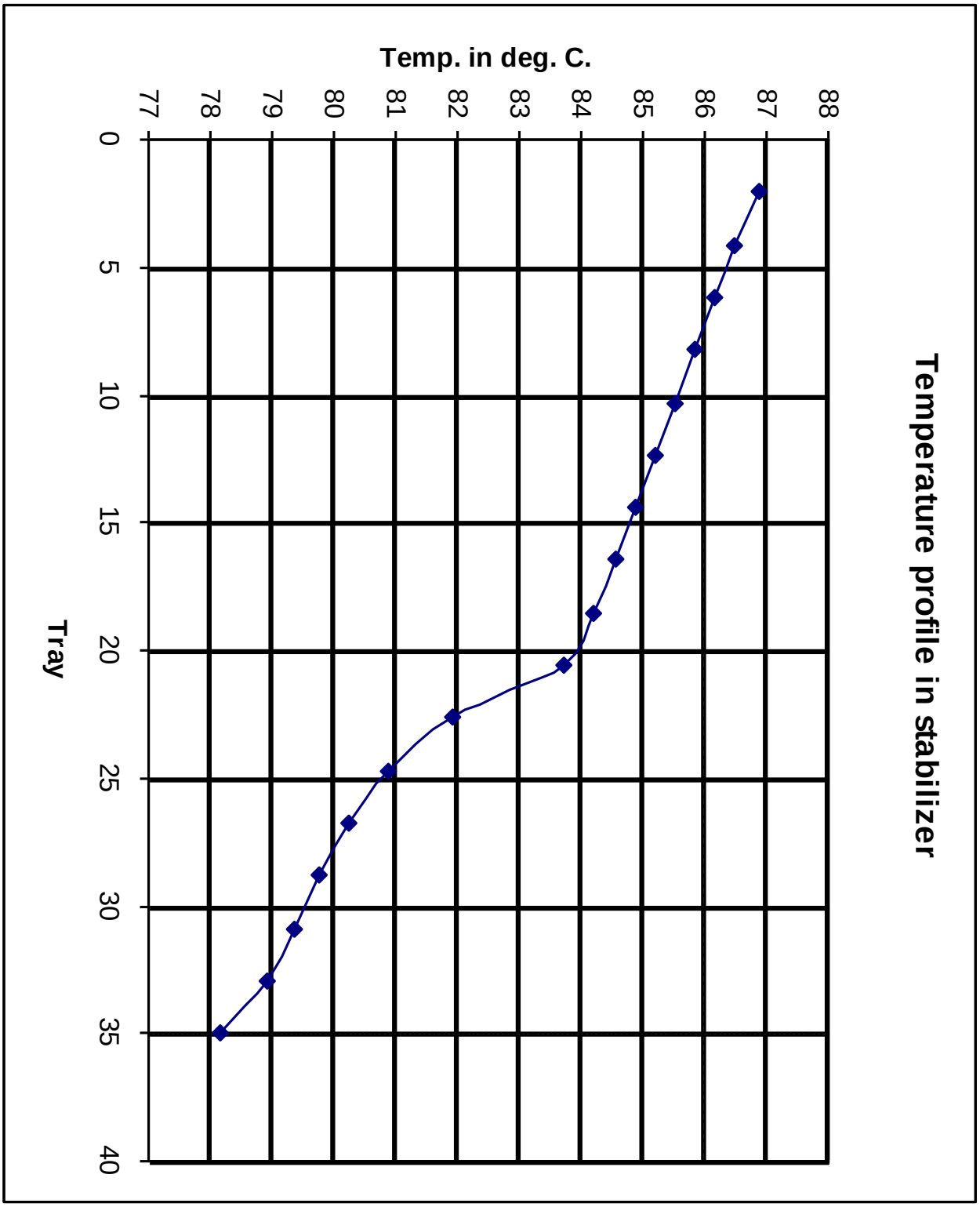
The stabilizer column steam reboiler, E 5001, is only foreseen either for start-up of the distillation section or when the front end is not operating. The start-up reboiler duty is controlled by the pressure controller, PIC-5069.

Besides the indicated components the off-gas will also contain small amounts of miscellaneous impurities such as acetone, TMA, ethers, hydrocarbons, amines, etc. The off gas is sent to the fuel gas header via ejector J 3001.

[1] Trimethylamine

A number of sample points are provided on the column. By analysing the samples on various trays it is possible to establish a concentration profile for the different components.


Liquid phase concentration profiles in stabilizer
Mole fractions in mole %
0.0001
0.001
0.01
0.1
1
10
100
Tray
0
10
20
30
40
Water
Methanol
Ethanol
Acetone
MeForm
DME+


Temp. in deg. C.
77
78
79
80
81
82
83
84
85
86
87
88
Tray
0
5
10
15
20
25
30
35
40
Temperature profile in stabilizer

6.8.3 LP methanol column and MP methanol column

As the operation of the above columns is closely interrelated, it appears most practical to describe them as one system.

Ethanol concentration in product:

Most of the bottom trays are used to separate methanol from ethanol. Ethanol concentration is controlled via the reflux ratio in the LP and MP methanol columns.

A number of sample points are provided on these columns. By analysing the samples on various trays it is possible to establish a concentration profile for the different components.

Too high concentration of ethanol in the product may be caused by malfunctioning of either one or both of the columns, T 5002, ref. sampling point AP-5171 (outlet from tray 50), and T 5003, ref. AP-5306 (outlet from MP OH column accumulator). Based on the analyses of samples from the above sample points, it can be decided which column does not function and adjustment of the reflux ratio via HIC-5337 and/or HIC-5336 can be made accordingly.

Liquid off-stream from T 5003:

By comparing analyses from the sampling points AP-5266/67/68 (5000-PID-010/P38) with the temperature profile, the relationship between temperature and content of higher alcohols can be verified. This relationship may be used for selecting the optimal draw-off tray.

The draw-off rate controlled by FICA -5441 (5000-PID-009/P37) should be adjusted according to the actual production of higher alcohols. However, due to the large accumulation of higher alcohols on the trays compared to the content of higher alcohols in the feed, adjustment of the draw-off rate needs to be made occasionally only i.e. changes in concentration of higher alcohols at the draw-off tray will be slow even if the concentration of higher alcohols in the feed changes.

It is to be pointed out that draw-off of higher alcohols can be done only from one tray at a time. This means that the block valves on the remaining trays have to be closed completely.

Purity of bottom water product from T 5003

The main impurity of the bottom product stream is methanol. Too high a methanol content may be caused by an unstable temperature profile (shown by TIA-5261/62/63/64/65/69 and TICA-5266/67/68) in the column. This means that the temperature profile moves up and down, giving periods with no methanol reaching the bottom followed by periods with excessive methanol reaching the bottom. If this is the case, better control of the temperature should be ensured.

If the temperature profile is constant, the methanol content can be reduced by pushing the temperature profile upwards. Such change will have only a marginal influence on the purity of the methanol product. The absolute value of the set point temperature of TICA-5266/67/68 is not very important. Nor is it deemed necessary to compensate the temperature for pressure variations as these are expected to be moderate.

Another reason why the methanol content of the bottom product is too high may be that the reflux ratio is too low for separation of methanol and water. Problems of this type are not expected because in most cases the critical separation will be the ethanol/methanol separation. This may, however, not be true if the water content of the raw methanol is very high for instance due to abnormal operation conditions in the front end. If this is the case, the reflux ratios must be increase beyond what is required for separation of methanol and ethanol.

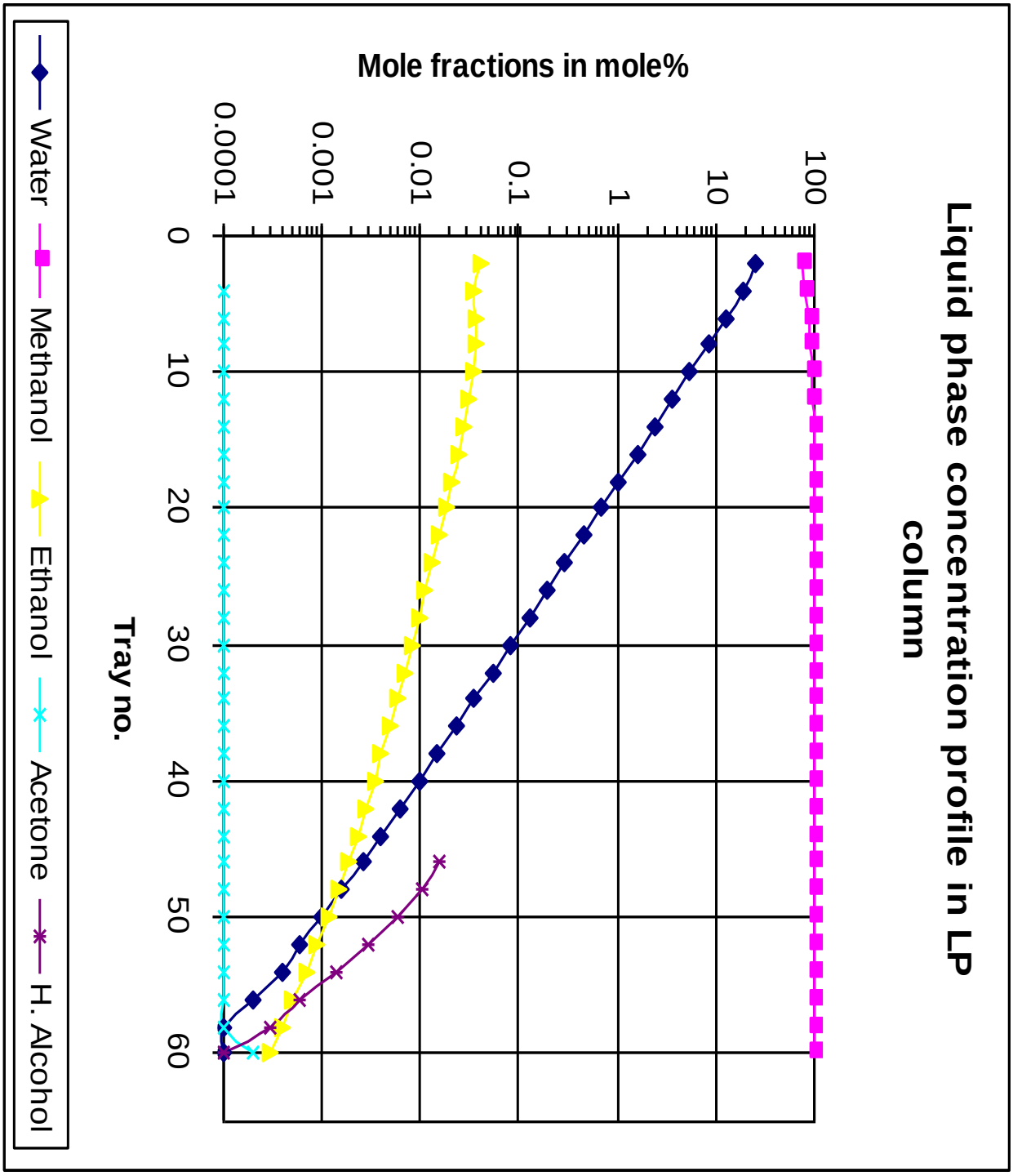
Excess water from distillation unit:

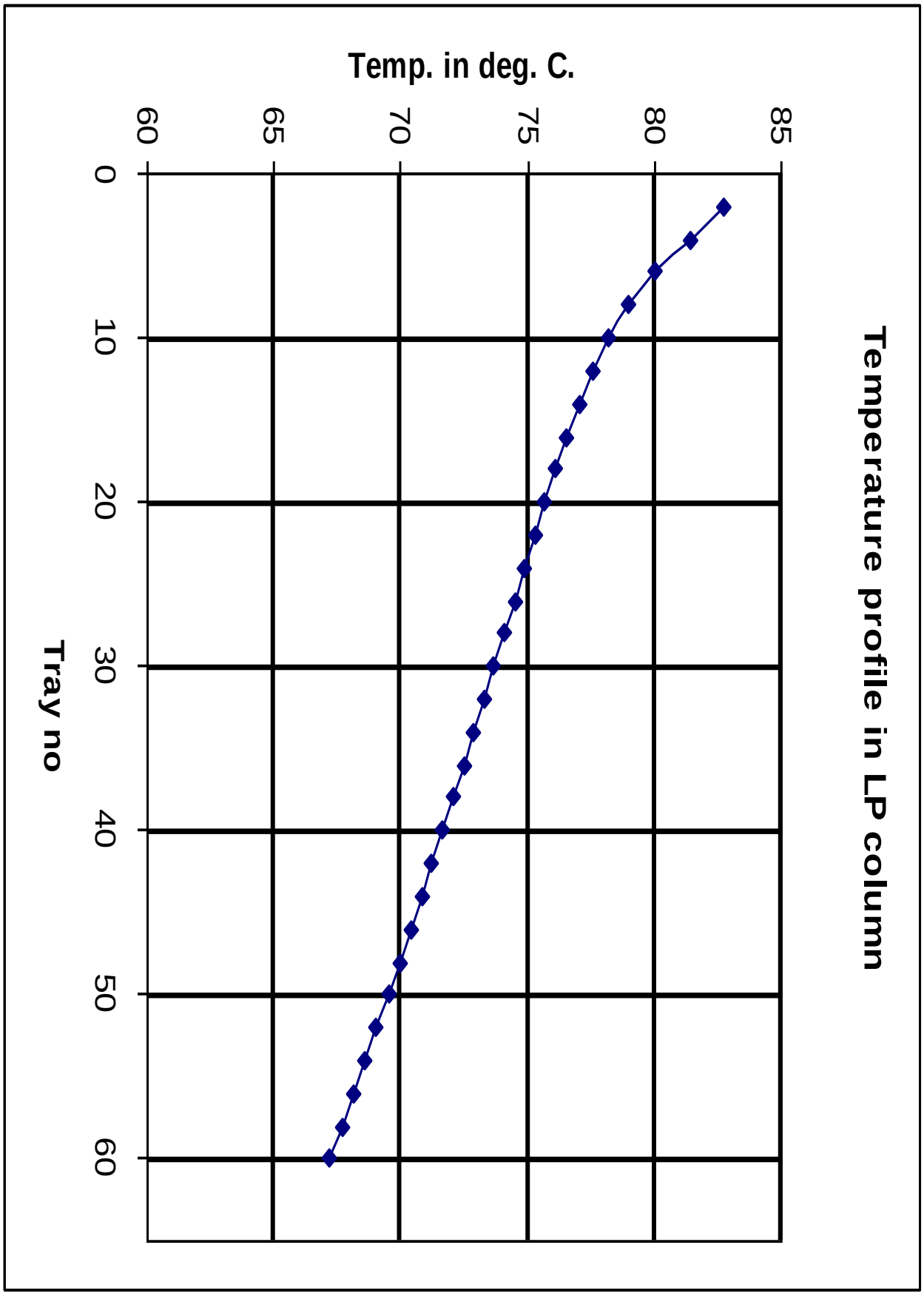
The net production of water is returned to the saturator section and in addition water will be recycled within the distillation section to be used as wash water in the vent wash column.

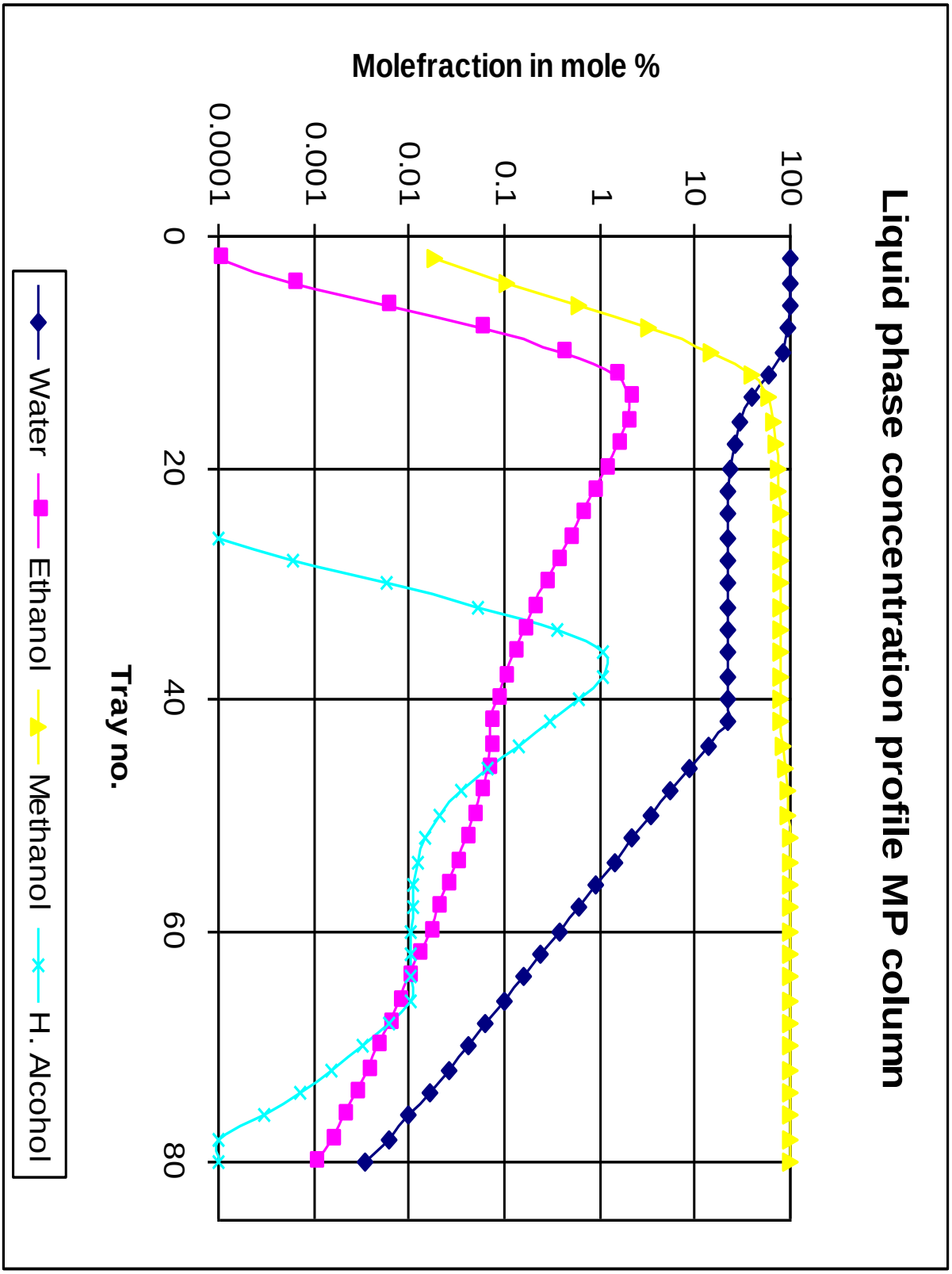
Temperature and pressure control:

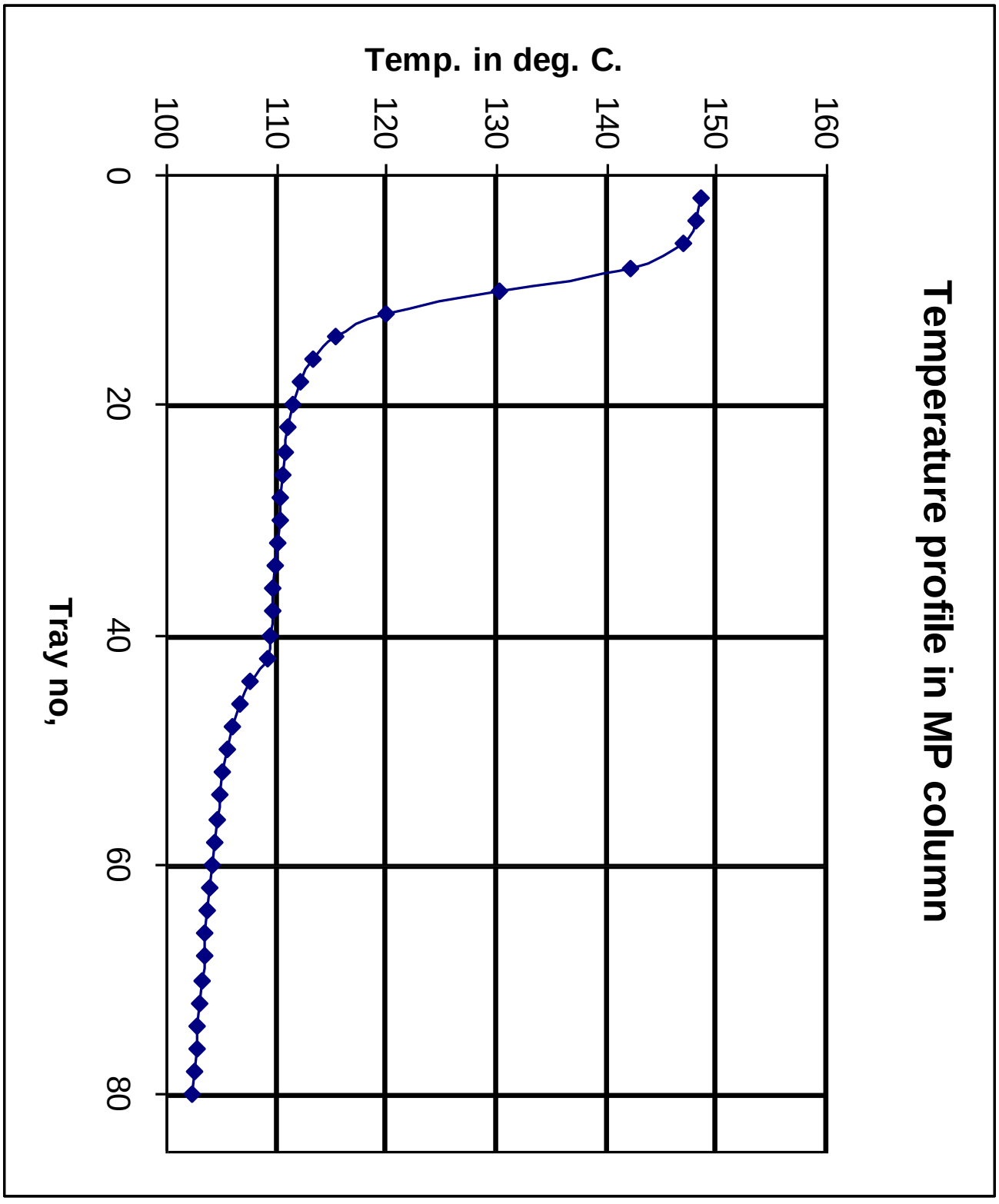
The column, T 5002, is connected to D 5002, which is operating close to atmospheric pressure. Consequently, the pressure in this column is defined by the pressure in D 5002 plus the pressure drop of the column which depends only on the boil-up rate.

The pressure in the bottom of T 5003 is defined by the pressure in the bottom of T 5002, the temperature difference in the reboiler, E 5002, and the pressure drop of the column, T 5003. This again means that for all practical purposes, the pressure in the bottom of the columns, T 5002 and T 5003, will be a function of duty in the MP column reboilers only. The MP column reboiler duty is controlled by FIC-5301 (5000-PID-011/P39) controlling the heat input to the steam fired MP column reboiler.


Liquid phase concentration profile in LP column
Mole fractions in mole%
0.0001
0.001
0.01
0.1
1
10
100
Tray no.
0
10
20
30
40
50
60
Water
Methanol
Ethanol
Acetone
H. Alcohol


Temp. in deg. C.
60
65
70
75
80
85
Tray no
0
10
20
30
40
50
60
Temperature profile in LP column


Liquid phase concentration profile MP column
Molefraction in mole %
0.0001
0.001
0.01
0.1
1
10
100
0
20
40
60
80
Tray no.
Water
Ethanol
Methanol
H. Alcohol


Temp. in deg. C.
100
110
120
130
140
150
160
0
20
40
60
80
Tray no,
Temperature profile in MP column

6.8.4 Liquid off-stream tank, TK 5003

Various cooled liquid off-streams will accumulate in TK 5003 having space for accumulation of around 24 hours' of production. The off-streams are foreseen to be pumped to the saturator section in order to be used as feed to the reforming section.

6.9 Boiler feed water

6.9.1 Steam/water conditioning

Demineralized water is sent from the BFW preparation unit to the DMW preheater, E 2025, where the water is preheated to about 72°C before it is sent to the deaerator, D 7001. In the deaerator oxygen is stripped off by means of low pressure steam until 7-10 ppb.

The deaerator consists of a horizontal tank with a packed tower. During normal operation the demineralised water is introduced above the packed bed and the stripping steam is introduced below the bed, controlled by the pressure controller, PIC-7094. During start-up, steam can be introduced at the bottom of the tank to heat up the stored quantity of water.

The deaerator is operated at approximately 120 °C. In order to ensure proper stripping of the water, it is important that a surplus of steam is available in the bed. Therefore, the inlet temperature of the water to D 7001 should be kept at minimum 5-10 °C below the temperature level in the deaerator. It should be checked that a reasonable flow of steam leaves D 7001 through the flow orifice FO-7096.

The quality of the water in the steam generating system should be continuously monitored through the analysis of samples taken from the outlet of the dearator, AP-7100. This is to ensure good operating conditions for the boilers and the turbines. However, it should be recalled that the steam is sent to the reformer and therefore catalyst poison in the steam will have serious consequence.

It should be kept in mind that sulphur or other catalyst poisons introduced with the steam are just as poisonous as when they are introduced with the process feedstock, so all possible sources of contamination of the boiler feed water should be avoided.

For conditioning of the boiler feed water, the following chemical dosing units are available.

a) Ammonia dosing unit
Ammonia water solution is added to the boiler feed water downstream the deaerator in order to adjust the pH value to 9.0 – 10.0.

b) Oxygen scavenger dosing unit
Oxygen scavenger is added to the boiler feed water in order to remove the last traces of oxygen left from the deaeration. Normally, the oxygen content downstream the deaerator is sufficiently low to prevent corrosion, but it is nevertheless recommended to add hydrazine of 0.1 mg/l in the boiler water in boiler drums, D 2001 and D 3003.

The concentration of hydrazine in the tank TK 7070, should not exceed 6% by weight as the oxygen in the air will cause oxidation of the hydrazine. A hydrazine concentration of about 1% in the tank is to be aimed at.

c) Phosphate dosing unit
Especially during periods when it is suspected that the boiler feed water preparation unit is not functioning properly, a solution of tri-sodium phosphate is added to the boilers in order to avoid corrosion and formation of deposits on the heat exchange surface. Tri-sodium phosphate is added to give a content of 1-3 mg/l as P_2O_5 in the boiler water. It is adjusted by the capacity of phosphate pumps, P 7051 A/B and P 7052 A/B supplying D 2001 and D 3003, respectively.

The blow down rate from the boilers is adjusted to maintain silica content in the boiler water within the limits specified by the vendor.

Note:
The general instruction indicated above should be adjusted in accordance with boiler vendor recommendations.

6.10 Boiler blow down

During the initial four weeks of operation the intermittent boiler blow-down valves, HV-2334 and HV-2335, should be actuated twice for 4 seconds in every shift, in order to remove accumulated dirt.

After the initial four weeks of operation, a single actuation of the blow-down valve every 24 hours will be sufficient. Also in this case the operating time of the blow-down valve should be 4 seconds.

These frequencies are empirical values. Higher or lower blow down frequencies may result from analyses of the boiler water. The total iron content in water for soluble and suspended Fe, and the conductivity is determined by analyses.

At each start-up and shut-down small quantities of the magnetite coating, which have been formed during operation, may chip off from the inner wall of the steam drum, D 2001, and the tube walls and deposit. In order to remove these deposits, the number of blow-downs is increased twice per shift for the first two days of operation after restart.

The continuous blow down is controlled by means of HV-2385 and is set in accordance with the boiler water analysis. Online analysers for pH, AI-2382, and for conductivity, AI-2384, are installed on this continuous blow down line. It is anticipated to blow down water from D 2001 corresponding to 1% of the boiler feed water flow.

The continuous blow-down from the MP steam drum, D 3003, is controlled by means of HV-3054 and is to be set in accordance with the boiler water analyses. It is anticipated to blow down boiler feed water corresponding to 1% of the boiler feed water flow.

During normal operation, the pressure control valve, PV-2363, outlet the steam super heater, should remain in a fully open position, in order not be increase the pressure drop to the HHP steam header. PIC-2363 should be left in automatic mode with the set point being a few bar below the actual operating pressure in order to protect the boiler in case of sudden depressurisation of the HHP steam header.

6.11 Methanol Tanks, TK 4001 1/2

6.11.1 Normal operation

The product methanol will be stored in the methano tank TK 4001 1/2 (4000-PID-001/4000-PID-002) if the methanol product tank outside battery limit can not receive it. TK 4001 1/2 (20000 m^3 each tank) have the space for accumulation of around 6 days' of production.

Dring the filling or unload of the tank, check the level of the other tank to be used before the switching. The details of the switching is described in section 6.11.2.

The stored product methanol can also be sent back to raw methanol tank TK 5001 if needed. The drains from TK 4001 1/2, P 4001 A/B and related pipes will be collected in the underground drum D 4001. The drains in D 4001 will be sent to the raw methanol tank TK 5001 by P 4002.

6.11.2 Methanol switching

Switching preparation

1）Make sure all the pipe and pipe element no leakage and deformation.
2）Check the integrity of all the pipe element.
3）Check the connetion of pipe and valve.
4）Make sure the tank and pump that to be used are runnable.
5）Check the level of tank.

Switching procedure

Filling tank switching

1）Recheck the level of tank. Check the integrity of the inlet pipe of tank. Only open the first valve on inlet pipe, and close the on-off valve.
2）Confirm the inspection of the filling system.
3）Open the valve on inlet pipe of the tank to be used generally, and close the valve on inlet pipe of the former tank. Inform the operator.
4）Observe the sound of liquid flow, temperature, pressure in inlet pipe and tank, and the increase of the level in the filling tank.
5）The depressurization of system should be done before the switching. Close the valve on inlet pipe of tank.
6）Make sure there is no leakage on the whole system, and the flow direction of methanol is correct.
7）The sample on the tank to be used should be analysed and recorded before switching.

Unload tank switching

1）Make sure the methanol in the tank to be used is acceptable.
2）Check the integrity of the system,and keep the first valve (nearest to the tank) on outlet pipe of tank.
3）Check the integrity of the system after the switching.
4）Open the first valve on inlet pipe of the tank to be used generally, and close the valve on inlet pipe of former tank. Inform the operator.
5）Observe the sound of liquid flow, temperature, pressure in inlet pipe and tank, and the decrease of the level in the filling tank.
6）The depressurization of system should be done before the switching. Close the valve on inlet pipe of tank.
7）Make sure there is no leakage on the whole system, and the flow direction of methanol is correct.

Switching attention

1）The valve needs to be fullly open or close.
2）Don not use the wrench to further open or close the valve after fully open or close.
3）The switching work should be done by more than two operators.
4）Non-explosion proof tools are not permitted for the switching.
5）All the safety regulation should be strictly followed.

6.12 Appendices

1. Z90 natural gas
2. Methane slip as function of primary reformer outlet temperature

Appendix 1

Z90 natural gas

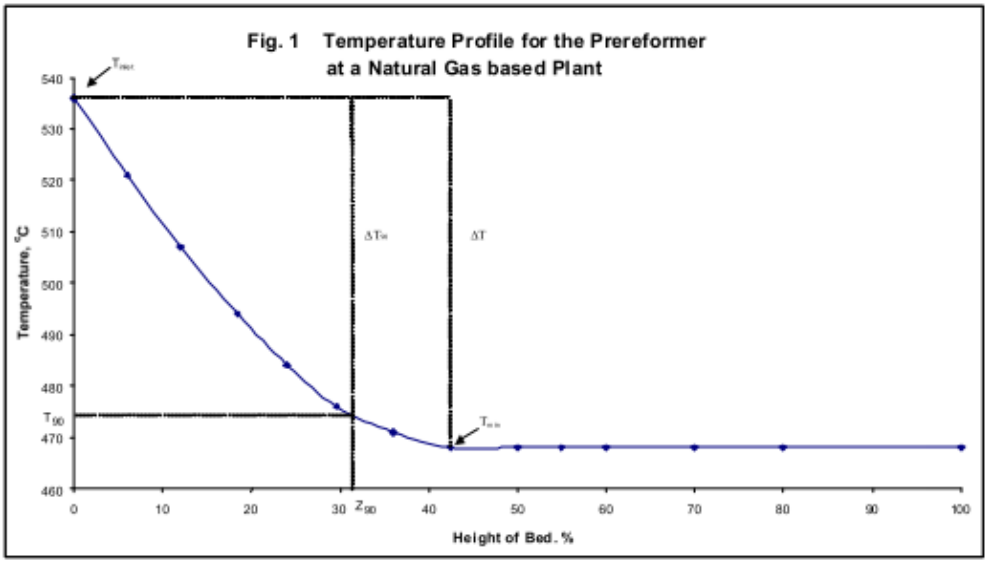
Z_{90} plot for natural gas feed

When in operation, prereforming catalysts will deactivate with time due to ageing and a slow poisoning of the catalyst. Topsøe has developed a simple method, denominated a Z_{90} plot, to evaluate the deactivation rate.

Procedure

Based on the measured temperature profile for the prereformer bed (Figure 1), reported over a period of time, the Z_{90} deactivation plot can be made as described below.

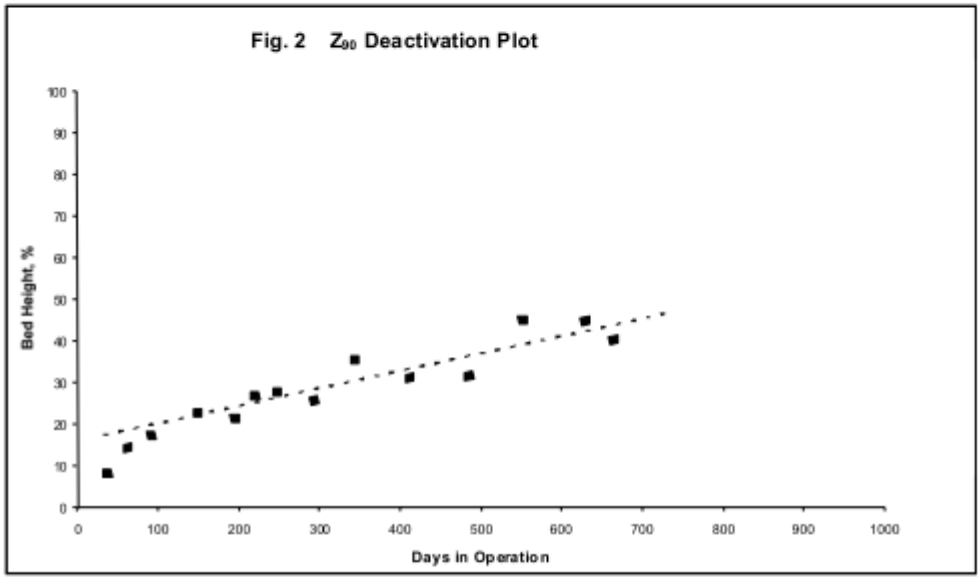
Fig. 1 Temperature Profile for the Prereformer at a Natural Gas based Plant



1. First, the difference between the temperature at the inlet of the prereformer and the minimum temperature of the prereformer is calculated. $\Delta T = (T_{inlet} - T_{minimum})$.
2. Then 90% of the temperature difference is calculated. $\Delta T_{90} = \Delta T \times 0.9$.
3. Then T_{90} is calculated as $T_{inlet} - \Delta T_{90}$ and the corresponding bed height Z_{90} is found (Figure 1).
4. In order for the Z_{90} values to be comparable, it is important that the selected operating data are collected at a somewhat similar plant load (± 10% of base case).

5. The Z_{90} values are then plotted against the time in operation. (X-axis is days on stream and Y-axis is bed height; Figure 2). The corresponding trend line shows the deactivation rate.

Fig. 2 Z_{90} Deactivation Plot



Interpretation

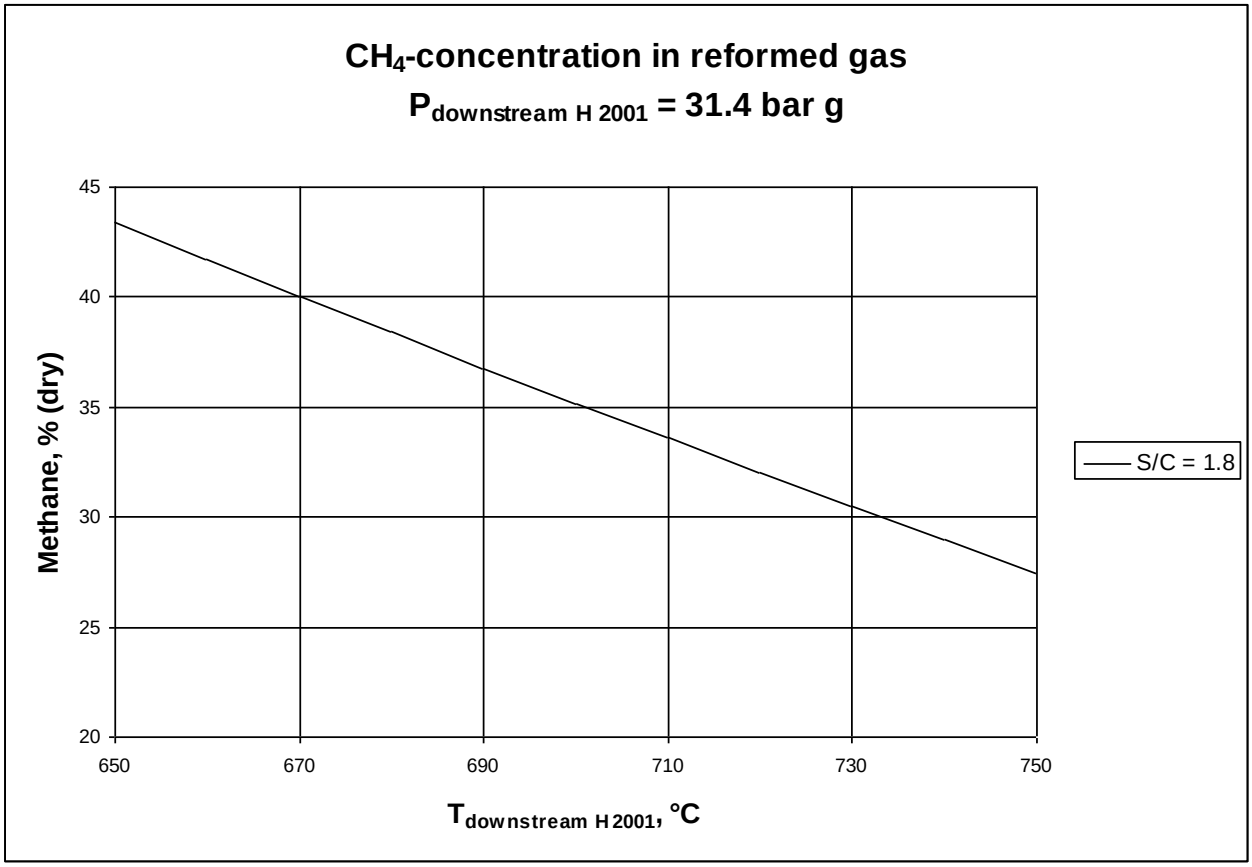
During stable operation, the Z_{90} plot will show a more or less straight line. The slope of this line indicates the deactivation rate.

An increase in the catalyst deactivation rate will often first be seen as a changed slope in the Z_{90} plot. Furthermore, when Z_{90} approaches the bottom of the bed, preparation for a replacement of the catalyst should be made. Generally, the catalyst should be replaced when Z_{90} is close to 90% of bed height. Operation beyond this level may lead to a severe leakage of higher hydrocarbons.

Limitations

If the exit temperature in the prereformer is considerably higher than the minimum bed temperature, it could be advisable to use another type of Z-plot.

Appendix 2
Methane slip as function of primary reformer outlet temperature



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Chapter 7 Shut-Down Procedures

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7 Shut-down procedures

7.1 Introduction

The procedure to be followed in case of a controlled, planned shut-down of the plant, total or partial, will depend on the circumstances, i.e. the foreseen duration, the purpose of the production stop, and the equipment to be inspected. The recommendations given in this chapter should therefore only be considered the basis, which will permit the operators to establish the most expedient shut-down procedure in the actual case.

Basically, the plant is designed for continuous operation during long periods.

All the critical pumps in the plant are provided with a spare unit and sulphur absorber catalyst may be replaced without shutting down.

A continuous operation of the plant is preferable, partly because the catalysts are maintained in their active state and partly due to a mechanical point of view because stresses due to temperature variations are avoided.

During a controlled shut-down, the set value of some of the active alarms in the trip system (low flow trips) might be reached, and they should therefore be by-passed before their trip values are reached.

For shut-down of particular equipment like blowers, compressors, fired heaters, pumps, etc., the procedure given by suppliers should be followed.

7.2 Desulphurization section

It is often convenient to keep the desulphurization section operating to allow a fast restart. However, this is only possible if the firing in the primary reformer is maintained, and if recycle gas is available.

The catalyst temperature in the hydrogenator must be decreased to maximum 300ºC, if the flow of recycle hydrogen to the hydrogenator catalyst is stopped. In the absence of hydrogen there is a risk of hydrocracking of higher hydrocarbons, causing carbon lay-down at temperatures above approximately 300ºC.

If the desulphurization section has to be shut down, the procedure is as follows:

- When the flow of natural gas to the primary reformer has been partially or fully cut off, the process gas is vented through PV-1045 until the temperature of the flue gas upstream from the coils E 2004 is below coil design temperatures.
- Stop the flow of recycle hydrogen by closing FV-2150.
- Isolate the system and leave the reactors in the desulphurization section blocked in under hot gas pressure.

If access to the desulphurization catalyst is required, the desulphurization system is depressurized and purged with nitrogen.

Before the vessel R 1001 is opened, the catalyst must cool down to 40°C. It should be noted that the sulphided hydrogenator catalyst in R 1001 is pyrophoric at temperatures above 70°C.

7.3 Reforming section

To the extent possible, the shut-down operation is carried out essentially in the same way as the start-up, but in opposite "direction". The normal shut-down procedure is as follows:

The capacity is reduced to about 40% of the normal capacity by stepwise adjustments of firing and process feed.

The steam to carbon ratio of 1.8 must be maintained as long as possible to avoid excess condensate, however it must be ensured that steam to carbon ratio never goes below 1.8.

The parameters must be adjusted in the following order:

(1) Oxygen flow is decreased
(2) Firing is decreased.
(3) Natural gas flow is decreased slightly. The steam flow will decrease automatically following the natural gas flow.

Catalyst temperature variations during capacity changes should be avoided.

The oxygen flow to the secondary reformer is controlled to obtain a module of 2.05 in the make-up gas to the synthesis loop.

At the time when the synthesis gas compressor is isolated, the gas is sent to flare through PV-2481.

Oxygen flow to the secondary reformer burner is gradually decreased and finally stopped. The steam to the burner is maintained in order to keep the burner cooled.

<u>Reduce load to 10%:</u>

The operating temperatures, the gas flow, and the pressure are decreased simultaneously.

Pressure: The operating pressure in the reforming section is gradually lowered to about 5 bar g. At the same time the operating pressure of the desulphurization section is decreased to approximately 20 bar g
Temperature: Steam reformer outlet temperature of about 650-700°C.
Flow: Natural gas flow of approximately 10% - 16,000 Nm3/h and steam flow of 68,000 kg/h.

The cooling rate of the steam reformer process gas as well as the flue gas should not exceed 50°C/h.

The temperatures inlet the hydrogenator and sulphur absorbers are not allowed to drop below 300°C.

When the above-mentioned condition of temperature, pressure, and flow has been obtained, the gas flow to the steam reformer is stopped completely by activation of the IS-1 trip.

The gas is now vented through PV-1045 (1000-PID-003/P04) located downstream of R 1002 2.

Recycle hydrogen:

During the entire shut down including purging with steam hydrogen must be added to protect the pre-reformer/reformer catalyst.

If sufficient hydrogen is not available in the methanol loop:
The hydrogen recycle compressor must be used to recycle hydrogen from the final separator to the HDS unit during the reduction of capacity.
The methanol start up pump must be started and methanol must be injected immediately when the natural gas is cut off. When the IS-1 trip is activated methanol injection is started automatically.

IS-1 trip:

By activating the IS-1 trip, the reformer section is purged automatically with steam and hydrogen. The steam and hydrogen are manually purged out with nitrogen.

Unnecessary cooling down of the reformer is not desired during a normal shutdown of the reformer in order to facilitate a faster restart, if required.

The hydrocarbon content in the nitrogen after purging should be maximum 0.1 vol%, calculated as methane.

7.4 Oxidation of secondary reformer catalyst

The secondary reformer catalyst is in principle pyrophoric.

Normally, oxidation of the secondary reforming catalyst is not considered necessary, even in case of inspection of top burner or the downstream waste heat boiler, as the reduced RKS- 2- 7H catalyst is stable at temperatures below 100°C.

However, if oxidation of the catalyst is deemed necessary, a mixture of steam and oxygen is recommended used.

During oxidation of the secondary reformer catalyst, the pre-reformer / reformer catalyst must be protected by a flow of nitrogen to avoid steam entering the pre-reformer / reformer.

An oxidation of the catalyst can only take place after a shutdown of the reforming section as described above.

Steam is added through the FV-2040. Oxygen is gradually admitted by opening FV-2009 slowly. The oxygen flow is increased from 0.2 to 2.0 mole% of the steam.

The maximum temperature increase across the secondary reforming catalyst must not exceed 100°C.

7.5 Synthesis loop

When the front end capacity is lowered to approximately 60%, the steam production will become insufficient for the synthesis gas compressor turbine driver. Therefore the synthesis must be shut down before lowering the capacity any further.

The purge gas for reformer fuel must be shut off in steps.

The make-up gas flow to the methanol synthesis section is decreased gradually to zero.

Start the reactor start-up ejector to prevent cooling of the methanol reactor. Check the level of the steam drum.

Keep the synthesis gas compressor/Recirculator C 3001/3002 running until the CO + CO2 content of the recirculation gas is below 0.2 vol%.

The synthesis loop now represents hydrogen storage for desulphurization or as emergency hydrogen

Stop the synthesis gas compressor/Recirculator in accordance with the instructions given by the compressor vendor.

If the duration of the shut-down exceeds approximately 12 hours, the loop must be depressurized and purged with nitrogen until the nitrogen content is more than 99 vol%. Maintain the loop under nitrogen pressure at approximately 5 bar g.

If the duration of the shut-down is less than approximately 12 hours, the methanol reactor is not depressurized and the reactor temperature is maintained at approximately 220-230°C by use of the start-up ejector. Condensation in methanol reactors must be avoided otherwise methanol catalyst may be damaged.

7.6 Distillation section

7.6.1 General description

A planned shut-down may be necessary in case raw product or utilities are not available or in case the product storage tanks are full. Under such conditions the distillation section should be shut down in a way to ensure an easy restart. The liquid normally contained in the columns will then be left in the sump and the columns are kept hot.

In case access to equipment is wanted, emptying and purging will be required.

7.6.2 Capacity reduction

The capacity of the distillation section is lowered simultaneously to the front end.

Product draw-off is reduced; first via HIC-5336 and HIC-5337 and finally by manually throttling directly on the corresponding valves FV-5336 and FV-5337.

At the same time it should be ensured that the levels in the sump of the columns are kept low to provide space for the liquid hold-up on the trays.

Draw-off of the off-streams should be cut off by closing FV-5441. This may be done at a relatively early stage in the shut-down sequence.

When the draw-off of product has been cut down to zero, the feed of raw methanol will stop. The feed pumps, the product pumps, the excess water pumps and the liquid off stream pumps may be stooped.

All reflux pumps must still be kept in operation at this stage.

The distillation unit can now be maintained in a standby condition with full reflux on the columns.

The columns are kept warm and minimum boil-up rate is maintained by the steam fired reboilers E 5001 and E 5003 1/2.

If the synthesis loop is shut down, the water flow to the vent wash column must be stopped (FV-5020 5000-PID-001/P29), or the raw methanol will be diluted with water. The vent wash column is isolated from the raw methanol tank by manual valves to prevent excessive nitrogen consumption.

7.6.3 Cut-off of reboiler heat

If a complete shut-down of the distillation unit is required, then the next step is to reduce the duty in the reboilers and finally cut-off the reboiler heat.

If the front end is running but the methanol synthesis loop and the distillation unit is out of operation it is possible to vent the process gas upstream the distillation reboilers through PV-2406.

The steam to the reboilers is cut off and now the liquid on the trays will drop to the bottom of the columns, causing the levels to increase to maximum, and operation of the reflux pumps is no longer required.

The system may then be allowed to cool down, or it may be kept hot by admitting a small flow of steam to reboilers E 5001 and E 5003 1/2. This will cause the levels in the reflux drums to increase, necessitating periodic operation of the reflux pumps.

When the columns are cooled down there is a risk of vacuum.

Vacuum may be prevented by:

- T 5001: Nitrogen is admitted upstream AE 5004 via PV-5091 A (5000-PID-004/P32) ensuring a slight positive pressure on the system.
- T 5002: Nitrogen will be admitted automatically by the action of PV-5207 A (5000-PID-008/P36).
- T 5003: Add nitrogen via the utility connection on the column

7.6.4 Draining and purging

In case access is required, liquid has to be emptied from the equipment in question and transferred either to the raw methanol buffer tank, TK 5001, or to another part of the distillation section.

Before emptying the column:

- The content of the overhead accumulators is transferred to the corresponding columns by the reflux pumps.
- The content on the shell side of the reboilers is drained through their respective drain lines to the sump of the column.

In order to avoid too high temperatures and thus excessive pressures in TK 5001, the temperature of the columns must have decreased to a suitable level before the transfer is initiated.

During the above described transfer operations the pressure inside T 5003 has to be maintained at a reasonably high level, possibly by pressurizing with nitrogen via the utility nozzle of the column.

After the equipment has been emptied to the extent possible by the procedures described above, draining at all low points in the piping system should be done.

The distillation unit is depressurized via the flare and all equipment is purged with nitrogen.

If access to any piece of equipment is required, nitrogen is replaced by air, e.g. by mounting a blower on a manhole and let the nitrogen leave through another manhole. This may also cool down the equipment.

7.6.5 Vent wash column, T 5004

In case of a prolonged shut-down of the synthesis the wash water to T 5004 can be shut off to prevent dilution of the crude methanol.

When F 2002 is not in operation the tanks out breathing is send to safe location through UV 5021.

7.7 Methanol Tanks Unit

7.7.1 Shut-Down Procedure

Methanol tank shut-down: when the filling is finished or the tank (TK 4001 1/2) level reaches the high alarm value during the tank feeding process, cut off the corresponding methanol valve (USV-4013/4015) on inlet pipe to stop feeding. When the methanol filling finishes or the methanol level reaches the high alarm value, the corresponding (USV-4013/4015) valve on inlet pipe will be closed by interlock.

After the inspection of the methanol in TK 4001 1/2 is fineshed, open the valve on outlet pipe (USV-4014/4016), and the qualified methanol stored in TK 4001 1/2 tank is transported to the area outside battery limit of the plant by methanol transfer pump (P 4001 A/B). When the delivery finshed, stop the pump, and close the inlet and outlet valves. When the methanol level reaches the low low interlock value, the system automatically cuts off the outlet valve (USV-4014/4016).

Methanol unit closed drain drum (D 4001) shut- down: stop methanol unit closed drain drum pump (P 4002), and close the inlet and outlet valves of D 4001.

7.7.2 Abnormal shut-down Procedure

When power, instrument air, and nitrogen supply stopped accidentally, contact the dispatcher of plant to confirm the details of the accident. Reset the methanol transfer pump (P 4001A/B) and the methanol tanks unit closed drain drum pump (P 4002). Close the outlet valve of pump. Close the hand valve and on-off valve (USV-4013/4014/4015/4016) both on the inlet and outlet pipe of methanol tank (TK 4001 1/2) and methanol tanks unit closed drain drum (D 4001).

7.7.3 Emergency shut-down Procedure for tank leakage

The inspection of the methanol tanks unit is in the charge of corresponding operator. During normal operation, the inspection should be performed each hour, and the frequency of inspections should be increased in case of bad weather or abnormal operation. In the process of inspection, if the tank was found to be leaking, the related personnel should be notified immediately. First assign personnel wearing protective device to dispose the leaked methanol on site according to the wind direction. If the leakage point after the tank's root valve, shut off the root valve and the valve associated with other systems, and inform the maintenance operators; if the leakage point is before the tank root valve, immediately cut off the connection between the tank and other system, and open the valve between this tank and the empty tank to make sure the methanol in the leaked tank can be transferred to the other empty tank. After the transfer process finshes, cut off the connection between the leaked tank and the other tank, and inform the related persons to start repair.

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8 Emergency procedures

8.1 General information about the trip systems

A number of instruments in the plant are equipped with passive alarms to warn the operators in the control room against deviating operating conditions, which may lead to dangerous situations or which may cause damage to the equipment or the catalysts.

Critical parameters such as essential flows, pressures and temperatures are provided with active alarms connected to the safety interlock trip system. Some of the above passive alarms are acting as pre-alarms for the active alarms.

These active alarms will initiate automatic safety actions to safely shut down certain process sections in order to protect the personnel and the equipment of the plant against hazards.

When a trip group has been activated, operators must act to maintain safe operating conditions in the plant.

Prior to restart, the operators must do the following:

- Check that all automatic trip actions have taken place.
- Check in the field that the tripped valves have all performed correctly.
- Carry out specific actions as described in the process description for each trip.
- Investigate the cause of the trip and remedy the fault.
- Adjust the relevant controllers as described in the following sections.
- Reset the trip group and restart according to the guidelines given in the start-up procedure in this manual

If there is a failure of a utility such as electric power, instrument air or cooling water, a general shut-down of the plant must be carried out.

A number of input signals to the trip system can be inactivated, but inactivation should only be used when absolutely necessary for carrying out an operation, e.g. possible low flows during start-up/shut-down. An inactivated process parameter should always be monitored closely, and it should be activated as soon as possible.

Some of the control valves activated by the trip system are provided with isolation valves and a bypass valve; others are only provided with an isolation valve. The field operators must regularly check that these valves are in the correct position: isolation valves must be open and bypass valves closed.

Furthermore, there are a number of interlock systems, which activate a shut-down of pumps, start-up equipment and other equipment if process parameters deviate too much.

Tables showing normal operations, alarms and trip values of the relevant process parameters are included in the appendix.

8.2 Distinguish between IS and I groups

Due to a considerable higher cost of IS than FCS hardware, consideration has been given to define which actions (groups) are to be performed in the IS system and which actions are to be performed in the FCS. Action performed in the IS are called IS-group (Interlock Safety) and actions performed in the FCS are called I-group (Interlock). In order to establish guidelines for the distinction of those actions, the following rules are applied:

Trips in IS groups are generally based on 2-out-of-3 voting.

IS-groups must protect:

- personnel against safety hazards
- critical plant equipment
- unit trips which will result in a significant production loss when initiated

I-groups must protect:

- auto start and stop of motors
- avoidance of PSV relief
- switching of operating mode

8.3 Interlock safety and interlock groups

8.3.1 IS-1: Trip of primary reformer H 2001

Trip of primary reformer H2001 is caused by the following:

- Manual panel trip
- Trip of the interlock sequence IS-12 of the flue gas blower (F 2001). If the flue gas blower shuts down, flue gas will accumulate in the furnace and create excessive over pressure.
- Trip of the interlock sequence IS-10 of the combustion air blower (F 2002). If the combustion air blower shuts down, the burners may extinguish and natural gas leaks to the re-former furnace leading to explosion risk. Stop of combustion air blower may also create excessive vacuum in the furnace.
- Too high temperature of HHP steam from E 2021 1, (TSAH-2355) may overheat the downstream turbines or damage E 2021 1.
- Too high temperature of HHP steam from E 2021 2, (TSAH-2356) may overheat the downstream turbines or damage E 2021 2.
- Too high level in the natural gas KO drum, D 1001 (LSAH-1004). Liquid from D 1001 is of unknown composition and is as such a potential hazard to the pre-reformer catalyst; furthermore liquid must be avoided in fuel piping.
- Too low natural gas flow to reformer (FSAL-6070). If the natural gas flow decreases, the heat absorbed by the endothermic reforming reaction will drop correspondingly. As a result, the tubes in the primary reformer and the primary reformer outlet system could overheat.

- Too high level in feed gas scrubber separator, D 6001, (LSAH-6051). Liquid may not be evaporated in the pre-reformer feed preheat coil due to the high wall temperatures. Any liquid entering the pre-reformer will cause damage to the catalyst.
- Low total flow of steam to feed gas, FSAL-2062.
- Too low steam/carbon ratio (FFSAL-2064). If the steam/carbon ratio is too low, carbon may form on the pre-reformer/reformer' catalyst.
- Too low combustion air pressure (PSAL-2163). If the combustion air pressure is too low, the burners may extinguish and natural gas leaks to the reformer furnace leading to explosion risk.
- Too low draught in furnace of H 2001 (PSAH-2224). If the pressure in the furnace in-creases above ambient pressure, hot flue gas (up to approximately 1200ºC) will leak out in numerous places. This presents a potential danger to personnel and/or damage to the steel casing of the reformer.
- Too high draught in the furnace of H 2001 (PSAL-2224). Too high vacuum may damage the furnace casing and refractory.
- Too high temperature of flue gas inlet H 2001 waste heat section (TSAH-2221) may damage coils.
- Too high temperature of reformed gas exit H 2001 (TSAH-2305). If the reformer outlet temperature is too high, the reformer tubes and outlet collector may be damaged due to overheating.
- To high temperature in the chamber between the waste heat boiler and steam super heater may damage the steam super heater, E 2021 1/ E 2021 2, (TSAH-2335/TSAH-2336).
- Too low level in the HHP steam drum, D 2001, (LSAL-2372). If the level in the steam drum is too low the boilers could run dry and thus be exposed to excessive temperatures.
- Too high fuel gas pressure to H 2001 (PSAH-2554), if the pressure in the fuel header gets too high, the furnace and the reforming tubes may overheat.
- Too low fuel gas pressure to H 2001 (PSAL-2556), if the pressure in the fuel header gets too low the burners may extinguish. Unburned natural gas may create an explosive mixture inside the furnace.
- Too low flow of start-up nitrogen to E 2002 (FSAL-2582), if the nitrogen flow is too low during heating the reforming tubes may overheat.
- Too low instrument air pressure to H 2001 (PSALL-7313), if the pressure of the instrument air gets too low the instrument and control may failure. This presents a potential danger to personnel and/or damage to the plant of the reformer. It will lead trip of the whole plant.

The following actions are carried out automatically in case of a trip of primary reformer:

- Trip of secondary reformer IS-2
- Trip of methanol synthesis, IS-3
- Conditional trip of emergency methanol to reformer IS-6
- Trip of combustion air blower F 2002, IS-10

- Trip of flue gas blower F 2001, IS-12
- Trip of purge gas to H2001 burners, IS-14
- Stop water to saturator T 6001, I-32

Block hydrocarbon feed to reformer unit:

- Block natural gas from B.L. to gas station, close USV-1003.
- Block natural gas between HDS and saturation unit, close FV-6070. Controller FIC-6070 is automatically switched to manual with 0% output.
- Block process gas between saturation unit and reforming unit; close FV-2061 and FV-2091.
- Close double block and bleed between saturation unit and reforming unit; close USV-2092/USV-2093 and open USV-2094.

Blocking of reformer unit:

- Stop hydrogen to desulphurisation, close FV-2150.
- Stop combustion air flow, controller FIC-2111 is automatically set in manual mode with 0% output.
- Block continuous blow-down from reformer steam drum D 2001, close USV-2381.
- Stop liquid off-stream pump P 5009 A, stop MP-5009A.
- Stop liquid off-stream pump P 5009 B, stop MP-5009B.
- Stop natural gas fuel to H 2001; close FV-2531 A/B. Controller FIC-2531 is automatically switched to manual mode with 0% output.
- Close double block and bleed of fuel gas to reformer, close USV-2541/USV-2542 open USV-2543.
- Close double block and bleed of fuel gas for leak test to reformer, close USV-2547/USV-2548 open USV-2549.

Depressurisation of reformer unit:

- The reformer unit is depressurised through PV-2481.
- When PIC-2481 *(2000-PID-016/P21)* receives the signal from IS-1, it is set in auto mode. The set point is set equal to the process value before trip. The set point must be ramped down to 3 bar a over 10 minutes.
- The reformer unit is depressurised, USV-2482 opened. Reformer unit is depressurised through the flow orifice FO-2483.

Purging hydrocarbons from reformer unit.

- When FIC-2072 (*2000-PID-003/*P09) receives the signal from IS-1, it is set in auto mode. The set point is automatically set to 68,000 kg/h. The set point is hereafter ramped down to zero in 10 minutes, hereafter FIC-2072 is set in manual with zero output. Close HV-2098 after 10 minutes.
- Stop process steam to primary reformer, close HV-2098 after 10 minutes.
- When FIC-5407 receives the signal from IS-1, it is set in auto mode. The set point is automatically set to 5,000 kg/h. The set point is hereafter ramped down to zero in 10 minutes, hereafter FIC-5407 is set in manual with zero output.

- Close guide vanes of flue gas blower, close PV-2224. Controller PIC-2224 is automatically switched to manual mode with 0% output
- Open false air dampers, I-15

8.3.2 Actions to be taken after activation of IS-1 trip

First of all, check that all trip actions connected to IS-1 have taken place as foreseen.

As long as trip group IS-1 is activated, various trip valves are either fully open or closed. The trip group has to be reset as soon as possible. Resetting is possible only when the process values are on the safe side of the trip setting, or when the activators of the trip group are bypassed.
The Burner tightness test and furnace purge must be completed before IS-1 can be reset.

When IS-1 trip get activated, the emergency steam flow via FIC-2072 and emergency hydrogen flow via FIC-2079 should be automatically pre-set to about 68 T/h and 4,300 Nm^3/h hydrogen (as 100% H_2), respectively, and ramped these set points down to zero in 10 minutes. However, the flow of steam can be altered by taking the controller on manual or automatic with local set point.

Unnecessary cooling down of the reformer is not desired, since it will prolong the subsequent restart.

The pressure in the reforming system is automatically reduced via PIC-2481.

If immediate restart of the steam reformer is not possible, the natural gas line to the desulphurization section must be blocked by means of the double block and bleed system, and the reformer unit must be purged with nitrogen.

An IS-1 automatically cuts the fuel gas to the steam reformer by double block and bleed. To further minimize the risk of fuel leaking into the furnace and to prepare the steam reformer for restart, the field operators should close the individual manual fuel valves on each of the burners.

8.3.3 Restart after IS-1 trip

It should be checked that the cause of IS-1 has been eliminated and that the unit can be restarted.

Before resetting of the trip group IS-1, the position of various valves and controllers should be checked as follows:

- Switch all the flow controls for process feed (FIC-6070, FIC-2061 and FIC-2091), direct steam (FIC-2072 and HV-2098), fuels (FIC-2351and FIC-2356) and hydrogen gas (FIC-2079) to manual and adjust the output to zero, corresponding to the closed position.
- Make sure that all manual fuel valves at each burner are closed.

Inactivate the activated input signals to IS-1 and reset the IS-1 trip group. Please note that the trip valves in the fuel system must be reset locally.

When trip group IS-1 and the individual final elements have been reset, the reforming section can be restarted in accordance with the procedures given in Chapters 5 'Start up procedure'.

8.4 IS-2: Trip of secondary reformer, R 2004

Trip of the secondary reformer, R 2004, is caused by the following:

- Manual panel trip.
- Trip of primary reformer H2001, IS-1
- Trip of air separation unit
- Too high oxygen-to-carbon ratio (FFSAH-2008) will cause too high temperatures in the combustion zone. Excessive temperatures may damage burner, refractory or waste heat boiler.
- Too low flow of process oxygen (FSAL-2007), if the combustion process is stopped by lack of oxygen and the oxygen flow then suddenly is increased, it may cause excessive temperatures in the combustion zone.
- Too low steam-to-oxygen flow (FSAL-2040), the burner must at all times be protected by a steam flow to avoid being damaged.
- Too low temperature of process oxygen to R 2004 (TSAL-2047), if cold oxygen is mixed with steam, condensation may occur. Condensate in the oxygen pipe can cause severe damage to the secondary reformer refractory, as the condensate will evaporate instantly when entering the hot combustion zone.
- Too high temperature above catalyst in R 2004 (TSAH-2325) may damage refractory or waste heat boiler.
- Too high temperature of secondary reformer burner (TSAH-2329) only occurs if the burner has been damaged, IS-2 trip must be activated to prevent further damage.
- Too high temperature in outlet channel of R 2004, (TSAH-2333) may damage refractory or waste heat boiler.
- Too high temperature in the bottom of the secondary reformer catalyst bed (TSAH-2334) may damage refractory or waste heat boiler.
- Too high temperature of steam going to the oxygen preheater, E 2008, (TSAH-7071). If the steam temperature exceeds the design temperature, the heat exchanger may be damaged.

The following actions are carried out automatically in case of a trip of secondary reformer

- Signal to air separation unit

Isolate secondary reformer from oxygen supply:

- FV-2007 located between the oxygen filter and the oxygen preheater is closed. The controller FIC-2007 (2000-PID-001/P02) is automatically switched to manual with 0% output.

- FV-2009 located between the oxygen filter and the oxygen preheater is closed. The controller FIC-2009 (2000-PID-001/P02) is automatically switched to manual with 0% output.
- USV-2010 (2000-PID-001/P02) located between the oxygen filter and the oxygen preheater is closed.
- Close double block and bleed of oxygen to reformer, close USV-2045/USV-2048
- Open bleeding valve open USV-2049 when limit switch USV-2045 and USV-2048 closed;
- Open oxygen bleed PDV-2051
- Stop steam flow to oxygen pre-heater, E 2008, PV-2015 is closed. The controller PIC-2015 is switched to manual with 0% output.
- Stop steam flow of to oxygen preheater E 2008, USV-2021 is closed.
- Allow operation of process vent via PV-2073. When IS-2 is reset, PIC-2073 is forced into manual mode with output 0%. PIC-2073 can only be used when IS-2 is in tripped state. The emergency system prevents venting of saturated gas via PV-2073 when oxygen is in operation because the flow meter is located upstream the vent. Meaning if gas is vented via PV-2073 while oxygen is allowed to R 2004, the oxygen/carbon ratio calculated by the trip system will be wrong.
- Safety system only allows venting of oxygen via PDV-2051 when
  - USY-2045 A/B, USY-2048 A/B and USY-2049 A/B have not been reset
  - USY-2051 has been reset.

If these conditions are not obliged, PDIC-2051 is forced in manual mode with 0% output.

8.4.1 Actions to be taken after activation of IS-2 Trip

The steam flow via FIC-2040 to the burner is maintained to ensure that the burner is kept “cool”. Otherwise it is not possible to start the secondary reformer before the burner is cooled down.

Before resetting IS-2 is allowed, the interlock I-20, must permit that the secondary reformer can be started.
Before double block and bleed in oxygen line (USV-2045, USV, 2048 and USV-209) can be opened

- Pressure of oxygen must be between 1 and 3 bar higher than pressure in burner steam (PDAH-2051 > 3 bar and PDAL-2051 < 1 bar), to prevent back flow.
- Trip function TSAL-2047 in IS-2 must be not active, to ensure sufficient temperature for ignition.
- Limit switch USV-2049 open.

If IS-2 is tripped either by TSAH-2329 or manually because of high pressure drop across R 2004 (PDI-2323 >0.75 bar) the secondary reformer must not be restarted without shut-down and inspection of equipment.

After resetting of trip group IS-2, the secondary reformer is taken into operation in accordance with the procedure given in Chapter 5.

8.5 IS-3: Trip of methanol synthesis

Trip of the methanol synthesis section is caused by the following:

- Manual panel trip.
- Trip of primary reformer H2001, IS-1
- Partial trip of synthesis gas compressor/recirculator, IS-40.
- Depressurisation of methanol synthesis, IS-41. The depressurisation of methanol synthesis loop must be activated manual in case of fire
- If the level in loop steam drum D 3003, (LSAL-3042) becomes too low, reactor tubes may not be protected by cooling of boiling water, this could cause overheating of catalyst and reactor tubes.
- Too high level in HP separator, D 3001, (LSAH-3161) must be avoided to protect the downstream synthesis gas compressor from any liquid.

The following actions are carried out automatically in case of a trip of the methanol synthesis section

- Partial trip of synthesis gas compressor/recirculator, IS-40
- Vent of synthesis make-up gas.
- The controller PIC-2481 is automatically put in manual mode open to an opening corresponding to the flow at time of trip.
- Then PIC-2481 is automatically put in automatic mode with a set point equal to the actual pressure at time of trip.
- Block by pass of the synthesis gas compressor. The bypass is used for adding hydrogen to the loop during reduction of the catalyst. If the temperature increment is too high or if the recirculator is tripped, the hydrogen must be cut off immediately to avoid possible damage of equipment. USV-3018 is closed.
- To avoid emptying D 3003, the continuous blow-down is blocked. USV-3052 is closed.
- The purge gas flow to ejector J 3001 is stopped, FV-3171 is closed. The controller FIC-3171 is automatically put in manual mode with 0% output.
- The purge gas flow to the fuel header is ramped down. The controller FIC-3169 is switched to auto mode with a set point equal to actual operating point, the set point is then ramped down to zero in 2 minutes. Hereafter FIC-3169 is set in manual with zero output. It is necessary to ramp down the purge gas fuel to allow the reformer fuel control system time to compensate with natural gas and thus avoiding an IS-1 trip.

8.5.1 Actions to be taken after activation of IS-3 trip

Confirm that the trip actions connected to IS-3 have taken place as foreseen.

Reference is made to ‘Shut down procedure –synthesis loop’, in case prolonged shut-down is foreseen

Prior to restart, the cause of IS-3 activation would have to be identified and rectified as required. If one or more active alarms are inhibited, the inhibition should be eliminated as soon as the respective operating conditions allow this to be done.

Before reset of the trip group IS-3, relevant controllers have to be switched to manual and the output adjusted, so that it corresponds to safe position of the related valve.

Reset IS-40.
After reset of IS-40, the synthesis gas compressor / recirculator can be restarted in accordance with the instructions given by the compressor vendor.

8.6 IS-4: Trip of distillation section

The causes for trip of the distillation section are:

- Manual trip.
- High pressure in LP column OH accumulator D 5002, PSAH-5207.

The following actions are carried out automatically in case of a trip of the distillation section:

- Partial trip of distillation, I-50, is activated.
- Stop LP steam to stabilizer steam reboiler E 5001, close PV-5069
- Stop LP steam to MP column steam reboiler E 5003 1/2, close USV-5302

High pressure in the LP column OH accumulator may be caused by several reasons. Excessive quantities of inerts in the column may occur in case of an uncontrolled start-up, the OH condenser, AE 5005, or the reflux pump, P 5004 A/B, may fail. In order to avoid release of excessive quantities of methanol through the safety valves to the flare on the OH lines of the columns and to atmosphere through PV-5207B downstream D 5002, the transfer of heat to the reboilers is cut off.

After resetting of trip group IS-4, the distillation is taken into operation in accordance with the procedure given in the ‘Start-up Procedure’.

8.7 IS-5: Trip of draining of D 1001

The causes for IS-5 trip are:

- Manual trip.
- Low level in NG KO drum D 1001, LSAL-1004

The following actions are carried out automatically in case of an IS-5 trip

- Stop draining from D 1001, close USV-1001.

8.8 IS-6: Stop emergency methanol to reformer

The causes for IS-6 trip are:

- Manual trip.
- Low emergency steam flow, FSAL-2072 and IS-1 trip

The following actions are carried out automatically in case of an IS-6 trip

- Stop emergency methanol flow, close USV-2071.
- FV-5407 is closed. The controller FIC-5407 is switched to manual with 0% output.

8.9 IS-10: Trip of combustion air blower

The causes for trip of combustion air blower are:

- Manual panel trip.
- Trip of primary reformer H2001, IS-1
- Trip of turbine FT-2002and trip of motor MF 2002
- Trip signal from F 2002

The following actions are carried out automatically in case of a trip of combustion air blower:

- Trip of primary reformer H 2001, IS-1
- Trip of turbine for combustion air blower FT 2002, XS-FT 2002
- Trip of vent gas to separator, I-61
- Stop motor for combustion air blower, MF 2002

It is possible to inactivate the IS-1 trip in order to perform the Burner tightness test and furnace purge.

8.10 IS-12: Trip of flue gas blower, F 2001

The causes for trip are:

- Manual panel trip.
- Trip of primary reformer H2001, IS-1
- Trip of turbine FT-2001and trip of motor for flue gas, MF 2001
- Trip signal from F 2001

The following actions are carried out automatically:

- Trip of Flue gas fan F 2001, IS-12
- Trip of turbine for flue gas blower FT 2001, XS-FT 2001
- Stop motor for flue gas blower MF 2001

It is possible to inactivate the IS-1 trip in order to perform the Burner tightness test and furnace purge.

8.11 IS-14: Trip of purge gas to H 2001 burners

The causes for trip are:

- Manual trip

- Trip of primary reformer H 2001, IS-1
- Low pressure of fuel gas to H 2001, PSAL-2554

The following actions are carried out automatically:

- Double block and bleed of purge gas to reformer, close USV-2544
- Double block and bleed of purge gas to reformer, open USV-2545
- Double block and bleed of purge gas to reformer, close FV-2536
- Stop purge gas from synthesis, close FV-2536. FIC-2536 is set automatically switched to manual mode with 0% output.

8.12 I-15: High pressure in reformer furnace box

The causes for trip are:

- Manual trip
- Trip of primary reformer H2001, IS-1
- High pressure in reformer furnace box, PAHH-2224

The following actions are carried out automatically:

- Open reformer furnace box false air dampers, open HV-2225 1/2
- Start reformer hazard flashers, XAL-2284

8.13 I-17: Stop quench water to process gas

The causes for trip are:

- Manual trip
- Too low temperature of process gas (TALL-2232) inlet the pre-reformer may damage pre-reformer catalyst

The following actions are carried out automatically

- Stop quench water to process gas, close FV-2233 1/2. FIC-2233 is automatically switched to manual mode with 0% output. Stop quench water to process gas, close UV-2233

8.14 I-20: Oxygen ready to start

I-20 ensures that plant is ready to receive oxygen before it is allowed to open the double block and bleed valves in the oxygen line between oxygen pre-heater and secondary reformer. Please refer to start up procedures.

8.15 IS-21: protection of HP steam net against oxygen entrainment

The causes for trip are:

- Manual panel trip
- Low differential pressure across FV-2040, PDSAL-2036

The following actions are carried out automatically:

- Trip of secondary reformer R2004, IS-2 Stop flow of HP steam to oxygen line, close FV-2040
- Block HP steam to oxygen line, close USV-2038. Free steam vent for use, energize USY-2041. May be opened by HS-1220
- Free steam vent valve for use, HIC-2031 no longer forced in manual closed (FMC).
- Block HP steam to oxygen line, close USV-2039.

8.16 IS-23: Block oxygen from BL

The causes for trip are:

- Manual panel trip

The following actions are carried out automatically:

- Block main oxygen line from BL, close HV-2003. HIC-2003 is automatically switched to manual mode with 0% output.
- Block bypass oxygen line from BL, close HV-2004. HIC-2004 is automatically switched to manual mode with 0% output.

Before reset of the main oxygen valve from BL, the downstream side must be pressurized PSAH-2001, and bypass valve to be open HZSH-2004 and main valve closed HZSL-2003

8.17 IS-29: Protection against gas breakthrough

The causes for trip are:

- Manual trip
- High temperature in saturator blow down T 6001 1/2, TSAH-6032
- Low level in saturator T 6001 1/2 top, LSAL-6035

The following actions are carried out automatically:

- Stop blow down from saturator T 6001 1/2 top, close FV-6081
- Stop blow down to D 6002 close USV-6081
-

8.18 IS-30: Trip of MP steam condensate return pumps P 6002 A/B/C

The causes for trip are:

- Manual trip
- Low condensate level in saturator T 6001, LSAL-6022

The following actions are carried out automatically:

- Stop MP steam condensate return pump P 6002 A, stop MP-6002 A
- Stop MP steam condensate return pump P 6002 B, stop MP-6002 B
- Stop MP steam condensate return pump P 6002 C, stop MP-6002 C
- Stop steam condensate return to thermal deaerator D 7001, close LV-6021B

Note:

P 6002 A /B/C will be stopped directly when its bearing and winding temperature reached high value.

8.19 IS-31: Trip of saturator circulation pumps P 6001 A/B

The causes for trip are:

- Manual trip
- Low level in feed gas scrubber separator D 6001, LSAL-6051

The following actions are carried out automatically:

- Stop saturator circulation pump P 6001 A, stop MP-6001A
- Stop saturator circulation pump P 6001 B, stop MP-6001B
- Stop blow down from saturator T 6001, close FV-6081
- Stop blow down from feed gas scrubber separator D 6001, close FV-6086
- Stop blow down to D 6002 close USV-6081
- Stop blowdown to D 6002, close USV-6082

8.20 I-32: Stop of water to saturator T 6001

The causes for trip are:

- Manual trip
- Trip of primary reformer IS-1

The following actions are carried out automatically:

- Stop process condensate to T 6001, close UV-6035
- Stop BFW to saturator, close FV-6031
- Trip of excess condensate return pump P 7004 A/B, I-38

8.21 IS-33: Trip of 1st separator D 2002

The causes for trip are:

- Manual trip
- Low level in 1st separator D 2002, LSAL-2404

The following actions are carried out automatically:

- Stop process condensate pump P 2001 A, stop MP-2001A
- Stop process condensate pump P 2001 B, stop MP-2001B
- Stop process condensate to particle filter X-6001 A/B, close LV-2403

8.22 IS-34: Trip of 3rd separator D 2004

The causes for trip are:

- Manual trip
- Low level in 3rd separator D 2003, LSAL-2442

The following actions are carried out automatically:

- Stop process condensate pump P 2002 A, stop MP-2002A

- Stop process condensate pump P 2002 B, stop MP-2002B
- Stop process condensate to particle filter X-6001 A/B, close LV-2441
- Stop process condensate to particle filter X-6002 A/B, close FV-6059 1

Note:
P 2002 A/B will be stopped directly when its bearing and winding temperature reached high value.

8.23 IS-35: Trip of final separator D 2005

The causes for trip are:

- Manual trip
- Low level in final separator D 2005, LSAL-2474

The following actions are carried out automatically:

- Stop process condensate pump P 2003 A, stop MP-2003A
- Stop process condensate pump P 2003 B, stop MP-2003B
- Stop process condensate to pre-heater E 6002, close LV-2474

8.24 I-36: Stop blow down to D 6002

The causes for trip are:

- Manual trip
- High level in saturator blow down drum D 6002, LAHH-6083

The following actions are carried out automatically:

- Stop blow down to D 6002, close USV-6082
- Stop blow down from saturator T 6001, close FV-6081
- Stop blow down from feed gas scrubber separator D 6001, close FV-6086
- Stop blow down to D 6002, close USV-6081

8.25 I-37: Trip of excess process condensate pumps, P 7003 A/B/C

The causes for trip are:

- Manual trip
- Low level in saturator blow down drum D 6002, LALL-6083

The following actions are carried out automatically:

- Stop blow down to battery limit, close FV-6082
- Stop excess process condensate pump P 7003 A, stop MP 7003A
- Stop excess process condensate pump P 7003 B, stop MP 7003B
- Stop excess process condensate pump P 7003 C, stop MP 7003C

8.26 I-38: Trip of excess condensate return pump, P 7004 A/B

The causes for trip are:

- Manual trip
- Low level in process condensate tank TK 7002, LALL-7102
- Stop of water to saturator, I-32

The following actions are carried out automatically:

- Stop excess condensate pump P 7004 A, stop MP 7004A
- Stop excess condensate pump P 7004 B, stop MP 7004B

8.27 I-39: Trip of process condensate to TK 7002

The causes for trip are:

- Manual trip
- Trip of excess process condensate pumps P 7003 A/B/C, I-37
- High level in process condensate tank TK 7002, LAHH-7102

The following actions are carried out automatically:

- Stop excess condensate to tank TK 7002, close LV-6082

8.28 IS-40: Partial trip of synthesis gas compressor/recirculator

The causes for trip are:

- Manual panel trip
- Trip of methanol synthesis, IS-3
- High level in final separator D 2005, LSAH-2474
- Trip of synthesis gas compressor vendor requirement

The following actions are carried out automatically

- Trip of methanol synthesis IS-3
- Partial trip of synthesis gas compressor.

Definition of partial shut down of synthesis gas compressor/recirculator:

During partial shut-down, the synthesis gas compressor/recirculator C 3001/C3002 runs at minimum governor speed and is isolated at make-up and recycle discharge and at recycle suction. Detailed descriptions of the internal safety interlock trip system and automatic safety operations, as well as proper operator response, must be provided in the suppliers' operating manuals.

The partial shut-down status defined here facilitates a fast restart

8.29 IS-41: Depressurisation of methanol synthesis

The causes for trip are:

- Manual trip

The following actions are carried out automatically:

- Trip of methanol synthesis, IS-3
- Depressurise methanol synthesis loop, open PV-3166. The controller PIC-3166B is ramped down to 50% of design pressure in 15 minutes.

Emergency depressurisation of the plant should be used only in case of emergency, such as fire or uncontrolled leak (within the unit itself).

8.30 IS-42: Trip of raw product from HP separator, D 3001

The causes for trip are:

- Manual trip
- Low level in HP separator D 3001, LSAL-3161
- High level in LP separator D 3002, LSAH-3192

The following actions are carried out automatically:

- Stop raw product to LP separator D 3002, close LV-3161A
- Stop raw product to LP separator D 3002, close LV-3161B
- Stop raw product to LP separator D 3002, close LV-3161 A/B. Controller LIC-3161 is automatically switched to manual mode with 0% output
- Stop raw product to LP separator D 3002, close USV-3172

8.31 IS-43: Low level in LP separator, D 3002

The causes for trip are:

- Manual trip
- If the level in LP separator D 3002 (LSAL-3192) is too low there is a risk of gas break-through.

The following actions are carried out automatically

- Stop crude methanol to TK 5001, close LV-3192

8.32 IS-44: High level in raw methanol buffer tank TK 5001

The causes for trip are:

- Manual trip
- High level in raw methanol buffer tank TK 5001, LSAH-5002

The following actions are carried out automatically:

- Stop water to vent wash column T 5004, close FV-5020
- Stop crude methanol to TK 5001, close LV-3192

8.33 I-50: Partial trip of distillation

The causes for trip are:

- Manual trip
- Trip of distillation section, IS-4
- High level in methanol product buffer tank TK 5002 1 and TK 5002 2, LSAH 5397 and LSAH-5414

The following actions are carried out automatically:

- Stop raw methanol to stabiliser column T 5001, close FV-5041
- Stop methanol/water to LP methanol column T 5002, close FV-5161
- Stop methanol to MP methanol column T 5003, close FV-5239
- Stop methanol product from P 5004 A/B, close FV-5337

- Stop methanol product from P 5006 A/B, close FV-5336

The purpose of this trip is to stop the draw-off of product methanol and to bring the distillation section into a state of stand-by operation, in case the product quality cannot be ensured any more. The stand-by mode should preferably be a state of full reflux from which normal operation of the entire unit can be resumed rather quickly when the cause of the mal-operation has been rectified.

In case the trip is initiated manually, transfer to the stand-by operation corresponding to full reflux should be straight forward. Then normal operation can be resumed as soon as the product draw-off can be resumed.

In case the trip is activated by IS-4, the reboiler duties will be reduced dramatically. In such a case, it must be foreseen that a large part of the liquid hold-up on the trays will be dumped, and the levels in the sumps may rise.

Excessive levels will be announced by alarms from the column level transmitters. Excess liquid must be transferred back to the raw methanol tank prior to restart.
Restart should be made as described in the 'Start-up procedure'.

Before reset of the trip group I-50, relevant controllers have to be switched to manual and the output adjusted so it corresponds to safe position of the related valve.

After reset of trip group I-50, the distillation is taken into operation in accordance with the procedure given in Chapter 6.

8.34 IS-51: Stop extraction of higher hydrocarbons

The causes for trip are:

- Manual trip
- High level in liquid off stream tank TK 5003, LSAH-5447

The following actions are carried out automatically:

- Stop liquid off stream from P 5003 A/B, close FV-5107
- Stop liquid off stream from T 5003, close FV-5441
- Trip of knock out drum pump, P 8511, IS-8502

8.35 IS-52: Trip of liquid off stream pump, P 5009 A/B

The causes for trip are:

- Manual trip
- Low level in liquid off stream tank TK 5003, LALL-5447

The following actions are carried out automatically:

- Stop liquid off stream pump P 5009 A, stop MP-5009A
- Stop liquid off stream pump P 5009 B, stop MP-5009B

8.36 IS-53: Trip of raw methanol pump, P 5001 A/B/C

The causes for trip are:

- Manual trip
- Low level in raw methanol buffer tank TK 5001, LSAL-5002

The following actions are carried out automatically:

- Stop raw methanol pump P 5001 A, stop MP-5001A
- Stop raw methanol pump P 5001 B, stop MP-5001B
- Stop raw methanol pump P 5001 C, stop MP-5001C

8.37 IS-54: Trip of stabilizer methanol pump, P 5002 A/B

The causes for trip are:

- Manual trip
- Low level in stabilizer column T 5001, LSAL-5042

The following actions are carried out automatically:

- Stop stabilizer methanol pump P 5002 A, stop MP-5002A
- Stop raw methanol pump P 5002 B, stop MP-5002B

8.38 IS-55: Trip of steam condensate pump, P 5011 A/B

The causes for trip are:

- Manual trip
- Low level in steam condensate pot D 5009, LSAL-5071

The following actions are carried out automatically:

- Stop steam condensate pump P 5011 A, stop MP-5011A
- Stop steam condensate pump P 5011 B, stop MP-5011B
- Stop steam condensate to D 7001, close LV-5070

8.39 IS-56: Trip of stabilizer column reflux pump, P 5003 A/B

The causes for trip are:

- Manual trip
- Low level in stabilizer column OH accumulator D 5001, LSAL-5094

The following actions are carried out automatically:

- Stop stabilizer column reflux pump P 5003 A, stop MP-5003A
- Stop stabilizer column reflux pump P 5003 B, stop MP-5003B

8.40 IS-57: Trip of MP column feed pump, P 5005 A/B

The causes for trip are:

- Manual trip
- Low level in MP column T 5002, LSAL-5162

The following actions are carried out automatically:

- Stop MP column feed pump P 5005 A, stop MP-5005A
- Stop MP column feed pump P 5005 B, stop MP-5005B

8.41 IS-58: Trip of LP column reflux pump, P 5004 A/B

The causes for trip are:

- Manual trip
- Low level in LP column OH accumulator D 5002, LSAL-5204

The following actions are carried out automatically:

- Stop LP column reflux pump P 5004 A, stop MP-5004A
- Stop LP column reflux pump P 5004 B, stop MP-5004B

Note:
P 5004 A/B will be stopped directly when its bearing and winding temperature reached high value.

8.42 IS-59: Trip of distillation water pumps P 5007 A/B and P 5010 A/B

The causes for trip are:

- Manual trip
- Low level in MP methanol column T 5003, LSAL-5271

The following actions are carried out automatically:

- Stop MP column recycle pump P 5007 A, stop MP-5007A
- Stop MP column recycle pump P 5007 B, stop MP-5007B
- Stop excess water pump P 5010 A, stop MP-5010A
- Stop excess water pump P 5010 B, stop MP-5010B

8.43 IS-60: Trip of MP column reflux pumps, P 5006 A/B

The causes for trip are:

- Manual trip
- Low level in MP column OH accumulator D 5003, LSAL-5322

The following actions are carried out automatically:

- Stop MP column reflux pump P 5006 A, stop MP-5006A
- Stop MP column reflux pump P 5006 B, stop MP-5006B

Note:
P 5006 A/B will be stopped directly when its bearing and winding temperature reached high value.

8.44 I-61: Trip of vent gas to reformer

The causes for trip are:

- Manual trip
- Trip of combustion air blower, IS-10

The following actions are carried out automatically

- Close vent gas to reformer, close UV-2125
- Open vent gas to atmosphere, open UV-5021

8.45 IS-62: High level in methanol product buffer tank TK 5002 1

When this group is reset, the tank TK 5002 1 is selected for filling.

The causes for trip are:

- High level in methanol product buffer tank TK 5002 1, LSAH-5397

The following actions are carried out automatically

- Automatic reset of high level in methanol buffer tank TK 5002 2, IS-63
- Stop methanol to product buffer tank TK 5002 1, close USV-5391

High level in product buffer tank automatically switches to other tank if the level in that tank is below high level unless automatic switchover is inactivated by the operator.

8.46 IS-63: High level in methanol product buffer tank TK 5002 2

When this group is reset, the tank TK 5002 2 is selected for filling.

The causes for trip are:

- High level in methanol product buffer tank TK 5002 2, LSAH-5414

The following actions are carried out automatically:

- Automatic reset of high level in methanol buffer tank TK 5002 1, IS-62
- Stop methanol to product buffer tank TK 5002, close USV-5392

High level in product buffer tank automatically switches to other tank if the level in that tank is below high level unless automatic switchover is inactivated by the operator.

8.47 IS-64: Select methanol product buffer tank, TK 5002 1

When this group is reset, the tank TK 5002 1 is selected for emptying.

The causes for trip are:

- Low level in methanol product buffer tank TK 5002 1, LSAL-5397

The following actions are carried out automatically:

- Trip of methanol product pumps P 5008 A/B, start-up pump P 5012, IS-66
- Stop methanol from product buffer tank TK 5002 1, close USV-5422
- Stop methanol from product buffer tank TK 5002 1, close USV-5393

Only one methanol buffer tank may be selected for emptying at a time.

8.48 IS-65: Select methanol product buffer tank, TK 5002 2

When this group is reset, the tank TK 5002 2 is selected for emptying.

The causes for trip are:

- Low level in methanol product buffer tank TK 5002 2, LSAL-5414

The following actions are carried out automatically

- Trip of methanol product pumps P 5008 A/B/C, start-up pump P 5012, IS-66
- Stop methanol from product buffer tank TK 5002 2, close USV-5420
- Stop methanol from product buffer tank TK 5002 2, close USV-5421

Only one methanol buffer tank may be selected for emptying at a time.

8.49 IS-66: Trip of methanol product pumps P 5008 A/B/C, start-up pump P 5012

The causes for trip are:

- Manual trip
- Low level in methanol product buffer tank TK 5002 1 (Pulse activated)
- Low level in methanol product buffer tank TK 5002 2 (Pulse activated)
- No product buffer tank selected

The following actions are carried out automatically:

- Stop methanol product pump P 5008A, stop MP-5008A
- Stop methanol product pump P 5008B, stop MP-5008B
- Stop methanol product pump P 5008C, stop MP-5008C
- Stop methanol start-up pump P 5012A, stop MP-5012A
- Stop methanol start-up pump P 5012B, stop MP-5012B

A buffer tank must be selected in order to reset pump trip group.

Note:
P 5008 A/B/C will be stopped directly when its bearing and winding temperature reached high value.

8.50 IS-70: Trip of BFW pumps, P 7001 A/B/C

The causes for trip are:

- Manual panel trip
- Low level in deaerator D 7001, LSAL-7091

The following actions are carried out automatically:

- Stop BFW pump P 7001A, IS-71
- Stop BFW pump P 7001B, IS-72
- Stop BFW pump P 7001C, IS-73

8.51 IS-71: Trip of HP BFW pump, P 7001 A

The causes for trip are:

- Manual trip

- Trip of BFW pumps P 7001 A/B/C, IS-70
- Low suction pressure of BFW pump P 7001 A, PSAL-7112

The following actions are carried out automatically

- Stop steam to turbine FP 7001 A, close USV-7130

8.52 IS-72: Trip of HP BFW pump, P 7001 B

The causes for trip are:

- Manual trip
- Trip of BFW pumps P 7001 A/B/C, IS-70
- Low suction pressure of BFW pump P 7001 B, PSAL-7116

The following actions are carried out automatically:

- Stop steam to turbine FP 7001 B, close USV-7135

8.53 IS-73: Trip of HP BFW pump, P 7001 C

The causes for trip are:

- Manual trip
- Trip of BFW pumps P 7001 A/B/C, IS-70
- Low suction pressure of BFW pump P 7001 C, PSAL-7120

The following actions are carried out automatically:

- Stop BFW pump P 7001 C, stop MP-7001C

8.54 IS-90: Trip of synthesis gas compressor/recirculator

The causes for trip are:

- Manual panel trip
- High level in reformer steam drum D 2001, LSAH-2372
- Trip of synthesis gas compressor vendor requirement

The following actions are carried out automatically

- Trip of methanol synthesis IS-3
- Trip of synthesis gas compressor.
- Vent of synthesis make-up gas.
- The controller PIC-2481 is automatically put in manual mode open to an opening corresponding to the flow at time of trip.
- Then PIC-2481 is automatically put in automatic mode with a set point equal to the actual pressure at time of trip.
- Block by pass of the synthesis gas compressor. The bypass is used for adding hydrogen to the loop during reduction of the catalyst. If the temperature increment is too high or if the recirculator is tripped, the hydrogen must be cut off immediately to avoid possible damage of equipment. USV-3018 is closed.
- To avoid emptying D 3003, the continuous blow-down is blocked. USV-3052 is closed.

- The purge gas flow to ejector J 3001 is stopped, FV-3171 is closed. The controller FIC-3171 is automatically put in manual mode with 0% output.
- The purge gas flow to the fuel header is ramped down. The controller FIC-3169 is switched to auto mode with a set point equal to actual operating point, the set point is then ramped down to zero in 2 minutes. Hereafter FIC-3169 is set in manual with zero output. It is necessary to ramp down the purge gas fuel to allow the reformer fuel control system time to compensate with natural gas and thus avoiding an IS-1 trip.

8.55 IS-91: Depressurization of synthesis gas compressor

The causes for trip are:

- Manual trip
- Trip of synthesis gas compressor vendor requirement, XS-3715

The following actions are carried out automatically

- Vent of synthesis gas compressor, open USV-3750
- Vent of synthesis gas compressor, open USV-3751

8.56 I-2001: Autostart of pumps, P 2001 A/B

The causes for trip are:

- Low pressure in downstream of P 2001 A/B
- No trip of IS-33

The following actions are carried out automatically:

- Start spare process condensate pump UY-2001 A/B

8.57 I-2002: Autostart of pumps, P 2002 A/B

The causes for trip are:

- Low pressure in downstream of P 2002 A/B
- No trip of IS-34
- Bearing and wingding temperature of P2002 A/B not reached high value.

The following actions are carried out automatically:

- Start spare process condensate pump UY-2002 A/B

8.58 I-2003: Autostart of pumps, P 2003 A/B

The causes for trip are:

- Low pressure in downstream of P 2003 A/B
- No trip of IS-35

The following actions are carried out automatically:

- Start spare process condensate pump UY-2003 A/B

8.59 I-2004: Trip of Final Separator and H2 Recycle Compressor

The causes for trip are:

- Manual trip
- High Level in Final Separator D 2005

The following actions are carried out automatically:

- Trip of Hydrogen Recycle Compressor C 2002

8.60 IS-4001: High level in methanol product buffer tank TK 4001 1

When this group is reset, the tank TK 4001 1 is selected for filling.

The causes for trip are:

- High level in methanol product buffer tank TK 4001 1, LSAH-4007

The following actions are carried out automatically

- Automatic reset of high level in methanol buffer tank TK 4001 2, IS-4003
- Stop methanol to product buffer tank TK 4001 1, close USV-4013

High level in product buffer tank automatically switches to other tank if the level in that tank is below high level unless automatic switchover is inactivated by the operator.

8.61 IS-4002: Select methanol product buffer tank, TK 4001 1

When this group is reset, the tank TK 4001 1 is selected for emptying.

The causes for trip are:

- Low level in methanol product buffer tank TK 4001 1, LSAL-4007

The following actions are carried out automatically:

- Trip of methanol product transfer pump P 4001 A/B, IS-4005
- Stop methanol from product buffer tank TK 4001 1, close USV-4014

Only one methanol buffer tank may be selected for emptying at a time.

8.62 IS-4003: High level in methanol product buffer tank TK 4001 2

When this group is reset, the tank TK 4001 2 is selected for filling.

The causes for trip are:

- High level in methanol product buffer tank TK 4001 2, LSAH-4008

The following actions are carried out automatically:

- Automatic reset of high level in methanol buffer tank TK 4001 1, IS-4001
- Stop methanol to product buffer tank TK 4001 2, close USV-4015

High level in product buffer tank automatically switches to other tank if the level in that tank is below high level unless automatic switchover is inactivated by the operator.

8.63 IS-4004: Select methanol product buffer tank, TK 4001 2

When this group is reset, the tank TK 4001 2 is selected for emptying.

The causes for trip are:

- Low level in methanol product buffer tank TK 4001 2, LSAL-4008

The following actions are carried out automatically

- Trip of methanol product pumps P 4001 A/B, IS-4005
- Stop methanol from product buffer tank TK 4001 2, close USV-4016

Only one methanol buffer tank may be selected for emptying at a time.

8.64 IS-4005: Trip of methanol product pumps P 4001 A/B

The causes for trip are:

- Manual panel trip
- Low level in methanol product buffer tank TK 4001 1 (Pulse activated)
- Low level in methanol product buffer tank TK 4001 2 (Pulse activated)
- No product buffer tank selected

The following actions are carried out automatically:

- Stop methanol product pump P 4001A, stop MP-4001A
- Stop methanol product pump P 4001B, stop MP-4001B

A buffer tank must be selected in order to reset pump trip group.

Note:
P 4001 A/B will be stopped directly when its bearing and winding temperature reached high value.

8.65 I-4006: Auto start of methanol product pumps P 4002

The causes for trip are:

- Manual panel trip
- High level in methanol tanks unit closed drain drum D4002
- No High level in raw methanol buffer tank TK 5001

The following actions are carried out automatically:

- Start methanol tanks closed drain drum pump P 4002

8.66 I-4007: Auto stop of methanol product pumps P 4002

The causes for trip are:

- Manual panel trip
- Low level in methanol tanks unit closed drain drum D4002

The following actions are carried out automatically:

- Stop methanol tanks closed drain drum pump P 4002

8.67 I-5001: Autostart of pumps, P 5001 A/B/C

The causes for trip are:

- Low flow rate of P 5001 A/B/C outlet FT-5041
- Trip of pumps P 5001 A/B/C (IS-53) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5001 A or P 5001 B or P 5001 C)

8.68 I-5002: Autostart of pumps, P 5002 A/B

The causes for trip are:

- Low pressure of P 5002 A/B outlet PT-5139
- Trip of pumps P 5002 A/B (IS-54) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5002 A or P 5002 B)

8.69 I-5003: Autostart of pumps, P 5003 A/B

The causes for trip are:

- Low pressure of P 5003 A/B outlet PT-5093
- Trip of pumps P 5003 A/B (IS-56) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5003 A or P 5003 B)

8.70 I-5004: Autostart of pumps, P 5004 A/B

The causes for trip are:

- Low pressure of P 5004 A/B outlet PT-5219
- Trip of pumps P 5004 A/B (IS-58) is not activated
- Bearing and winding temperature of P5004 A/B does not reach high value.

The following actions are carried out automatically:

- Autostart the standby Pump (P 5004 A or P 5004 B)

8.71 I-5005: Autostart of pumps, P 5005 A/B

The causes for trip are:

- Low pressure of P 5005 A/B outlet PT-5240
- Trip of pumps P 5005 A/B (IS-57) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5005 A or P 5005 B)

8.72 I-5006: Autostart of pumps, P 5006 A/B

The causes for trip are:

- Low pressure of P 5006 A/B outlet PT-5335
- Trip of pumps P 5006 A/B (IS-60) is not activated
- Bearing and winding temperature of P5006 A/B does not reached high value.

The following actions are carried out automatically:

- Autostart the standby Pump (P 5006 A or P 5006 B)

8.73 I-5007: Autostart of pumps, P 5007 A/B

The causes for trip are:

- Low pressure of P 5007 A/B outlet PT-5369
- Trip of pumps P 5007 A/B (IS-59) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5007 A or P 5007 B)

8.74 I-5010: Autostart of pumps, P 5010 A/B

The causes for trip are:

- Low pressure of P 5010 A/B outlet PT-5367
- Trip of pumps P 5010 A/B (IS-59) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5010 A or P 5010 B)

8.75 I-5011: Autostart of pumps, P 5011 A/B

The causes for trip are:

- Low pressure of P 5011 A/B outlet PT-5083
- Trip of pumps P 5011 A/B (IS-55) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 5011 A or P 5011 B)

8.76 I-5013: Autostart of pumps, P 5013

The causes for trip are:

- High liquid level in Closed Drain Drum D5011, LAHH-5701

The following actions are carried out automatically:

- Autostart the Pump P 5013

8.77 I-5014: Autostop of pumps, P 5013

The causes for trip are:

- Low liquid level in Closed Drain Drum D5011, LALL-5701

The following actions are carried out automatically:

- Autostop the Pump P 5013

8.78 I-6010: Autostart of Pumps, P 6002 A/B

The causes for trip are:

- Low pressure of PT-6010.
- Trip of MP steam condensate return pumps P 6002 A/B/C (IS-30) is not activated
- Bearing and winding temperature of P6002 A/B/C does not reached high value.

The following actions are carried out automatically:

- Autostart the standby Pump (P 6002 B or P 6002 A).

8.79 I-6068: Autostart of Pumps, P 6001 A/B

The causes for trip are:

- Low flow rate of FT-6068.
- Trip of saturator circulation pumps P 6001 A/B (IS-31) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 6001 B or P 6001 A).

8.80 I-6088: Autostart of Pumps, P 7003 A/B/C

The causes for trip are:

- Low pressure of PT-6088.
- Trip of excess process condensate pumps P 7003 A/B/C (I-37) is not activated

The following actions are carried out automatically:

- Autostart the standby Pump (P 7003 B or P 7003 C OR P 7003 A).

8.81 I-7005: Trip of Boiler Blow-down Pumps, P 7005 A/B

The causes for trip are:

- Manual panel trip
- Low level in continuous blow down drum D 7002, LALL-7251.
- Low level in intermittent blow down drum NO.1 D 7003, LALL-7255.

The following actions are carried out automatically:

- Stop boiler blow-down pump P 7005 A, stop MP 7005A
- Stop boiler blow-down pump P 7005 B, stop MP 7005B

8.82 I-7091: Trip of Demin water pump

The causes for trip are:

- The main high level of deaerator D7001, LAHH-7091. LT-7091.

The following actions are carried out automatically:

- Stop DEMIN water pump P 7002 A/B

8.83 I-7307A: In Tripped Position Open Nitrogen Firstly Closed Instrument Air followingly

The causes for trip are:

- Low instrument air pressure from 3”-IA-70-101-B50-N, PSALL-7313.

The following actions are carried out automatically:

- Open nitrogen, open UV-7307B
- Close instrument air, close UV-7307A

Note:
Only when the pressure of instrument air pressure from 3”-IA-70-101-B50-N is higher than 6.5 barg, PAL-7313 is not active, I-7307A could be reset.

8.84 IS-8501: Autostart of Knock Out Drum Pumps, P 8511

The causes for trip are:

- High level in flare knock out drum D8511, LAHH-8512.
- Negation of trip of stop extraction of higher hydrocarbons (IS-51)

The following actions are carried out automatically:

- Autostart the knock out drum pump P 8511

8.85 IS-8502: Trip of Knock Out Drum Pumps, P 8511

The causes for trip are:

- Manual panel trip
- Low level in flare knock out drum D8511, LALL-8512
- Trip of stop extraction of higher hydrocarbons (IS-51)

The following actions are carried out automatically:

- Stop knock out drum pump P 8511, stop MP 8511
-

8.86 I-0501A Trip of Cooling Tower Fan, F 0501 A

The causes for trip are:

- High vibration in cooling tower fan F 0501 A, VAHH-0518A.
- ~~Low oil level in cooling tower fan F 0501 A, LALL-0518A.~~
- High temperature in cooling tower fan F 0501 A, TAHH-0518A.

The following actions are carried out automatically:

- Stop cooling tower fan F 0501 A

Note:
F 0501 A will be stopped directly when its bearing and winding temperature reached high value.

8.87 I-0501B Trip of Cooling Tower Fan, F 0501 B

The causes for trip are:

- High vibration in cooling tower fan F 0501 B, VAHH-0518B.
- ~~Low oil level in cooling tower fan F 0501 B, LALL-0518B.~~
- High temperature in cooling tower fan F 0501 B, TAHH-0518B.

The following actions are carried out automatically:

- Stop cooling tower fan F 0501 B

Note:
F 0501 B will be stopped directly when its bearing and winding temperature reached high value.

8.88 I-0501C Trip of Cooling Tower Fan, F 0501 C

The causes for trip are:

- High vibration in cooling tower fan F 0501 C, VAHH-0518C.
- ~~Low oil level in cooling tower fan F 0501 C, LALL-0518C.~~
- High temperature in cooling tower fan F 0501 C, TAHH-0518C.

The following actions are carried out automatically:

- Stop cooling tower fan F0501C

Note:
F 0501 C will be stopped directly when its bearing and winding temperature reached high value.

8.89 I-0501D Trip of Cooling Tower Fan, F 0501 D

The causes for trip are:

- High vibration in cooling tower fan F 0501 D, VAHH-0518D.
- ~~Low oil level in cooling tower fan F 0501 D, LALL-0518D.~~
- High temperature in cooling tower fan F 0501 D, TAHH-0518D.

The following actions are carried out automatically:

- Stop cooling tower fan F 0501 D

Note:
F 0501 D will be stopped directly when its bearing and winding temperature reached high value.

8.90 I-0502A Trip of Cooling Water Pump, P 0502 A

The causes for trip are:

- High temperature in cooling water pump P 0502 A, TAHH-0541A.
- High temperature in cooling water pump P 0502 A, TAHH-0542A.
- High temperature in cooling water pump P 0502 A, TAHH-0543A.
- High temperature in cooling water pump P 0502 A, TAHH-0544A.
- High temperature in cooling water pump P 0502 A, TAHH-0545A.

The following actions are carried out automatically:

- Stop cooling water pump P 0502 A

Note:
P 0502 A will be stopped directly when its bearing and winding temperature reached high value.

8.91 I-0502B Trip of Cooling Water Pump, P 0502 B

The causes for trip are:

- High temperature in cooling water pump P 0502 B, TAHH-0541B.
- High temperature in cooling water pump P 0502 B, TAHH-0542B.
- High temperature in cooling water pump P 0502 B, TAHH-0543B.
- High temperature in cooling water pump P 0502 B, TAHH-0544B.
- High temperature in cooling water pump P 0502 B, TAHH-0545B.

The following actions are carried out automatically:

- Stop cooling water pump P 0502 B

Note:
P 0502 B will be stopped directly when its bearing and winding temperature reached high value.

8.92 I-0511 Trip of Cooling Water Pump and Side Filter Pump

The causes for trip are:

- Low level in cooling water pond PD 0501, LALL-0511.

The following actions are carried out automatically:

- Stop cooling water pump steam turbine P 0501 1.
- Stop cooling water pump steam turbine P 0501 2.
- Stop cooling water pump P 0502 A.
- Stop cooling water pump P 0502 B.
- Stop side filter pump P 0504 A.
- Stop side filter pump P 0504 B.

8.93 I-0513 Trip of Clean Salty Water P 0505 A/B

The causes for trip are:

- Low level in clean salty water pond PD 0502, LALL-0512.

The following actions are carried out automatically:

- Stop clean salty water pump P 0505 A.
- Stop clean salty water pump P 0505 B.

8.94 I-0514 Autostart of Clean Salty Water P 0505 A/B

The causes for trip are:

- High level in clean salty water pond PD 0502, LAHH-0512.

The following actions are carried out automatically:
- Start clean salty water pump P 0505 A or P 0501 B.

8.95 I-0515 Trip of Inhibitor Dosing Pump P 0510 A/B

The causes for trip are:
- Low level in inhibitor dosing tank TK 0508, LALL-0515.

The following actions are carried out automatically:
- Stop inhibitor dosing pump P 0510 A.
- Stop inhibitor dosing pump P 0510 B.

8.96 I-0522 Trip of Antiscale Dosing Pump P 0511 A/B

The causes for trip are:
- Low level in antiscale dosing tank TK 0509, LALL-0516.

The following actions are carried out automatically:
- Stop antiscale dosing pump P 0511 A.
- Stop antiscale dosing pump P 0511 B.

8.97 I-0523 Trip of $Ca(ClO)_2$ Dosing Pump P 0506 A/B

The causes for trip are:
- Low level in $Ca(ClO)_2$ dosing tank TK 0503, LALL-0503.

The following actions are carried out automatically:
- Stop $Ca(ClO)_2$ dosing pump P 0506 A.
- Stop $Ca(ClO)_2$ dosing pump P 0506 B.

8.98 I-0525 HV-0511 Auto-open

The causes for trip are:
- High conductivity in monitoring heat exchanger E 0501.

The following actions are carried out automatically:
- Open Blow-down Valve.

8.99 I-0526 Trip of NaOH Dosing Pump P 0512 A/B

The causes for trip are:
- Low level in NaOH dosing tank TK 0510, LALL-0517.
- High pH in cooling water supply 1”-CWS-05-233-B24-N, AIH-0511

The following actions are carried out automatically:
- Stop NaOH dosing pump P 0512 A.
- Stop NaOH dosing pump P 0512 B.

8.100 I-0524 Autostart of NaOH Dosing Pump P 0512 A/B

The causes for trip are:

- Low pH in cooling water supply 1”-CWS-05-233-B24-N, AIL-0511

The following actions are carried out automatically:

- Start NaOH dosing pump P 0512 A or P 0512 B.

8.101 I-9401 Trip of POC Pump for Unit 5003 P 9401A/B

The causes for trip are:

- Low level in POC pond for unit 5003 PD 9401, LALL-9401

The following actions are carried out automatically:

- Stop POC pump for unit 5003 P 9401 A.
- Stop POC pump for unit 5003 P 9401 B.
-

8.102 I-9402 Trip of POC Pump for Unit 5001 P 9402 A/B

The causes for trip are:

- Low level in POC pond for unit 5003 PD 9402, LALL-9402

The following actions are carried out automatically:

- Stop POC pump for unit 5001 P 9402 A.
- Stop POC pump for unit 5001 P 9402 B.
-

8.103 I-9403 Trip of POC Pump for Unit 3001 P 9403 A/B

The causes for trip are:

- Low level in POC pond for unit 3001 PD 9403, LALL-9403

The following actions are carried out automatically:

- Stop POC pump for unit 3001 P 9403 A.
- Stop POC pump for unit 3001 P 9403 B.
-

8.104 I-9404 Trip of POC Pump for Unit 4000 P 9404 A/B

The causes for trip are:

- Low level in POC pond for unit 4000 PD 9404, LALL-9404

The following actions are carried out automatically:

- Stop POC pump for unit 4000 P 9404 A.
- Stop POC pump for unit 4000 P 9404 B.
-

8.105 I-9408 Trip of POC Pump for Unit 0203 P 9408 A/B

The causes for trip are:

- Low level in POC pond for unit 0203 PD 9408, LALL-9408

The following actions are carried out automatically:

- Stop POC pump for unit 0203 P 9408 A.
- Stop POC pump for unit 0203 P 9408 B.
-

8.106 I-9409 Trip of POC Pump for Unit 0500 P 9409 A/B

The causes for trip are:

- Low level in POC pond for unit 0500 PD 9409, LALL-9409

The following actions are carried out automatically:

- Stop POC pump for unit 0500 P 9409 A.
- Stop POC pump for unit 0500 P 9409 B.
-

8.107 I-9412 Autostart of POC Pump for Unit 0500 P 9409 A/B

The causes for trip are:

- High level in POC pond for unit 0500 PD 9409, LAHH-9409

The following actions are carried out automatically:

- Stop POC pump for unit 0500 P 9409 A or P 9409 B.
-

8.108 I-9410 Trip of POC Pump for Unit 2000 P 9410 A/B

The causes for trip are:

- Low level in POC pond for unit 2000 PD 9410, LALL-9410

The following actions are carried out automatically:

- Stop POC pump for unit 2000 P 9410 A.
- Stop POC pump for unit 2000 P 9410 B.

8.109 I-9411 Autostart of POC Pump for Unit 2000 P 9410 A/B

The causes for trip are:

- High level in POC pond for unit 2000 PD 9410, LAHH-9410

The following actions are carried out automatically:

- Stop POC pump for unit 2000 P 9410 A or P 9410 B.

8.110 I-9413 Trip of POC Pump for Unit 3002 P 9411

The causes for trip are:

- Low level in POC pond for unit 3002 PD 9411, LALL-9411

The following actions are carried out automatically:

- Stop POC pump for unit 3002 P 9411.

8.111 Appendix

Normal operation, alarm and trip values

Process conditions covering normal operation. Alarm and trip values

8.111.1 Analyses

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Natural gas from BL	1000-PID-002 P01	AI-1001	0.578	AAH-1001 AAL-1001	0.68 0.54				Specific gravity
Outlet R 1001 hydrogenator	1000-PID-003 P04	AI-1035	5.0	AAH-1035	22.0				v/v PPM
Outlet R 1002 2 sulphur absorber	1000-PID-003 P04	AI-1045	0.05	AAH-1045	0.10				v/v PPM
Waste heat section	2000-PID-007 P13	AI-2223 1	1.5 (wet basis)	AAH-2223 1 AAL-2223 1	3.00 1.30				v/v %
Waste heat section	2000-PID-007 P13	AI-2223 2	<20	AAH-2223 2	100				-
Waste heat section	2000-PID-007 P13	AI-2224	1.5 (wet basis)	AAH-2224 AAL-2224	3.00 1.30				v/v %
Waste heat section	2000-PID-007 P13	AIC-2225	1.5 (wet basis)	AAL-2225	1.30				v/v %
Outlet D 2001 HHP steam drum	2000-PID-013 P18	AI-2379	<1.0	AAH-2379	1.0				uS/cm2
Blowdown D 2001 HHP steam drum	2000-PID-013 P18	AI-2382	9-11	AAH-2382 AAL-2382	11.0 9.0				pH
Blowdown D 2001 HHP steam drum	2000-PID-013 P18	AI-2384	<60	AAH-2384	90				uS/cm2
Outlet D 2005 final separator	2000-PID-021 P21	AI-2479	0.65	AAH-2479	0.80				v/v %
Inlet C 3001/C 3002 synthesis gas compressor/recirculator	3000-PID-001 P22	AFI-3004 1	2.15	AFAL-3004	1.90				-

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Outlet D 3003 MP steam drum	3000-PID-002 P23	AI-3053	9-11	AAH-3053 AAL-3053	11.0 9.0				pH
Outlet D 3003 MP steam drum	3000-PID-002 P23	AI-3055	<60	AAH-3055	90				uS/cm2
Outlet D 7001 Deaerator	7000-PID-012 U09	AIC-7099	9-10	AAH-7099 AAL-7099	10.0 9.0				pH
E 0501 Conductivity	0500-PID-006	AI-0512		AAH-0512 AAL-0512	3000 1000	AAHH-0512	3500	I-0525	uS/cm2

8.111.2 Flow

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Process oxygen to E 2008 oxygen preheater	2000-PID-001 P02	FIC-2007	64,530	FAL-2007 FAD-2007	38,700 SP±3%	FSAL-2007	25,800	IS-2	Nm3/hr
O2/carbon ratio	2000-PID-001 P02	FFSY-2008	0.41			FFSAH-2008	0.45	IS-2	Nm3/Nm3
O2/carbon ratio	2000-PID-001 P02	FFI-2020	0.41	FFAH-2020	0.43				Nm3/Nm3
HP steam to mixing point	2000-PID-002 P03	FIC-2040	4500	FAL-2040	4300	FSAL-2040	4000	IS-2	Kg/hr
Saturated natural gas to steam/NG mixture	2000-PID-004 P10	FIC-2061	416,727	FAL-2061	250,000				Nm3/hr
Process steam (excl. quench)	2000-PID-003 P09	FSY-2062	225,839			FSAL-2062	90,000	IS-1	Kg/hr
Steam/carbon ratio	2000-PID-003 P09	FFSY-2064	1.80			FFSAL-2064	1.70	IS-1	Nm3/Nm3

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Steam added in saturator T 6001	2000-PID-003 P09	FI-2065	200,464	FAL-2065	120,300				Kg/hr
Process steam (incl. quench)	2000-PID-003 P09	FI-2069	225,839	FAL-2069	135,500				Kg/hr
Steam/carbon ratio	2000-PID-003 P09	FFI-2069	1.80	FFAL-2069	1.75				Nm3/Nm3
Emergency steam to H 2001	2000-PID-003 P09	FIC-2072	68,000	FAD-2072	SP±10%				Kg/h
Emergency steam to H 2001	2000-PID-003 P09	FIC-2072	68,000			FSAL-2072	61,000	IS-6	Kg/h
Outlet F 2002 combustion air blower	2000-PID-005 P11	FIC-2111	334,082	FAL-2111	300,700				Nm3/hr
H2 recycle from header	2000-PID-006 P12	FIC-2150	4562	FDAL-2150 FAL-2150	SP-10 % 4000				Nm3/hr
H2 Recycle/NG ratio	2000-PID-006 P12	FFI-2152	0.028	FFAL-2152	0.025				Nm3/Nm3
BFW from header	2000-PID-014 P19	FIC-2417	383,956	FAH-2417 FAL-2417	460,000 307,000				Kg/hr
Outlet D 2005 final separator	2000-PID-016 P21	FI-2476	540,133	FAH-2476	600,000				Nm3/hr
Purge gas to fuel header	2000-PID-017 U01	FIC-2536	54,266	FAL-2536	45,000				Nm3/hr
Outlet C 2001 start-up nitrogen compressor	2000-PID-018 U02	FI-2582	31,200	FAL-2582	28,000	FSAL-2582	20,000	IS-1	Nm3/hr

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Outlet D 3001 HP separator	3000-PID-006 P27	FI-3167	SOR : 1,356,000 EOR : 1,649,000	FAH-3167	1,830,000				Nm3/hr
Wash water to T 5004 vent wash column	5000-PID-001 P29	FICA-5020	LEAN GAS: 6679 RICH GAS: 8197	FAL-5020	5400				Kg/hr
Raw methanol to T5001	5000-PID-002 P30	FIA-5041	245539			FALL-5041	171,864	I-5001	Kg/hr
Reflux to T 5001	5000-PID-004 P32	FICA-5093	111,377	FAH-5093 FAL-5093	133,000 89,100				Kg/hr
Reflux to T 5002	5000-PID-008 P36	FICA-5203	285,504	FAH-5203 FAL-5203	340,000 230,000				Kg/hr
Methanol to T-5003	5000-PID-012 P40	FICA-5321	350,862	FAH-5321 FAL-5321	421,000 285,000				Kg/hr
Methanol product from E 5012	5000-PID-012 P40	FICA-5336	82,328	FAH-5336 FAL-5336	98,800 66,000				Kg/hr
Methanol product from E 5008	5000-PID-012 P40	FICA-5337	126,009	FAH-5337 FAL-5337	151,200 100,000				Kg/hr
Liquid off-stream from T 5003	5000-PID-009 P37	FICA-5441	2472	FDAL-5441	SP-10 %				Kg/hr
Liquid off-stream from T 5003	5000-PID-009 P37	FICA-5441	2472	FDAH-5441	SP+10 %				Kg/hr
Process condensate to T 6001 1/2	6000-PID-002 P06	FIC-6031	206,144	FAL-6031	185,000				Kg/hr
Wash Waster to D 6001	6000-PID-003 P07	FI-6059	27,989	FAL-6059	13,400				Kg/hr

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Ratio Liquid off-stream/natural gas	6000-PID-003 P07	FFI-6059	0.015	FFAH-6059	0.045				Mole/mole
Outlet P 6001 A/B saturator circulation pump	6000-PID-003 P07	FI-6068	257,600	FAL-6068	230,000	MP 6001 A/B	182, 896	I-6068	Kg/hr
Natural gas to E 6001 saturator feed/ effluent exchanger	6000-PID-003 P07	FIC-6070	167,967	FAL-6070 FAD-6070	100,000 SP±10%	FSAL-6070	67,000	IS-1	Nm3/hr
DMW to D 7001 deaerator	7000-PID-012 U09	FIC-7091	208,036	FAH-7091 FAL-7091	250,000 165,000				Kg/hr
POC flow rate at B.L.	8000-PID-001	FICA-8304	5	FAH-8304	10				m3/h

8.111.3 Level

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
D 1001 natural gas KO drum	1000-PID-002 P01	LI-1004	700	LAH-1004 LAL-1004	800 600	LSAH-1004 LSAL-1004	900 500	IS-1 IS-5	mm
D 2011 steam condensate KO drum for E 2008	2000-PID-001 P02	LIC 2016	1640	LAH-2016 LAL-2016	2200 1075				mm
D 2001 HHP steam drum	2000-PID-013 P18	LIC-2372	2350	LAH-2372 LAL-2372	2500 2150	LSAH-2372 LSAL-2372	2625 1675	IS-90 IS-1	mm
D 2001 HHP steam drum	2000-PID-013 P18	LI-2373	2350	LAH-2373 LAL-2373	2500 2150				mm
D 2002 1st separator	2000-PID-014 P19	LIC-2403	700	LAH-2403 LAL-2403	800 600				mm
D 2002 1st separator	2000-PID-014 P19	LI-2404	700			LSAL-2404	500	IS-33	mm
D 2003 2nd separator	2000-PID-014 P19	LIC-2419	700	LAH-2419 LAL-2419	800 600				mm
D 2004 3rd separator	2000-PID-015 P20	LIC-2441	900	LAH-2441 LAL-2441	1075 700				mm
D 2004 3rd separator	2000-PID-015 P20	LI-2442	900			LSAL-2442	500	IS-34	mm
D 2005 final separator	2000-PID-016 P21	LIC-2474	750	LAH-2474 LAL-2474	1075 700	LSAH-2474 LSAL-2474	1275 500	IS-40, I-2004 IS-35	mm
D 3003 MP steam drum	3000-PID-002 P23	LI-3042	2000	LAH-3042 LAL-3042	2225 1750	LSAL-3042	1300	IS-3	mm
D 3003 MP steam drum	3000-PID-002 P23	LI-3043	2000	LAH-3043 LAL-3043	2225 1750				mm
D 3001 HP separator	3000-PID-006 P27	LIC-3161	-550	LAH-3161 LAL-3161	-225 -850	LSAH-3161 LSAL-3161	75 -1225	IS-3 IS-42	mm

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
D 3002 LP separator	3000-PID-007 P28	LIC-3192	1050	LAH-3192 LAL-3192	1400 725	LSAH-3192 LSAL-3192	1800 325	IS-42 IS-43	mm
TK 5001 raw methanol buffer tank	5000-PID-001 P29	LIA-5001	15200	LAH-5001 LAL-5001	17800 600				mm
TK 5001 raw methanol buffer tank	5000-PID-001 P29	LI-5002	15200			LSAH-5002 LSAL-5002	18000 200	IS-44 IS-53	mm
T 5001 stabilizer column	5000-PID-002 P30	LICA-5041	1550	LAH-5041 LAL-5041	2300 800				mm
T 5001 stabilizer column	5000-PID-002 P30	LIA-5042	1550	LAH-5042	2300	LSAL-5042	0	IS-54	mm
E 5024 2 stabilizer column reboiler	5000-PID-002 P30	LIA-5065	1515	LAL-5065	1430				mm
D 5009 steam condensate pot for E 5001	5000-PID-003 P31	LICA-5070	1700	LAH-5070 LAL-5070	2300 1100				mm
D 5009 steam condensate pot for E 5001	5000-PID-003 P31	LI-5071	1700			LSAL-5071	500	IS-55	mm
D 5001 stabilizer column OH accumulator	5000-PID-004 P32	LICA-5093	1050	LAH-5093 LAL-5093	1200 875				mm
D 5001 stabilizer column OH accumulator	5000-PID-004 P32	LIA-5094	1050	LAH-5094	1200	LSAL-5094	325	IS-56	mm
T 5002 LP methanol column	5000-PID-006 P34	LICA-5161	350	LAH-5161 LAL-5161	500 200				mm
T 5002 LP methanol column	5000-PID-006 P34	LIA-5162	350	LAH-5162	500	LSAL-5162	0	IS-57	mm
E 5002 4 LP column reboiler	5000-PID-006 P34	LIA-5182	2285	LAL-5182	2210				mm
D 5002 LP column OH accumulator	5000-PID-008 P36	LICA-5203	1650	LAH-5203 LAL-5203	1900 1375				mm

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
D 5002 LP column OH accumulator	5000-PID-008 P36	LIA-5204	1650	LAH-5204	1900	LSAL-5204	500	IS-58	mm
T 5003 MP methanol column	5000-PID-010 P38	LICA-5270	350	LAH-5270 LAL-5270	500 200				mm
T 5003 MP methanol column	5000-PID-010 P38	LIA-5271	350	LAH-5271	500	LSAL-5271	0	IS-59	mm
E 5003 2 MP column reboiler no. 1	5000-PID-011 P39	LIA-5278	1950	LAL-5278	1875				mm
E 5003 1 MP column reboiler no. 1	5000-PID-011 P39	LIA-5308	500-0	LAL-5308	0				mm
E 5003 2 MP column reboiler no. 1	5000-PID-011 P39	LIA-5310	500-0	LAL-5310	0				mm
D 5003 MP column OH accumulator	5000-PID-012 P40	LICA-5321	1700	LAH-5321 LAL-5321	1975 1425				mm
D 5003 MP column OH accumulator	5000-PID-012 P40	LI-5322	1700			LSAL-5322	525	IS-60	mm
TK 5002 1 methanol product buffer tank	5000-PID-015 P43	LIA-5396	15500	LAH-5396 LAL-5396	22500 1500				mm
TK 5002 1 methanol product buffer tank	5000-PID-015 P43	LI-5397	15500			LSAH-5397 LSAL-5397	23000 850	IS-62 IS-64	mm
TK 5002 2 methanol product buffer tank	5000-PID-016 P44	LIA-5413	15500	LAH-5413 LAL-5413	22500 1500				mm
TK 5002 2 methanol product buffer tank	5000-PID-016 P44	LI-5414	15500			LSAH-5414 LSAL-5414	23000 850	IS-63 IS-65	mm
TK 5003 liquid off-stream tank	5000-PID-017 P45	LIA-5446	4500	LAH-5446 LAL-5446	5330 1500				mm
TK 5003 liquid off-stream tank	5000-PID-017 P45	LI-5447	4500			LSAH-5447 LALL-5447	5460 1300	IS-51 I-52	mm

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
TK 5050 NaOH tank	5000-PID-020 U24	LIA-5511	~1500	LAL-5511	200				mm
T 6001 1 saturator	6000-PID-002 P06	LIC-6021	1250	LAH-6021 LAL-6021	2100 400				mm
T 6001 1 saturator	6000-PID-002 P06	LI-6022 1	1250	LAH-6022 1	2900	LSAL-6022 1	-500	IS-30	mm
T 6001 2 saturator	6000-PID-002 P06	LI-6022 2	1250	LAH-6022 2	2900	LSAL-6022 1	-500	IS-30	mm
T 6001 1 saturator (top)	6000-PID-002 P06	LI-6033 1	220	LAH-6033 1 LAL-6033 1	300 200	LSAL-6035	170	IS-29	mm
T 6001 2 saturator (top)	6000-PID-002 P06	LI-6033 2	220	LAH-6033 2 LAL-6033 2	300 200	LSAL-6035	170	IS-29	mm
T 6001 1 saturator (top)	6000-PID-002 P06	LI-6034 1	220	LAL-6034 1	200	LSAL-6035	170	IS-29	mm
T 6001 2 saturator (top)	6000-PID-002 P06	LI-6034 2	220	LAL-6034 2	200	LSAL-6035	170	IS-29	mm
D 6001 feed gas separator	6000-PID-003 P07	LIC-6051	450	LAH-6051 LAL-6051	4975 -125	LSAH-6051 LSAL-6051	5625 -850	IS-1 IS-31	mm
D 6002 saturator blow down drum	6000-PID-004 P08	LIC-6082	1750	LAH-6082 LAL-6082	2375 1125				mm
D 6002 saturator blow down drum	6000-PID-004 P08	LI-6083	1750			LAHH-6083 LALL-6083	3000 500	I-36 I-37	mm
D 7001 deaerator	7000-PID-012 U09	LIC-7091	3300	LAH-7091 LAL-7091	3500 1500	LSAH-7091 LSAL-7091	3650 675	I-7091 IS-70	mm
TK 7002 process condensate tank	7000-PID-015 U22	LI-7101	2000	LAH-7101 LAL-7101	9200 400				mm
TK 7002 process condensate tank	7000-PID-015 U22	LI-7102	2000			LAHH-7102 LALL-7102	9300 300	I-39 I-38	mm

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
TK 7050 phosphate solution tank	7000-PID-023 U12	LI-7162	~1000	LAL-7162	200				mm
TK 7060 ammonia tank	7000-PID-024 U13	LI-7192	~1000	LAL-7192	200				mm
TK 7070 oxygen scavenger tank	7000-PID-025 U14	LI-7212	~1000	LAL-7212	200				mm
D 7002 continuous blow down drum	7000-PID-026 U16	LIC-7251	1350	LAH-7251 LAL-7251	1775 925	LALL-7251	500	I-7005	mm
D 7003 intermittent blow down drum NO.1	7000-PID-026 U16	LIC-7255	350	LAH-7255 LAL-7255	500 250	LALL-7255	200	I-7005	mm
Flare KO drum	8500-PID-003 U21	LI-8511	600	LAH-8511	1000				mm
Flare KO drum	8500-PID-003 U21	LST-8512	600	LAHH-8512 LALL-8512	1200 -200	LAHH-8512 LALL-8512	1200 -200	IS-8501 IS-8502	mm

8.111.4 Pressure

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Outlet D 1001 natural gas KO drum	1000-PID-002 P01	PIC-1006	50.0	PAL-1006	48.0				Barg
Fuel gas to H 2001 primary reformer	1000-PID-002 P01	PIC-1011	4.0	PAH-1011 PAL-1011	5.0 3.0				Barg
Across R 1001 hydrogenator	1000-PID-003 P04	PDI-1032	0.2	PDAH-1032	0.75				Bar

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Outlet R 1002 2 sulphur absorber	1000-PID-003 P04	PIC-1045	47.3	PAH-1045 PAL-1045	50.0 45.0				Barg
Process oxygen from BL	2000-PID-001 P02	PI-2001	41.6	PAH-2001 PAL-2001	42.0 38.0	PSAH-2001	46		Barg
Across X 2001 A/B oxygen filter	2000-PID-001 P02	PDI-2004	0.2	PDAH-2004	0.5				Bar
Inlet E 2008 oxygen preheater	2000-PID-001 P02	PIC-2015	43.5	PAL-2015	38.0				Barg
Across X 2002 A/B steam filter	2000-PID-002 P03	PDI-2032	0.2	PDAH-2032	0.5				Bar
Outlet X 2002 A/B steam filter	2000-PID-002 P03	PI-2035	43.8	PAL-2035	38.0				Barg
Across valves outlet X 2002 A/B steam filter	2000-PID-002 P03	PDI-2036	10.0	PDAL-2036	6.0	PDSAL-2036	4.0		Bar
Across mixing point	2000-PID-002 P03	PDI-2051	1.5~2			PDAH-2051	3.0	IS-2	Bar
Across mixing point	2000-PID-002 P03	PDI-2051	1.5~2			PDAL-2051	1	IS-2	Bar
Saturated natural gas to steam/NG mixture	2000-PID-003 P09	PIC-2073	42.3	PAH-2073	45.0				Barg
HP steam to steam/NG mixture	2000-PID-003 P09	PI-2077	42.0	PAH-2077 PAL-2077	45.0 38.0				Barg
Process gas to E 2002 prereformer feed preheat coil	2000-PID-004 P10	PI-2099	42.1	PAH-2099	44.0				Barg
Air intake F 2002 combustion air blower	2000-PID-005 P11	PI-2111	-30	PAL-2111	-60				mm H2O

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
H2 recycle from header	2000-PID-006 P12	PI-2150	50.4	PAH-2150 PAL-2150	53 48				Barg
Combustion air to H 2001 primary reformer	2000-PID-006 P12	PIC-2163	200	PAL-2163	100	PSAL-2163	50		mm H2O
Waste heat section	2000-PID-007 P13	PIC-2224	-5	PAH-2224 PAL-2224	-3 -20	PSAH-2224 PAHH-2224 PSAL-2224	5 0 -50		mm H2O
Across R 2003 prereformer	2000-PID-008 P14	PDI-2252	0.4	PDAH-2252	0.7				Bar
Outlet R 2003 prereformer	2000-PID-008 P14	PI-2268	37.7	PAH-2268	40.0				Barg
Inlet H 2001 primary reformer	2000-PID-009 P15	PI-2282	36.3	PAH-2282	38.0				Barg
Across H 2001 primary reformer	2000-PID-009 P15	PDI-2283	5.0	PDAH-2283	6.0				Bar
R 2004 secondary reformer (catalyst)	2000-PID-010 P16A	PDI-2323	0.12	PDAH-2323	0.5				Bar
Outlet E 2021 1&2 steam superheater	2000-PID-012 P17	PIC-2361	100.0	PAH-2361	105.0				Barg
Outlet E 2021 1&2 steam superheater	2000-PID-012 P17	PIC-2363	100.0	PAL-2363	95.0				Barg
D 2001 HHP steam drum	2000-PID-013 P18	PI-2372	102.0	PAH-2372 PAL-2372	107.0 97.0				Barg
Outlet D 2005 final separator	2000-PID-016 P21	PIC-2481	24.0	PAH-2481	26.0				Barg
Fuel gas to mixing point[1]	2000-PID-017 U01	PI-2540	2.0	PAH-2540 PAL-2540	2.3 1.0				Barg

[1] To be confirmed by burner vendor

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Fuel gas to H 2001	2000-PID-017 U01	PIC-2554	2.0	PAH-2554 PAL-2554	2.5 0.5	PSAH-2554 PSAL-2554	3.6 0.25	IS-1 IS-14	Barg
Fuel gas to H 2001	2000-PID-017 U01	PSY-2556	2.0			PSAL-2556	0.02	IS-1	Barg
~~Outlet C2001 start-up nitrogen compressor~~	~~2000-PID-018 U02~~	~~PI-2579~~	~~9.5~~	~~PAH-2579~~					~~Barg~~
Inlet C 3001/C 3002 synthesis gas compressor/recirculator	3000-PID-001 /P22	PIC-3007	24.0	PAH-3007 PAL-3007	26.0 21.0				Barg
D 3003 MP steam drum	3000-PID-002 /P23	PIC-3042	SOR: 33.7 EOR: 40.8	PAH-3042 PAL-3042	43.0 31.0				Barg
Across E 3001 1 feed/effluent exchanger	3000-PID-004 /P25	PDI-3112	EOR: 2.2	PDAH-3112	2.7				Bar
Across E 3001 2 feed/effluent exchanger	3000-PID-004 /P25	PDI-3115	EOR: 2.2	PDAH-3115	2.7				Bar
Across E 3001 3 feed/effluent exchanger	3000-PID-004 /P25	PDI-3117	EOR: 2.2	PDAH-3117	2.7				Bar
Outlet D 3001 HP separator	3000-PID-006 /P27	PIC-3166 A	SOR: 76.2 EOR: 84.1	PAH-3166 A PAL-3166 A	91.0 70.0				Barg
D 3002 LP separator	3000-PID-007 /P28	PIC-3194	4.0	PAH-3194 PAL-3194	4.5 3.5				Barg
TK 5001 raw methanol buffer tank	5000-PID-001 P29	PIA-5004	-0.003~ 0.015	PAH-5004 PAL-5004	0.01 -0.003				Barg
Outlet P 5001	5000-PID-001 P29	PIA-5022	5	PAL-5022	4.5				Barg
T 5001 stabilizer column	5000-PID-002 P30	PIA-5047	1	PAH-5047	1.5				Barg
T 5001 stabilizer column	5000-PID-002 P30	PDIA-5048	0.18	PDAH-5048	0.27				Bar

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
T 5001 stabilizer column	5000-PID-002 P30	PDIA-5050	0.14	PDAH-5050	0.21				Bar
Outlet P 5011 A/B steam condensate pump	5000-PID-003 P31	PIA-5083	5.2	PAL-5083	4.6	PALL-5083	4	I-5011	Barg
Inlet AE 5004 stabilizer column OH condenser	5000-PID-004 P32	PICA-5091	0.7	PAH-5091	1.2				Barg
Outlet P 5003 A/B stabilizer column reflux pump	5000-PID-004 P32	PIA-5093	3.8	PAL-5093	3.0	PALL-5093	2.5	I-5003	Barg
Outlet P 5002 A/B stabilizer methanol pump	5000-PID-005 P33	PIA-5139	2.5	PAL-5139	2	PALL-5139	1.7	I-5002	Barg
T 5002 LP methanol column	5000-PID-006 P34	PDIA-5167	0.05	PDAH-5167	0.08				Bar
T 5002 LP methanol column	5000-PID-006 P34	PDIA-5169	0.18	PDAH-5169	0.27				Bar
T 5002 LP methanol column	5000-PID-006 P34	PDIA-5171	0.18	PDAH-5171	0.27				Bar
T 5002 LP methanol column	5000-PID-006 P34	PDIA-5173	0.14	PDAH-5173	0.21				Bar
D 5002 LP column OH accumulator	5000-PID-008 P36	PICA-5207	0	PAH-5207 PAL-5207	0.15 -0.05	PSAH-5207	0.3	IS-4	Barg
Inlet E 5008 methanol product cooler no. 1	5000-PID-008 P36	PIA-5219	4.5	PAL-5219	3.5	PALL-5219	3	I-5004	Barg
Outlet P 5005 A/B MP column feed pump	5000-PID-009 P37	PIA-5240	6.5	PAL-5240	5.6	PALL-5240	5	I-5005	Barg
T 5003 MP methanol column	5000-PID-010 P38	PIA-5252	2.7	PAL-5252	2.3				Barg
T 5003 MP methanol column	5000-PID-010 P38	PDIA-5253	0.20	PDAH-5253	0.30				Bar

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
T 5003 MP methanol column	5000-PID-010 P38	PDIA-5255	0.18	PDAH-5255	0.27				Bar
T 5003 MP methanol column	5000-PID-010 P38	PDIA-5257	0.22	PDAH-5257	0.33				Bar
T 5003 MP methanol column	5000-PID-010 P38	PDIA-5259	0.20	PDAH-5259	0.30				Bar
T 5003 MP methanol column	5000-PID-010 P38	PIA-5260	3.6	PAH-5260	4.2				Barg
Outlet E 5003 1/2 MP column reboiler no. 1	5000-PID-011 P39	PIA-5307	6.5	PAH-5307 PAL-5307	7.5 5.0				Barg
Inlet E 5012 methanol product cooler no. 2	5000-PID-012 P40	PIA-5335	8	PAL-5335	7	PALL-5335	6	I-5006	Barg
Outlet P 5010 A/B excess water pump	5000-PID-013 P41	PIA-5367	50	PAL-5367	48	PALL-5367	47	I-5010	Barg
Outlet P 5007 A/B MP column recycle pump	5000-PID-013 P41	PIA-5369	4.5	PAL-5369	4	PALL-5369	3.5	I-5007	Barg
Outlet X 5001 product polisher unit	5000-PID-014 P42	PDIA-5385	0.1	PDAH-5385	0.5				Bar
TK 5002 1 methanol product buffer tank	5000-PID-015 P43	PIA-5398	-0.003~ 0.015	PAH-5398 PAL-5398	0.01 -0.003				Barg
Outlet P 5012 Methanol Start-up pump	5000-PID-015 P43	PIA-5410	47	PAH-5410 PAL-5410	50 43				Barg
TK 5002 2 methanol product buffer tank	5000-PID-016 P44	PIA-5415	-0.003~ 0.015	PAH-5415 PAL-5415	0.01 -0.003				Barg
Methanol product to product tank	5000-PID-016 P44	PIA-5421	4.3	PAH-5421	5.2				Barg
TK 5003 liquid off-stream tank	5000-PID-017 P45	PIA-5448	-0.003~ 0.015	PAH-5448 PAL-5448	0.01 -0.003				Barg

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Outlet P 6002 A/B/C steam condensate return pump	6000-PID-001 P05	PIA-6010	45.0	PAL-6010	40.0	PALL-6010	36	I-6010	Barg
Outlet LV-6021A steam condensate return pump	6000-PID-001 P05	PIA-6015	44.0	PAH-6015	45.0				Barg
MP Steam to T 6001 1/2 Saturator	6000-PID-002 P06	PIC-6025	32.2	PAH-6025 PAL-6025	35 28				Barg
Across X 6001 A/B particle filter	6000-PID-002 P06	PDI-6028	0.2	PDAH-6028	0.5				Bar
Across X 6002 A/B particle filter	6000-PID-003 P07	PDI-6057	0.2	PDAH-6057	0.5				Bar
Outlet P 7003 A&B Excess Process Condensate Pumps	6000-PID-004 P08	PI-6088	6.2			PALL-6088	5.6	I-6088	Barg
HP steam header	7000-PID-006 U03	PIC-7004	44.0	PAH-7004 PAL-7004	47.0 41.0				Barg
HP steam header	7000-PID-007 U04	PIC-7021	42.0	PAH-7021 PAL-7021	45.0 40.0				Barg
MP steam header	7000-PID-008 U05	PIC-7034	SOR: 32.7 EOR: 39.8	PAH-7034 PAL-7034	30.0 42.0				Barg
LP steam header	7000-PID-009 U06	PIC-7056	7.0	PAH-7056 PAL-7056	8.0 6				Barg
D 7001 deaerator	7000-PID-012 U09	PIC-7094	1.0	PAH-7094 PAL-7094	1.2 0.8				Barg
Inlet P 7001 A BFW pump	7000-PID-013 U10	PI-7112	2.0	PAL-7112	1.5	PSAL-7112	1.0	IS-71	Barg
Inlet P 7001 B BFW pump	7000-PID-013 U10	PI-7116	2.0	PAL-7116	1.5	PSAL-7116	1.0	IS-72	Barg
Inlet P 7001 C BFW pump	7000-PID-013 U10	PI-7120	2.0	PAL-7120	1.5	PSAL-7120	1.0	IS-73	Barg

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
Outlet P 7001 A/B/C BFW pump	7000-PID-013 U10	PI-7127	110	PAL-7127	108	PSAL-7127	106	I-7001	Barg
Outlet P 7001 A/B/C BFW pump	7000-PID-014 U11	PI-7141	50	PAL-7141	48.0				Barg
Low instrument air pressure at B.L.	7000-PID-019	PI-7313	8.3	PAH-7313 PAL-7313	10 6	PSAL-7313 PSALL-7313	5.5 5	IS-1 I-7307A	Barg
Low instrument air pressure at B.L.	7000-PID-019	PI-7307	8.3	PAH-7307A PAL-7307A	9 7.5	PSAL-7307	6.5	I-7307A	Barg
Methanol product pressure at B.L.	8000-PID-001	PIA-8301	5	PAH-8301 PAL-8301	8 3.5				Barg
CSW pressure at B.L.	8000-PID-001	PIA-8302	5.0	PAH-8302 PAL-8303	8 1.5				Barg
Cooling water make-up pressure at B.L.	8000-PID-001	PIA-8303	5.3	PAH-8304 PAL-8304	10 3				Barg
POC pressure at B.L.	8000-PID-001	PIA-8304	3	PAH-8304 PAL-8304	5 1.5				Barg
Boiler blow down pressure at B.L.	8000-PID-001	PIA-8306	5.6	PAH-8306 PAL-8306	7 1.5				Barg
COC pressure at B.L.	8000-PID-001	PIA-8307	4.7	PAH-8307 PAL-8307	6 1.5				Barg
Methanol product pressure at B.L.	8000-PID-001	PIA-8308	58.3	PAH-8308 PAL-8308	62 54.1				Barg
Natural gas pressure at B.L.	8000-PID-001	PIA-8309	4~5	PAH-8309 PAL-8309	6 3.5				Barg

8.111.5 Duty

Description	P&I Diagram	Normal Operation Instrument	Normal Operation Value	Alarm System Instrument	Alarm System Value	Trip System Instrument	Trip System Trip Value	Trip System Trip Group	Unit
Total duty based on LHV	2000-PID-017 U01	QIC-2535	1130	QAH-2535 QDAH-2535	1200 SP+ 10 %				GJ/hr

8.111.6 Speed (RPM)

Description	P&I Diagram	Normal Operation Instrument	Normal Operation Value	Alarm System Instrument	Alarm System Value	Trip System Instrument	Trip System Trip Value	Trip System Trip Group	Unit
FT 2002 steam turbine for F 2002	2000-PID-005 P11	SI-2118	5970	SAH-2118 SAL-2118	6270 5740				RPM
FT 2001 steam turbine for F 2001	2000-PID-006 P12	SI-2168	4185	SAH-2168 SAL-2168	4395 4024				RPM

8.111.7 Temperature

Description	P&I Diagram	Normal Operation Instrument	Normal Operation Value	Alarm System Instrument	Alarm System Value	Trip System Instrument	Trip System Trip Value	Trip System Trip Group	Unit
Fuel gas to H 2001 primary reformer	1000-PID-002 P01	TI-1012	35	TAL-1012	20				°C
R 1001 hydrogenator	1000-PID-003 P04	TI-1034	380	TAH-1034 TAL-1034	410 350				°C
R 1001 hydrogenator	1000-PID-003	TI-1035	380	TAH-1035	410				°C

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
	P04			TAL-1035	350				
Outlet R 1002 2 sulphur absorber, vent	1000-PID-003 P04	TI-1047	Amb.	TAH-1047	100				°C
Process oxygen from BL	2000-PID-001 P02	TI-2001	35	TAH-2001 TAL-2001	50 20				°C
Process oxygen to mixing point, vent	2000-PID-002 P03	TI-2044	Amb.	TAH-2044	100				°C
Process oxygen/steam to R 2004 secondary reformer	2000-PID-002 P03	TI-2046	236	TAL-2046	200				°C
Process oxygen to mixing point	2000-PID-002 P03	TI-2047	230	TAL-2047	200	TSAL-2047	180	IS-2	°C
Process oxygen to mixing point, vent	2000-PID-002 P03	TI-2050	Amb.	TAH-2050	100				°C
Steam to mixing point, vent	2000-PID-002 P03	TI-2051	Amb.	TAH-2051	100				°C
Temperature in saturator blow down	6000-PID-002 P06	TI-6032	170	TAH-6032	230	TSAH-6032	250	IS-29	°C
Process gas to mixing point, vent	2000-PID-004 P10	TI-2091	Amb.	TAH-2091	100				°C
Outlet F 2002 combustion air blower	2000-PID-005 P11	TI-2112	54	TAL-2112	5				°C
Outlet E 2006 1st natural gas feed preheat coil	2000-PID-006 P12	TI-2148	250	TAH-2148	300				°C
Outlet E 2006 1st natural gas feed preheat coil	2000-PID-006 P12	TI-2149	250	TAH-2149	300				°C
WHS between E 2006 and E 2007	2000-PID-006 P12	TI-2154	236	TAH-2154	251				°C
WHS between E 2007 and F 2001	2000-PID-006	TI-2155	150	TAH-2155	175				°C

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
	P12			TAL-2155	135				
Outlet E 2004 2nd natural gas feed preheat coil	2000-PID-007 P13	TIC-2220	380	TAH-2220 TAL-2220	410 350				°C
Radiant section outlet H 2001	2000-PID-007 P13	TI-2221	1090	TAH-2221 A	1110	TSAH-2221	1130	IS-1	°C
WHS inlet E 2001	2000-PID-007 P13	TI-2226	1090	TAH-2226	1110				°C
WHS between E 2004 and E 2006	2000-PID-007 P13	TI-2229	353	TAH-2229	368				°C
Process gas to E 2002 prereformer feed preheat coil	2000-PID-007 P13	TIC-2232	267	TAL-2232	240	TALL-2232	235	I-17	°C
Outlet E 2001 reformer feed preheat coil	2000-PID-007 P13	TI-2234	638	TAH-2234	660				°C
Inlet R 2003 prereformer	2000-PID-008 P14	TIC-2253	496	TAH-2253 TAL-2253	510 480				°C
Outlet R 2003 prereformer	2000-PID-008 P14	TI-2268	441	TAH-2268 TAL-2268	470 430				°C
Radiant section outlet H 2001	2000-PID-009 P15	TI-2295	1090	TAH-2295 TDAH-2295	1110 50				°C °C /hr
Radiant section outlet H 2001	2000-PID-009 P15	TI-2297	1090	TAH-2297 TDAH-2297	1110 50				°C °C/hr
Cold collector	2000-PID-009 P15	TI-2303	738	TAH-2303	750				°C
Cold collector	2000-PID-009 P15	TI-2304	738	TAH-2304	750				°C
Cold collector	2000-PID-009 P15	TI-2305	738	TAH-2305	750	TSAH-2305	765	IS-1	°C
R 2004 secondary reformer	2000-PID-010	TI-2325	1240	TAH-2325	1270	TSAH-2325	1290	IS-2	°C

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
(combustion zone)	P16A			TAL-2325	1000				
R 2004 secondary reformer, skin temperature	2000-PID-010 P16A	TI-2326	160	TAH-2326	250				°C
R 2004 secondary reformer, skin temperature	2000-PID-010 P16A	TI-2327	160	TAH-2327	250				°C
R 2004 secondary reformer, skin temperature	2000-PID-010 P16A	TI-2328	160	TAH-2328	250				°C
R 2004 secondary reformer (burner interval)	2000-PID-010 P16A	TI-2329	236	TAH-2329	600	TSAH-2329	700	IS-2	°C
R 2004 secondary reformer, skin temperature	2000-PID-010 P16A	TI-2330	160	TAH-2330	250				°C
R 2004 secondary reformer, skin temperature	2000-PID-010 P16A	TI-2331	160	TAH-2331	250				°C
R 2004 secondary reformer, skin temperature	2000-PID-010 P16A	TI-2332	160	TAH-2332	250				°C
R 2004 secondary reformer, outlet	2000-PID-010 P16A	TI-2333	1020	TAH-2333	1035	TSAH-2333	1050	IS-2	°C
R 2004 secondary reformer (catalyst)	2000-PID-010 P16A	TIC-2334	1020	TAH-2334 TAL-2334	1035 970	TSAH-2334	1050	IS-2	°C
Outlet E 2020 1 waste heat boiler	2000-PID-011 P16B	TIC-2335	544	TAH-2335	560	TSAH-2335	580	IS-1	°C
Outlet E 2020 2 waste heat boiler	2000-PID-011 P16B	TIC-2336	544	TAH-2336	560	TSAH-2336	580	IS-1	°C
Outlet E 2020 1/2 waste heat boiler	2000-PID-011 P16B	TDI-2337	0-3	TDAH-2337	15				°C
Outlet E 2021 1 steam superheater	2000-PID-012 P17	TI-2351	409	TAH-2351	430				°C
Outlet E 2021 3 steam superheater	2000-PID-012	TI-2352	360	TAH-2352	385				°C

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
	P17								
Outlet E 2021 2 steam superheater	2000-PID-012 P17	TI-2353	409	TAH-2353	430				°C
Outlet E 2021 1 steam superheater	2000-PID-012 P17	TI-2355	460	TAH-2355	475	TSAH-2355	490	IS-1	°C
Outlet E 2021 2 steam superheater	2000-PID-012 P17	TI-2356	460	TAH-2356	475	TSAH-2355	490	IS-1	°C
Outlet E 2021 1&2 steam superheater	2000-PID-012 P17	TIC-2360	460	TAH-2360 TAL-2360	475 445				°C
Inlet D 2001 HHP steam drum	2000-PID-013 P18	TI-2371	276	TAH-2371	308 (Calculated)				°C
Outlet E 2025 DMW preheater	2000-PID-015 P20	TIC-2457	72	TAH-2457	100				°C
Outlet D 2005 final separator	2000-PID-016 P21	TI-2476	48	TAH-2476	60				°C
Outlet D 3001 HP separator	3000-PID-006 P27	TI-3164	48	TAH-3164	90				°C
Outlet E 5024 Stabilizer column reboiler no. 2	5000-PID-002 P30	TICA-5064	138	TAH-5064	180				°C
Fuel gas to mixing point	2000-PID-017 U01	TI-2540	35	TAL-2540	20				°C
Start-up N2 from D 2005	2000-PID-018 U02	TI-2572	48	TAH-2572	60				°C
~~Outlet C 2001 start-up nitrogen compressor~~	~~2000-PID-018 U02~~	~~TI-2579~~	~~84[1]~~	~~TAH-2579~~	~~By vendor~~	~~TAHH-2579~~	~~By vendor~~	~~I-16~~	~~°C~~

[1] Vendor to confirm actual temperature

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
MP steam from header	3000-PID-002 P23	TI-3045	242	TAH-3045	280				°C
Outlet R 3001 1 methanol reactor	3000-PID-003 P24	TI-3073	SOR : 246 EOR : 260	TAH-3073 TAL-3073	270 236				°C
Outlet R 3001 2 methanol reactor	3000-PID-003 /P24	TI-3077	SOR : 246 EOR : 260	TAH-3077 TAL-3077	270 236				°C
Outlet R 3001 3 methanol reactor	3000-PID-003 /P24	TI-3081	SOR : 246 EOR : 260	TAH-3081 TAL-3081	270 236				°C
MP steam for heating of R 3001 1/2/3	3000-PID-003 /P24	TI-3084	410	TAH-3084	430				°C
Outlet E 3001 1 feed/effluent exchanger	3000-PID-004 /P25	TIC-3113	SOR : 210 EOR : 230	TAH-3113	240				°C
Outlet E 3001 2 feed/effluent exchanger	3000-PID-004 /P25	TIC-3116	SOR : 210 EOR : 230	TAH-3116	240				°C
Outlet E 3001 3 feed/effluent exchanger	3000-PID-004 /P25	TIC-3118	SOR : 210 EOR : 230	TAH-3118	240				°C
Outlet AE 3002 1 loop air cooler	3000-PID-005 /P26	TI-3142	65	TAH-3142	75				°C
Outlet AE 3002 2 loop air cooler	3000-PID-005 /P26	TI-3145	65	TAH-3145	75				°C
Outlet AE 3002 3 loop air cooler	3000-PID-005 /P26	TI-3148	65	TAH-3148	75				°C
Outlet E 3003 1 loop water cooler	3000-PID-005 /P26	TI-3144	48	TAH-3144	60				°C
Outlet E 3003 2 loop water cooler	3000-PID-005 /P26	TI-3147	48	TAH-3147	60				°C
Outlet E 3003 3 loop water cooler	3000-PID-005 /P26	TI-3150	48	TAH-3150	60				°C

Description	P&I Diagram	Normal Operation Instrument	Normal Operation Value	Alarm System Instrument	Alarm System Value	Trip System Instrument	Trip System Trip Value	Trip System Trip Group	Unit
T 5003 MP methanol column	5000-PID-010 P38	TIA-5261	103	TAH-5261 TAL-5261	113 93				
T 5003 MP methanol column	5000-PID-010 P38	TIA -5262	104	TAH-5262 TAL-5262	114 94				°C
T 5003 MP methanol column	5000-PID-010 P38	TIA -5263	105	TAH-5263 TAL-5263	115 95				°C
T 5003 MP methanol column	5000-PID-010 P38	TIA -5264	109	TAH-5264 TAL-5264	119 99				°C
T 5003 MP methanol column	5000-PID-010 P38	TIA -5265	112	TAH-5265 TAL-5265	122 102				°C
T 5003 MP methanol column	5000-PID-010 P38	TICA-5266	113	TAH-5266 TAL-5266	123 103				°C
T 5003 MP methanol column	5000-PID-010 P38	TICA -5267	121	TAH-5267 TAL-5267	131 111				°C
T 5003 MP methanol column	5000-PID-010 P38	TICA -5268	143	TAH-5268 TAL-5268	153 133				°C
T 5003 MP methanol column	5000-PID-010 P38	TIA-5269	149	TAH-5269 TAL-5269	159 139				°C
Outlet E 5023 MP column reboiler no. 2	5000-PID-010 P38	TICA -5277	159	TAH-5277	180				°C
Outlet T 5003 MP methanol column	5000-PID-010 P38	TIA-5280	102	TAH-5280 TAL-5280	112 92				°C
Inlet X 5001 product polisher unit	5000-PID-014 P42	TIA -5381	48	TAH-5381	60				°C
Outlet E 5011 liquid off-stream cooler	5000-PID-009 P37	TIA -5443	48	TAH-5443	60				°C
Process condensate to saturator T 6001 1/2	6000-PID-002 P06	TI-6024	179	TAH-6024	210				°C

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
HP steam header	7000-PID-006 U03	TIC-7002	345	TAH-7002 TAL-7002	370 325				°C
HP steam header	7000-PID-006 U03	TIC-7003	345	TAH-7003 TAL-7003	370 325				°C
HP steam header	7000-PID-006 U03	TIC-7004	345	TAH-7004 TAL-7004	370 325				°C
HP steam header	7000-PID-006 U03	TI-7007	345	TAH-7007 TAL-7007	370 325				°C
HP steam export/import	7000-PID-007 U04	TI-7021	410	TAH-7021 TAL-7021	450 400				°C
HP import steam to header	7000-PID-007 U04	TIC-7025	345	TAH-7025 TAL-7025	370 325				°C
HP steam to export	7000-PID-007 U04	TIC-7026	410	TAH-7026 TAL-7026	430 400				°C
HP steam to export	7000-PID-007 U04	TIC-7027	410	TAH-7027 TAL-7027	430 400				°C
MP steam header	7000-PID-008 U05	TI-7031	SOR : 240 EOR : 252	TAH-7031 TAL-7031	280 220				°C
MP steam header	7000-PID-008 U05	TIC-7032	SOR : 260 EOR : 270	TAH-7032 TAL-7032	280 250				°C
MP steam header	7000-PID-008 U05	TIC-7033	SOR : 260 EOR : 270	TAH-7033 TAL-7033	280 250				°C
LP steam header	7000-PID-009 U06	TIC-7052	200	TAH-7052 TAL-7052	220 180				°C
LP steam header	7000-PID-009 U06	TIC-7053	200	TAH-7053 TAL-7053	220 180				°C
LP steam header	7000-PID-009 U06	TI-7056	189	TAH-7056	220				°C

Description	P&I	Normal Operation		Alarm System		Trip System			Unit
	Diagram	Instrument	Value	Instrument	Value	Instrument	Trip Value	Trip Group	
HP steam to E 2008	7000-PID-010 U07	TIC-7071	272	TAH-7071 TAL-7071	290 260	TSAH-7071	310	IS-2	°C
Deaerator vent steam to atmosphere	7000-PID-012 U09	TI-7098	Amb.	TAH-7098	100				°C
Methanol product temperature at B.L.	8000-PID-001	TIA-8301	48	TAH-8301 TAL-8301	75 5				°C
CSW temperature at B.L.	8000-PID-001	TIA -8302	48	TAH -8302 TAL -8303	60 5				°C
Cooling water make-up temperature at B.L.	8000-PID-001	TIA -8303	48	TAH -8304 TAL -8304	60 5				°C
POC temperature at B.L.	8000-PID-001	TIA -8304	5~35	TAH -8304 TAL -8304	60 5				°C
Boiler blow down temperature at B.L.	8000-PID-001	TIA -8306	48	TAH -8306 TAL -8306	70 40				°C
COC temperature at B.L.	8000-PID-001	TIA -8307	48	TAH -8307 TAL -8307	60 5				°C
Natural gas temperature at B.L.	8000-PID-001	TIA -8308	25~37	TAH -8308 TAL -8308	52 5				°C
Methanol product temperature at B.L.	8000-PID-001	TIA -8309	47	TAH -8309 TAL -8309	75 5				°C

Preliminary Plant Operation Manual

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Chapter 9 Analytical Manual

REV.	DATE	PURPOSE OF ISSUE	PREPARE	CHECK	REVIEW	APPROVE
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9 Analytical manual

9.1 Introduction

The present manual deals with the sampling and the analytical laboratory methods, which must be applied, in most cases on a regular basis, in order to check the various streams and thus the operation of the methanol plant.

It is essential that the collected samples are representative, meaning that the sampling is performed correctly.

Many samples are subject to ageing, so the analysis should be performed immediately upon sampling.

Most of the analyses are carried out in the laboratory. Sampling and analyses in the laboratory are usually made on a regular basis, but certain analyses are only required under particular operating conditions such as start-up.

Several measurements of the concentration of specific components can conveniently be made by "sniffer" tubes supplied by specialist manufacturers.

Some analyses are made and continuously registered by automatic analysers installed in the plant. However, the automatic analysers must be checked from time to time by laboratory analyses, especially during start-up. Also, laboratory analyses must be made during maintenance and repair of the automatic analysers.

In section 2 of this chapter, a survey is given of the scope of analyses, streams to be analysed, sample points, frequencies of analyses, and the analytical methods to be used.

A summary of various laboratory analytical methods is given in *section 4*. For a detailed description of the analytical methods, reference is made either to a standard, a book or to the Topsøe analytical methods attached in the appendix. The standards and books referred to are needed to get a complete description of the analytical methods. They should be procured and be part of the instructions for the laboratory of the plant.

The frequency of analysis is indicated in section 2. The term ‘as required’ means: When necessary during start-up, at operating disturbances, or in case of special investigations.

The frequencies stated are indicative only and may be changed according to experience and requirement.

During start-up and restart, the analyses that give the development in operating conditions must be made regularly performed in order to enable the operators to achieve the transition from start-up to normal operation in a controlled way.

Methods for analyses of streams in units supplied under separate license will be given in the manuals for these units.

9.2 Survey of scope of analyses

	Sample point position	Analyses	Analytical methods No.	Frequency
CWR	Cooling water return pipe（AP 0501）	pH： suspended solids turbidity conductivity petroleum Cl^- total iron total alkalinity (by CaCO3) Ca hardness+MO alkalinity (by CaCO3) free residual chlorine SO_4^{2-}	ASTM D1293 ASTM D5907 ASTM D7315 Topsøe AM-1191 ASTM D3921 ASTM D 4327 Topsøe AM-1026 ASTM D1067 ASTM D1126 ASTM D1253 ASTM D 4327	every shift 1~2/month every shift every shift daily daily daily daily daily daily daily
RO waterr	Make-up water pipe（AP 0502）	pH： suspended solids turbidity conductivity petroleum Cl^- total iron total alkalinity (by CaCO3) Ca hardness+MO alkalinity (by CaCO3) free residual chlorine SO_4^{2-}	ASTM D1293 ASTM D5907 ASTM D7315 Topsøe AM-1191 ASTM D3921 ASTM D 4327 Topsøe AM-1026 ASTM D1067 ASTM D1126 ASTM D1253 ASTM D 4327	every shift 1~2/month every shift every shift daily daily daily daily daily daily daily

	Sample point position	Analyses	Analytical methods No.	Frequency
CWS	Cooling water supply pipe(AP 0503)	pH: suspended solids turbidity conductivity petroleum Cl^- total iron total alkalinity (by CaCO3) Ca hardness+MO alkalinity (by CaCO3) free residual chlorine SO_4^{2-}	ASTM D1293 ASTM D5907 ASTM D7315 Topsøe AM-1191 ASTM D3921 ASTM D 4327 Topsøe AM-1026 ASTM D1067 ASTM D1126 ASTM D1253 ASTM D 4327	every shift 1~2/month every shift every shift daily daily daily daily daily daily daily
Natural gas	Inlet methanol plant (AP-1002)	H_2S Total sulphur Composition Heating value Specific gravity	ASTM D6228\ASTM D5504 ASTM D6228\ASTM D5504 ASTM D 1945 ASTM D 3588 ASTM D 3588	Every shift Every shift Every shift Every shift Every shift
Natural gas, hydrogenated	Downstream R 1001 (AP-1036)	H_2S Total sulphur	ASTM D6228\ASTM D5504 ASTM D6228\ASTM D5504	Every shift Every shift
Natural gas, desulphurised	Downstream R 1002 1 (AP-1040)	H_2S Total sulphur	ASTM D6228\ASTM D5504 ASTM D6228\ASTM D5504	Every shift Every shift
	Downstream R 1002 2 (AP-1046)	H_2S Total sulphur	ASTM D6228\ASTM D5504 ASTM D6228\ASTM D5504	Every shift Every shift
Natural gas	R1002 1（AP1039）	H_2S Total sulphur	ASTM D6228\ASTM D5504 ASTM D6228\ASTM D5504	Weekly Weekly
Natural gas	R1002 2（AP1044）	H_2S Total sulphur	ASTM D6228\ASTM D5504 ASTM D6228\ASTM D5504	Weekly Weekly

	Sample point position	Analyses	Analytical methods No.	Frequency
HP steam	HP steam to R 2004(AP-2031)	Conductivity TDS SiO_2 SO_4^{2-} Cl^- Na^++K^+	Topsøe AM-1191 ASTM D5907 Topsøe AM-1077 ASTM D 4327 ASTM D 4327 ASTM D 3561	Daily As required Weekly Weekly Weekly Weekly Weekly
Flue gas	Exit Flue gas blower F 2001 at stack (AP-2160)	O_2 CO_2 CO SO_2, SO_3 NO_X	flue gas analyser flue gas analyser flue gas analyzer flue gas analyser flue gas analyzer	Weekly Weekly Weekly Weekly Weekly
Flue gas	Inlet waste heat section（AP-2222）	O_2 CO_2 CO SO_2, SO_3	flue gas analyser flue gas analyser flue gas analyzer flue gas analyser	Weekly Weekly Weekly Weekly
Process gas	Downstream of prereformer R 2003 (AP-2267)	Composition	ASTM D 1946	Daily
Process gas, prereformed	In prereformer In R 2003 (AP-2266)	Higher hydrocarbons Steam-to-carbon ratio	ASTM D 1946* Topsøe AM-1160	Daily Daily
Flue gas	Outlet combustion chamber (AP-2294)	O_2 CO_2 CO SO_2, SO_3	flue gas analyser flue gas analyser flue gas analyzer flue gas analyser	Weekly Weekly Weekly Weekly
Flue gas	Outlet combustion chamber (AP-2296)	O_2 CO_2 CO SO_2, SO_3	flue gas analyser flue gas analyser flue gas analyzer flue gas analyser	Weekly Weekly Weekly Weekly
Process gas	Downstream of primary reformer H 2001 (AP-2306)	Composition	ASTM D 1946	Daily

	Sample point position	Analyses	Analytical methods No.	Frequency
HHP steam	HHP steam from steam drum D 2001 （AP-2380）	Conductivity TDS SiO_2 SO_4^{2-} Cl^- Na^++K^+	Topsøe AM-1191 ASTM D5907 Topsøe AM-1077 ASTM D 4327 ASTM D 4327 ASTM D 3561	Daily As required Weekly Weekly Weekly Weekly Weekly
Boiler blow-down of D 2001	Exit HHP steam drum D 2001 （AP-2383）	pH Conductivity TDS SiO_2 N_2H_4 PO_4^{3-} Fe Cu^{2+} SO_4^{2-} Cl^- Na^++K^+ NH_3	ASTM D 1293 Topsøe AM-1191 ASTM D5907 Topsøe AM-1077 ASTM D 1385 ASTM D 4327 Topsøe AM-1026 Topsøe AM-1021 ASTM D 4327 ASTM D 4327 ASTM D 3561 ASTM D1426	Daily Daily Daily Daily As required Daily Daily Daily Weekly Weekly As required Weekly
Synthesis gas in front-end	Downstream of D 2005 (AP-2480)	Composition H_2S Cl^-	ASTM D 1946* ASTM D6228\ASTM D5504 ASTM D 4327	As required As required As required
Purge gas	Purge gas to burners（AP-2539）	Composition CH_4O	ASTM D 1946* SP-693-EN	Weekly Weekly
Nitrogen for start-up & shut-down	Nitrogen from D 2005（AP-2571）	Composition	ASTM D 1946*	As required
Synthesis gas in loop	Inlet synthesis gas compressor C 3001（AP-3005）	Composition H2S+COS	ASTM D 1946* ASTM D6228\ASTM D5504	Every shift Every shift
Hydrogen for start-up	Inlet to C 3002（AP-3019）	Composition	ASTM D 1946*	As required
Synthesis gas in loop	Recycle gas exit HP separator D 3001（AP-3019）	Composition	ASTM D 1946*	Every shift

	Sample point position	Analyses	Analytical methods No.	Frequency
Synthesis gas in loop	Make up/ recycle gas from C 3001/ C 3002(AP-3022)	Composition	ASTM D 1946*	Every shift
MP steam	MP steam from MP steam drum D 3003（AP-3049）	Conductivity TDS SiO_2 SO_4^{2-} Cl^- Na^++K^+	Topsøe AM-1191 ASTM D5907 Topsøe AM-1077 ASTM D 4327 ASTM D 4327 ASTM D 3561	Daily As required Weekly Weekly Weekly Weekly
Boiler blow-down of D 3003	Exit HHP steam drum D 3003（AP-3054）	pH Conductivity TDS SiO_2 N_2H_4 PO_4^{3-} Fe Cu^{2+} SO_4^{2-} Cl^- Na^++K^+ NH_3 HPO_4^{2-} HCN HCOOH	ASTM D 1293 Topsøe AM-1191 ASTM D5907 Topsøe AM-1077 ASTM D 1385 ASTM D 4327 Topsøe AM-1026 Topsøe AM-1021 ASTM D 4327 ASTM D 4327 ASTM D 3561 ASTM D1426 ASTM D 4327 ASTM D 2036 Topsøe AM-1434	Daily Daily Daily Daily As required Daily Daily Daily Weekly Weekly As required Daily Daily As required As required
Synthesis gas in loop	Exit methanol reactor R 3001 1（AP-3074）	Composition CH_3OH	ASTM D 1946* SP-693-EN	Weekly
Synthesis gas in loop	Exit methanol reactor R 3001 2（AP-3078）	Composition CH_3OH	ASTM D 1946* SP-693-EN	Weekly Weekly
Synthesis gas in loop	Exit methanol reactor R 3001 2（AP-3082）	Composition CH_3OH	ASTM D 1946* SP-693-EN	Weekly Weekly

	Sample point position	Analyses	Analytical methods No.	Frequency
Synthesis gas in loop	Inlet methanol reactor R 3001 1/2/3 (AP-3114)	Composition	ASTM D 1946*	Every shift
Purge gas	Exit LP separator D 3002（AP-3195）	Composition	ASTM D 1946*	Weekly
Raw methanol	Exit LP separator D 3002（AP-3197）	Impurities pH	ASTM E346 ASTM D 1293	As required As required
cooling water	outlet from E3003 1 the drain nozzle（AP-3120）	methanol	ASTM D3695	every shift
cooling water	outlet from E3003 2 the drain nozzle（AP-3121）	methanol	ASTM D3695	every shift
cooling water	outlet from E3003 3 the drain nozzle（AP-3122）	methanol	ASTM D3695	every shift

	Sample point position	Analyses	Analytical methods No.	Frequency
methanol	TK4001A/B（AP-4001A/B）	Acetone and aldehydes Acetone Ethanol Acidity (as acetic acid) Appearance and hydrocarbons Carbonizable substances colour Distillation range Specific gravity, max methanol Non-volatile content Odor Permanganate fading time Water content Alkalinity (as ammonia) Iron Chloride TMA Total sulphur	ASTM E346，ASTM E2313 O-M-232，ASTM E346 ASTM E346 ASTM E346，ASTM D1613 ASTM E346，O-M-232 ASTM E346，ASTM D1209 ASTM E346 ASTM E346 ASTM E346, ASTM D891 100%-Impurities ASTM D1353 ASTM D1296 ASTM E346, ASTM D1363 ASTM E346 ASTM D1614 Topsøe AM-1026 ISO 7393-2 ASTM E346 ASTM D5453	As required As required
waste methanol	D4001（AP-4002）	Methanol Water other alcohol other composition	ASTM E346 ASTM E346 ASTM E346 ASTM E346	As required As required As required As required
Methanol tank vent	Exit vent wash column T 5004 (AP-5021)	Methanol Hydrocarbons, C1-C9	SP-693-EN Topsøe AM-1132	As required As required

	Sample point position	Analyses	Analytical methods No.	Frequency
Raw methanol	Exit raw methanol buffer tank TK 5001 (AP-5010)	pH	ASTM D 1293	As required
	Exit raw methanol pump P 5001 A/B (AP-5019)	Impurities Water pH Hydrocarbons Amines	ASTM E346 ASTM E 203 ASTM D 1293 TOPSOE AM-1158 TOPSOE AM-1304	Every day Every day Every shift As required As required
Stabilized methanol	Bottom: Exit stabilizer column T 5001 (AP-5044)	Impurities Water pH Hydrocarbons Amines	ASTM E346 ASTM E 203 ASTM D 1293 TOPSOE AM-1158 TOPSOE AM-1304	Weekly Weekly Every shift As required As required
	Profile: Various trays in stabilizer column T 5001 (AP-5052/5053/5055/5056/5057)	Impurities Water	ASTM E346 ASTM E 203	As required As required
Stabilizer reflux	Exit stabilizer column OH accumulator D 5001 (AP-5098)	Impurities Water Hydrocarbons Amines	ASTM E346 ASTM E 203 TOPSOE AM-1158 TOPSOE AM-1304	Weekly Weekly As required As required
Stabilizer OH gas	Exit OH gas condenser E 5010 (AP-5112)	CO_2, CH_4 Methanol + impurities Hydrocarbons, C1-C9	ASTM D 1946* SP-693-EN TOPSOE AM-1132	Daily Daily As required
LP Column methanol	Profile: Various trays in LP methanol column T 5002 (AP-5171/5173/5174/5175/5180/5167)	Composition Water	ASTM E346 ASTM E 203	As required As required
LP Column methanol	Bottom: LP Methanol Column T 5002 (AP-5164)	Composition Water pH	ASTM E346 ASTM E 203 ASTM D 1293	Every shift As required Daily

	Sample point position	Analyses	Analytical methods No.	Frequency
LP Column methanol	Reflux exit LP column OH accumulator D 5002 (AP-5218)	Impurities Water Hydrocarbons Amines Purity	ASTM E 346 ASTM E 203 TOPSOE AM-1158 TOPSOE AM-1304 ASTM E 346	Every shift Weekly As required As required Every shift
LP Column methanol	OH gas exit LP column accumulator (AP-5208).	Methanol + impurities	SP-693-EN	Daily
LP Column methanol	Product methanol from LP methanol column, D 5002 (AP-5164)	Purity	ASTM E346	Every shift
MP Column methanol	Profile: Various trays in MP methanol column T 5003 (AP-5261/5262/5264/5265/5269)	Composition Water	ASTM E346 ASTM E203	As required As required
	Product methanol MP methanol column T 5003, exit D 5003 (AP-5326)	Purity	ASTM E346	Every shift
	Product methanol to storage (AP-5382/8383)	Purity Amines	ASTM E346 TOPSOE AM-1304	As required As required
	Product methanol to storage (AP-5431)	Purity Amines	ASTM E346 TOPSOE AM-1304	As required As required
MP methanol column condensate	Bottom: Exit MP methanol column T 5003 (AP-5274)	Composition Water pH Methanol HCOO- HCN	ASTM E346 ASTM E 203 ASTM D 1293 ASTM D3695 Topsøe AM-1434 ASTM D 2036	As required As required As required Daily As required As required
Higher alcohols/liquid off-stream	Draw-off trays in MP methanol column T 5003 (AP5266/5267/5268)	Composition Water	ASTM E346 ASTM E 203	As required As required

	Sample point position	Analyses	Analytical methods No.	Frequency
	Exit liquid off-stream tank TK 5003 (AP-5452)	Composition Water	ASTM E346 ASTM E 203	Daily Daily
Methanol Water Gas	Outlet E5024 1 shell side(AP-5060)	CO H2	portable combustible gas tester	Daily
Methanol Water Gas	Methanol Water Gas (AP-5061)	CO H2	portable combustible gas tester	Daily
Methanol Water Gas	Outlet E5023 shell side (AP-5078)	CO H2	portable combustible gas tester	Daily
Methanol/Water Liquid	Outlet D5011（AP-5701）	Methanol Water Impurities	ASTM E 346 ASTM E 203 ASTM E346	As required As required As required
Process condensate	Excess condensate from TK 7002 (AP-7101)	HCOO- HCN NH_3 Na^+	Topsøe AM-1434 ASTM D 2036 ASTM D1426 ASTM D 3561	As required As required As required As required
Process condensate	Blowdown/process condensate from D 6001 (AP-6059)	pH Conductivity CH_3OH SiO_2 NH_3 Fe Cu^{2+} SO_4^{2-} Cl^- Na^+, K^+	ASTM D 1293 Topsøe AM-1191 ASTM D3695 Topsøe AM-1077 ASTM D1426 Topsøe AM-1026 Topsøe AM-1021 ASTM D 4327 ASTM D 4327 ASTM D 3561	Daily Daily As required Daily Daily Weekly Weekly Weekly Weekly Daily
Boiler feed water	Boiler feed water outlet deaerator D 7001 (AP-7100)	pH Conductivity O_2 N_2H_4	ASTM D 1293 Topsøe AM-1191 ASTM D 888 ASTM D 1385	Every shift Every shift Daily Daily
HHP boiler feed water	HHP boiler feed water to header (AP-7126)	O_2 N_2H_4	ASTM D 888 ASTM D 1385	Daily Daily

	Sample point position	Analyses	Analytical methods No.	Frequency
condensate	water inlet pipe of condensate （AP-7201/7203）	Conductivity pH： iron oil COD	Topsøe AM-1191 ASTM D1293 Topsøe AM-1026 ASTM D3921 ASTM D1252	Every shift Every shift Daily Daily Daily
second class Demineralized water	water outlet pipe of mixed bed(AP-7202A/ 7202B)	Conductivity pH： iron	Topsøe AM-1191 ASTM D1293 Topsøe AM-1026	Every shift Every shift Daily
second class Demineralized water	water outlet pipe of Demineralized water pump(AP-7204)	Conductivity pH： iron SiO_2	Topsøe AM-1191 ASTM D1293 Topsøe AM-1026 SiO2 tester	Every shift Every shift Daily Daily
2~5% HCl	water from acid ejector (HCl) （AP-7205）	HCl	Note2	Regularly
2~5% NaOH	water from alkali ejector (NaOH) （AP-7206）	NaOH	Note3	Regularly

9.3 Typical list of laboratory equipment

Ser.No	Name	Specification	Unit	Q'TY	Remarked
1	balance	*Sartorius BSA224S-CW*	set	1	
2	balance	*Sartorius BSA8201*	set	1	
3	barometer	*Omega HHP241-015A*	set	1	
4	conductivity meter	*JENWAY 4510*	set	2	
5	densimeter	*KEM, model: DA-640*	set	1	
6	DEW point meter	*SADP Y*	set	1	
7	flue gas analyzer	*LANCOM 4*	set	1	
8	gas meter	*Shinagawa seiki DC-1C*	set	1	

Ser.No	Name	Specification	Unit	Q'TY	Remarked
9	gas meter	*G.H.ZEAL LTD. model: NO.DM3A*	set	1	
10	Hot plate	*CERAN-4A*	set	2	
11	ICE cube maker	*Ziegra type: ZBE 110-35*	set	1	
12	karl fisher titrator	*Metrohm, model: 831*	set	1	
13	Muffle furnace	*nabertherm LE 6/11*	set	1	
14	oven	*nabertherm TR60*	set	1	
15	Oxygen advanced instruments + probe	*ALL GPR-1200+GPR-12-333*	set	1	
16	pH meter	*Metrohm,913 pH meter*	set	1	
17	Refrigerator	*AQUALYTIC, EX220*	set	1	

Ser.No	Name	Specification	Unit	Q'TY	Remarked
18	thermostatic water bath	*JULABO, CD-300F*	set	1	
	low temprature				
19	titrator	*KEM, AT-710S*	set	1	
20	total sulphure analyzer	*Trace Elemental Xplorer TS-UV*	set	1	
21	UV-VIS spectrophotometer	*Agilent CARY60*	set	1	
22	water deionizer	*ELGA PURELAB Option Q7*	set	1	
23	COD determinates APP	*HACH, DRB200+DR 6000*	set	1	
24	magnetic stirrer	*Velp Sientifica (AGE)*	set	4	
25	magnetic stirrer with heater	*Velp Sientifica, model: (ARE)*	set	4	
26	water bath	*FALC , model: WB U4*	set	1	

Ser.No	Name	Specification	Unit	Q'TY	Remarked
27	Ion chromalograph	*Metrohm , model: 883*	set	1	
28	Atomic absorption spectrometer	*.AGILENT 240FS*	set	1	
29	Centrifuge	*Heraeus Multifuge X1*	set	1	
30	Hydrogen generator	*PEAK SientificPrecision Hydrogen Trace 500cc*	set	1	
31	Nitrogen generator	*PEAK Sientific, model:NG3000A*	set	1	
32	Electric Heater	*Xi'an Bo'ao ZNHW*	set	1	
33	SiO_2 tester	*Shidai Xinwei TP306*	set	1	
34	ultrasonic washer	*.Kunshan KH3200DE*	set	1	
35	Oil Content Analyzer	*Horiba OCMA-550*	set	1	

Ser.No	Name	Specification	Unit	Q'TY	Remarked
36	Drager Gas Detector	*Drager Accuro*	set	1	
37	GC-1	*analyte:refinery gas, NG, process gas*	set	1	
		Agilent 7890B			
	GC-2	*analyte:metanol in gas sample and water*	set	1	
		Agilent 7890B			
	GC-3	*analyte:Impurity metanol (Ethanol,aceton, hydrocarbons)in product*	set	1	
		Agilent 7890B			
	GC-4	*analyte:TMA in methanol*	set	1	
		Agilent 7890B			
	GC-5	*analyte:sulfur*	set	1	
		Agilent 7890B			

Ser.No	Name	Specification	Unit	Q'TY	Remarked
38	vacuum source	*Tianjin auto science AP-9925N*	set	1	
39	turbidimeter	*Shidai Xinwei TP309*	set	1	
40	dissolved oxygen analyzer	*Shidai Xinwei TP350*			
41	GC Spare part	*AGILENT*			
Gas management					
41-1	*CP17988*	*Gas Clean carrier gas kit for 7890 (1/8 in*	*SET*	*3*	
41-2	*CP736530*	*Gas Clean FID filter kit (includes 4 filters for carrier gas and detector gases, 1/8 in)*	*KIT*	*3*	
Replacement filters					
41-3	*CP17973*	*Gas Clean carrier gas filter*	*PK*	*5*	
41-4	*CP17970*	*Gas Clean oxygen filter*	*PK*	*5*	
41-5	*CP17971*	*Gas Clean moisture filter*	*PK*	*5*	
41-6	*CP17972*	*Gas Clean hydrocarbon filter*	*PK*	*5*	
ADM flow meters					
41-7	*220-1171-E*	*ADM 2000, battery or 120 VAC, with*	*SET*	*3*	
41-8	*G3388B*	*Gas leak detector, handheld electronic*	*SET*	*1*	

Ser.No	Name	Specification	Unit	Q'TY	Remarked
Ferrules, 10/pk					
41-9	*5181-3323*	*Ferrule id 0.4 mm, column id 0.1, 0.2,0.25 mm*	*PK*	*3*	
41-10	*5080-8853*	*Ferrule id 0.5 mm, column id 0.1, 0.2,0.25, 0.32 mm*	*PK*	*3*	
41-11	*5062-3514*	*Ferrule id 0.5 mm, column id 0.32 mm*	*PK*	*3*	
41-12	*5062-3512*	*Ferrule id 0.8 mm, column id 0.45,0.53 mm*	*PK*	*3*	
41-13	*5080-8773*	*Ferrule id 1.0 mm, column id 0.53 mm*	*PK*	*3*	
Column installation					
41-14	*5181-8830*	*Universal column nut*	*PCS*	*10*	
41-15	*19251-80680*	*Column ferrule installation tool*	*PCS*	*10*	
41-16	*420-1000*	*Diamond-tipped column cutting pencil*	*PCS*	*10*	
Thermal Conductivity detector (TCD)					
41-17	*5182-9673*	*TCD Front Ferr for 0.53mm id col，10/PK*	*PK*	*3*	
41-18	*5182-9676*	*TCD Front Ferr for 0.32mm id col，10/PK*	*PK*	*3*	
41-19	*5190-9578*	*TCD Adapter for Flow Meter*	*SET*	*3*	
41-20	*CP17981*	*Gas Clean Filter Starter Kit for TCD/ECD*	*SET*	*1*	
41-21	*G1532-60675*	*TCD Replacement Cell 6890*		*1*	
41-22	*18710-60170*	*FID/TCD performance evaluat. sample kit*	*KIT*	*2*	
Non-stick inlet septa					

Ser.No	Name	Specification	Unit	Q'TY	Remarked
41-23	*5183-4757*	*11 mm certified BTO septa, 50/pk*	*PK*	*3*	
41-24	*5183-4761*	*11 mm long life septa, 50/pk*	*PK*	*3*	
Liners for split/splitless and multimode inlets					
41-25	*19251-60540*	*1/pk*	*PK*	*3*	
41-26	*5183-4691*	*5/pk*	*PK*	*3*	
41-27	*5183-4692*	*25/pk*	*PK*	*3*	
41-28	*5190-3172*	*100/pk*	*PK*	*3*	
Programmed temperature vaporizer inlet					
41-29	*5183-2037*	*Septumless head PTV inlet liner, multi baffled*		*2*	
41-30	*5188-5356*	*High temp PTV inlet liner*	*PK*	*2*	
Flame ionization detector (FID)					
41-31	*5020-8294*	*lanking plug, finger-tight style*	*SET*	*3*	
41-32	*G1531-80560*	*Jet, capillary, standard, 0.011 in tip*	*SET*	*3*	
41-33	*G1531-80620*	*High temperature jet, simdis, 0.018 in id tip*	*SET*	*3*	
41-34	*19244-80560*	*Jet, capillary, adaptable, 0.011 in id tip*	*SET*	*3*	
41-35	*18710-20119*	*Jet, packed, adaptable, 0.018 in id tip*	*SET*	*3*	
41-36	*19301-60660*	*FID flow measuring insert*	*SET*	*3*	
41-37	*9301-0985*	*FID cleaning kit*	*KIT*	*3*	

Ser.No	Name	Specification	Unit	Q'TY	Remarked
Flame Photometric Detector (FPD)					
41-38	*19256-60800*	*FPD ignitor replacement kit*	*SET*	*2*	
41-39	*19256-80030*	*First heat shield window*	*PCS*	*1*	
41-40	*0854-0141*	*Glow plug,*	*PCS*	*1*	
41-41	*19256-80560*	*Emission chamber*	*PCS*	*1*	
Valve Replacement Parts					
41-42	*5062-9509*	*6-port replacement valve WE series, Hastelloy C, 400 psi, 225 °C*	*SET*	*2*	
41-43	*5062-9508*	*port replacement valve WE series, -400 psi, 225 °C*	*SET*	*2*	
42	*sodium meter*	*shaihai Leici DWS-51*	*set*	*1*	
43	*Methanol Distillation Range Test Device*	*Shidai Xinwei TP662*	*set*	*1*	

9.4 Appendices

1. 2000/E List of analytical methods
2. 1021/E Determination of Copper in Water
3. 1026/E Determination of Iron in Water
4. 1077/E Determination of Soluble Silica in Water
5. 1132 Determination of Hydrocarbons C1-C9 in Gases
6. 1158 Determination of Trace Amounts of Hydrocarbons in Methanol
7. 1160/E Determination and calculation of the steam to carbon ratio for reformer feed gas
8. 1191/E Conductance (specific) of boiler water and steam condensate
9. 1434/E Determination of formate, formamide, acetate and fluoride by ion chromatography
10. 1304 Determination of Impurities in Methanol by Ion Chromatography
11. SP-693-EN Determination of Dimethylether (DME) and Methanol in Gases (LP 1131)
12. Note 2:

Hydrochloric Acid is determined by titration with standard sodium hydroxide using phenolphthalein indicator solution.

12.1 The standard sodium hydroxide （1mol/L）is prepared according to ASTM E200

12.2 Phenolphthalein Indicator Solution (10 g/L)—Dissolve 1 g of phenolphthalein in 100 mL of ethanol (95 %).

12.3 Procedure: add 2 drops of phenolphthalein indicator solution to the specimen and titrate with standard NaOH solution to a pink color or accord to the indication of titrator.

12.4 Calculate the concentration of the HCl solution, as follows:

$$C1 = \frac{C2 * V2}{V1}$$

where:

C1 = molar concentration of HCl solution, mol/L

C2 = molar concentration of NaOH solution, mol/L

V1 = volume of HCl solution, mL

V2 = volume of NaOH solution consumed, mL

13. Note 3:

Sodium hydroxide is determined by titration with standard hydrochloric acid using methyl red indicator solution.

13.1 The standard hydrochloric acid solution （1mol/L）is prepared according to ASTM E200.

13.2 Methyl Red Indicator Solution (1 g/L)—Dissolve 1 g of methyl red in 1 L of ethanol (95 %).

13.3 Procedure: add 2~3 drops of methyl red indicator solution to the specimen and titrate with standard HCl solution to a red color

13.4 Calculate the concentration of the HCl solution, as follows:

$$C1 = \frac{C2 * V2}{V1}$$

where:

C1 = molar concentration of NaOH solution, mol/L

C2 = molar concentration of HCl solution, mol/L

V1 = volume of NaOH solution, mL

V2 = volume of HCl solution consumed, mL

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Chapter 10 Safety Instructions

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10 Safety instructions

10.1 General remarks

General rules for protection of personnel from moving machinery, electricity, hot equipment and risk of falling should be observed.

The plant includes pipes and equipment containing water, steam and gas at high temperatures and pressures. Protection of personnel from burns caused by these substances at places where they are vented, for example, should be provided.

The particular hazards presented by this plant are poisoning, fire and explosion due to the materials handled. The fact that the plant is an open-air installation reduces the effects of these risks, and any unnecessary housing or casing of the equipment should be avoided. Unnecessary use or storage of combustible materials at the site should be avoided.

Hand-operated fire extinguishers, fire carpets and emergency showers should be installed according to the requirements and recommendations of the relevant authorities. Extinguishers should be used to fight small fires and showers used when clothing has caught fire or if there are chemical burns. Fire carpets may be used to extinguish fire in clothing and/or the person in question must be placed under a shower as quickly as possible.

If there is a fire, it is normal to use water to keep the surroundings cool until the leak, which caused the fire, can be found and blocked off. If the fire is extinguished before the leak is stopped, it may create an explosion hazard.

Eye washers are to be installed where relevant.

The performance of safety equipment, including showers and eye washers, should be checked regularly.

If a person becomes unconscious due to poisoning, artificial respiration should be arranged.

- Smoking should be prohibited.
- All sparks should be avoided where combustible gases may be present.
- Welding should be performed only with the proper consideration for the risks as outlined above.

The safety procedures described in this chapter are those which specifically apply to potential hazards in the below units:

- Desulphurization.
- Reforming.
- Waste heat steam generation.
- Methanol synthesis.
- Methanol distillation and storage.

It is assumed that safety practices with general application or with specific application to other

processes are described elsewhere.
The above general practices include the following:

- Traffic safety.
- Fire-fighting.
- First aid.
- Work permits procedures.
- Vessel entry procedures.
- Sampling procedures.

It is recommended that a system is worked out, which always registers who is where in the plant.

10.2 Equipment for protection of personnel

For protection of personnel, the following equipment should be available:

a) Safety helmets and shoes, which should be worn by personnel whenever they are in the plant.

b) Goggles to protect the eyes against harmful liquids and gases.

c) Gloves for protection against acid and alkaline solutions (rubber gloves) or heat (asbestos gloves).

d) Respiration masks with filters for dust and gas masks for poisonous matters (methanol, etc.).

e) Positive pressure self-contained breathing apparatus (SCBA) for protection against CO poisoning.

f) Various clothing such as boots, hoods, aprons or complete suits for protection against acid and alkaline solutions, catalyst dust, heat, etc.

g) Ear muffs, ear plugs or other devices for protection against noise.

h) Instruments for measuring of explosive concentrations.

i) Dräger equipment (tubes and "sniffers") for measuring poisonous gases, such as CO and methanol.

10.3 Toxicity of chemicals and catalysts hazardous components

The primary hazardous components normally present within the battery limits of the unit are methane, hydrogen, carbon monoxide, methanol and oxygen.

Information on the components can be found in the ‘Hazardous substances data bank’ (HSDB) at the National Library of Medicine (NLM):

http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

Main components	**CAS no.**
Carbon monoxide	630-08-0
Methanol	67-56-1
Hydrogen	1333-74-0
Methane	74-82-8
Ethane	74-84-0
Propane	74-98-6
Carbon dioxide	124-38-9
Hydrogen sulphide	7783-06-4
Hydrazine	302-01-2
Ammonia/ammonia solution	7664-41-7 /1336-21-6
Sodium hydroxide	1310-73-2

10.3.1 Amine

Amine in the form of ammonia solution is used for control of acidity in the deaerator.

Great care should be taken to avoid either direct or airborne exposure of skin, mucous membranes or eyes to amine solutions.

When handling amine, all personnel should wear rubber suits covering their whole body, rubber gloves and self-contained breathing apparatus.

10.3.2 Hydrazine

Hydrazine is used in the BFW preparation for control of the oxygen content in the deaerated BFW. The commercial grade of the hydrazine is a solution of 16% by weight of hydrazine in water.

Great care should be taken not to expose the skin, the mucous membranes and the eyes to hydrazine solution either airborne or directly.

When handling hydrazine, all personnel should wear rubber suits covering the whole body, rubber gloves and self-contained breathing apparatus.

10.3.3 Phosphate solution

Aqueous phosphate solution is used for pH control in the steam drums.

Great care should be taken not to expose the skin, the mucous membranes and the eyes, to phosphate solutions, either airborne or directly.

When handling phosphate solutions, all personnel should wear rubber suits covering the whole body, rubber gloves and self-contained breathing apparatus.

10.3.4 Caustic solution

Caustic solution (sodium hydroxide) is used for control of pH of the raw methanol in to the distillation section.

Great care should be taken not to expose the skin, the mucous membranes and the eyes, to caustic solutions, either airborne or directly.

When handling caustic solutions, all personnel should wear rubber suits covering the whole body, rubber gloves and self-contained breathing apparatus.

10.3.5 Catalyst

The catalysts in the various reactors contain nickel and other metal salts, which in the form of dust can be poisonous and irritating if brought into contact with skin, eyes or mucous membranes.

When the plant is running, catalysts are inaccessible: thus there is no hazard involved. However, when loading or unloading catalysts, it is vital for the personnel doing the work to be dressed in adequate protective clothing, including dust masks, eye goggles and gloves.

Safety data sheets for the individual catalysts used in the plant, including toxicological information for individual components, are included as an appendix to this chapter.

10.4 Explosive limits and auto ignition temperatures

Below are given the auto ignition temperatures and explosive limits in atmospheric air of the most common gases in the methanol plant:

	Flammable limits	**Auto ignition temp.**
Hydrogen	4.0 - 75 vol%	500°C
Carbon monoxide	12.5 - 74 vol%	700°C
Hydrogen sulphide	4.0 - 44 vol%	260°C
Methane	5.0 - 15.0 vol%	537°C
Ethane	3.0 - 12.5 vol%	472°C
Propane	2.1 - 9.5 vol%	450°C
Methanol	6.0 - 36.5 vol%	464°C
Ethanol	3.3 - 19.0 vol%	363°C
Dimethyl ether	3.4 – 26.7 vol%	350°C
Methyl formate	4.5 - 23.0 vol%	449°C
Propanol	2.2 – 14.0 vol%	371°C
Isobutanol	1.2 – 10.9 vol%	415°C

10.5 Appendices

Material safety data sheets for catalysts

- TK-261 Hydrogenation catalyst
- HTZ-51 Sulphur absorption catalyst
- AR-401 Steam reforming catalyst
- R-67-7H Steam reforming catalyst
- RKA-02 Steam reforming catalyst
- RKS-2-7H Steam reforming catalyst
- RKS-2 Steam reforming catalyst
- MK-151 Methanol catalyst