Haldor Topsøe A/S

HAZOP

5000 MTPD Methanol plant, Bandar Assaluyeh, Iran

July 2010

COWI

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1 Executive summary

COWI has on request of Haldor Topsøe A/S facilitated a HAZOP study of a Methanol plant, designed by Haldor Topsøe A/S (HTAS). The unit is to be operated by Middle East Kimiaye Pars Company, Iran.

The study meetings were conducted in Haldor Topsøe A/S' office in Lyngby from the 9th until 28th of June 2010. The HAZOP participants represented three companies: MEKPCO, MJPC and HTAS

The HAZOP study was based upon process descriptions, PFD's, and P&ID's.

The objective of the HAZOP study was to identify scenarios leading to loss of containment or damage to equipment with potential to cause major shutdowns. Preventive and mitigating measures were identified.

Recommendations were given to improve the design. A full list of the 125 (19 are duplicates) recommendations is given in Appendix B of this report.

The HAZOP was generally based upon normal operation.

2 Background

COWI has on request of HTAS facilitated a HAZOP study of a Methanol plant, designed by HTAS. The unit is to be operated by Middle East Kimiaye Pars Company, Iran.

The objective of the study was to identify scenarios, which can lead to a) loss of containment, or b) substantial damage to process equipment leading to major unintended shutdowns. Consequences of the identified scenarios were qualitatively expressed and preventive and mitigating measures were identified.

Appendix A contains the HAZOP sheets. Appendix B contains a full list of the 125 (19 are duplicates) recommendations.

2.1 Basis of the study

Basis for the HAZOP study was:

Process description (No. 4338384 WBS 40, Rev.1)

Process Flow Diagram drawing numbers 1338092-1338098 rev. 1, 1343963 rev 0.

Piping and Instrument Diagram drawing numbers 1341582-1341626 rev 1, 1341630-1341646 rev 1, 1341647 rev 0 (U18).

2.2 Scope

The HAZOP study comprised the main process from battery limit to battery limit. Utility systems were also considered, mainly water and steam systems. The effect of external fires on process equipment was not considered, apart from pressure relief of equipment.

The meetings were conducted in Haldor Topsøe A/S office in Lyngby from the 9th until 28th of June 2010. The participants were:

HTAS: Hans Pedersen
Lars Moerner
Lone Johnsen (part time)
Søren Toft (part time)

MJPC & MEKPCO:
M. Mavadati
M. Nabian
S. Shaker
H. Moayeri (part time)

COWI: Gunilla Kay Christiansen, HAZOP leader (9-16 June)
Finn Pedersen, HAZOP leader (18-28 June)
Birgitte Madsen, HAZOP secretary

2.3 Abbreviations

HTAS	Haldor Topsøe A/S
MEKPCO	Middle eats Kimiaye Pars Company
MJPC	Marjan Petrochemical Company
PID	Piping and Instrument Diagrams
BL	Battery limit
FO	Fails open
FC	Fails close
BFW	Boiler feed water
MeOH	Methanol

2.4 Nodes and deviations

The table below lists the nodes to which records were made in the HAZOP sheets. The nodes are marked on PIDs.

No	Node
1	Natural gas knock out drum (D1001)
2	Preheating (E2006/E2004), hydrogenation (R1001) and desulphurization (R1002 1/2
3	NG Saturation system (E6001, T6001, D6001)
4	S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)
5	Primary reformer (H2001)
6a	Secondary reformer (R2004)
6b	Waste heat boilers and steam super heaters (E2020, 2021 1/2/3)
7	Process gas cooling I (E2022 1/2 and D2002)
8	Process gas cooling II (E2023, D2003)
9	Process gas cooling III (E2024 1/2, D2004)
10	Process gas cooling IV (E2025, AE 2026, E2027, D2005)
11	Synthesis gas compressor (C3001/C3002)
12a	Synthesis loop (E3001 1, R3001 1)
12b	Synthesis loop (AE3002, E3003, D3001)
13	LP separator (D3002, X3001)
14	Raw methanol tank (TK5004)
15	Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)
16	LP Methanol Column (T5002, P5005 A/B)
17	MP methanol column (T5003, E5002, D5003, P5006, E5012)
18	Product polisher (X5002 A/B)
19	Product buffer tank and product pump (TK5002, P5008A/B)
20	Liquid off stream (E 5011, TK 5003, P 5009 A/B)
21	Bottom product to wash column T5004 (AE 5006, E5007, T5004)
22	Fuel gas to primary reformer
23	Flue gas system
24	Oxygen system
25	Demin water system
26	Deaerator
27	BFW pumps and distribution
28	HHP boiler (D2001, E2022 1/2)
29	HHP steam header
30	HP steam header
31	MP steam header
32	LP steam header
33	MP steam drum (D3003)
34	Blow down system
35	H_2 recycle system
36	Start up blower

37	General

High risk scenarios were identified along with the safeguards and has been marked with a * in the HAZOP sheet in the column named SR. The consequences of failure of the safeguards marked with a * will be evaluated at a later stage by HTAS.

Appendix A: HAZOP sheets

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MJPC & MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 1 Natural gas K.O. drum (D1001)	P&ID no.: P01	Intention: Knock out liquids	Date: 09.06.2010
	Design P/T: 60 barg, 85 C	Operating P/T: 52 barg ,40 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
No	Blocked inlet or blocked outlet	No consequences				
More (from BL)	Fully open outlet	No consequences				
Less		No consequences				
Parameter: Pressure		**Intention:**				
High	Failure of pressure control valve, PIC 1006	Exceeding design pressure down-stream of drum D1001 due to blocked outlet High pressure in drum due to external fire	PSV 1008 and 1009 PSV 1015	1. Maximum delivery pressure of NG at BL (60 barg) to be as-sured	MEKPCO / DAMAVAND	
Low	Low pressure from BL	No consequences				

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Level in drum D1001		**Intention:**				
High (in D1001)	Liquid in feed	Liquid carry over to reactors, potentially damage of catalyst	High level alarm, LI 1004 Trip on high level (stop downstream unit) LSAH			*
		Liquid carry over to fuel gas system leading to malfunction of burners.	Trip on high level (stop downstream unit) LSAH			*
Low (in D1001)	Open drain valve	Gas break-through to drain system.	Procedure to ensure level gauge is checked while draining	2. Drain valve to be visible from level gauge.	MEKPCO/detailed engineering	

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Node: 2 Preheating (E2006/E2004), hydrogenation (R1001) and desulphurization (R1002 1/2)	P&ID no.: P04, P12, P13	Intention: Preheating, hydrogenation and desulphurization of NG	Date: 09.06.2010
	Design P/T: 55 barg, 85 C upstream E2006, 375 C between E2006 and E2004, 410 C downstream E2004, H2 system: 60 barg, 100 C	Operating P/T: 50 barg, 40 C upstream E2006, 49.4 barg , 246 C between E2006 and E2004, 48.8 barg , 480 C downstream E2004 48.3 barg, 375 C between R1001 and R1002 2, 47.3 barg , 365 C out of R1002 2. H2 system: 55 barg, 48 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High flow (NG)	Higher delivery pressure Down stream flow control failure (open)	Reduced sulphur conversion. No consequence for this node.	Upstream pressure control valve, PIC 1006 Down stream flow control valve FIC 6070 Sulphur analyser, AI 1045			
High (H2)	Failure of inlet flow valve, FV 2150	No consequences				
No / Low (NG)	Failure of control valve down stream, FV 6070 Low pressure at BL	High temperature in coils, E2006 or E2004 (see high temp)	Temperature control, TIC 2220 FSAL 6070, low flow will trip plant	3. Open false air dampers on IS-1trip (on shutdown of system)	HTAS	*

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low flow during start up		High temperatures in coils	Venting during start up to create flow through system			
No / Low (H2/N2)	Failure of flow valve, FV 2150 Loss of H2 recycle gas pressure	Insufficient sulphur conversion. Damaging catalyst	Analyser AI 1045 downstream reactor			
Reverse flow (NG into H2 system)	Low pressure of H2	NG into H2 system	FIC 2150, low alarm on H2 inlet Check valve			
Reverse flow (H2 into NG)	Low pressure of NG	H2 into NG system. No consequence	Check valve at inlet to KO drum, D1001			

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse flow (liquid off stream into reactors)	No flow through desulphurzier	Liquid off stream into reactors. No consequences Evaporation of MeOH				
High (R1001)	See high flow above	Slip of sulphur from R1002	High margin on flow			
Low (R1001)		No consequences for the catalyst				
High (R1002)	See high flow above	More flow or more sulphur will change life time of the catalyst in R1002	Regular sampling for sulphur content in analysis point in bottom of R1002 1, AP 1039			
Low (R1002)		No consequences for the catalyst in R1002				

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High (inside and out of E2006)	Low NG flow Open bypass, TV 2220	Exceeding design temperature	High temperature alarm, TI 2148 (outlet of preheat coil E2006)			
	Closure of throttle valve at E2006 inlet	High temperature (not exceeding design temp)	Minimum stop at throttle valve Sufficient design temperature on preheat coil E2006 Temperature alarm, TI 2148 (outlet of preheat coil E2006)	4. Check minimum flow rate required	HTAS	
High (out of E2004)	Failure of temperature regulation and low flow of NG	Exceeding design temperature on piping after E2004	Increased temperature for short time does not damage catalyst	5. Add high temperature alarm on TIC 2220 (E2004 outlet)	HTAS	

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
	Olefins in feed stock could increase temperature in hydrogenator R1001	Damage of catalyst	High temperature alarms, TI 1034 and TI 1035 on hydrogenator			
Low	Low flue gas temp	Insufficient sulphur conversion				
High (R1001)	See high temperature above	Damage of catalyst in hydrogenator	The catalyst in the hydrogenator is able to run up to 400 C			
Low(R1001)	See low temperature above	Decreasing catalyst activity in hydro-genator R1001, the activity decreases significantly at operation below 330 C, the activity is very low at temperatures below 300 C				
Low temp and no H2 (R1001)		Operating below 300 C without H2 will give sulphur slip and it will deac-tivate the catalyst in prereformer R2003				

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (R1002)	See high temperature above	Damage of catalyst	The catalyst in the sulphur absorber R1002 is able to run up to 400 C			
Low (R1002)	See low temperature above	Slower reactions, no short time consequences for the catalyst Operating below 360 C will reduced catalyst life time				
Parameter: Pressure		**Intention:**				
High (from H2 system)	Blocked outlet, FV 6070 closed	Pressure exceeding design pressure	High alarm on safety valve, PIC 1045 Vent capacity is larger than H2 flow			
High	External fire	High pressure in vessel	PSV 1031, 1038, 1043 are designed for fire case			

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Low pressure at inlet Open vent, PV 1045 (at R1002 2outlet)	Low flow to reformer, no safety consequence	Trip of reformer, IS-1 Low alarm, PIC 1045 (at R1002 2outlet)			
High pressure drop (across reactor R1001)	Dirt, piping not cleaned properly.	Reduced plant capacity	High differential alarm, PDAH 1032			
High pressure drop (across R 1002 1/2)	Dirt, piping not cleaned properly.	Reduced plant capacity	R1002 1/2 are protected by the first reactor (R1001) Low alarm, PIC 1045 (at R1002 2outlet)			
High (R1001)		Operating pressures within design pressure have no consequences for the catalyst				

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (R1001)		No consequences for the catalyst				
High (R1002)		No consequences for the catalyst				
Low (R1002)		No consequences for the catalyst				
Parameter: Composition		**Intention:**				
High sulphur content from feed stock		Sulphur break-through, sulphur deposit on catalyst in prereformer	Sulphur analyser, AI 1035	6. Add high alarm on AI 1045 7. Consider procedure to ensure operator shut down plant on high alarm AI 1045	HTAS HTAS	
Liquid in feed	Liquid carry over from KO drum D1001	Disintegration of hydrogenation cata-lyst	LI 1004, high alarm (on KO drum D1001) LSAH 1004, IS 1 trip			*

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
H2	No H2	Carbon formation in hydrogenator R1001 will deactivate/damage catalyst	FIC 2150, deviation alarm on H2 flow (at H2 inlet) (manual) shut down if H2 cannot be re-established shortly			
High sulphur (R1001)			High margin on catalyst activity Sulphur analyser with high alarm, AI 1045 out of HDS section			
High sulphur (R1002)		Reduced life time of catalyst	AI 1035 high alarm on total sulphur			
No sulphur (R1001)	No sulphur in feed	Especially for new catalyst, deactivation of cat in R1001 for long term operation with no sulphur	AI 1035 (total sulphur) inlet to R1002 1			

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Iron to R1002	Very high content of iron in feed	Formation of iron carbide in the second reactor R1002 2 causing high pressure drop across reactor. Reduced performance of R1002 2	Iron in feed not expected			
Lean gas (R1001 and R1002)		No consequences for the catalyst				
Liquid (R1001 and R1002)	Carry over from KO drum (water) Carry over from KO drum (HC)	No consequences for the catalyst No consequences for the catalyst				
Parameter: Reaction		**Intention:**				
Run away reactions	Unsaturated hydrocarbons in hydrogenator R1001	High temperature in reactor (see high temperature)				

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Run away (R1001)	Opening a warm reactor (shut down) Pyrophoric	Temperature increases rapidly, run away reaction	Operating manual include procedure on cooling down (below 75 C) before opening reactor			
Parameter: Other		**Intention:**				
Poisoning (R1001)	No causes					

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Node: 3 NG Saturation system (E6001, T6001, D6001) – gas system	P&ID no.: P06, P07	Intention: Saturation of NG with water	Date: 09.06.2010
	Design P/T: P = 55 barg (gas system),410 C Upstream E6001, 290 C between E6001 and T6001, 260 C upstream T6001, 290 C downstream E6001	Operating P/T:43.8 barg, 358 C Upstream E6001, 43.3 barg, 265 C between E6001 and T6001, 42.8 barg, 226 C upstream T6001, 42.3 barg , 262 C downstream E6001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (NG)	Flow valve FV 6070 fully open	Evaporation of more condensate in E6001, no consequences for this note Reduced level in D6001 Lower steam to carbon ratio into re-forming. See node 4	Increased steam pressure in saturator and added BFW, controlled by LIC 6051, FIC 6031 and PIC 6025 Additional steam is added to adjust S/C ration			
Low NG	Failure of FV 6070	Water level increases in D6001 and temperature will then increase. S/C ratio increases, no consequences	Controlled by LIC 6051, FIC 6031, PIC 6025			
Reverse flow (NG into off stream liquid)		Gas into liquid off steam tank TK 5003. Venting to safe location	Check valve Reciprocating pumps prevent back flow to tank			

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Node: 3 NG Saturation system (E6001, T6001, D6001) – gas system	P&ID no.: P06, P07	Intention: Saturation of NG with water	Date: 09.06.2010
	Design P/T: P = 55 barg (gas system),410 C Upstream E6001, 290 C between E6001 and T6001, 260 C upstream T6001, 290 C downstream E6001	Operating P/T:43.8 barg, 358 C Upstream E6001, 43.3 barg, 265 C between E6001 and T6001, 42.8 barg, 226 C upstream T6001, 42.3 barg , 262 C downstream E6001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High/low flow of off stream liquid		No consequences				
NG into Steam system	Pipe rupture in T6001	Pressure control valve PIC 6025closes if pressure increases in T6001 (back flow not possible)	FI 2065 low alarm (water added in the saturator)			

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Node: 3 NG Saturation system (E6001, T6001, D6001) – gas system	P&ID no.: P06, P07	Intention: Saturation of NG with water	Date: 09.06.2010
	Design P/T: P = 55 barg (gas system),410 C Upstream E6001, 290 C between E6001 and T6001, 260 C upstream T6001, 290 C downstream E6001	Operating P/T:43.8 barg, 358 C Upstream E6001, 43.3 barg, 265 C between E6001 and T6001, 42.8 barg, 226 C upstream T6001, 42.3 barg , 262 C downstream E6001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High (T6001 NG)	Loss of process condensate	Saturator will heat up Hammering in D6001	FI 6068, low condensate circulation alarm	8. Increase design temperature to 290 C 9. (If design temperature is not increased then consider temperature alarms out of T6001) 10. Consider low level alarms on LI 6033 and LI 6034	HTAS HTAS HTAS	
Low	Interrupted steam supply Low pressure of steam	Reduced evaporation inT6001 giving low S/C ratio and increased level in D6001.	FI 2065 low saturated steam alarm			

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Node: 3 NG Saturation system (E6001, T6001, D6001) – gas system	P&ID no.: P06, P07	Intention: Saturation of NG with water	Date: 09.06.2010
	Design P/T: P = 55 barg (gas system),410 C Upstream E6001, 290 C between E6001 and T6001, 260 C upstream T6001, 290 C downstream E6001	Operating P/T:43.8 barg, 358 C Upstream E6001, 43.3 barg, 265 C between E6001 and T6001, 42.8 barg, 226 C upstream T6001, 42.3 barg , 262 C downstream E6001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High	Blocked outlet, closure of FIC 2061 downstream E6001	High pressure due to liquid off stream filling the system upstream and down stream (low flow)	PV 1045 vent down stream desul-phurization PSVs 1031, 1038, 6053 Reformer will trip due to no flow and stop liquid off stream pump	11. Consider high alarm on PIC 2073	HTAS	
High	Fire below vessel D6001or E6001	Rupture of vessel	PSV 6053 (common)			
Low	Fully open outlet valve Blocked inlet Low pressure from inlet	Increased flow for a period (see flow) Loose flow (see flow) Low flow, no safety consequence	PIC 2073 (downstream) closes outlet valve FV 2061 PIC 2073 (downstream) opens outlet valve FV 2061			

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Node: 3 NG Saturation system (E6001, T6001, D6001) – gas system	P&ID no.: P06, P07	Intention: Saturation of NG with water	Date: 09.06.2010
	Design P/T: P = 55 barg (gas system),410 C Upstream E6001, 290 C between E6001 and T6001, 260 C upstream T6001, 290 C downstream E6001	Operating P/T:43.8 barg, 358 C Upstream E6001, 43.3 barg, 265 C between E6001 and T6001, 42.8 barg, 226 C upstream T6001, 42.3 barg , 262 C downstream E6001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
Chloride in water (process water makeup)	Regeneration of ion exchanger with HCL	Chloride in saturator, stress corrosion in saturator	H2SO4 for regeneration of ion exchanger. HCL is not allowed	12. Ensure operating manual covers H2SO4 is used as regenerator.	HTAS	
Dirt	Dirt in gas/liquid system	Blockage of holes in top of tubes in saturator	Filter on process water makeup LI 6033, high alarm	13. Check / clean tubes to be included in detailed procedure 14. To be highlighted in operating manual	MEKPCO HTAS	

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Node: 3 NG Saturation system (E6001, T6001, D6001) – gas system	P&ID no.: P06, P07	Intention: Saturation of NG with water	Date: 09.06.2010
	Design P/T: P = 55 barg (gas system),410 C Upstream E6001, 290 C between E6001 and T6001, 260 C upstream T6001, 290 C downstream E6001	Operating P/T:43.8 barg, 358 C Upstream E6001, 43.3 barg, 265 C between E6001 and T6001, 42.8 barg, 226 C upstream T6001, 42.3 barg , 262 C downstream E6001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Leaks	Leaks in E6001	Reduced evaporation in saturator T6001 Level increases in D6001. Surplus of condensate will go to BL	FV 6081 opens			

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Node: 3 NG saturation system (E6001, T6001, D6001) – Liquid system	P&ID no.: P06 and P07	Intention: Saturate feed gas with water	Date: 10.06.2010
	Design P/T: P = 55 barg (gas system),410 C before E6001, 290 after E6001, 260 C after saturator, 290 C out of E6001	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
More liquid (process water)	Increased S/C ratio Malfunction of upstream level control valves, LIC 2441, LIC 2403 or LIC 2474.	High level in D6001 Potentially carry over (see level)	Level control LIC 6051 (high alarm) PIC 6025 will control steam pressure FV 6081 will open (excess liquid to BL)			
More liquid (BFW)	Malfunction of flow valve FV 6031	High level in D6001 Potentially carry over (see level)	Level control LIC 6051 (high alarm) PIC 6025 will control steam pressure FV 6081 will open (excess liquid to BL)			

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Node: 3 NG saturation system (E6001, T6001, D6001) – Liquid system	P&ID no.: P06 and P07	Intention: Saturate feed gas with water	Date: 10.06.2010
	Design P/T: P = 55 barg (gas system),410 C before E6001, 290 after E6001, 260 C after saturator, 290 C out of E6001	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
More distillation water	Malfunction of flow control FIC 5367	High level in D6001 Potentially carry over (see level)	Level control LIC 6051 (high alarm) PIC 6025 will control steam pressure FV 6081 will open (excess liquid to BL)			
Less (liquid into system)	Closed inlets	Reduced S/C ratio	Direct steam addition downstream controlled by FV 2072 (system designed for 100%)			
Less (liquid in system)	Open outlet valve ,FV 6081	Low level in D6001 (see level) Reduced S/C ratio	 Direct steam addition downstream controlled by FV 2072 (system designed for 100%)			

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Node: 3 NG saturation system (E6001, T6001, D6001) – Liquid system	P&ID no.: P06 and P07	Intention: Saturate feed gas with water	Date: 10.06.2010
	Design P/T: P = 55 barg (gas system),410 C before E6001, 290 after E6001, 260 C after saturator, 290 C out of E6001	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Less (circulation)	Failure of circulation pump 6001 A/B	Reduced S/C ratio Potentially high level in D6001	Autostart of standby pump Direct steam addition downstream controlled by FV 2072 (system designed for 100%) FI 6068 (low alarm on circulation flow) See high level			
Parameter: Temperature		**Intention:**				
See node 3 gas system						
Parameter: Pressure		**Intention:**				
High	Pump failure		Discharge pressure cannot exceed design pressure			

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Node: 3 NG saturation system (E6001, T6001, D6001) – Liquid system	P&ID no.: P06 and P07	Intention: Saturate feed gas with water	Date: 10.06.2010
	Design P/T: P = 55 barg (gas system),410 C before E6001, 290 after E6001, 260 C after saturator, 290 C out of E6001	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (from BFW)	Failure UV 6035 (FC).	High pressure from BFW between FV6031 and UV 6035. Exceeding design pressure		15. Install PSV down-stream FV 6031	HTAS	
High (process condensate / distillation water)	Failure of UV 6035 (FC).	Potential of exceeding design pressure	Design pressure to be checked against maximum possible shut off pressure given by pump vender. Is noted on pump spec, instrument data sheet and line number registration.	16. Design pressure out of process water streams to be checked against maximum shut off pressure from P2001, P2002, P2003, P5010.	MEKPCO	
Low	See gas system					
Parameter: **Level**		**Intention:**				
High (top of T6001)	Blocked holes in top of tubes	Lower S/C ratio	LI 6033 (high alarm)			
High (bottom of T6001, steam side)	See steam node					

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Node: 3 NG saturation system (E6001, T6001, D6001) – Liquid system	P&ID no.: P06 and P07	Intention: Saturate feed gas with water	Date: 10.06.2010
	Design P/T: P = 55 barg (gas system),410 C before E6001, 290 after E6001, 260 C after saturator, 290 C out of E6001	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (in D6001)	Failure of level control, LIC 6051 or Blocked outlet valve, FV 6086 is closed	Liquid carry over to gas system. Potential damage of equipment and catalyst.	High level trip, LSAH 6051 (separate from LIC 6051) LIC 6051 high alarm			*
Low (top of T6001)	Low circulation flow (see low flow)	Gas break-through to blow down system. Potentially over pressuring of blow down system.	Atmospheric vent on D6002 to safe location (simultaneous loss of process water, BFW, distillation and circulation pump gives the consequence).			
Low (D6001)	Failure of LIC 6051 (BD opens) or Blocked inlet (no BFW or process water or distillation)	Cavitation of circulation pump, potential pump damage Gas into blow down system. Potential overpressure of blow down system	LALL 6051 Interlock stops circulation pump and closes blow down	17. Add LSAL and USV on blow down at D6002 inlet	HTAS	* *

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
S/C ratio (low)	Loss of direct steam by failure of FIC 2072. Failure of flow transmitters (FST 2061 A/B/C, FST 6070 A/B/C, FST 2072 A/B/C) Wrong input from operator on carbon number and Mw. Failure of specific gravity analyser (AST 1001 A/B/C) if installed	C on prereformer catalyst. Potential damage of catalyst.	FI 2069 low alarm (total steam), IS 1 trip on low S/C ration FFSAL 2064. 2 out of 3, discrepancy alarm, IS 1 trip on low S/C ration FFSAL 2064. IS 1 trip on low S/C ration FFSAL 2064	18. Consider additional flow meters for reference 19. Consider installing specific gravity analyser (2 out of 3) with discrepancy alarm and automatic input to S/C ratio calculation (AST)	HTAS HTAS	*

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Start up				20. Assure correct installation, calibration and function of flow elements and meters for S/C ratio during commissioning		
S/C ratio (high)	Failure of FIC 2072. Failure of flow transmitters (FST 2061 A/B/C, FST 6070 A/B/C, FST 2072 A/B/C)	Surplus of process condensate (limited possibility of discharge) Other module into synthesis loop. This may affect production.	Long term correction has to be made by operators. Long term correction has to be made by operators.	21. Consider additional flow meters for reference (previously added, see action no 18)	HTAS	

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
	Wrong input from operator on carbon number (HSIC 2063) and Mw (HIC 6068). Failure of specific gravity analyser (AST 1001 A/B/C) if installed (see ration low above)			22. Consider installing specific gravity analyser (2 out of 3) with discrepancy alarm and automatic input to S/C ratio calculation (AST) (previously added, see action no. 19)	HTAS	
Parameter: **Flow**		**Intention:**				
High	Failure of control loops, FV 2061 opens	Initially reduced S/C ratio	See S/C ratio low			

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
		Reduced inlet temperature to prere-former R2003 (see temperature) High delta P across prereformer R2003. Reduced conversion of HC in R2003. Operational upsets downstream	PDI 2252, high alarm			

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low/no	Failure of FV 2061	Overheating prereformer and coils (see high temperature)	FIC 2061, low alarm			
	Failure of direct steam controlled by FIC 2072		FSAL 6070 IS 1, low NG			*
			FSAL 2062 IS 1, low total steam flow			*
	Loss of upstream pressure	Incorrect S/C ratio	FI 2069, total steam flow low alarm			
			FFI 2069 low S/C ratio alarm			*
			FFSAL 2064 going to IS 1, low S/C ratio			
Reverse flow	Open upstream vent, PIC 2073	Stream, BFW or process condensate into vent system.	Check valve			
		Back flow in prereformer	Forced closed (PV 2073) when secondary reformer is in operation			

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High	Low flow High flue gas temperature (see node 23)	Exceeding design temperature of coils E2002 and E2001 and prereformer R2003. Carbon on catalyst in prereformer and higher delta P across prereformer	TIC 2253 adds process condensate (or BFW) TI 2268, high alarm TI 2234, high alarm FIC 2061, low alarm FSAL 6070 IS 1, low NG flow FSAL 2062 IS 1, low total steam flow FI 2069, total steam flow low alarm PDI 2252, high alarm			* *

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	To much quench (FV 2233 1/2 FC, failure of TIC 2232, 2233) or liquid carry over Low flue gas temperature (see node 23)	Reduced conversion of HC in prere-former R2003 Liquid carry over (or condensation) may damage catalyst	TIC 2253 low alarm TI 2268 and TI 2234 low alarms Normal operations well above dew point Start up procedure ensures operating temperature well above dew point during start up	23. Consider adding low alarm on TIC 2232	HTAS	
High (R2003)		No consequences for the catalyst if operated within design temp				
High R2003		Risk of carbon formation on catalyst in R2003 when temp is high (above 520 C) combined with rich gas. This will damage the catalyst	TI 2253 high alarm at performer inlet			

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High	Blocked outlet or stop of synthesis compressor C3001	Potentially exceeding design pressure	PSV 2354 to 2359 after steam super heater (110% capacity) PIC 2481 will open vent to flare			
Low	Open vent, PV 2481 or Loss of feed (e.g. PV 2073 opens)	Low or no production. Low flow (see low flow)	PIC 3007, low alarm at synthesis. gas compressor inlet			
High (R2003)		No consequences for the catalyst				
Low (R2003)		No consequences for the catalyst				

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Node: 4 S/C ratio control, preheating (E2002) and pre-reformer (R2003), preheating (E2001)	P&ID no.: P07, P09, P10, P13, P14	Intention: S/C ratio control, preheating of process gas and conversion of higher HC in pre-reformer R2003	Date: 10.06.2010
	Design P/T: 55 barg , 290 C 46 barg, 550 C after E2002 46 barg, 500 C after R2003, 46 barg, 675 C after E2001	Operating P/T:42.3 barg, 262 C before mixing 41.1 barg, 267 C after mixing 38.4 barg, 496 inlet R2003, 37.7 barg, 441 C inlet E2001, 36.3 barg, 638 C outlet E2001	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Reaction		**Intention:**				
Reaction	heavy gas	Temperature increases in R2003. Potential of carbon formation on catalyst which will reduce catalyst life time.	Specific gravity analyser AI 1001, high alarm TI 2268, high alarm FHIC 2070, increase S/C ratio manually			
Runaway	Pyrophoric	See run away reactions for R1001 in node R1001				
Poisoning	Sulphur Silica, Sodium, Potassium	Sulphur will reduce life time Dependent on cat history, reduces life time	Deactivation plot (temperature profile as function of time) Ensure clean steam			

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
High (process gas)	Failure of control loop, valve FV 2061 opens	Initially reduced S/C ratio Lower inlet and outlet temp will increase slip of CH4. Lower efficiency of plant. Increased pressure drop	See S/C ratio low TI 2268 low alarm out of prereformer PDI 2283, high alarm			
Low flow (process gas)	Failure of valve FV 2061 Failure of direct steam controlled by FIC 2072 Loss of upstream pressure	Overheating of reformer tubes (see high temperature) Incorrect S/C ratio	FIC 2061, low alarm FSAL 6070 IS 1, low NG FSAL 2062 IS 1, low total steam flow FI 2069, total steam flow low alarm FFI 2069 low S/C ratio alarm FFSAL 2064 going to IS 1, low S/C ratio			 * * *

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low flow (local process gas)	Uneven distribution of gas due to poor catalyst loading	Local overheating of reformer tube	Catalyst is loaded in accordance with manual Regularly measurements of tube skin temperature Visual inspection			
Low (purge gas)	Failure of FIC 2536 Trip of synthesis, IS 3	Low total fuel gas to reformer. Under firing	QIC 2535 will increase NG fuel. FALL 2536, interlock alarm I 14, closes purge gas valve, FV 2536 See safeguards for under firing			*
Low/no (NG fuel)	Failure of PIC 1011 or FIC 2531 Closure of manual valves	Low total fuel gas to reformer. Under firing	PI 2540 (NG fuel) PIC 2554 low alarm (total fuel gas) PSAL 2554, IS 1 (total fuel gas)			 *

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (combustion air)	Failure of dampers or FD fan	Increased pressure in waste heat section (flue gas section) Risk to personnel during visual inspection Lower temperature of flue gas (radiant section) Air in flue gas and potential explosive atmosphere if HC ingress to flue gas (see flue gas node 23)	PIC 2224, high alarm (maintain flue gas pressure by increasing speed of flue gas blower F 2001) PAHH 2224 interlock, I 15, opens the false air dampers and gives visual alarm (hazard flasher), XAL 2284 PSAH 2224, gives IS 1 trip AI 2223 1 and AI 2224 (O_2 in flue gas)	24 Consider high alarm on AI 2223 1 and AI 2224	HTAS	* *

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (combustion air)	Failure of dampers or FD fan	Under firing Incomplete combustion, HC in flue gas, potential explosive atmosphere if air ingress to flue gas (see flue gas node 23)	FIC 2111, low alarm (comb air flow) PIC 2163, low alarm (ensuring minimum combustion air pressure) PSAL 2163, IS 1 trip (comb air) AI 2223 2, high alarm (combustibles) AI 2223 1, low alarm (O_2) AI 2224, low alarm (O_2) Autostart of motor drive in case of turbine trip			*
High (H2001)		No consequences for the catalyst				
Parameter: Temperature		**Intention:**				
High	Over firing (operator error or failure of FIC 2531 (NG) or FIC 2536 (purge gas))	Damage of reformer tubes	TI 2295, TI 2297, high alarm (flue gas) TSAH 2221, IS 1 trip (flue gas) TI 2305, TI 2303, TI 2304 high alarm (pro-			*

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
	Composition of fuel (LHV) Lean feed gas Low process gas flow (see		cess gas) TSAH 2305, IS 1 trip (process gas) QIC 2535 (duty control by manual set point) AI 2531 (LHV analyser on NG) AI 2532 (LHV analyser on purge gas)	25. Consider installing deviation alarm and high alarm on QIC 2535 26. Consider LTM (load and temperature management) system for duty control. LTM will include input from LHV analysers.	HTAS HTAS	*

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
	above)					
High (local)	Some of the burners are damaged Uneven fuel distribution	Damage of reformer tubes	Regularly measurements of tube skin temperature Visual inspection	27. Procedure to be included in operating manual	HTAS	
Low	Under firing (operator error or failure of FIC 2531 (NG), FIC 2536 (purge gas), insufficient air supply) Composition of fuel (LHV)	Down stream disturbances CH4 slip increases	AI 2479 (CH4 analyser) Operator increase heat input AI 2531 (LHV analyser on NG) AI 2532 (LHV analyser on purge gas)	28. Add high alarm on AI 2479 (is added, see a	HTAS	
High (combustion air)	High flue gas temperature in E2007 Low flow of combustion air (see low flow)	More production of NO_X, no serious consequences Exceeding design temperature of coil E2007	Normal operation temperature below critical NO_X formation temperature Design temperature of E2007 (280 C) and flue gas blower (250 C) is selected with sufficient margin			

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (combustion air)		More fuel consumption. No consequences				
High (fuel gas)	No causes					
High (purge)	No causes					
Low (fuel gas)	Low temperature at BL	Hydrate formation after pressure reduction	Fuel gas temperature after depressurization PV1011 is above hydrate formation temperature			
Low (purge)	Not possible					
Parameter: Pressure		**Intention:**				
High (process gas)	Blocked outlet or stop of synthesis compressor C3001	Potential exceeding design pressure	PSV 2354 to 2359 after steam super heater (110% capacity) PIC 2481 will open vent to flare			

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (process gas)	Open vent, PV 2481 Loss of feed (e.g. PV 2073 opens)	High flow (see high flow) Low flow (see low flow)	PIC 3007, low alarm at synthesis gas compressor inlet P3001			
High (fuel gas)	Malfunction of PIC 1011	Exceeding design pressure of down stream piping Over firing (see high flow)	PSV 1013 and 1014 FIC 2531 will regulate flow/pressure down stream PIC 2454 high alarm, total fuel gas PI 2540 (NG fuel gas) PSAH 2554, IS 1 trip			*
High (purge)	Failure of FIC 2536 (closed)	Exceeding design pressure	PIC 2536 B, (purge gas vent) PSVs 3173, 3174			

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (purge)	Failure of upstream control FIC 3169, FIC 3171	Exceeding design pressure	PIC 2536 B, (purge gas vent) PSVs 3173, 3174 PSAH 2554, IS 1 trip PIC 2454 high alarm, total fuel gas			*
High (comb air)	Maloperation of combustion air dampers for burners	Potentially limitations of combustion air supply, less combustion air, see low flow of combustion air.	Combustion air duct designed for stalling pressure of combustion air blower.			
Low (NG fuel gas)	Loss of NG fuel (see low flow)					
Low (purge)	Loss of purge gas (see low flow)					
Low (comb Air)	Loss of combustion air (see low flow)					

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
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Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Composition		**Intention:**				
Composition of feed gas	Higher HC not converted in prereformer	Potential carbon laydown in primary reformer H2001. Destruction of catalyst.	AP 2267 out of prereformer according to analysis schedule. PDI 2283 (delta P across H2001 reactor)			
High / low HV	Composition of NG feed from BL	High /low temperature (see temperature)				
Reducing atmosphere in radiant camber	Low combustion air flow	Damage of reformer tubes due to reducing flue gas	See low flow of combustion air above Assure uniform distribution of fuel and combustion air to individual burners			
Parameter: Reaction		**Intention:**				
Less reaction	Reduced activity of catalyst (poisoning or end of life)	Increased CH4 slip to secondary reformer.	AP 2306 sample point for regular sampling of CH4 content downstream H2001			

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Node: 5 Primary reformer (H2001)	P&ID no.: P15	Intention: Conversion of CH4 to H2, CO, CO2	Date: 11.06.2010
	Design P/T: 40.2 barg, 675 C inlet, 34.7 barg, 800 C outlet	Operating P/T:36.3 barg, 638 C inlet, 742 C outlet	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Tube rupture	High temperature	Damage of primary reformer Sudden increased flue gas temperature Reduced oxygen content in flue gas Potentially fire outside primary reformer	TI 2295, TI 2297, high alarm (flue gas) TSAH 2221, IS 1 trip (flue gas)	29. Add rate of change alarm on temperature TI 2295 and TI 2297.	HTAS	*
Poisoning	Sulphur Silica, Sodium, Potassium	Sulphur will reduce life time Dependent on cat history, reduces life time	Ensure clean steam. Steam is added before pre-reformer and the problem will occur in the pre-reformer			

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (reformed gas)	Failure of control loop, FV 2061 opens	Reduced O/C ratio Reduced outlet temperature from R2004, No consequences Increased CH4 slip	AI 2479 (CH4 analyser) PDI 2323 high alarm	30. Add high alarm on AI 2479. (previously added, see action no. 28)	HTAS	

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	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (reformed gas)	Loss of feed	Increased O/C ratio (see high temperature) Increased reformer temperatures (see high temperature) Potential damage of cat and equipment (see temperature)	FFI 2020, high O/C ratio alarm Operator reduces O_2 flow by FIC 2007 FFSAH 2008, high O/C ratio, trip of secondary reformer (IS 2) TI 2333 high temperature alarm TSAH 2333 (outlet) TI 2325 (temperature in combustion zone) TSAH 2325 (temperature in combustion zone)	31. Consider automatic O/C ratio control as part of LTM	HTAS	 * * *
No (reformed gas)	No feed Tube rupture in primary reformer H2001	Increased reformer temperatures (see high temperature) Potential damage of cat and equipment (see temperature)	FSAL 6070, IS1 trip which will trip IS 2 Tube rupture in H2001 should initiate IS 1.			*

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (O_2)	Malfunction of flow control FIC 2007	Increased O/C ratio Increased reformer temp in R2004. Potential damage of cat, reformer and downstream equipment.	FFI 2020, high O/C ratio alarm FFSAH 2008, high O/C ratio, trip of secondary reformer (IS 2) TI 2333 high temperature alarm TSAH 2333 (outlet) TI 2325 (temperature in combustion zone) TSAH 2325 (temperature in combustion zone)			* * *
Low (O_2)	Malfunction of flow control FIC 2007 Upstream blockage, failure of O_2 supply (e.g. O_2 filer)	Low O/C ratio Reduced outlet temperature from R2004, no consequences Increased CH4 slip	AI 2479 (CH4 analyser)	32. Add high alarm on AI 2479. (previously added, see action no. 28)	HTAS	

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse (HC in O_2/steam)	Simultaneous failure of O_2 and steam supply	Explosion in O_2-piping	Check valves FIC 2040 low alarm on steam flow FSAL 2040, trip, IS 2 steam flow			 *
Reverse (O_2 into HC)	No feed flow	Explosion	IS 1 will activate IS 2 which will stop O_2 flow			

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High (inside R2004)	Malfunction of flow control FIC 2007 Increased O/C ratio	Increased reformer temperature in R2004. Potential damage of catalyst reformer and downstream equipment	FFI 2020, high O/C ratio alarm FFSAH 2008, high O/C ratio, trip of secondary reformer (IS 2)			 *
		Increased HHP steam production	TI 2333 high temp alarm TSAH 2333 (outlet) TI 2325 (temp in comb zone) TSAH 2325 (temp in comb zone)			 * *
		Burner damage	TI 2329 high alarm internally in burner TSAH 2329, trip IS 2 PDI 2320 (O_2 part of burner)			 *

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (outside R2004)	Refractory damaged	Hot spots, damage of R2004	Visual inspection of reactor R2004 (thermal indicative paint) Deluge (manually activated water spray) outside surface of reactor Skin temp alarms TI 2328, 2326, 2327 2330, 2331, 2332 high alarms	33. Add note to PID defining water system	HTAS	
Low (inside R2004)	Low oxygen/steam flow (see above)					
Low (gas temperature out of primary reformer)		Increased CH4 slip, no consequences Reduced stream production	AI 2479 (CH4 analyser)			
Low (O_2)	Loss of steam to O_2 preheater, malfunction of PIC 2015	Condensate into burner. Potential damage of burner and refractory	TI 2047 low alarm on O_2 temp TSAL 2047, trip IS 2 on low O_2 temp			*

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High (gas)	Blocked outlet or stop of synthesis compressor C3001	Potential exceeding design pressure	PSV 2354 to 2359 after steam super heater (110% capacity) PIC 2481 will open vent to flare			
Low (gas)	Open vent, PV 2481 or Loss of feed (e.g. PV 2073 opens)	High flow (see high flow) Low flow (see low flow)	PIC 3007, low alarm at synthesis gas compressor inlet			
High (O_2 supply)	High delivery pressure from BL	High O_2 flow (see high flow)				
Low (O_2 supply)	Low delivery pressure from BL Failure of O_2 feed control	Low O_2 flow (see low flow)				

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Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High pressure drop	Ruby formation (caused by impurities in refrac-tory)	High pressure drop across R2004 and potentially hot spots. Blockages of catalyst	PDI 2323 high alarm	34. Skimming of cat (change top layer) according to operating manual	MEKPCO	
Parameter: Reaction		**Intention:**				
Side reaction	See ruby formation			35. When replacing tiles ensure high qual-ity of tiles to avoid ruby formation	MEKPCO	

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Slow reaction	Deactivated catalyst Low temperature (see low temperature)	Increased temperature Increased CH4 slip	Catalyst volume is selected with ample surplus (has been considered by HTAS) TI 2333, high alarm out of reformer TSAH 2333, trip AI 2479 (CH4)	36. High alarm on AI 2479 (previosly added, see action no. 28)		*
Reaction	Soot formation	Soot formation during start up, black condensate, blockage of filters X6001 A/B	Soot filters Start up procedure ensures short time operation in soot formation range			
Parameter: Mixing		**Intention:**				
O_2 and process gas	Burner damage	High temperature (see high temperature)				

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
Liquid in gas feed	NA					
Poisoning		No consequences for catalyst				
Liquid in O_2	Pockets of condensate in piping during start up Insufficient heating of steam and O_2	Damage of equipment Damage of refractory lining Damage of catalyst	Preheating of steam and O_2 according to manual TI 2047 Low temperature alarm TSAL 2047 trip Double block and bleed valve to prevent steam in O_2. The bleed is from the bottom of the pipe No pockets (slope) Heat tracing to 250 C	37. MEKPCO should supervise detailed design of piping layout according to HTAS requirements as indicated on the PIDs.	MEKPCO	*
Low S/C	See node 4	No consequences in this node				

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Node: 6a Secondary reformer (R2004)	P&ID no.: P16	Intention: Conversion of CH4 to H2, CO and CO2	Date: 11.06.2010
	Design P/T: 34.7 barg (reactor R2004)	Operating P/T: 1600 C above catalyst in R2004 1000 C out of reactor R2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High S/C	See node 4	No consequences in this node				

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 6b Waste heat boilers and steam super heaters (E2020, 2021 1/2/3)	P&ID no.: P 16, P17	Intention: Cooling of reformed gas	Date: 14.06.2010
	Design P/T: 31.0 barg, 575 C outlet E2020 1/2, 29.0 barg ,290 C outlet E2021 3	Operating P/T: 26.7 barg, 544 C outlet E2020 1/2, 26.3 barg ,260 C outlet E2021 3	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
Mal distributed flow	Mal distribution of flow Incorrect position of damper out of waste heat boiler, THIC 2360 1/2/3/4.	Uneven temperature out of boilers E2020 1/2. Exceeded design temp in E2021 1 or 2	Refractory lined in waste heat boilers TI 2335, TI 2336 high alarm, inlet to E2021 1/2	38 Check mechanical design of E2021 1/2 for consequences of high temperature, alternatively include trip on high temp	HTAS	
Parameter: Temperature		**Intention:**				
High	Mal distributed flow (see above) Failure of TIC 2360 (on the super heated steam)	Uneven temperature out of boilers E2020 1/2. Exceeding design temp in E2021 1 or 2	TI 2335, TI 2336 high alarm, inlet to E2021 1/2 TIC 2360 high alarm (super heated steam) TSAH 2360, IS 1 (do not detect all failure modes, potential overheating of one train does not cause high temp of super heated steam)	39. Consider one THIC on each boiler operating both sets of dampers, TV 2360 1 and 2 and one THIC for TV 2360 3 and 4. **(Post HAZOP meeting HTAS decision as per 08.07.2010: Not recommended)** 40. Consider high temp alarm on TI 2351 and 2353 (gas	HTAS HTAS	*

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Node: 6b Waste heat boilers and steam super heaters (E2020, 2021 1/2/3)	P&ID no.: P 16, P17	Intention: Cooling of reformed gas	Date: 14.06.2010
	Design P/T: 31.0 barg, 575 C outlet E2020 1/2, 29.0 barg ,290 C outlet E2021 3	Operating P/T: 26.7 barg, 544 C outlet E2020 1/2, 26.3 barg ,260 C outlet E2021 3	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
				out of E2021 1/2) and TI 2355 and 2358 (steam out of E2021 1/2) 41. Add failure modes of TV 2360 1/2/3/4 on PID and correct node 8 42. Consider cascade control for TIC 2360 and TI 2335 and TI 2336 to prevent un-even flows	HTAS HTAS	
High	Loss of S steam to E2021 1/2/3 by lifting PSVs on steam drum D2001 Loss of steam to E2021 1/2/3 by closure of PV 2363 out of E2021 1/2	Potential overheating of E2021 1/2/3	If only one S steam PSV opens PIC 2361 vent will supply sufficient steam PIC 2361, high alarm (steam vent) TIC 2360 high alarm (super heated steam) TSAH 2360, IS 1	43. Correct FLO in-stead of FLC on PV 2363 44. Consider LO on block valves before automatic vents	HTAS HTAS	* *

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Node: 6b Waste heat boilers and steam super heaters (E2020, 2021 1/2/3)	P&ID no.: P 16, P17	Intention: Cooling of reformed gas	Date: 14.06.2010
	Design P/T: 31.0 barg, 575 C outlet E2020 1/2, 29.0 barg ,290 C outlet E2021 3	Operating P/T: 26.7 barg, 544 C outlet E2020 1/2, 26.3 barg ,260 C outlet E2021 3	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
	Loss of circulating boiler water to E2020 1/2. Not possible Mal distribution of steam between 2021 1/2 by un-symmetrical piping Increasing pressure drop due to mechanical prob-lems	High temperature, exceeding design temperature	TI 2352 high alarm (on process gas) TI 2355 and TI 2356 (on the steam side)	45. Consider high alarm on TI 2355 and TI 2356 (previously added, see action no. 40)	HTAS	
Low (gas side)	Dampers in wrong posi-tion	Low steam temperature. Opera-tional problems in the steam tur-bines. No consequences on gas side.				
Low (from re-former)	Low temp out of reformer	Low steam production, no con-sequence				

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Node: 6b Waste heat boilers and steam super heaters (E2020, 2021 1/2/3)	P&ID no.: P 16, P17	Intention: Cooling of reformed gas	Date: 14.06.2010
	Design P/T: 31.0 barg, 575 C outlet E2020 1/2, 29.0 barg ,290 C outlet E2021 3	Operating P/T: 26.7 barg, 544 C outlet E2020 1/2, 26.3 barg ,260 C outlet E2021 3	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High	See node 6a					
Low	See node 6a					
Parameter: composition		**Intention:**				
Composition of gas	Low S/C ratio	Potential metal dusting causing equipment failure (super heaters)	See S/C in node 4			
Composition of gas	Low S/C ratio	Potential metal dusting causing equipment failure (waste heat boilers)	No potential problem as covered by design			
Impurities	Impurities in refractory lining	Fouling of waste heat boilers High temp of process gas out of boilers (see high temperature)				

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Node: 6b Waste heat boilers and steam super heaters (E2020, 2021 1/2/3)	P&ID no.: P 16, P17	Intention: Cooling of reformed gas	Date: 14.06.2010
	Design P/T: 31.0 barg, 575 C outlet E2020 1/2, 29.0 barg ,290 C outlet E2021 3	Operating P/T: 26.7 barg, 544 C outlet E2020 1/2, 26.3 barg ,260 C outlet E2021 3	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Leakages (steam to gas side)	Tube rupture Corrosion	Lower steam production, higher process condensate. Increasing pressure (see high pressure) Damage to refractory in boilers E2020 1/2				
Dust	Failure of refractory lining of tube sheet on waste heat boilers	Metal dusting on tube sheet Dust carried over to downstream equipments (liquid side)	Waste heat boilers are supplied by prequali-fied vendor Visual inspection of tube sheet during turn around			

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Node: 7 Process gas cooling I (E2022 1/2 and D2002)	P&ID no.: P19	Intention: Cooling of reformed gas by BFW preheaters	Date: 14.06.2010
	Design P/T: 29 barg, 390 C inlet E2022 1, 200 C downstream E2022 2	Operating P/T:26.3 barg ,260 C inlet E2022 25.8 barg 65 C down stream E2022 2	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
High (process gas)	Upstream failure	High temperature, see high temperature Higher pressure Higher pressure drop across E2022 1/2. Potential capacity restrictions Minor liquid carry over from D2002, no critical consequence	See high flow in upstream nodes PV 2406 (vent) PIC 3007 high alarm at compressor suction side			
Low (process gas)	See reformer node	Low temperature, see low temperature				
Reverse flow	Upstream PSVs opens PV 2354-2359	No consequences				
Parameter: Temperature		**Intention:**				
High	High flow of gas	Exceeding design temperature	Sufficient margin in design temperature as			

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Node: 7 Process gas cooling I (E2022 1/2 and D2002)	P&ID no.: P19	Intention: Cooling of reformed gas by BFW preheaters	Date: 14.06.2010
	Design P/T: 29 barg, 390 C inlet E2022 1, 200 C downstream E2022 2	Operating P/T:26.3 barg ,260 C inlet E2022 25.8 barg 65 C down stream E2022 2	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
			condensation takes place in E2022 1/2 TI 2352, high alarm, process gas to heat exchanger E2022 1/2			
	Loss/reduced of BFW		FIC 2417 low flow alarm on BFW TI 2371 high alarm TI 2323 high alarm			
	High temperature in re-former		See high temperature alarms in reformer node			
	Fouling, no consequence					

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Node: 7 Process gas cooling I (E2022 1/2 and D2002)	P&ID no.: P19	Intention: Cooling of reformed gas by BFW preheaters	Date: 14.06.2010
	Design P/T: 29 barg, 390 C inlet E2022 1, 200 C downstream E2022 2	Operating P/T:26.3 barg ,260 C inlet E2022 25.8 barg 65 C down stream E2022 2	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Running at low capacity	Condensate in first shell E2022 1, which will result in corrosion (requires long time period with low temperature)	Normal operation is 50 C above dew point			
Parameter: Pressure		**Intention:**				
High	Blocked outlet see node 6a and 6b High pressure from pump and blocked outlet from pump	Exceeding design pressure	Design pressure corresponds to max shut off pressure			
Low (process gas)	Down stream or upstream vent is open	Low suction pressure for pump, pump cavitations, maybe damaged pump Pumps cannot transfer liquid which results in high level in D2002 (see level)	Sufficient margin on NPSH			

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Node: 7 Process gas cooling I (E2022 1/2 and D2002)	P&ID no.: P19	Intention: Cooling of reformed gas by BFW preheaters	Date: 14.06.2010
	Design P/T: 29 barg, 390 C inlet E2022 1, 200 C downstream E2022 2	Operating P/T:26.3 barg ,260 C inlet E2022 25.8 barg 65 C down stream E2022 2	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
Dust from gas stream		Dust in liquid part of D2002. Dust in gas part has no consequence in this node.	Strainer in pump inlet and downstream pressure gauge for the pump			
Parameter: Level		**Intention:**				
High	Stop of pumps Failure of LIC 2403	Liquid carry over	LIC 2403 high alarm Autostart of spare pump			
Low/no	Failure of LIC 2403	Cavitation and potential damage of pumps. Stagnant gas in pumps as down stream pressure is higher than upstream pressure. Gas breakthrough not possible	LIC 2403 low alarm LALL 2404 low level trip of pumps			*

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Node: 7 Process gas cooling I (E2022 1/2 and D2002)	P&ID no.: P19	Intention: Cooling of reformed gas by BFW preheaters	Date: 14.06.2010
	Design P/T: 29 barg, 390 C inlet E2022 1, 200 C downstream E2022 2	Operating P/T:26.3 barg ,260 C inlet E2022 25.8 barg 65 C down stream E2022 2	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Leakages (BFW into gas)	Tube rupture	High level in D2002 (see high level) Exceeding design pressure of E2022 1/2 and D2002	Upstream PSVs 2354-2359 Vent 2406 downstream D2002 (50% of gas flow) Vent PIC 2481 (full flow of gas)			

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Node: 8 Process gas cooling II (E2023, D2003)	P&ID no.: P19, P38	Intention: Cooling by MP column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T: 25.8 barg, 165 C inlet E2023 25.3 barg, 159 C downstream E2023	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (E2023)	Failure of TIC 5277	Increased duty transfer in re-boiler E2023, no consequence Decreasing temp in D2023, no consequence				
High (total flow)		High temperature, see high temp Higher pressure Higher pressure drop across E2023. Potentially capacity re-strictions Minor liquid carry over from D2003, no critical consequence	See high flow in upstream nodes PV 2406 (vent) PI C 3007 high alarm at compressor suction side			

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Node: 8 Process gas cooling II (E2023, D2003)	P&ID no.: P19, P38	Intention: Cooling by MP column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T: 25.8 barg, 165 C inlet E2023 25.3 barg, 159 C downstream E2023	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (E2023)	Failure open of bypass valve TV 2577	Less transferred duty, no consequence Higher outlet temperature of E2023, no consequence Upsets in MP column T5003 (see node 17)				
Low total flow		No consequences				
Reverse flow	NA					
Parameter: Temperature		**Intention:**				
High	Bypass fully open TV 5277 or no MeOH	No consequence, temp is always below design temp.				
Low	Failure of TIC 5277	Increased duty transfer in re-boiler E2023, no consequence Decreasing temp in D2003, no consequence				

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Node: 8 Process gas cooling II (E2023, D2003)	P&ID no.: P19, P38	Intention: Cooling by MP column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T: 25.8 barg, 165 C inlet E2023 25.3 barg, 159 C downstream E2023	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention:**				
High (E2023)	Blocked outlet see node 6a and 6b	Exceeding design pressure	Vent PV 2406 Vent PIC 2481 PSV 2354-2359			
Low (process gas)	Down stream or upstream vent is open	Less condensation in E2023, no critical consequence				
Parameter: Level		**Intention:**				
High (D2003)	Failure of LIC 2419	Liquid carry over to downstream nodes	LIC 2419 high level alarm			
Low (D2003)	Failure of LIC 2419	Gas break-through to D2004, no consequence	Same design pressure for D2003 and D2004 LIC 2419 low level alarm			

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Node: 8 Process gas cooling II (E2023, D2003)	P&ID no.: P19, P38	Intention: Cooling by MP column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T: 25.8 barg, 165 C inlet E2023 25.3 barg, 159 C downstream E2023	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Leak	Gas into MeOH	Exceeding design pressure of MeOH side	PSV 5251 and PSV 5250 on top of MP column (designed for loss of reflux)	46. Consider install-ing PSV on shell side on E2023 for tube rupture as the current PSV 5250, 5251 are on the top of the MP column.**(Post HAZOP meeting HTAS decision as per 08.07.2010: Not recommended)**	HTAS	

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Node: 9 Process gas cooling III (E2024 1/2, D2004)	P&ID no.: P20, P30	Intention: Cooling by stabilizer column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T:25.3 barg, 159 C inlet E2024, 24.8 barg, 136 C inlet D2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (reboilers E2024)	Failure of TIC 5064	Increased duty transfer in re-boiler E2024, no consequence Decreasing temp in D2004, no consequence				
High (total flow)		High temp, see high temp Higher pressure Higher pressure drop across E2024. Potential capacity re-strictions Minor liquid carry over from D2004, no critical consequence	See high flow in upstream nodes PV 2406 (vent upstream) PI C 3007 high alarm at compressor suction side			

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Node: 9 Process gas cooling III (E2024 1/2, D2004)	P&ID no.: P20, P30	Intention: Cooling by stabilizer column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T:25.3 barg, 159 C inlet E2024, 24.8 barg, 136 C inlet D2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (E2024)	Failure open of bypass valve TV 5064	Less transferred duty, no consequence Higher outlet temp of E2024, no consequence Upsets in stabilizer column T5001 (see node 15)				
Low total flow		No consequence				
Reverse flow	NA					
Mal distributed flow between E2024 1 and 2	Uneven pressure drop	Decreased efficiency of tower T 5001	Symmetrical piping specified by HTAS			
High flow from upstream separator D2003	Failure of level control FV 2419	High level in drum D2004 (see high level)				

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Node: 9 Process gas cooling III (E2024 1/2, D2004)	P&ID no.: P20, P30	Intention: Cooling by stabilizer column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T:25.3 barg, 159 C inlet E2024, 24.8 barg, 136 C inlet D2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High	Bypass fully open TV 5064 or no MeOH/water	No consequences, temperature is always below design temperature. Upsets in T 5001				
Low	Failure of TIC 5064	Increased duty transfer in reboiler E2024 1/2, no consequence Decreasing temp in D2004, no consequence				
Parameter: Pressure		**Intention:**				
High (E2024 1/2)	Blocked outlet see node 6a and 6b	Exceeding design pressure	Vent PV 2406 Vent PIC 2481 PSV 2354-2359			
Low (process gas)	Down stream or upstream vent is open	Less condensation in E2024 1/2, no critical consequence				

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Node: 9 Process gas cooling III (E2024 1/2, D2004)	P&ID no.: P20, P30	Intention: Cooling by stabilizer column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T:25.3 barg, 159 C inlet E2024, 24.8 barg, 136 C inlet D2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Level**		**Intention:**				
High (D2004)	Failure of LIC 2441 Liquid from D2003 by failure of LV 2419	Liquid carry over to downstream nodes	LIC 2441 high level alarm Potential liquid carry over is handled in the final separator. Normal condensate flow from D2003 is significant lower than normal condensate flow from D2004. Pumps are able to handle both.			
Low (D2004)	Failure of LIC 2441	Cavitation and potential damage of pumps. Stagnant gas in pumps as down stream pressure is higher than upstream pressure. Gas breakthrough not possible	LIC 2441 low alarm LALL 2442 low level trip of pumps			*

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Node: 9 Process gas cooling III (E2024 1/2, D2004)	P&ID no.: P20, P30	Intention: Cooling by stabilizer column reboilers	Date: 14.06.2010
	Design P/T: 29 barg, 200 C	Operating P/T:25.3 barg, 159 C inlet E2024, 24.8 barg, 136 C inlet D2004	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Leak	Gas into MeOH/water	Exceeding design pressure of MeOH/water side	PSV 5058 and PSV 5059 and 5060 on top of stabilizer column T5001 (designed for loss of reflux)	47. Consider installing PSV protecting shell side on E2024 for tube rupture as the current PSV 5058, 5059 and 5060 are on the top of the stabilizer column. **(Post HAZOP meeting HTAS decision as per 08.07.2010: Not recommended)**	HTAS	

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Node: 10 Process gas cooling IV (E2025, AE 2026, E2027, D2005)	P&ID no.: P20, P21	Intention: Cooling in DMW preheater, air cooler and water cooler	Date: 14.06.2010
	Design P/T: 29 barg, 200 C upstream AE2026, 120 C inlet E2027, 100 C downstream E2027	Operating P/T: 24.8 barg, 138 C inlet E2025, 24.4 barg, 132 C inlet AE2026, 24.2 barg 65 C inlet E2027 24.0 barg, 48 C outlet D2005	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter:	Flow	**Intention:**				
High (E2025)	Failure of TIC 2457	Increased preheat temperature of demin water, See demin water node Lover inlet temperature to AE 2026, no consequence				
High (total flow)	Open vent downstream, PV 2481 Upstream failure	High temp, see high temperature Higher pressure Higher pressure drop across E2025, AE2026, E2027. Potential capacity restrictions Minor liquid carry over from D2005, potential damage to compressor.	See high flow in upstream nodes PV 2481 (vent downstream) PI C 3007 high alarm at compressor suction side FT 2476 high flow alarm PSV 2354-2359			

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Node: 10 Process gas cooling IV (E2025, AE 2026, E2027, D2005)	P&ID no.: P20, P21	Intention: Cooling in DMW preheater, air cooler and water cooler	Date: 14.06.2010
	Design P/T: 29 barg, 200 C upstream AE2026, 120 C inlet E2027, 100 C downstream E2027	Operating P/T: 24.8 barg, 138 C inlet E2025, 24.4 barg, 132 C inlet AE2026, 24.2 barg 65 C inlet E2027 24.0 barg, 48 C outlet D2005	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (E2025)	Failure open of bypass valve TV 2457	Less transferred duty, no consequence Higher outlet temp of E2025, no consequence Upsets in demin water for deaerator due to low demin water temperature (see node 26)				
Low total flow		No consequence				
Reverse flow of condensate	Back flow through LV 2474 or FV 2233	High level in D2005, liquid carry over, damage of compressors	Check valves at pump outlet (combined check valve and minimum flow) LIC 2474 high alarm LSAH 2474, trip of compressor IS40			*

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Node: 10 Process gas cooling IV (E2025, AE 2026, E2027, D2005)	P&ID no.: P20, P21	Intention: Cooling in DMW preheater, air cooler and water cooler	Date: 14.06.2010
	Design P/T: 29 barg, 200 C upstream AE2026, 120 C inlet E2027, 100 C downstream E2027	Operating P/T: 24.8 barg, 138 C inlet E2025, 24.4 barg, 132 C inlet AE2026, 24.2 barg 65 C inlet E2027 24.0 barg, 48 C outlet D2005	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High	Failure of cooling flows (E2025, AE 2026, E2027) High gas flow High temperature up-stream	Reduce capacity of compressor, C3001, No consequence	TI 2476 high alarm, out of D2005			
Low	Low gas flow Low temperature upstream Low temperature of cool-ing media High flow of cooling me-dia	No consequences				

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Node: 10 Process gas cooling IV (E2025, AE 2026, E2027, D2005)	P&ID no.: P20, P21	Intention: Cooling in DMW preheater, air cooler and water cooler	Date: 14.06.2010
	Design P/T: 29 barg, 200 C upstream AE2026, 120 C inlet E2027, 100 C downstream E2027	Operating P/T: 24.8 barg, 138 C inlet E2025, 24.4 barg, 132 C inlet AE2026, 24.2 barg 65 C inlet E2027 24.0 barg, 48 C outlet D2005	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High	Blocked outlet, e.g. at comp C3001 High pressure upstream External fire below vessels	Potentially exceeding design pressure	PV 2481 (vent downstream) PI C 3007 high alarm at compressor suction side PSV 2354-2359	48. Change design pressure of comp C3001 inlet to 29 barg	HTAS	
High (out of pump P2003)	Blocked outlet	Exceeding design pressure	Design pressure is higher than max shut off pressure Minimum flow (recycle)			
Low	Open vent downstream Low pressure upstream	Capacity limitations Compressor surge (see node 11)	PIC 3007 low alarm on compressor suction			
Low suction pressure to pump P2003	Low level in D2005	Cavitation	Large margin on NPSH LIC 2474 low level alarm Interlock LALL 2474, I35 trip of pumps P2003 A/B			

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Node: 10 Process gas cooling IV (E2025, AE 2026, E2027, D2005)	P&ID no.: P20, P21	Intention: Cooling in DMW preheater, air cooler and water cooler	Date: 14.06.2010
	Design P/T: 29 barg, 200 C upstream AE2026, 120 C inlet E2027, 100 C downstream E2027	Operating P/T: 24.8 barg, 138 C inlet E2025, 24.4 barg, 132 C inlet AE2026, 24.2 barg 65 C inlet E2027 24.0 barg, 48 C outlet D2005	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low discharge pressure at pumps P2003	Stop of pumps	High level in D2005 (see high level)				
Parameter: Composition		**Intention:**				
Liquid	Liquid carry over from upstream node	No consequence				
Parameter: Level		**Intention:**				
High	Stop of pumps P2003	Liquid carry over, damage to compressor	LIC 2474 high alarm LSAH 2474, trip of compressor IS40 Autostart of standby pump			*
Low (D2005)	Failure of level control LV 2474	Cavitaiton of pumps Gas break-through, not possible as pressure downstream is higher than upstream pressure	LIC 2474 low alarm LALL 2474, trip of pumps P2003 IS35			*

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Node: 10 Process gas cooling IV (E2025, AE 2026, E2027, D2005)	P&ID no.: P20, P21	Intention: Cooling in DMW preheater, air cooler and water cooler	Date: 14.06.2010
	Design P/T: 29 barg, 200 C upstream AE2026, 120 C inlet E2027, 100 C downstream E2027	Operating P/T: 24.8 barg, 138 C inlet E2025, 24.4 barg, 132 C inlet AE2026, 24.2 barg 65 C inlet E2027 24.0 barg, 48 C outlet D2005	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
Leaks in E2025	Tube rupture	Process gas to demin water, potentially exceeding design pressure	PSV 2458 on demin water side, designed for tube rupture			
Leaks in E2027	Tube rupture	Process gas to cooling water, potentially exceeding design pressure	PSV 2494 on cooling water side, designed for tube rupture			
Leaks in AE 2026	Tube rupture	Synthesis gas release to atmosphere (toxic and flammable)	Fire and gas detection system Located in classified area	49. Fire and gas detection system (entire plant) to be considered by detailed engineering	MEKPCO	

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Node: 11 Synthesis gas compressor (C3001/C3002)	P&ID no.: P22	Intention: Compression of synthesis gas	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter:		**Intention:**				
				50. Detailed HAZOP on compressor C3001/C3002 to be made when documentation is available from compressor vendor (PIDs) for compliance with HTAS process specifications.	MEKPCO/detailed engineering contractor	

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (discharge compressor)	High flow from compressor discharge	Increased pressure drop Low temperature in tube sheet Increased conversion in R3001 1/2/3.	Flow limited by compressor performance			
Low	Low flow from compressor	High temperature in tube sheet, exceeding design temperature, see high temp Reduced conversion and capacity, low steam production and low MeOH production				
Mal distributed flow	Uneven pressure drop Restricted flow from reactor R3001 1/2/3	High temperature in one reactor, potential exceeding design temperature (see high temperature)	Symmetrical piping Pressure drop across rectors are high (about 2 bars) – higher than pressure drop in piping/exchangers			

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Temperature		**Intention:**				
High	Low flow through reactor R3001 1/2/3 Insufficient cooling for catalyst tubes in R3001 1/2/3	Overheating of catalyst, exceeding design temperature of reactor R3001 and downstream equipment. Long term operation at higher temperature will reduce catalyst life time	TI 3081 high alarm (reactor outlet) TI 3080 high alarm (top of upper tube sheet) TAHH 3080 (top of upper tube sheet), trip I47, reduces set point of TIC 3113 by 10 degrees, and thereby opens bypass TSAH 3080, trip IS 3, trip compressor and stops synthesis (top of upper tube sheet) PIC 3042 high alarm, steam pressure			* *
High (out of E3001 1/2/3)	High temp out of E3001 1/2/3 due to high temperature in R3001 1/2/3	Increasing temperature Potentially overheating of cat. Potentially exceeding design temperature	Bypass around E3001 1/2/3 controlled by TIC 3113	51. Add high alarm on TIC 3113 and TIC 3116 and TIC 3118	HTAS	

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (out of E3001 1/2/3)	Low reactor R3001 outlet temperature Malfunctioning of bypass Low pressure in steam drum D3003	Increased wax production (impurities (corrosion products) in synthesis gas) when temperature is below 200 C (deposited downstream) Less reaction Affects evaporation in saturation T6001 (see node 33)	TI 3081 (reactor outlet) low alarm PIC 3042, low alarm, low steam pressure			

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High	Insufficient conversion in R3001 Blockages downstream External fire	High pressure from compressor discharge Exceeding design pressure	Full flow PSV within vendor scope for C3001/C3002 package PIC 3166 A high alarm at HP separator out-let, controlling the purge rate PIC 3166 B, venting to flare PSV 3163 located on D3001 PSV 3021 upstream E3001			
Low	Lower discharge pressure from compressor High purge rate by failure of FIC 3169 Vent open, PIC 3166 B	Reduced efficiency Reduced conversion	PIC-3166 A low alarm at HP separator outlet			

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High delta P	Blocked catalyst	Reduced circulation rate and reduced capacity. Potential damage of internals in R3001	PDI 3112 high alarm			
	High flow	Potential damage of catalyst				
Parameter: Composition		**Intention:**				
Carbonyls	Synthesis gas in combination with carbon steel above 150 C can form carbonyls	Carbonyls catalyse wax formation in R3001	Selection of stainless steel in synthesis loop Proper precommissioning (cleaning of pipes and equipment from iron dust)			
Low module (2.05)	Improper operation of reformer section	Operation below stoichiometric ratio 2.0 will cause module at inlet at rector to drop further and increase byproduct formation	AFI 3004 1, low alarm for module, makeup gas inlet AFI 3004 2, low alarm for module, outlet E3001 1			
High module	Improper operation of reformer section	Lower loop efficiency, more purge, less production, no consequence				

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Liquid	Condensation in MeOH reactor R3001 during shut down	Damage of catalyst	Temperature in R3001 below values given in operating manual, purge with N2 is re-quired			
Parameter: Reactions		**Intention:**				
Run away (R3001 1/2/3)		No run away reaction				
By products	High temperature High partial pressure of CO	Increases formation of : Ethanol and higher alcohols Ketones e.g. MEK acetone, methyl formation DME Low quality product?				
Parameter: Other		**Intention:**				
Leaks (E3001)	Tube rupture	Reduced production				
Leaks (R3001)	Tube rupture	Gas into steam system, potential exceeding design pressure	PIC 3042 high alarm on steam pressure PSV 3047, PSV 3048, designed for max production of steam			

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Node: 12a Synthesis loop (E3001 1, R3001 1)	P&ID no.: P22, P24, P25	Intention: conversion of H2, CO and CO_2 into crude MeOH and H2O	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Poisoning	e.g. Sulphur chlorine, arsenic	Deactivation of catalyst	See node 2 Chlorine and arsenic are not expected Impurities in steam is handled in prere-former			
	Condensation on catalyst	Weakening of catalyst				

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Node: 12b Synthesis loop (AE3002, E3003, D3001)	P&ID no.: P26, P27	Intention: Cooling of synthesis gas and separation of crude MeOH from recycle gas.	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High	See above (12a)	Less cooling (see high temp) Entrainment in D3001 (liquid to comp causing comp damage)	FI 3167 high alarm D3001 equip with demister			
Low	See above	More cooling (see low temp) Problems with transfer of gas from FE exchanger to air cooler. Air cooler located high causing fluctuation in flow due to slugs	Reduced pipe size to increase flow velocity			
Mal distribution	Uneven pressure drop	See high / low flow				

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Node: 12b Synthesis loop (AE3002, E3003, D3001)	P&ID no.: P26, P27	Intention: Cooling of synthesis gas and separation of crude MeOH from recycle gas.	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Temperature		**Intention:**				
High	Loss of cooling media High gas flow Wax deposit in E3003	Exceeding design temperature	Sufficient margin on design temperature Cannot loose two coolers simultaneous, air cooler will always provide some cooling TI 3142, high alarm, outlet air cooler TI 3164, high alarm outlet HP separator			
Low	Low gas flow Low temp out of E3001/reactor R3001	More condensation, no consequences				
Parameter: Pressure		**Intention:**				
High	See above					
Low	See above					
High pressure drop	Wax deposits in demister in D3001, on LV 6133 (liquid outlet of HP separator) and in loop water cooler	Poor performance of recycle compressor C3002, reduced production	Water cooler designed for maintenance (cleaning of wax) PDI 3024, across synthesis loop			

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Node: 12b Synthesis loop (AE3002, E3003, D3001)	P&ID no.: P26, P27	Intention: Cooling of synthesis gas and separation of crude MeOH from recycle gas.	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High	External fire		PSV 3163 on D3001			
Parameter: Level		**Intention:**				
High in D3001	Mal function of LIC 3161 Wax deposits on LST 3161	Liquid carry over Damage to compressor C3001/2	Traced the impulse lines, LST are with diaphragm seals Spare control valve LV 3161 A/ 3161 B for cleaning during operation LIC 3161 high alarm LSAH high alarm, IS 3 trip			*
Low	Mal function of LIC 3161	Gas break-through to D3002 (low pressure separator) Exceeding design pressure downstream	LIC 3161 low alarm LSAL 3161, trip IS 42 (closes downstream valves to prevent gas break-through)			*
Parameter: Other		**Intention:**				
Leaks in E3003	Tube rupture	Process gas to cooling water, potentially exceeding design pressure	PSV 3143 on cooling water side, designed for tube rupture			

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Node: 12b Synthesis loop (AE3002, E3003, D3001)	P&ID no.: P26, P27	Intention: Cooling of synthesis gas and separation of crude MeOH from recycle gas.	Date: 15.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Leaks in AE 3002	Tube rupture	Synthesis gas release to atmosphere (toxic and flammable)	Fire and gas detection system Located in classified area	52. Fire and gas detection system (entire plant) to be considered by detailed engineering (previously added, see action 49)	MEKPCO	

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Node: 13 LP separator (D3002, X3001)	P&ID no.: P28	Intention: Partly degassing of crude MeOH	Date: 16.06.2010
	Design P/T: 10.0 barg, 100 C at inlet D3002 8.0 barg, 100 C downstream D3002	Operating P/T: 4.0 barg, 48 C	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Flow		**Intention:**				
High	Failure of upstream level control LIC 3161	High level D3002, potential gas break-through from D3001 causing high pressure (see high pressure)	LIC 3161 low alarm LSAL 3161, trip IS 42 (closes downstream valves to prevent gas break-through)			*
Low	Failure of upstream level control LIC 3161	No consequence				
Reverse flow	PSV not closing after relief	Back flow of gases from flare header creating stagnant atmosphere in separator D3002 during shut down		53. Assure blockages of all connecting pipes including PSVs before entering vessel, see node 37	MEKPCO	
Parameter: Temp		**Intention:**				
High (out of HP sep)	High inlet temp.	More flashing More wax to raw MeOH tank, TK5001	TI 3164 high alarm See upstream node			

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Node: 13 LP separator (D3002, X3001)	P&ID no.: P28	Intention: Partly degassing of crude MeOH	Date: 16.06.2010
	Design P/T: 10.0 barg, 100 C at inlet D3002 8.0 barg, 100 C downstream D3002	Operating P/T: 4.0 barg, 48 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Low inlet temp	Less flashing More dissolved gas in MeOH stream				
Parameter: Pressure		**Intention:**				
High	Failure of PIC 3194 (gas to fuel) Gas break-through	Increased inerts in raw MeOH Exceeding design pressure	PSV 3196, 3197 FO3191 (on LP sep inlet line), restricting the gas break-through flow			
	Failure of LIC 3192 (blocked outlet)	High level (see high level)	PIC 3194 (opens vent) PIC 3194 high alarm PSV 3196, 3197			

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Node: 13 LP separator (D3002, X3001)	P&ID no.: P28	Intention: Partly degassing of crude MeOH	Date: 16.06.2010
	Design P/T: 10.0 barg, 100 C at inlet D3002 8.0 barg, 100 C downstream D3002	Operating P/T: 4.0 barg, 48 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
	Blocked filters, X3001 A/B/C External fire	Exceeding design pressure of vessel	PSV 3196, 3197			
Low	Failure of PIC 3194	No consequences (D3002 floating on fuel gas header pressure)				
High pressure drop across filter	Wax deposits in filters X3001 A/B/C	High level in D3002	PDI 3200 high alarm Automatic switching between filters X3001 A/B/C on high delta P PDAHH 3200 causing I48, which opens bypass valve UV 3199 on high delta P, I48	54. Filters are still under evaluation. HTAS has to specify details	HTAS	*

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Node: 13 LP separator (D3002, X3001)	P&ID no.: P28	Intention: Partly degassing of crude MeOH	Date: 16.06.2010
	Design P/T: 10.0 barg, 100 C at inlet D3002 8.0 barg, 100 C downstream D3002	Operating P/T: 4.0 barg, 48 C	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Composition		**Intention:**				
Wax on instru-mentation	Impurities in synthesis gas (corrosion products). Was deposits at low tempera-ture	Mal function of instruments	Diaphragm seals on level transmitters and PDT 3200	55. Add heat tracing on instrument piping to/from level trans-mitters, level gauges and PDT 3200. 56. Add note on PIDs on Shortening instru-ment piping as much as possible	HTAS HTAS	
Wax on valves	Impurities in synthesis gas (corrosion products). Was deposits at low tempera-ture	Mal function of valve LV 3192 Mal function of valve UV3199 or blockage of bypass	Upstream wax filters	57. Consider tracing of bypass piping	HTAS	

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Node: 13 LP separator (D3002, X3001)	P&ID no.: P28	Intention: Partly degassing of crude MeOH	Date: 16.06.2010
	Design P/T: 10.0 barg, 100 C at inlet D3002 8.0 barg, 100 C downstream D3002	Operating P/T: 4.0 barg, 48 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Level		**Intention:**				
High (D3002)	Failure of upstream level control Failure of level control LIC 3192 Blockages of filets	Liquid to purge/fuel system	LIC 3129 high alarm LSAH 3192, trip IS 42 (closes inlet to D3002) See high delta P			*
Low	Failure of level control LIC 3192	Gas into raw MeOH tank TK5001, potentially over pres-surising tank (see node 14)	LIC 3129 low alarm LALL 3192, I43 (closes outlet valve LV 3192)			*

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Node: 14 Raw methanol tank (TK5004)	P&ID no.: P29	Intention: Storage of raw MeOH	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C	Operating P/T: 1.0 barg, 47 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
High	More MeOH from separator, Failure of LIC 3192	High level, high pressure	LI 5001 High alarm LAHH 5002 high alarm, interlock I44 (closes upstream valve LV 3192) PSV 5006			*
High	Recycle from MeOH polisher X5001 Recycle from MeOH product tank via transfer pump, P5008	High level, high pressure	LI 5001 High alarm LAHH 5002 high alarm, interlock I44 (closes upstream valve LV 3192) PSV 5006			*
Low (total)		Low level in tank, low suction pressure for pumps P5001 A/B	LI 5001 low alarm LALL 5002, I53 trip (stop of pumps)			*
Low (from morpholine dosing pump)	Blocked outlet	Exceeding design pressure of discharge line	PSV 7235, 7238			

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Node: 14 Raw methanol tank (TK5004)	P&ID no.: P29	Intention: Storage of raw MeOH	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C	Operating P/T: 1.0 barg, 47 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse		Raw MeOH into upstream piping	Inlet pipe located high to prevent back flow from tank			
Reverse	Dosing pump failure, P7080 A/B	Back flow of MeOH into morpholine system	Check valves (at pump discharge and at mixing point) Reciprocating pump			
Parameter: Temperature		**Intention:**				
High	High inlet temperature from D3002 by failure of water cooler E3003	Increased evaporation from tank TK 5001. Slip of MeOH vapour	Washing of vapour from T 5004 TI 3146 high alarm (out of HP separator D3001) Vapour is used as combustion air in the reformer (not during reformer shut down)			
Low	Not possible					

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Node: 14 Raw methanol tank (TK5004)	P&ID no.: P29	Intention: Storage of raw MeOH	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C	Operating P/T: 1.0 barg, 47 C	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention: Atmospheric conditions**				
High	Blocked outlet from T5004 by failure of vent valve UV 5021	Exceeding design pressure	PI 5004 high alarm (On TK 5001)			
			PSV 5007 (breather valve)			
	Failure of valve UV 2125 (FC)		PSV 5006 (relief valve)			
			See node 13 low level			
	Gas break-through from separator D3002					
			PSV 5006 (relief valve)			
	External fire					
			PSV 5006 (relief valve), vent line dimensions are sufficient			
	PCV 5009 FO					

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Node: 14 Raw methanol tank (TK5004)	P&ID no.: P29	Intention: Storage of raw MeOH	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C	Operating P/T: 1.0 barg, 47 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Emptying tank TK 5001 and simultaneous failure of PCV 5009	Vacuum during emptying tank TK5001 Air ingress, flammable atmosphere	PI 5004 low alarm PCV 5009 which will open at low pressure, N2 make up PSV 5007 (breather) Tank internal/external is classified			
Parameter: Composition		**Intention:**				
High concentration of MeOH	Recycle of MeOH to TK 5001and distillation water to saturator	No consequences				
By products	Upstream wax formation	Wax in tank TK5001	Upstream wax filter X3001			
No morpholine injection	Failure of dosing pump	Potentially increased corrosion due to formic acid in distillation and product sections Too low pH	AP 5019, manual analysis to be made according to analytical manual AP 5010, upstream raw MeOH tank			

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Node: 14 Raw methanol tank (TK5004)	P&ID no.: P29	Intention: Storage of raw MeOH	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C	Operating P/T: 1.0 barg, 47 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Level		**Intention:**				
High	No liquid draw from tank (pump failure P5001 A/B)	Static head build up (high static pressure at the PSVs) Tank rupture	LI 5001 high alarm LAHH 5002, I44 block of product from separator D3002	58. Check PSV 5006 layout to avoid static pressure build up	HTAS	*
Low	Shut down of upstream section (synthesis)	Pump cavitation P5001 A/B	LI 5001 low alarm LALL 5002, trip I53 (shut down of pumps)			*

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
High (inlet to T5001)	Failure of LIC 5041 (open)	Level build up in T5001, damage to column trays, operational disturbances in distillation sections	LIC 5041 high alarm PDI 5048 high alarm LI 5042, indicator	59. Consider adding high alarm on LI 5042	HTAS	
High (reflux)	Failure of FV 5093	Low level in overhead separator, only operational disturbances				
High (steam flow in reboiler)	Steam valve opens from closed position	Much more reboiling Increasing flow in column, and ultimately increasing pressure Damage of trays in column	See reverse flow	60. Check if system can handle three reboiler in operation at same time alternative consider blocking in E5001	HTAS	

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (inlet to T5001)	Failure of LIC 5041 (closed)	Small increased vapour flow from top of column T5001				
Low (reflux)	Closure of valve FV 5093 Stop of reflux pump P5003 A/B	Liquid level will build up Pressure will increase Liquid carry over to coolers and fuel system Liquid into fuels system could disturb burner performance	LIC 5093 high alarm (on separator D5001) FIC 5093 low alarm (on reflux) PSV 5059, 5058, 5060 designed for loss of reflux Autostart of standby reflux pump Separator can contain loss of reflux for 8 minutes (based on empty drum) LI 5094, indicator	61. Consider adding high alarm on LI 5094	HTAS	

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
No flow from pumps (P5001 A/B, P5002 A/B or P5003 A/B)	Blocked outlet	Cavitaiton, potential damage of pump	Minimum flow valves protects pumps (P5001 A/B, P5002 A/B, P5003 A/B)			
Reverse (off gas to fuel header)	Ejector switches off	Back flow of fuel from header to D5001. Potentially exceeding design pressure	Check valve PIC 5091 high alarm PIC 5109, Vent to flare PSV 5058, 5059, 5060			
Parameter: Temperature		**Intention:**				
High (overhead system)	Failure of air cooler AE 5004	Low reflux flow High pressure	(see reverse flow)			

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (tube in-side reboiler)	No liquid to reboiler	Exceeding design temperature	Design temperature selected accordingly			
Low		Reduced stripping efficiency, no consequences				
Parameter: Pressure		**Intention:**				
High	Failure of air cooler AE 5004 Loss of reflux flow Tube rupture in E2024 1/2 External fire	Exceeding design pressure	PIC 5091 high alarm PIC 5109, Vent to flare PSV 5058, 5059, 5060			

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gasses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	No N2	Operational disturbances				
	Shut in of tower during cooling	Vacuum	Tower is designed for full vacuum			
Parameter: Composition		**Intention:**				
Pure water in tower	start up, mistake	Increasing boiling temperature	Tower is designed for boiling point of water			
Pure MeOH	Recycle of off-spec MeOH	Operating at lower temperature, no off gasses, decreasing pressure, N2 make up required				

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Level**		**Intention:**				
High (in T5001)	Blocked outlet, closure of FIC 5161	Increasing level in T5001 Potential damage of trays	LIC 5041 high alarm PDI 5048 high alarm LI 5042			

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (D5001)	Closure of valve FV 5093 Stop of reflux pump P5003 A/B	Liquid level will build up Pressure will increase Liquid carry over to coolers and fuel system Liquid into fuels system could disturb burner performance	LIC 5093 high alarm (on separator D5001) FIC 5093 low alarm (on reflux) PSV 5059, 5058, 5060 designed for loss of reflux Autostart of standby reflux pump Separator can contain loss of reflux for 8 minutes (based on empty drum) LI 5094, indicator	62. Consider adding high alarm on LI 5094 (previously added, see action no. 61)	HTAS	
High (E5010 over head gas condenser)		Liquid to fuel system	Designed for self draining			
High (reboiler)	Not possible					

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Node: 15 Methanol stabilizer (P5001 A/B, T5001, AE 5004, D5001, P5003 A/B,E2024 1/2 P5002 A/B)	P&ID no.: P29, P30, P31, P32, P33	Intention: Stripping of volatile compounds and dissolved gas-ses	Date: 16.06.2010
	Design P/T: 4.5 barg, 100 C inlet to pump P5001 A/B 11.0 barg, 100 C inlet T5001 3.5 barg, 150 C out of top T5001 4.5 barg, 150 after LP separator 5.0 barg 150 C after P5003 A/B 5.0 barg, 160 C out of bottom T5001 8.0 barg, 160 C after P5002 A/B	Operating P/T: 1 barg, 47 C inlet to pump P5001 A7B 5.0 barg, 47 C inlet T5001 0.7 barg, 78 C out of top T5001 0.6 barg, 65C after air cooler 2.7 barg, 65 C after P5003 A/B 1.0 barg, 88 C out of bottom T5001 2.5 barg, 88 C after P5002 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (in T5001)	Failure of valve FV 5161 (opens)	Pump cavitation, P5002 A/B	LIC 5041 low alarm LALL 5042, I54 (stop of pump, P5002 A/B)			*
Low (D5001)	Failure of reflux valve FV 5093 (open)	Pump cavitation, P5003 A/B	LIC 5093 low alarm LALL 5094, I56 (stop of pump, P5003 A/B)			*
Low (reboilers)	Loss of liquid inlet from take off tray	Operational upsets, decreasing duty		63. Check design temperature of tubes in reboiler E5001 (dry running)	HTAS	

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Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (inlet to T5002)	Failure of LIC 5161 (open)	Level build up in T5002, damage to column trays, operational disturbances in distillation sections	LIC 5161 high alarm PDI 5167 high alarm LI 5162, indicator	64. Consider adding high alarm on LI 5162	HTAS	
High (reflux)	Failure of FIC 5203 (open) Failure of FV 5337 (closed)	Low level in overhead separator, pump cavitation P5004 A/B (see low level) Disturbances in separation				
High (vapour outlet to atmosphere)	Open vent, PV 5207	Increased N2 consumption				

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (bottom product)	Failure of valve FV 5239 (open)	See low level				
Low (inlet to T5002)	Failure of LIC 5161 (closed)	Minor increasing overhead vapour flow from top of column T5002, no consequences				
Low (reflux)	Closure of valve FV 5203 Stop of reflux pump P5004 A/B	Liquid level will build up Off-spec MeOH Minor pressure increase Liquid carry over to atmosphere (venting) See high level	LIC 5203 high alarm (on separator D5002) FIC 5203 low alarm (on reflux) Autostart of standby reflux pump LI 5204, indicator	65. Consider adding high alarm on LI 5204	HTAS	
Low (product)	Failure of FV 5337 (closed)	Increased reflux flow, more MeOH in T5002 High level in D5002 (see high level)				

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (column bottom)		See high level				
No flow from pumps (P5005 A/B)	Blocked outlet	Cavitaiton, potential damage of pump, P5005 A/B	Minimum flow valve protects pumps,P5005 A/B			
No flow from P5004	Closure of FV 5203 and FV 5337	Cavitaiton, potential damage of pump P5004 A/B	Minimum flow valve protects pumps, P5004 A/B			
Low (reboiler)	Low level in column	Exceeding design temperature of reboiler (not possible)				
Reverse (of column bottom)	Pump failure	Gas break-through from T5003. Potentially exceeding design pressure	Check valve Normal back pressure does not exceed de-sign pressure of T5002			

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Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High (overhead system)	Failure of air cooler AE 5005	Low reflux flow High pressure	PV 5207 (open vent) PIC 5207 high alarm PSAH 5207(on D5002), IS 4, shut down of distillation section (to prevent large releases to atmosphere) The maximum pressure possible at reboiler temperature at 102 C is below 3.5 barg			*
High (to storage)	Loss of cooling	Increased evaporation from storage	TI 5381 high alarm (on combined product run down)			
High (tube inside reboiler)	No liquid to reboiler	Exceeding design temperature	Design temperature selected accordingly			
Low	Low temperature of heating media to reboiler	Potential reduced reboiler duty Reduced capacity of column				

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Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High	Failure of air cooler AE 5005 Loss of reflux flow Tube rupture in E5002 1/2/3/4 External fire	Increasing pressure	PIC 5207 high alarm PSAH 5207, IS 4 trip, stop of distillation PSV 5179			*
Low	No N2 Shut in of tower during cooling	Operational disturbances Vacuum	 Tower is designed for full vacuum			
Parameter: Composition		**Intention:**				
Pure water in tower	start up, mistake	Increasing boiling temperature	Tower is designed for boiling point temperature of water			

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Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Pure MeOH	Recycle of off-spec MeOH	Operating at lower temperature, no off gasses, decreasing pressure, N2 make up required				
Parameter: **Level**		**Intention:**				
High (in T5002)	Blocked outlet, closure of FIC 5239	Increasing level in T5002 Potentially damage of trays	LIC 5161 high alarm PDI 5167 high alarm LI 5162, indicator			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (D5002)	Closure of FV 5203 and FV 5337 Stop of reflux pump P5004 A/B	Liquid level will build up Pressure will increase Liquid carry over to atmosphere, release of liquid MeOH	LIC 5203 high alarm (on separator D5002) FIC 5203 low alarm (on reflux) PSAH 5207 IS 4 trip, trip of distillation section Autostart of standby reflux pump Separator can contain loss of reflux for 8 minutes (based on empty drum) LI 5204 indicator	66. Consider adding high alarm on LI 5204 (previously added, see action 65) 67. Check set pressure of PSAH 5207 to prevent release of liquid from PV 5207 B (static head)	HTAS HTAS	 *
High (reboiler)	Not possible					
Low (in T5002)	Failure of valve FV 5239 (opens)	Pump cavitation, P5005 A/B	LIC 5161 low alarm LALL 5162, I57 (stop of pump, P5005 A/B)			*

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Node: 16 LP Methanol Column (T5002, P5005 A/B)	P&ID no.: P27, P34, P 36, P37, P40	Intention: Distillation of MeOH	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 3.5 barg, 160 C out of top T5002 5.0 barg, 160 C out of bottom T5002 15.0 barg, 160 C after pumps, P5005 A/B	Operating P/T: 2.5 barg, 88 C inlet 0.1 barg, 67 C out of top T5002 0.7 barg, 86 C out of bottom T5002 6.5 barg, 86 C after pumps, P5005 A/B	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (D5002)	Failure of reflux valve, FIC 5203 and FIC 5337 (open)	Pump cavitation, P5004 A/B	LIC 5203 low alarm LALL 5204, I58 (stop of pump, P5004 A/B)			*
Low (reboilers)	Not possible					

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Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (inlet to T5003)	Failure of FIC 5239 (open)	Level build up in T5003, damage to column trays, operational disturbances in distillation sections	LIC 5270 high alarm PDI 5259 high alarm TIC 5266, 5267, 5268 low alarms LI 5271, indicator	68. Consider adding high alarm on LI 5271	HTAS	
High (reflux)	Failure of FIC 5321 (open) Failure of FV 5336 (closed)	Low level in overhead separator, pump cavitation P5006 A/B (see low level) Disturbances in separation				

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Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (vapour outlet to flare)	Open vent (HIC xx)	No consequences				
High (bottom product to wash water)	Failure of FV 5020 (open)	No consequences				
High (bottom product to satu-rator)	Failure of FV 5367 (open)	Loss of level in column T5003, consequently pump P5010 cavi-tation	LIC 5270 low alarm LALL 5271, I59 trip of pumps			*
High (liquid off stream)	Failure of FIC 5441 (open)	Better removal of impurities (higher alcohols) Loss of MeOH		69. Consider devia-tion alarm on FIC 5441	HTAS	

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Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (final product to polisher)	Failure of FV 5336 (open)	Reduced reflux Water in MeOH product	FIC 5336 high flow alarm FIC 5321 low alarm (on reflux) TI 5280 high alarm (overhead vapour temperature)			
High (final product to polisher)	Failure of LIC 5321(reflux flow and product flow valves fully open)	Low level in D5003 Cavitation of P5006	LIC 5321 low alarm LALL 5322, I60 trip of pump P5006			* *
Low (inlet to T5003)	Failure of FV 5239 (closed)	Low level in bottom of T5003 (see low level) Increased off-spec MeOH (more water) Increasing temperature in overhead vapour	High alarm on all TIs in T5003 Reduced steam input by operator and operating in 100% reflux mode Trip of pumps P5007, P5010 by I59 (see low level)			

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Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (reflux)	Closure of FV 5321 (with or without simultaneous closure of FV 5336) Stop of reflux pump P5006 A/B	Liquid level will build up in overhead separator D5003 Increased product flow Off-spec MeOH Flooding condenser Pressure increases, potentially exceeding design pressure	FIC 5321 low alarm (on reflux) High alarm on all TIs in T5003 LIC 5321 high alarm PI 5260 high alarm (bottom of column) PSVs 5250, 5251 Autostart of spare pump P5006 A/B			

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Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (product)	Failure of FV 5336 (closed) Pump failure, P5006 A/B	Increased reflux flow, more MeOH in T5003 bottom water Increasing pressure Decreasing temperature Build up level in column Flooding of column	PI 5260 high alarm (bottom of column) PSVs 5250, 5251 Autostart of spare pump P5006 A/B Reduced feed flow, TIC 5266, 5267, 5268 PDI 5253, 5255, 5257, 5259 high alarm			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (column bottom to wash water)	Failure of valve FV 5020 (closed) Pump failure, P5007 A/B	Increased flow to saturator Loss of water washing in raw MeOH tank Dry running of reboiler E5003, potentially exceeding design temperature of shell side		70. Check design temperature of re-boiler E5003 (dry running)	HTAS	
Low (column bottom to satu-rator)	Failure of FV 5367 (closed) Pump failure, P5010 A/B	Level build up in column Potentially damage of trays Less evaporation in saturator	LIC 5270 high alarm PDI 5259 high alarm LI 5271, indicator Autostart of spare pump, P5010	71. Consider adding high alarm on LI 5271 (previously added, see action no. 68)	HTAS	

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
No flow from pumps (P5007, P5010 A/B, P5006)	Blocked outlet	Cavitaiton, potential damage of pumps	Minimum flow valve protects pumps (P5010 A/B, P5006) Low head of P5007 and open recycle line			
Low (reboiler)	Low level in column	Exceeding design temperature of reboiler (see low flow of column bottom to wash water)				
Low (liquid off stream)	Failure of FV 5441 (closed)	Higher alcohols in MeOH product		72. Consider deviation alarm on FIC 5441 (previously added, see action no. 69)	HTAS	

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse (process condensate from saturator into T5003)	Pump failure, P5010	Increasing level in column, potentially damage of trays Potentially increasing pressure	2 check valves series LIC 5270 high alarm LI 5271, indicator PSVs 5250, 5251			
Parameter: Temperature		**Intention:**				
High (overhead system)	Failure of overhead condenser E5002 1/2/3/4 (loss of cooling)	Low/no reflux flow High pressure	PI 5260 high alarm High temperature alarms on all TIs in T5003 PSVs 5250, 5251			
High (to polisher)	Loss of cooling in E5012	Increased evaporation from storage	TI 5381 high alarm (on combined product run down)			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (tube in-side reboiler)	No liquid to reboiler	See low flow				
Low	Low steam flow to re-boiler	Potentially reduced reboiler duty Reduced capacity of column				
Parameter: Pressure		**Intention:**				
High	Loss of condenser cooling in E5002 Loss of reflux flow (de-termines the size of PSVs) Tube rupture in E2023 See above deviations External fire	Increasing pressure, potentially exceeding design pressure	PI 5260 high alarm High temperature alarms on all TIs in T5003 PSVs 5250, 5251			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Pure water in column and cooling down of column	Slight vacuum	Tower is designed for full vacuum			
Parameter: Composition		**Intention:**				
Pure MeOH	Recycle of off-spec MeOH	Higher pressures	PI 5260 high alarm (bottom of column) PSVs 5250, 5251			
Low pH value in column due to byproducts	Insufficient injection of morpholine into upstream raw MeOH tank TK5001	Potentially corrosion Off-spec product (amines)	Manual analysis of acidity of raw MeOH and distillation water out of bottom of column T5003 according to operating manual			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Level**		**Intention:**				
High (in T5003)	Blocked outlet, closure of FV 5367 Failure of pump, P5010	Increasing level in T5003 Potentially damage of trays	LIC 5270 high alarm PDI 5259 high alarm LI 5271, indicator Autostart of spare pump, P5010			
High (D5003)	Failure of LIC 5321 Failure of pump P5006	Liquid level will build up in overhead separator D5003 Flooding condenser Pressure increases, potentially exceeding design pressure	High alarm on all TIs in T5003 LIC 5321 high alarm PI 5260 high alarm (bottom of column) PSVs 5250, 5251 Autostart of spare pump P5006 A/B			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 17 MP methanol column (T5003, E5002, D5003, P5006, E5012)	P&ID no.: P34, P35, P38, P39, P40, P41	Intention: Water and higher alcohols are removed from methanol	Date: 18.06.2010
	Design P/T: 8.0 barg, 160 C inlet 6.0 barg, 165 C out of top T5003 7.5 barg, 175 C out of bottom T5003 6.0 barg, 165 inlet to D5003 18.0 barg, 165 C after pumps, P5006 A/B 18.0 barg, 75 C after E5012	Operating P/T: 3.5 barg, 86 C inlet 2.7 barg, 102 C out of top T5003 3.6 barg, 149 C out of bottom T5003 2.6 barg, 101 inlet to D5003 6.0 barg, 101 C after pumps, P5006 A/B 3.0 barg, 48 C after E5012	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (in re-boiler E5003)	Not possible (controlled by weir)					
Low (in T5003)	Failure of valve FV 5367 (opens)	Loss of level in column T5003, consequently pump P5010 cavi-tation	LIC 5270 low alarm LALL 5271, I59 trip of pumps			 *
Low (D5003)	Failure of reflux valve LIC 5321	Low level in D5003 Cavitation of P5006	LIC 5321 low alarm LALL 5322, I60 trip of pump P5006			 *
Low (reboiler)	Stop of recycle pump P5007 A/B	Dry running of reboiler E5003, potentially exceeding design temperature of shell side (see low flow of wash water)				
Parameter: Other		**Intention:**				
Uncondensables		Increasing pressure	Manual venting from D5003 (HIC xx)			

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Node: 18 Product polisher (X5002 A/B)	P&ID no.: P42	Intention: Removal of impurities (amines)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C	Operating P/T: 3.0 barg, 48 C	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Flow		**Intention:**				
High	Failure of FV 5336 (open)	No consequences				
Low	Failure of FV 5336 (closed)	No consequences				
Parameter: Temperature		**Intention:**				
High	Failure of upstream cooling E5012 or E5008	Exceeding design temperature Evaporation of MeOH	TI 5381 high alarm (inlet) Higher mass flow of low temperature MeOH from E5008 than potential high temperature flow (loss of cooling) from E5012. Prevents exceeding design temperature			
Low		No consequences				

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Node: 18 Product polisher (X5002 A/B)	P&ID no.: P42	Intention: Removal of impurities (amines)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C	Operating P/T: 3.0 barg, 48 C	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention:**				
High	Blocked outlet	Operating at maximum pump shut off pressure which is less than 18 barg	Design pressure is 18 barg (product line)			
		Pressure build up in demin water line (leaking manual block valve)		73. Install blinds at individual inlet to polishers.	HTAS	
	External fire		PSVs 5384, 5386	74. Consider installing common PI and PG on inlet to polishers	HTAS	
High pressure drop across strainer	Absorber dust	Blocked strainer Higher upstream pressure (see above)	PDI 5385 high alarm			
Low		No consequences				
Parameter: Composition		**Intention:**				
Higher concentration of impurities	Loss of morpholine injection	Reduction of life time (see raw MeOH tank node 14)				

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Node: 18 Product polisher (X5002 A/B)	P&ID no.: P42	Intention: Removal of impurities (amines)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C	Operating P/T: 3.0 barg, 48 C	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Level**		**Intention:**				
No level in pol-isher						

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Node: 19 Product buffer tank and product pump (TK5002, P5008A/B)	P&ID no.: P43, P44	Intention: Storage of methanol and pumping to product tank (BL)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C inlet 3.5 barg, 75 C TK5002 4.5 barg, 75 C after TK5002 17.0 barg, 75 C after P5008	Operating P/T: 3.0 barg, 48 C 0.0 barg, 40 C TK5002 0.0 barg, 48 C after TK5002 5.0 barg, 48 C after P5008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High	More MeOH from T5002/3, separators, fail-ure of level control	High level (see high level)				

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Node: 19 Product buffer tank and product pump (TK5002, P5008A/B)	P&ID no.: P43, P44	Intention: Storage of methanol and pumping to product tank (BL)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C inlet 3.5 barg, 75 C TK5002 4.5 barg, 75 C after TK5002 17.0 barg, 75 C after P5008	Operating P/T: 3.0 barg, 48 C 0.0 barg, 40 C TK5002 0.0 barg, 48 C after TK5002 5.0 barg, 48 C after P5008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (to product tank at BL)	Blocked outlet	Pump cavitation	Minimum flow valve returning to tank	75. Consider installing a three way control valve on the return line to ensure direct connection to at least one tank 76. Consider installing common PI with high alarm on discharge line of pump P5008 77. Consider thermal expansion valve on run down line (note on PID)	HTAS HTAS HTAS	
Reverse	Back flow of MeOH from run down line when pump P5008 is out of operation	Back flow of MeOH to buffer tank	Check valves on pump discharge			

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Node: 19 Product buffer tank and product pump (TK5002, P5008A/B)	P&ID no.: P43, P44	Intention: Storage of methanol and pumping to product tank (BL)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C inlet 3.5 barg, 75 C TK5002 4.5 barg, 75 C after TK5002 17.0 barg, 75 C after P5008	Operating P/T: 3.0 barg, 48 C 0.0 barg, 40 C TK5002 0.0 barg, 48 C after TK5002 5.0 barg, 48 C after P5008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High	High inlet temperature from D5003 by failure of water cooler E5012	Increased evaporation from tank TK 5002 1/2. Slip of MeOH vapour	Washing of vapour from T 5002 TI 5381 high alarm (inlet of polisher) Vapour is used as combustion air in the re-former (not during reformer shut down)			
Low	Not possible					
Parameter: Pressure		**Intention: Atmospheric conditions**				
High	Blocked outlet from T5002 by failure of vent valve UV 5021 (FO) Failure of valve UV 2125 (FC) External fire PCV 5412 or 5395 (opens N2 blanketing)	Exceeding design pressure	PI 5398, 5415 high alarm PSV 5419 (breather valve, common for both tanks, opens to the wash column) PSV 5400, 5417 (relief valves)			

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Node: 19 Product buffer tank and product pump (TK5002, P5008A/B)	P&ID no.: P43, P44	Intention: Storage of methanol and pumping to product tank (BL)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C inlet 3.5 barg, 75 C TK5002 4.5 barg, 75 C after TK5002 17.0 barg, 75 C after P5008	Operating P/T: 3.0 barg, 48 C 0.0 barg, 40 C TK5002 0.0 barg, 48 C after TK5002 5.0 barg, 48 C after P5008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Emptying tank TK 5002 Failure of PCV 5412 or PCV 5395	Vacuum during emptying tank TK5002 Air ingress, flammable atmos-phere	PI 5398, 5415 low alarm PCV 5412 or 5395 which will open at low pressure, N2 make up PSV 5401, 5418 (breather) Tank internal/external is classified	78 Consider separate breather valves on tank TK5002 1/2	HTAS	
Parameter: Composition		**Intention:**				
Off-spec MeOH	Mistake	Requirement of recycle of off-spec MeOH to TK5001				
Parameter: Level		**Intention:**				
High	Liquid not pumped from tank TK 5002 Pump failure, P5008	Static head build up (high static pressure at the PSVs) Tank rupture	LI 5396, 5413 high alarm LAHH 5397, 5414, I62, I63 block inlet to tank and put the other tank in service	79. Check PSV 5400, 5417 layout to avoid static pressure build up	HTAS	*

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Node: 19 Product buffer tank and product pump (TK5002, P5008A/B)	P&ID no.: P43, P44	Intention: Storage of methanol and pumping to product tank (BL)	Date: 22.06.2010
	Design P/T: 18.0 barg, 75 C inlet 3.5 barg, 75 C TK5002 4.5 barg, 75 C after TK5002 17.0 barg, 75 C after P5008	Operating P/T: 3.0 barg, 48 C 0.0 barg, 40 C TK5002 0.0 barg, 48 C after TK5002 5.0 barg, 48 C after P5008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Shut down of upstream section (distillation)	Pump cavitation P5008 A/B	LI 5396, 5413 low alarm LALL 5397, 5414, trip I64, I65 (shut down of pumps)			*

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Node: 20 Liquid off stream (E 5011, TK 5003, P 5009 A/B)	P&ID no.: P01, P07, P32, P45	Intention: Storage of higher alcohol	Date: 23.06.2010
	Design P/T: 7.5 barg, 175 C inlet E5011 7.5 barg, 75 C inlet TK5003 4.5 barg, 75 C outlet TK5003 60.0 barg, 75 C outlet P5009	Operating P/T: 2.6 barg, 115 C inlet E5011 2.0 barg, 48 C inlet TK5003 0.0 barg, 48 C outlet TK5003 50.0 barg, 50 C outlet P5009	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (from T5003)		No consequences				
High (from P5003)		No consequences				

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Node: 20 Liquid off stream (E 5011, TK 5003, P 5009 A/B)	P&ID no.: P01, P07, P32, P45	Intention: Storage of higher alcohol	Date: 23.06.2010
	Design P/T: 7.5 barg, 175 C inlet E5011 7.5 barg, 75 C inlet TK5003 4.5 barg, 75 C outlet TK5003 60.0 barg, 75 C outlet P5009	Operating P/T: 2.6 barg, 115 C inlet E5011 2.0 barg, 48 C inlet TK5003 0.0 barg, 48 C outlet TK5003 50.0 barg, 50 C outlet P5009	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (D1001)	Manual valve left open	Gas break through Exceeding design pressure of tank TK5003, tank rupture	PI 5448 high alarm PSV 5450	80. PSV 5450 to be designed for gas break through from D1001 81. Consider chang-ing manual drain valve from KO D1001 from 2” to 1” 82. Consider install-ing separate shut off valve at low level in D1001	HTAS HTAS HTAS	
High (from P5009)	Fail open of FV 6057	Decreasing level in tank, poten-tially cavitation of pump P5009	LI 5446 low alarm LALL 5447 low alarm, I52(trip of pump P5009)			*

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Node: 20 Liquid off stream (E 5011, TK 5003, P 5009 A/B)	P&ID no.: P01, P07, P32, P45	Intention: Storage of higher alcohol	Date: 23.06.2010
	Design P/T: 7.5 barg, 175 C inlet E5011 7.5 barg, 75 C inlet TK5003 4.5 barg, 75 C outlet TK5003 60.0 barg, 75 C outlet P5009	Operating P/T: 2.6 barg, 115 C inlet E5011 2.0 barg, 48 C inlet TK5003 0.0 barg, 48 C outlet TK5003 50.0 barg, 50 C outlet P5009	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (from T5003)	Fail close of FV 5441	No consequence for the tank				
Low (from P5003)	Fail close of FV 5107	No consequence for the tank				
Low (from P5009)	Fail close of FV 6057	Pumping against blocked outlet High level in tank TK5003 (see high level)	Minimum flow protection			
Reverse (from saturator into tank)	Pump failure, P5009	Exceeding design pressure Tank rupture	One check valve and reciprocating pump PSV 5450 PI 5448 high alarm	83. PID to be updated to actual pump type (reciprocating pump)	HTAS	

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Node: 20 Liquid off stream (E 5011, TK 5003, P 5009 A/B)	P&ID no.: P01, P07, P32, P45	Intention: Storage of higher alcohol	Date: 23.06.2010
	Design P/T: 7.5 barg, 175 C inlet E5011 7.5 barg, 75 C inlet TK5003 4.5 barg, 75 C outlet TK5003 60.0 barg, 75 C outlet P5009	Operating P/T: 2.6 barg, 115 C inlet E5011 2.0 barg, 48 C inlet TK5003 0.0 barg, 48 C outlet TK5003 50.0 barg, 50 C outlet P5009	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High (to tank)	Failure of cooling water	Increasing evaporation Exceeding boiling point Increasing pressure in tank TK5003	PI 5448 high alarm PSV 5450	84. Consider adding high alarm on TI 5443	HTAS	
Low		No consequences				

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Node: 20 Liquid off stream (E 5011, TK 5003, P 5009 A/B)	P&ID no.: P01, P07, P32, P45	Intention: Storage of higher alcohol	Date: 23.06.2010
	Design P/T: 7.5 barg, 175 C inlet E5011 7.5 barg, 75 C inlet TK5003 4.5 barg, 75 C outlet TK5003 60.0 barg, 75 C outlet P5009	Operating P/T: 2.6 barg, 115 C inlet E5011 2.0 barg, 48 C inlet TK5003 0.0 barg, 48 C outlet TK5003 50.0 barg, 50 C outlet P5009	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High (in tank)	Loss of cooling water(see flow) Gas break through from D1001(see flow) Back pressure from satura-tor (see flow) External fire Fail close of breather valve Fail open of PCV 5445 (N2 blanketing)	Increasing pressure in tank TK5003, potentially tank rupture	PI 5448 high alarm PSV 5450			
Low (in tank)	Fail close of PCV 5445 (N2 blanketing)	Vacuum in tank TK5003	Vacuum breaker PSV 5451 PI 5448 low alarm			

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Node: 20 Liquid off stream (E 5011, TK 5003, P 5009 A/B)	P&ID no.: P01, P07, P32, P45	Intention: Storage of higher alcohol	Date: 23.06.2010
	Design P/T: 7.5 barg, 175 C inlet E5011 7.5 barg, 75 C inlet TK5003 4.5 barg, 75 C outlet TK5003 60.0 barg, 75 C outlet P5009	Operating P/T: 2.6 barg, 115 C inlet E5011 2.0 barg, 48 C inlet TK5003 0.0 barg, 48 C outlet TK5003 50.0 barg, 50 C outlet P5009	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Level		**Intention:**				
High (in tank)	Pump failure, P5009 Operator mistake	Static head build up (high static pressure at the PSVs) Tank rupture	LI 5446 high alarm LAHH 5447, I51trip (blockages of all inlets)	85. Check PSV 5450 layout to avoid static pressure build up	HTAS	*
Low (in tank)	Fail open of FV 6057	Decreasing level in tank, potential cavitation of pump P5009	LI 5446 low alarm LALL 5447 low alarm, I52(trip of pump P5009)			*

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Node: 21 Bottom product to wash column T5004 (AE 5006, E5007, T5004)	P&ID no.: P29, P41	Intention:	Date: 23.06.2010
	Design P/T: 7.5, 175 C inlet 10.0 barg, 175 C outlet P5007 7.5 barg, 120 C outlet AE5006 7.5 barg, 100 C outlet E5007	Operating P/T: 3.8, 149 C inlet 4.5 barg, 149 C outlet P5007 4.3 barg, 65 C outlet AE5006 4.0 barg, 48 C outlet E5007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Flow		**Intention:**				
High (wash water)	Fail open of control valve FV 5020	Reduced strength of raw MeOH Level build up in wash water T5004(not possible, drain pipe sufficient for full flow)				
Low	Fail close of FV 5020	Loss of washing Increased MeOH loss Slight increase in MeOH concentration in T5001	FIC 5020 low alarm			
Parameter: Temperature		**Intention:**				
High (wash water to T5004)	Failure of cooling water	Slightly reduced washing capacity, consequently more loss of MeOH				
Low		No consequences				

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Node: 21 Bottom product to wash column T5004 (AE 5006, E5007, T5004)	P&ID no.: P29, P41	Intention:	Date: 23.06.2010
	Design P/T: 7.5, 175 C inlet 10.0 barg, 175 C outlet P5007 7.5 barg, 120 C outlet AE5006 7.5 barg, 100 C outlet E5007	Operating P/T: 3.8, 149 C inlet 4.5 barg, 149 C outlet P5007 4.3 barg, 65 C outlet AE5006 4.0 barg, 48 C outlet E5007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High		See node 14				
Low		No consequences				

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Node: 22 Fuel gas to primary reformer	P&ID no.: U01, P01, P15, P27	Intention:	Date: 23.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Flow		**Intention:**				
High/low		See node 5				
Parameter: Temperature		**Intention:**				
High/low		No consequences				
Parameter: Level		**Intention:**				
High		See node 1 and 12				
Parameter: Pressure		**Intention:**				
High (after de-pressurization of NG)	Fail open of pressure con-trol valve PIC 1011	Exceeding design pressure	PSV 1013			
High (after de-pressurization of purge gas)	Fail open of pressure con-trol valve	Exceeding design pressure	PSV 3173 PIC 2536 B (vent)			
High (during N2 purge)	Supply pressure of N2 is high	Exceeding design pressure of mixer	PSV 2546			

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Node: 23 Flue gas system	P&ID no.: P12, P13, P15	Intention: Preheating of NG feed and combustion air	Date: 23.06.2010
	Design P/T:	Operating P/T: 1090 C outlet H2001, 790 C outlet E2001, 436 C outlet E2002, 348 C outlet E2004, 234 C outlet E2006, 150 C outlet E2007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High flue gas flow at unaffected temperature	Higher combustion air flow due to combustion/air control is leading to over firing of the reformer H2001	More heat available for the coils Increased flue stack temperature	Outlet temperature from reformer will increase and give alarm TI 2303, 2304, 2305 (on common outlet) TSAH 2305, IS1 trip of reformer TI 2295 2297 high alarm Sufficient margin on coil design temperatures			*
High process flow in flue gas coils		No consequences				

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Node: 23 Flue gas system	P&ID no.: P12, P13, P15	Intention: Preheating of NG feed and combustion air	Date: 23.06.2010
	Design P/T:	Operating P/T: 1090 C outlet H2001, 790 C outlet E2001, 436 C outlet E2002, 348 C outlet E2004, 234 C outlet E2006, 150 C outlet E2007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (flue gas)	Maloperation of PIC 2224	Increasing pressure in flue gas duct	PIC 2224 high alarm			
			PAHH 2224, I15 trip (opens dampers)			*
		Potential harm to operators affected by hot flue gasses	PSAH 2224, IS1 trip of reformer section			*
		Heat accumulation causing damage to reformer				
	Trip of flue gas fan		Motor driver with autostart			
			IS12 trip of flue gas fan will cause IS 1			

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Node: 23 Flue gas system	P&ID no.: P12, P13, P15	Intention: Preheating of NG feed and combustion air	Date: 23.06.2010
	Design P/T:	Operating P/T: 1090 C outlet H2001, 790 C outlet E2001, 436 C outlet E2002, 348 C outlet E2004, 234 C outlet E2006, 150 C outlet E2007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low process flow in flue gas coils	Partly loss of process stream	Increased temperature in H2001 and increased temperature profile in flue gas duct. Potentially exceeding design temperature	Outlet temperature from reformer will increase and give alarm TI 2303, 2304, 2305 (on common outlet) TSAH 2305, IS1 trip of reformer TI 2295 2297 high alarm (flue gas) TSAH 2221, IS1 trip of reformer (flue gas) Sufficient margin on coil design temperatures (see process specification for design temperature)	86. Ensure design temperature of the coils take reduced process gas flow into account	HTAS	 * *
Parameter: Temperature		**Intention:**				
High (flue gas from H2001)	Over firing	Exceeding design temperatures	TI 2295 2297 high alarm (flue gas) TSAH 2221, IS1 trip of reformer (flue gas)			 *
Low (flue gas from H2001)	Under firing	Operational disturbances	TI 2155 low alarm (stack temperature)			

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Node: 23 Flue gas system	P&ID no.: P12, P13, P15	Intention: Preheating of NG feed and combustion air	Date: 23.06.2010
	Design P/T:	Operating P/T: 1090 C outlet H2001, 790 C outlet E2001, 436 C outlet E2002, 348 C outlet E2004, 234 C outlet E2006, 150 C outlet E2007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Pressure		**Intention:**				
High (flue gas)	Failure of PIC 2224	Increasing pressure in flue gas duct Potential harm to operators affected by hot flue gasses Heat accumulation causing damage to reformer	PIC 2224 high alarm PAHH 2224, I15 trip (opens dampers) PSAH 2224, IS1 trip of reformer section			 * *
	Trip of flue gas fan		Motor driver with autostart IS12 trip of flue gas fan will cause IS 1			

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Node: 23 Flue gas system	P&ID no.: P12, P13, P15	Intention: Preheating of NG feed and combustion air	Date: 23.06.2010
	Design P/T:	Operating P/T: 1090 C outlet H2001, 790 C outlet E2001, 436 C outlet E2002, 348 C outlet E2004, 234 C outlet E2006, 150 C outlet E2007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (flue gas)	Failure of PIC 2224 Failure of combustion air FIC 2111	Increased vacuum in flue gas section Potentially damage of insulation/casing	PIC 2224 low alarm (outlet of H2001) PSAL 2224 low alarm (outlet of H2001), IS 1 trip of reformer AI 2223 2, high alarm (combustibles) AI 2223 1, low alarm (O_2) AI 2224, low alarm (O_2)	87. Consider opening of false air damper at low pressure 88. Assure correct installation of atmospheric leg at pressure instruments according to HTAS hook up drawing J24	HTAS MEKPCO	*

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Node: 23 Flue gas system	P&ID no.: P12, P13, P15	Intention: Preheating of NG feed and combustion air	Date: 23.06.2010
	Design P/T:	Operating P/T: 1090 C outlet H2001, 790 C outlet E2001, 436 C outlet E2002, 348 C outlet E2004, 234 C outlet E2006, 150 C outlet E2007	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
Leakages from coils	Coil rupture	Increasing pressure Combustibles into flue gas Increased temperature in the upper part of the flue gas duct	Proper material selection in design of coils Fully welded coils inside flue gas duct Coil rupture is unlikely to happen due to coil dimensions (wall thickness)			
Condensation of flue gas	Low temperature	Potential corrosion in combustion air preheater E2007	TI 2155 low alarm Bypass of combustion air preheater can control stack temperature			
Parameter: Other		**Intention:**				
Operating at no combustion air surplus	Maloperation of combustion air control	Post combustion when air is leaking into flue gas system, increasing temperature	Design has taken into account minimisation of air leaks AI 2223 2, high alarm (combustibles) AI 2223 1, low alarm (O_2) AI 2224, low alarm (O_2)			

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (O_2)	Malfunction of flow control FIC 2007	Increased O/C ratio Increased reformer temp in R2004. Potential damage of cat, reformer and downstream equipment.	FFI 2020, high O/C ratio alarm FFSAH 2008, high O/C ratio, trip of secondary reformer (IS 2) TI 2333 high temperature alarm TSAH 2333 (outlet) TI 2325 (temperature in combustion zone) TSAH 2325 (temperature in combustion zone)			* * *
Low (O_2)	Malfunction of flow control FIC 2007 Upstream blockage, failure of O_2 supply (e.g. O_2 filter)	Low O/C ratio Reduced outlet temperature from R2004, no consequences Increased CH4 slip	AI 2479 (CH4 analyser)	89. Add high alarm on AI 2479 (previouly added see action 28)	HTAS	

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (steam)	Fail open of flow control FV 2040	No consequences				
Low (steam)	Fail close of flow control FV 2040	Low steam/O2 ratio Potential overheating of burner Risk of auto ignition of stainless steel piping downstream mixing point	FIC 2040 low alarm FSAL 2040, IS 2 trip of secondary reformer Filters on O2 and HP steam flows			 *
Reverse (HC in O_2/steam)	Simultaneous failure of O_2 and steam supply	Explosion in O_2-piping	Check valves FIC 2040 low alarm on steam flow FSAL 2040, trip, IS 2 steam flow			 *

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse (O_2 into Steam)	No steam pressure	O_2 into steam system Corrosion Risk of auto ignition of piping in steam system	Check valve FIC 2040 low alarm on steam flow FSAL 2040, trip, IS 2 steam flow PDI 2036 low alarm (across steam valve) PDSAL 2036, IS 21, blocks steam line			 * *

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse (steam into O2)	No pressure in O2 system during start up	Condensation in O2 system, potentially burner damage	Double block and bleed on O2 line before start up situation Check valve Permissive actions to be fulfilled before opening O2: TSAL 2047 prevents low temperature of O2 Establish O2 pressure higher than reforming pressure before resetting IS 2.	90. Ensure piping layout is in accordance with PIDs (no pockets).	MEKPCO	*
	Loss of pressure during operation		Check valve FIC 2007 low alarm FSAL 2007, IS 2 trip of secondary reformer			*

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High (O2)	Fail open of pressure control, PIC 2015 (HP steam)	Increased O2 temperature Increased temperature of the combined stream	Temperature is limited to temperature level of the steam			
Low (O_2)	Loss of steam to O_2 preheater, malfunction of PIC 2015	Condensate into burner. Potential damage of burner and refractory	TI 2047 low alarm on O_2 temp TSAL 2047, trip IS 2 on low O_2 temp			*
Parameter: Pressure		**Intention:**				
High (O_2 supply)	High delivery pressure from BL	High O_2 flow (see high flow)				
High (O_2)	External fire Tube rupture in E2008	Exceeding design pressure Condensate in O_2, potentially damage of burner	PSV 2014 TI 2047 low alarm	91. Consider if PSV 2014 is necessary	HTAS	
Low (O_2 supply)	Low delivery pressure from BL Failure of O_2 feed control	Low O_2 flow (see low flow)				

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
Impurities in O2 from supplier				92. Consider if local analysis point on in-coming O2 line is possible from safety point of view	HTAS	
Parameter: Other		**Intention:**				
Liquid in O_2	Pockets of condensate in piping during start up Insufficient heating of steam and O_2	Damage of equipment Damage of refractory lining Damage of catalyst	Preheating of steam and O_2 according to manual TI 2047 Low temperature alarm TSAL 2047 trip Double block and bleed valve to prevent steam in O_2. The bleed is from the bottom of the pipe No pockets (slope) Heat tracing to 250 C	93. MEKPCO should supervise detailed design of piping layout according to HTAS requirements as indicated on the PIDs (is added, see action no. 37).	MEKPCO	*

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Node: 24 Oxygen system	P&ID no.: P02, P03	Intention:	Date: 24.06.2010
	Design P/T: 47.0 barg, 85 C inlet 47.0 barg, 255 C after E2008	Operating P/T: 40.0 barg, 35 C inlet 34.0 barg, 230 C after E2008	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Operating manual valves (non monel) with differential pressure	Maloperation	Risk of auto ignition due to high O_2 velocity		94. Ensure correct opening sequence of valve in detailed operating manual 95. Alternatively change system to monel	MEKPCO HTAS	

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Node: 25 Demin water system	P&ID no.: U18, P20	Intention:	Date: 24.06.2010
	Design P/T: ¤4.5 barg, 65 C out of TK7001 7.0 barg, 65 C after P7002 7.0 barg, 130 C after E2025	Operating P/T: 0.0 barg, 35 C out of TK7001 5.0 barg, 35 C after P7002 4.5 barg, 72 C after E2025	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (inlet to TK7001)	Fully open butterfly valve	Overfilling of tank (see high level)				
High (from TK7001)	Failure of FV 7091	No consequences in this node (see node 26)				
Low (from pump P7002)	Blocked outlet	Pump damage if running for long time with no flow	Loss of demin water in the deaerator will be detected before pump damage FIC 7091 low alarm			
Reverse (from deaerator)	Pump failure	Not likely	2 check valves (at inlet to deaerator and at pump discharge) Open overflow line			

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Node: 25 Demin water system	P&ID no.: U18, P20	Intention:	Date: 24.06.2010
	Design P/T: ¤4.5 barg, 65 C out of TK7001 7.0 barg, 65 C after P7002 7.0 barg, 130 C after E2025	Operating P/T: 0.0 barg, 35 C out of TK7001 5.0 barg, 35 C after P7002 4.5 barg, 72 C after E2025	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Temperature		**Intention:**				
High	Failure of TIC 2457 which is controlling the bypass of process gas	Increased temperature of demin water (see node 26) Potentially increased pressure in the deaerator (see node 26)	TIC 2457 high alarm Operating pressure is sufficient to avoid boiling			
Low (to deaera-tor)	Fail open of TIC 2457	Operational disturbances in deaerator, increased steam con-sumption in deaerator				
Parameter: Pressure		**Intention:**				
High	Tube rupture in E2025	Exceeding design pressure in E2025, piping and TK7001	Tank open overflow Check valves at pump discharge PSV 2458 (down stream E2025, designed for tube rupture)			

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Node: 25 Demin water system	P&ID no.: U18, P20	Intention:	Date: 24.06.2010
	Design P/T: ¤4.5 barg, 65 C out of TK7001 7.0 barg, 65 C after P7002 7.0 barg, 130 C after E2025	Operating P/T: 0.0 barg, 35 C out of TK7001 5.0 barg, 35 C after P7002 4.5 barg, 72 C after E2025	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Level		**Intention:**				
High (tank)	Fully open butterfly valve	Increased level	LI 7001 and 7002 high alarm Open overflow			
Low (tank)	Fully open butterfly valve	Pump cavitation	LI 7001 and 7002 low alarm			

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Node: 26 Deaerator	P&ID no.: U09, U13, U14	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: **Flow**		**Intention:**				
High (demin water)	Failure of control valve FV 7091 (open)	High level	LIC 7091 high alarm FIC 7091 high alarm			
High (steam)	Fail open of PV 7094	High pressure	PIC 7094 high alarm PIC 7101 venting from deaerator PSVs 7095, 7096			
High (conden-sates)	Fail open of valve in con-densate line	High level High pressure due to flashing stream	LIC 7091 high alarm PIC 7094 high alarm PIC 7101 venting from deaerator PSVs 7095, 7096			
High (Amine)	Set point mistake Failure of analyser AIC 7099	Higher pH value, corrosion in waste heat boiler	AIC 7099 high alarm Overconsumption to be seen by operator Regular analysis of BW			

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Node: 26 Deaerator	P&ID no.: U09, U13, U14	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (O2 scavenger)	Set point mistake	Increased chemical consumption, no consequence				
High (BFW recycle)	Fail open of HV 2371 during normal operation	Increased generation of flash steam High pressure	PIC 7094 high alarm PIC 7101 venting from deaerator PSVs 7095, 7096			
Low (demin water)	Fail close of valve FV 7091	Loss of cooling Increasing pressure Low level in D7001 (see level)	PIC 7094 high alarm PIC 7101 venting from deaerator PSVs 7095, 7096 (probably design case) FIC 7091 low alarm (on demin water)			
Low (condensates)	Fail close of upstream valves	No consequences	LIC 7091 will compensate			

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Node: 26 Deaerator	P&ID no.: U09, U13, U14	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (amine)	Dosing pump failure	Corrosion in boiler	AIC 7099 low alarm Regular analysis of BW			
	Blocked outlet	Exceeding dosing pump discharge pressure	PSVs 7195, 7198			
Low (O2 scavenger)	Dosing pump failure	Corrosion in boiler	Regular analysis of BW			
	Blocked outlet	Exceeding dosing pump discharge pressure	PSVs 7215, 7218			
Low (BFW to boiler)	Failure of level control for the boiler, FIC 2417	Increasing level in D7001	LIC 7091 high alarm LIC will close demin water make up Hold up volume in deaerator greater than hold up volume in boiler PSVs 7095, 7096			

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Node: 26 Deaerator	P&ID no.: U09, U13, U14	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Back flow of BFW	Pump failure	Potentially vapour break through High pressure	2 check valves 2 pumps running in parallel Auto start of spare pump Pumps are specified with anti reversing device LSAL 2372, IS1 trip			*
Reverse flow of demin water to demin tank	Pump failure	See node 25				
Reverse flow to chemical injection		Not possible (check valves and reciprocating pumps)				
Parameter: Temperature		**Intention:**				
High		See high pressure				
Low	No cause					

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Node: 26 Deaerator	P&ID no.: U09, U13, U14	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention:**				
High		See flow				
Low	Missing heat input from steam or condensate Failure of demin water preheating due to fully open bypass on preheater TV 2457	Decreasing temperature, potentially below 100 C, air ingress from vent line resulting in reduced stripping efficiency Corrosion in boiler system	PIC 7094 low alarm			
Parameter: Level		**Intention:**				
High (D7001)	Failure of level control LIC 7091	Increasing level Level build up High pressure Release through open vent (two phase)	LIC 7091 high alarm (2 out of 3) PIC 7094 high alarm PIC 7101 venting from deaerator PSVs 7095, 7096			
Low (D7001)	Failure of level control LIC 7091	Pump cavitation of P7001	LIC 7091 low alarm LSAL 7091, IS70 trip, stop of BFW pumps			*

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Node: 27 BFW pumps and distribution	P&ID no.: U10, U11	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: **Flow**		**Intention:**				
High (HHP BFW)	Failure of FIC 2417 on the boiler	Reduced discharge pressure Operational disturbances	PI 7127 low alarm Autostart of spare pump			
High (HP BFW)	Failure of FIC 3041	Increased extraction flow Reduced pump discharge pressure HHP	PI 7127 low alarm (HHP BFW) PI 7125 low alarm (HP BFW) Autostart of spare pump Pumps (two pumps running) designed for maximum extraction of HP BFW flow			
Low (HHP BFW)	Failure of boiler level control	Flow from pump close to zero Increasing pressure	Minimum flow protection			
Low (HP BFW)	Failure of boiler level control	Flow from pump close to zero Increasing pressure	Covered by minimum flow protection for HHP BFW			

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Node: 27 BFW pumps and distribu-tion	P&ID no.: U10, U11	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Back flow		See node 26				

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Node: 28 HHP boiler (D2001, E2022 1/2)	P&ID no.: P17, P18, P19	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (BFW)	Fail open of control valve FV 2417	High level in D2001 Liquid carry over to super heater, consequently liquid to turbines	LIC 2372 high alarm LI 2373 high alarm	96. Consider adding low alarm on TIC 2360	HTAS	
High (steam flow)	Opening of vent, PIC 2361	Decreasing pressure Increased evaporation Loss of steam	Stop of steam export to BL (see HHP steam control)			
High (blow down)	Unintended full open valve HV 2385	No consequences				
High (deaerator recycling)	Fail open of HV 2371	Reduced BFW temperature Reduced steam production				
High (phos-phate)	Wrong adjustment of dos-ing pump	Increased chemical consumption No significant consequences	Overconsumption to be seen by operator Regular analysis of BW			

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Node: 28 HHP boiler (D2001, E2022 1/2)	P&ID no.: P17, P18, P19	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (intermit-tent blow down)	Mechanical failure of valve (valve cannot be left open due to spring and lever operation)	Reduced steam production				
Low (BFW)	Fail close of control valve FV 2417	Low level in D2001 Overheating of waste heat boiler E2020	LIC 2372 low alarm LI 2373 low alarm LSAL 2372, IS 1 trip of reformer			 *
Low (phos-phate)	Wrong adjustment of dos-ing pump Blocked outlet	Increased scale formation Exceeding dosing pump dis-charge pressure	Regular analysis of BW PSVs 7165, 7168			
Low (blow down)	Unintended closure of valve HV 2385	Build up of impurities	Regular analysis of BW AI 2348 high alarm (conductivity)			

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Node: 28 HHP boiler (D2001, E2022 1/2)	P&ID no.: P17, P18, P19	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (blocked outlet)	Closure of PIC 2363	Increasing pressure in the boiler Potentially exceeding design pressure	PIC 2361 alarm high (opens vent) PI 2372 high alarm PSVs 2376-2379			
Reverse flow to chemical injec-tion		Not possible (check valves and reciprocating pumps)				
Reverse flow (into phosphate system)		Back flow of BFW	2 check valves (before injection point and at pump discharge) Reciprocating dosing pump			
Parameter: Temperature		**Intention:**				
High	Failure of TIC 2360 (open bypass on the super heated steam) Loss of S steam to E2021 1/2/3 by lifting PSVs on steam drum D2001	Exceeding design temp in E2021 1 or 2	TIC 2360 high alarm (super heated steam) TSAH 2360, IS 1 (do not detect all failure modes, potential overheating of one train does not cause high temp of super heated steam)	97. Consider adding high alarm on TI 2355 and TI 2356 (previ-ously added, see ac-tion no. 40)	HTAS	*

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Node: 28 HHP boiler (D2001, E2022 1/2)	P&ID no.: P17, P18, P19	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
	Loss of steam to E2021 1/2/3 by closure of PV 2363 out of E2021 1/2	Potential overheating of E2021 1/2/3	If only one S steam PSV opens PIC 2361 vent will supply sufficient steam PIC 2361, high alarm (steam vent) TIC 2360 high alarm (super heated steam) TSAH 2360, IS 1 TI 2352 high alarm (on process gas)	98. Correct FLO in-stead of FLC on PV 2363. (previously added, see action no. 43)	HTAS	*
	Loss of circulating boiler water to E2020 1/2. Not possible					
	Mal distribution of steam between 2021 1/2 by un-symmetrical piping		TI 2355 and TI 2356 (on the steam side)	99. Consider LO on block valves before automatic vents. (pre-viously added, see action no. 44)	HTAS	
	Increasing pressure drop due to mechanical problems	High temperature, exceeding design temperature				

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Node: 28 HHP boiler (D2001, E2022 1/2)	P&ID no.: P17, P18, P19	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (steam)	Closure of bypass TIC 2360	Increased condensation risk in turbine Increased steam production	TIC 2360 (on combined stream)	100. Consider adding low alarm on TIC 2360 (previously added, see action no. 96)	HTAS	
Low (preheated BFW)		Reduced steam production				
Parameter: Pressure		**Intention:**				
High (in D2001)	Blocked outlet by closure of PIC 2363	Increasing pressure in the boiler Potentially exceeding design pressure	PIC 2361 alarm high (opens vent) PI 2372 high alarm PSVs 2376-2379			
Low (in D2001)	Open vent Increased consumption of HHP steam	Decreasing pressure Increased evaporation Loss of steam	Stop of steam export to BL (see HHP steam control) PIC 2363 maintains pressure in D2001 PIC 2363 low alarm PI 2372 low alarm (on D2001)			

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Node: 28 HHP boiler (D2001, E2022 1/2)	P&ID no.: P17, P18, P19	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Composition		**Intention:**				
Impurities in boiler water		See flow				
Parameter: Level		**Intention:**				
High	Fail open of control valve FV 2417	High level in D2001 Liquid carry over to super heater, consequently liquid to turbines	LIC 2372 high alarm LI 2373 high alarm	101. Consider adding low alarm on TIC 2360 (previously added, see action no. 96)	HTAS	
Low	Fail close of control valve FV 2417	Low level in D2001 Overheating of waste heat boiler E2020	LIC 2372 low alarm LI 2373 low alarm LSAL 2372, IS 1 trip of reformer			*

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Node: 29 HHP steam header	P&ID no.: U03, U04, U07	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (to turbine FT3001)	Over consumption in turbine	Less steam export Low pressure in HHP header	PIC 2363 low alarm PIC 2372 low alarm PIC 7025 (export steam)			
High (to HP header)	Fail open of PIC 7002	Depressurize HHP steam header to HP steam header pressure Less steam to turbine	PIC 2363 low alarm PIC 2372 low alarm PIC 7025 (export steam)			
High (export steam)	Fail open of PIC 7025	Low pressure in HHP header Less steam to turbine	PIC 2363 low alarm PIC 2372 low alarm			
High (through vent)	Fail open of vent	See node 28				

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Node: 29 HHP steam header	P&ID no.: U03, U04, U07	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (to turbine)	Trip of turbine FT3001	Increasing pressure in HHP header	PV 7002 (open letdown valve to preset position based on HP extraction steam flow prior to trip and activated by turbine trip) PIC 7025 (export steam) PIC 7002 (on HHP header which will force open PV 7002) PIC 2363 high alarm (and venting (25% capacity) PSV on D2001			
Low (export steam)	Fail close of PIC 7025	Increasing pressure in HHP header	PIC 7002 (on HHP header which will force open PV 7002) PIC 2363 high alarm and venting (25% capacity) PI 2372 high alarm			
Parameter: Temperature		**Intention:**				
High	See high temperature in node 28					

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Node: 29 HHP steam header	P&ID no.: U03, U04, U07	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (export steam)	Fail close of BFW, TIC 7026 or TIC 7027	High temperature of export steam	TIC 7026, 7027 high alarm Design temperature of export steam line is higher than normal temperature in HHP header (470 C vs. 460 C)	102. Consider adding high alarm on TI 7021	HTAS	
Low (export steam)	Fail open of BFW, TIC 7026 or TIC 7027	Low temperature of export steam Potentially liquid in export steam	TIC 7026, 7027 low alarm	103. Consider adding low alarm on TI 7021	HTAS	
Parameter: Pressure		**Intention:**				
High (HHP header)	See low flow					
High (HHP BFW quench line)	Expanding liquids in between blocked valves	Tube rupture	PSV (depending upon type of valve chosen)			
Low (HHP header)	See high flow					

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Node: 30 HP steam header	P&ID no.: U02, U03, U05, U6, U07	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: **Flow**		**Intention:**				
High (from turbine)	Fail open of extraction steam valve	Increasing pressure in HP header Condensing turbine FT3001/2 will be unloaded and the system will call for more HHP steam to extraction turbine	PIC 7004 venting of excess steam	104. Consider adding high alarm on PT 7003 or PT 7004	HTAS	
High (letdown flow)	Fail open of PIC 7002	Increasing pressure in HP header	PIC 7004 venting of excess steam			
High (steam to turbine)	Over consumption	Decreasing pressure in HP header	PIC 7001 (extraction steam) PIC 7003 (letdown)	105. Consider adding low alarm on PT 7003 or PT 7004	HTAS	
Low (to header)	Fail close of extraction steam valve	Decreasing pressure in HP header	PIC 7003 (letdown)			
Low (steam to turbine)	Trip of turbine	Increasing pressure in HP header	PIC 7001 (extraction steam) PIC 7004 venting of excess steam PSVs 7010, 7011			

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Node: 30 HP steam header	P&ID no.: U02, U03, U05, U6, U07	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse	No cause					
Parameter: Temperature		**Intention:**				
High (HHP let-down)	Fail close of BFW quench valve	Potentially exceeding design temperature (410 C)	TIC 7002, 7003, 7004 high alarms (on let-down line) Operator has the opportunity to switch to spare letdown valve	106. Consider adding high alarm on TI 7007	HTAS	
High (BFW to import steam during start up)	Fail close of quench valve	Increased temperature in HP header	Normal temperature of import steam is 410 C which is corresponding to mechanical design temp of HP header			
Low (HHP let-down)	Fail open of BFW quench valve	Decreasing temperature of HP header Potential condensation	TIC 7002, 7003, 7004 low alarms (on let-down line) Operator has the opportunity to switch to spare letdown valve	107. Consider adding low alarm on TI 7007	HTAS	
Low (extraction steam temp)	Low temperature of HHP steam inlet to turbine	Decreasing temperature of HP header	TIC 2360 low alarm (superheated steam)	108. Consider adding low alarm on TI 7007 (previously added, see action no 107)	HTAS	

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Node: 30 HP steam header	P&ID no.: U02, U03, U05, U6, U07	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention:**				
High (HP header)		See flow				
High (HHP BFW quench line)	Expanding liquids in between blocked valves	Tube rupture	PSV (depending upon type of valve chosen)			
Low (HP header)		See flow				

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Node: 31 MP steam header	P&ID no.:	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (letdown to LP header)	Fail open of PV 7031 C or D	Decreasing pressure in MP header	PIC 7031 A or B (letdown of HP steam)	109. Consider adding low alarm on PI 7034	HTAS	
High (letdown from HP header)	Fail open of PV 7031 A or B	Increasing pressure in MP header	PIC 7031 C or D (letdown to LP steam) PIC 7034 vent PSV 7036	110. Consider adding high alarm on PI 7034	HTAS	
High (through vent)	Fail open of PIC 7034	Decreasing pressure in MP header	PIC 7031 A or B (letdown of HP steam)			
Low (to LP header)	Fail close of PV 7031 C or D	Increasing pressure in MP header	PIC 7031 C or D (letdown to LP steam) PIC 7034 vent PSV 7036			
Low (from synthesis)	Trip of synthesis	Decreasing pressure in MP header	PIC 7031 A or B (letdown of HP steam)			

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Node: 31 MP steam header	P&ID no.:	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Temperature		**Intention:**				
High	Loss of BFW quench during letdown from HP header	Potentially exceeding design temperature	TIC 7033, 7032 high alarms Operator has the opportunity to switch to spare letdown valve	111. Consider adding high alarm on TI 7031	HTAS	
Low	Fail open of BFW quench	Potential condensation (Steam is normally saturated)	TIC 7033, 7032 low alarms Operator has the opportunity to switch to spare letdown valve			
Parameter: Pressure		**Intention:**				
High (MP header)	Letdown from HP header	See flow				
High (HP BFW quench line)	Expanding liquids in between blocked valves	Tube rupture	PSV (depending upon type of valve chosen)			
Low (MP header)		See flow				

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Node: 32 LP steam header	P&ID no.:	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Flow		**Intention:**				
High (inlet to LP header)	Fail open of extraction valve Fail open of letdown valve from HP steam header Fail open of letdown valve from MP steam header	Increasing pressure in LP header, potentially exceeding design pressure	PIC 7056 venting PSVs 7056 - 7060	112. Consider adding high alarm on PIC 7056	HTAS	
Low (inlet to LP header)	Fail close of extraction valve Fail close of letdown valve from HP steam header Trip of HP to LP turbines	Decreasing pressure in LP header Reduction of distillation capacity	PIC 7055 (extraction) PIC 7051 (letdown from HP header) PI 5307 low alarm (MP column reboiler)			
Parameter: Temperature		**Intention:**				
High	Loss of BFW quench during letdown from HP header	Increasing temperature Potential damage of reboiler tube sheet		113. Consider adding high alarm on TI 7056, 7052, 7053	HTAS	

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Node: 32 LP steam header	P&ID no.:	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Fail open of BFW quench during letdown from HP header	Decreasing temperature, potentially condensation		114. Consider adding low alarm on TIC 7052, 7053		
Parameter: Pressure		**Intention:**				
High (LP header)		See flow				
High (HP BFW quench line)	Expanding liquids in between blocked valves	Tube rupture	PSV (depending upon type of valve chosen)			
Low (LP header)		See flow				

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Node: 33 MP steam drum (D3003)	P&ID no.: P05, P23	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (BFW)	Fail open of control valve FV 3041	High level in D3003 Liquid carry over to MP steam header	LIC 3042 high alarm LI 3034 high alarm			
High (conden-sate)	Fail open of control valve LV 6021 A	High level in D3003 Liquid carry over to MP steam header	LIC 3042 high alarm LI 3034 high alarm			
High (steam flow)	Opening of MP steam header vent, PIC 7034	Decreasing pressure Increased evaporation Loss of steam	PIC 3042 low alarm (maintaining pressure in D3003)			
High (blow down)	Unintended full open valve HV 3054	No consequences				
High (phos-phate)	Wrong adjustment of dos-ing pump	Increased chemical consumption No significant consequences	Overconsumption to be seen by operator Regular analysis of BW			

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Node: 33 MP steam drum (D3003)	P&ID no.: P05, P23	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (intermit-tent blow down)	Mechanical failure of valve (valve cannot be left open due to spring and lever operation)	Reduced steam production				
Low (BFW)	Fail close of control valve FV 3041	Low level in D3003 Overheating of reactor R3001	LIC 3042 low alarm LI 3043 low alarm LSAL 3042, IS3 trip of synthesis			 *
Low (conden-sate)	Fail close of control valve LV 6021 A	Low level in D3003 Overheating of reactor R3001	LIC 3042 low alarm (adding BFW) LI 3034 low alarm LSAL 3042, IS3 trip of synthesis			 *

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Node: 33 MP steam drum (D3003)	P&ID no.: P05, P23	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (phos-phate)	Wrong adjustment of dos-ing pump Blocked outlet	Increased scale formation Exceeding dosing pump dis-charge pressure	Regular analysis of BW PSVs 7171, 7174			
Low (blow down)	Unintended closure of valve HV 3054	Build up of impurities	Regular analysis of BW AI 3055 high alarm (conductivity)			
Low (steam)	Closure of PIC 3042	Increasing pressure in the boiler Potentially exceeding design pressure	PIC 3042 high alarm (2 out of 3) PSVs 3047, 3048			
Reverse flow to chemical injec-tion		Not possible (check valves and reciprocating pumps)				

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Node: 33 MP steam drum (D3003)	P&ID no.: P05, P23	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Reverse flow (into phosphate system)		Back flow of BFW	2 check valves (before injection point and at pump discharge) Reciprocating dosing pump			
Parameter: Temperature		**Intention:**				
High	High operating pressure	Exceeding design temperature	Design temperature selected as boiling point at design pressure			
Low	Low operating pressure	Reduced reaction temperatures in R3001 (see temperature node 12a)	PIC 3042 low alarm (maintaining pressure in D3003)			
Parameter: Pressure		**Intention:**				
High (in D3003)	Closure of PIC 3042 Tube rupture in R3001	Increasing pressure in the boiler Potentially exceeding design pressure Inert build up in steam condensers reducing performance	PIC 3042 high alarm (2 out of 3) PSVs 3047, 3048 Check of inerts in MP steam AP 3049 and MeOH in MP blow down AP 3054 and pressure temperature relation in steam in case tube leaks is suspected	115. Check PSV for R3001 tube rupture case	HTAS	

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Node: 33 MP steam drum (D3003)	P&ID no.: P05, P23	Intention:	Date: 25.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low (in D3003)	Opening of MP steam header vent, PIC 7034	Decreasing pressure Increased evaporation Loss of steam	PIC 3042 low alarm (maintaining pressure in D3003)			
Parameter: Composition		**Intention:**				
Impurities in boiler water		See flow				
Parameter: Level		**Intention:**				
High	Fail open of control valve FV 3041 Fail open of control valve LV 6021 A	High level in D3003 Liquid carry over to MP header	LIC 3042 high alarm LI 3043 high alarm			
Low	Fail close of control valve FV 3041 Fail close of control valve LV 6021 A	Low level in D3003 Overheating of reactor R3001	LIC 3042 low alarm LI 3043 low alarm LSAL 3042, IS3 trip of synthesis			 *

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Node: 34 Blow down system	P&ID no.: U16	Intention:	Date: 28.06.2010
	Design P/T: 9.5 barg, 340 C D7002, 5.0 barg, 160 C D7003	Operating P/T: 7.5 barg D7002, 0.0 barg D7003	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (from D2001)	Open blow down valve HV 2385	Higher LP steam production Increased level in D7002	LIC 7251 high alarm			
High (from D3003)	Open blow down valve HV 3054	Higher LP steam production Increased level in D7002	LIC 7251 high alarm			
High (to D7003)	Fail open of LV 7251	Increased level in D7003	Open drain Level determined by gravity			
High (from E2020)	Fail open of HV 2334 or HV2335	Increased level in D7003	Spring/lever operated blow down valve (avoids opening for long time)			
High (from R3001)	Fail open of HV 3087, HV 3090 or HV 3093	Increased level in D7004	Spring/lever operated blow down valve (avoids opening for long time)			
Low		No consequences				
Reverse	No causes					

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 34 Blow down system	P&ID no.: U16	Intention:	Date: 28.06.2010
	Design P/T: 9.5 barg, 340 C D7002, 5.0 barg, 160 C D7003	Operating P/T: 7.5 barg D7002, 0.0 barg D7003	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Temperature		**Intention:**				
High (D7002)		Not possible	Upstream piping is rated for upstream pressure and temperature conditions. Temperature in D7002 is determined by LP steam pressure			
High (D7003)		Not possible	Upstream piping is rated for upstream pressure and temperature conditions. Temperature in D7003 is determined by atmospheric pressure			
High (D7004)		Not possible	Upstream piping is rated for upstream pressure and temperature conditions. Temperature in D7004 is determined by atmospheric pressure			
High (after E7001)	Cooling water failure	Hot water to drain system Small evaporation from vent				
High (after E7002)	Cooling water failure	Hot water to drain system Small evaporation from vent				

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Node: 34 Blow down system	P&ID no.: U16	Intention:	Date: 28.06.2010
	Design P/T: 9.5 barg, 340 C D7002, 5.0 barg, 160 C D7003	Operating P/T: 7.5 barg D7002, 0.0 barg D7003	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention:**				
High (D7002)	Blocked outlet on LP steam by closing manual valve	Increasing pressure, exceeding design pressure	PSV 7253			
High (D7003)	Gas break through from LP header due to fully open FV 7251 or fully open intermittent blow down valve	Increasing pressure (Exceeding design pressure is not possible)	Open vent to atmosphere			
High (D7004)	Fully open intermittent blow down valve	Increasing pressure (Exceeding design pressure is not possible)	Open vent to atmosphere			
Low		No consequences				
Parameter: Level		**Intention:**				
High (D7002)	Fail close of LIC 7251	Condensate into LP steam system	LIC 7251 high alarm	116. Regular inspection of level gauge on D7002 during operation	MEKPCO	

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Node: 34 Blow down system	P&ID no.: U16	Intention:	Date: 28.06.2010
	Design P/T: 9.5 barg, 340 C D7002, 5.0 barg, 160 C D7003	Operating P/T: 7.5 barg D7002, 0.0 barg D7003	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (D7003/D7004)	Fully open intermittent blow down valve	Liquid build up	Liquid will be removed by gravity flow			
Low (D7002)	Fail open of LIC 7251	See high pressure				

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Node: 35 H_2 recycle system	P&ID no.: U17, P09, P12, P27	Intention:	Date: 28.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: **Flow**		**Intention:**				
High (to desul-phurization)	Fail open of FV 2150	Decreasing pressure in header, increasing H2 recycle	PIC 2608 PI 2150 low alarm			
High (to re-former, small compared to recycle flow in loop)	Fail open of FIC 2079 dur-ing normal operation	Decreasing pressure in header (PIC 2608 not dimensioned for simultaneous opening of FV 2150 and FV 2079) , increasing H2 recycle	PIC 2608 PI 2150 low alarm			
	Shut down of reformer	Decreasing pressure in header (sufficient gas hold up in loop for more than 5 minutes supply)	PIC 2608 PI 2150 low alarm			
High (H2 im-port)	Fail open of PV 2603	Increasing pressure in header upstream compressor C2002	Design pressure for upstream C2002 corre-sponds to design pressure of H2 import			
High (recycle from D2005)	No causes					

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Node: 35 H_2 recycle system	P&ID no.: U17, P09, P12, P27	Intention:	Date: 28.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High (recycle from loop)	Fail open of PC 2608	Increasing pressure in header, exceeding design pressure	PSV 2604	117. Consider adding high alarm on PI 2150	HTAS	
Low (to desul-phurization)	Fail close of FV 2150	Increasing pressure in header	PIC 2608 FIC 2150 low alarm, low deviation alarm PSV 2604			
	Trip of compressor C2002 or fail close of PV 2608	Decreasing pressure in header	PI 2150 low alarm FIC 2150 low alarm, low deviation alarm			
Low (to re-former during shut down)	Fail close of FV 2079	Increasing pressure in header	PIC 2608 PSV 2604			
Reverse	Trip of compressor C2002	Back flow	Reciprocating compressor Check valve (at compressor outlet down-stream kick back line) Kick back line valve closes			

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Node: 35 H_2 recycle system	P&ID no.: U17, P09, P12, P27	Intention:	Date: 28.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Reverse (from consumers to header)	Loss of H2 recycle header pressure	Loss of H2 supply	Check valves (in supply line to desulphurizer and tubular reformer)			
Reverse (to synthesis)	Trip of synthesis compressor and loss of pressure in loop	Back flow	Check valve in recycle line from loop			
Parameter: Temperature		**Intention:**				
High (from recycle compressor C2002)	Loss of cooling	Increasing temperature, exceeding design temperature	TI 2150, indicator	118. Consider increasing design temperature on H2 recycle header to 200 C corresponding to C2002 discharge temperature	HTAS	
Parameter: Pressure		**Intention:**				
High (H2 header)	Fail open of PV 2608	Exceeding design pressure, see high flow				

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Node: 35 H_2 recycle system	P&ID no.: U17, P09, P12, P27	Intention:	Date: 28.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
High	Failure of compressor discharge pressure control, C2002	Exceeding design pressure	PSV 2604	119. Consider adding high alarm on PI 2150 (previously added, see action no 117)	HTAS	
High	Fail close of FV 2150 or FV 2079	See low flow				
Low (H2 header)	Fail close of PV 2608	Decreasing pressure in header	PI 2150 low alarm FIC 2150 low alarm, low deviation alarm			
Low (upstream compressor C2002)	Fail close of PV 2603	Decreasing suction pressure Loss of H2 supply to consumers	Trip of compressor, to be covered by compressor vendor scope PI 2150 low alarm FIC 2150 low alarm, low deviation alarm			

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Node: 36 Start up blower	P&ID no.: U02	Intention:	Date: 28.06.2010
	Design P/T: 12 barg	Operating P/T: 6 barg	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: **Flow**		**Intention:**				
High (reformer section)		No consequences				
High (anti surge line)	Fail open of PDV 2575	Reduced flow to reforming section, potentially overheating of reformer	FI 2582 low alarm FSAL 2582, IS 1 trip of reformer			* *
Low (reformer section)	Stop of blower, C2001 Open anti surge line	Reduced flow to reforming section, potentially overheating of reformer	FI 2582 low alarm FSAL 2582, IS 1 trip of reformer			* *
Reverse (to N2 header)	Trip of blower C2001 Introduction of process gas during start up	Back flow	Check valve on N2 supply line Check valve Block valves on N2 supply closed according to operating manual before introduction of process gas			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 36 Start up blower	P&ID no.: U02	Intention:	Date: 28.06.2010
	Design P/T: 12 barg	Operating P/T: 6 barg	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Parameter: Pressure		**Intention:**				
High	Blocked outlet from blower C2001	Surge of blower C2001	PDIC 2575 high alarm PI 2579 high alarm PDAHH 2575, I16 trip of N2 blower C2001			*
		Exceeding design pressure	PSV 2581 (designed for blocked outlet) PDIC 2575 high alarm PI 2579 high alarm PDAHH 2575, I16 trip of N2 blower C2001			*
High	Maloperation during start up (pressurizing system before isolation of start up circuit)	Exceeding design pressure	PI 2579 high alarm PSV 2581 (not dimensioned for this case) Operating manual/start up procedure			

	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri, MEKPCO Søren Toft, Lars Moerner, Lone Johnsen, Hans Pedersen, HTAS Finn Pedersen, Gunilla Kay Christiansen, Birgitte Madsen, COWI	
Node: 36 Start up blower	P&ID no.: U02	Intention:	Date: 28.06.2010
	Design P/T: 12 barg	Operating P/T: 6 barg	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Low	Closed N2 make up and leaks from system	Reduced circulation of N2 Overheating of reformer	PI 2579 low alarm FI 2582 low alarm (temperature and pressure compensated)	120. Consider installing pressure compensated trip on low flow FSAL 2582	HTAS	
Parameter: Temperature		**Intention:**				
High (D2005)	Loss of cooling	Reduced circulation of N2	TI 2572 high alarm			
High (discharge C2001)	Loss of cooling	Potential damage of blower C2001	TI 2579 high alarm TAHH 2579, I16 trip of N2 blower C2001			*
Low		No consequences				
Parameter: Composition		**Intention:**				
Low Mw of start up circulation gas	Introduction of process gas	Surge and high pressure	PDIC 2575 Antisurge control PIC 2481 vent (out of D2005) PI 2579 high alarm			

COWI A/S	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran.	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri (part time), MEKPCO Hans Pedersen, Lars Moerner, Lone Johnsen, HTAS Finn Pedersen, Birgitte Madsen, COWI	
Node: 37 General	P&ID no.:	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	**Causes**	**Consequence**	**Safeguards**	**Recommendations**	**By**	**SR**
Parameter: Other		**Intention:**				
PSVs not opening on demand	Block valves around PSVs are closed	Over pressuring system, damage of equipment, rupture, release to atmosphere, potential fire, hazard to personnel		121. HTAS do not recommend block valves around PSVs without interlock 122. Implement mechanical interlock between isolating valves on PSV during detailed engineering (API 520) 123. Add note on PIDs regarding mechanical interlock	HTAS MEKPCO HTAS	
External fire		Over pressurising and potential rupture of vessels	Depressurising of systems	124. Consider sprinkler system on major vessels	MEKPCO/detailed engineering	

COWI A/S	HAZOP 5000 MTPD Methanol Plant Bandar Assaluyeh, Iran.	HAZOP Group: N. Mavadati, S. Shaker, M. Nabian, H. Moayeri (part time), MEKPCO Hans Pedersen, Lars Moerner, Lone Johnsen, HTAS Finn Pedersen, Birgitte Madsen, COWI	
Node: 37 General	P&ID no.:	Intention:	Date: 24.06.2010
	Design P/T:	Operating P/T:	

Deviation	Causes	Consequence	Safeguards	Recommendations	By	SR
Entering equipment under flare pressure	Back flow from flare (through not blinded lines)	Danger to personnel entering equipment	Authorized entry permit to ensure blinding before entering.	125. Assure incorporation in detailed operating manual and maintenance procedure	MEKPCO/detailed engineering	

Appendix B: List of recommendations

Node	ID	Recommendations	Action by
1	1	Maximum delivery pressure of NG at BL (60 barg) to be assured	MEKPCO / DAMAVAND
1	2	Drain valve to be visible from level gauge	MEKPCO/detailed engineering
2	3	Open false air dampers on IS-1trip (on shutdown of system)	HTAS
2	4	Check minimum flow rate required	HTAS
2	5	Add high temperature alarm on TIC 2220 (E2004 outlet)	HTAS
2	6	Add high alarm on AI 1045	HTAS
2	7	Consider procedure to ensure operator shut down plant on high alarm AI 1045	HTAS
3-gas	8	Increase design temperature to 290 C	HTAS
3-gas	9	If design temperature is not increased then consider temperature alarms out of T6001	HTAS
3-gas	10	Consider low level alarms on LI 6033 and LI 6034	HTAS
3-gas	11	Consider high alarm on PIC 2073	HTAS
3-gas	12	Ensure operating manual covers H2SO4 is used as regenerator.	HTAS
3 –gas	13	Check / clean tubes to be included in detailed procedure	HTAS
3-gas	14	To be highlighted in operating manual	HTAS
3-liquid	15	Install PSV downstream FV 6031	HTAS
3-liquid	16	Design pressure out of process water streams to be checked against maxi-mum shut off pressure from P2001,	MEKPCO

		P2002, P2003, P5010.	
3-liquid	17	Add LSAL and USV on blow down inlet D6002	HTAS
4	18	Consider additional flow meters for reference	HTAS
4	19	Consider installing specific gravity analyser (2 out of 3) with discrepancy alarm and automatic input to S/C ratio calculation (AST)	HTAS
4	20	Assure correct installation, calibration and function of flow elements and meters for S/C ratio during commissioning	MEKPCO/ detailed engineering contractor
4	21	Consider additional flow meters for reference (**previously added, see action no 18)**	HTAS
4	22	Consider installing specific gravity analyser (2 out of 3) with discrepancy alarm and automatic input to S/C ratio calculation (AST) **(previously added, see action no 19)**	HTAS
4	23	Consider adding low alarm on TIC 2232	HTAS
5	24	Consider high alarm on AI 2223 1 and AI 2224	HTAS
5	25	Consider installing deviation alarm and high alarm on QIC 2535	HTAS
5	26	Consider LTM (load and temperature management) system for duty control. LTM will include input from LHV analysers.	HTAS
5	27	Procedure to be included in operating manual	HTAS
5	28	Add high alarm on AI 2479	HTAS
5	29	Add rate of change alarm on temperature TI 2295 and TI 2297.	HTAS

6a	30	Add high alarm on AI 2479. **(previously added, see action no. 28)**	HTAS
6a	31	Consider automatic O/C ratio control as part of LTM	HTAS
6a	32	Add high alarm on AI 2479. **(previously added, see action no. 28)**	HTAS
6a	33	Add note to PID defining water system	HTAS
6a	34	Skimming of cat (change top layer) according to operating manual	MEKPCO
6a	35	When replacing tiles ensure high quality of tiles to avoid ruby formation	MEKPCO
6a	36	High alarm on AI 2479 **(previously added, see action no. 28)**	HTAS
6a	37	MEKPCO should supervise detailed design of piping layout according to HTAS requirements as indicated on the PIDs.	MEKPCO
6b	38	Check mechanical design of E2021 1/2 for consequences of high temperature, alternatively include trip on high temp	HTAS
6b	39	Consider one THIC on each boiler operating both sets of dampers, TV 2360 1 and 2 and one THIC for TV 2360 3 and 4. (Post HAZOP meeting HTAS decision as per 08.07.2010: **Not recommended)**	HTAS
6b	40	Consider high temp alarm on TI 2351 and 2353 (gas out of E2021 1/2) and TI 2355 and 2358 (steam out of E2021 1/2)	HTAS
6b	41	Add failure modes of TV 2360 1/2/3/4 on PID and correct node 8	HTAS
6b	42	Consider cascade control for TIC 2360 and TI 2335 and TI 2336 to prevent uneven flows	HTAS
6b	43	Correct FLO instead of FLC on PV 2363	HTAS
6b	44	Consider LO on block valves before	HTAS

		automatic vents	
6b	45	Consider high alarm on TI 2355 and TI 2356 **(previously added, see action no. 40)**	HTAS
8	46	Consider installing PSV on shell side on E2023 for tube rupture as the current PSV 5250, 5251 are on the top of the MP column. (Post HAZOP meeting HTAS decision as per 08.07.2010: **Not recommended)**	HTAS
9	47	Consider installing PSV protecting shell side on E2024 for tube rupture as the current PSV 5058, 5059 and 5060 are on the top of the stabilizer column. (Post HAZOP meeting HTAS decision as per 08.07.2010: **Not recommended)**	HTAS
10	48	Change design pressure of comp C3001 inlet to 29 barg	HTAS
10	49	Fire and gas detection system (entire plant) to be considered by detailed engineering	MEKPCO
11	50	Detailed HAZOP on compressor C3001/C3002 to be made when documentation is available from compressor vendor (PIDs) for compliance with HTAS process specifications.	MEKPCO/ detailed engineering contractor
12a	51	Add high alarm on TIC 3113 and TIC 3116 and TIC 3118	HTAS
12b	52	Fire and gas detection system (entire plant) to be considered by detailed engineering **(previously added, see action no. 49)**	MEKPCO
12b	53	Assure blockages of all connecting pipes including PSVs before entering vessel see, node 37	MEKPCO
13	54	Filters are still under evaluation. HTAS has to specify details	HTAS
13	55	Add heat tracing on instrument piping to/from level transmitters, level gauges and PDT 3200.	HTAS

13	56	Add note on PIDs on Shortening instrument piping as much as possible	HTAS
13	57	Consider tracing of bypass piping	HTAS
14	58	Check PSV 5006 layout to avoid static pressure build up	HTAS
15	59	Consider adding high alarm on LI 5042	HTAS
15	60	Check if system can handle three reboiler in operation at same time alternative consider blocking in E5001	HTAS
15	61	Consider adding high alarm on LI 5094	HTAS
15	62	Consider adding high alarm on LI 5094 **(previously added, see action no. 61)**	HTAS
15	63	Check design temperature of tubes in reboiler E5001 (dry running)	HTAS
16	64	Consider adding high alarm on LI 5162	HTAS
16	65	Consider adding high alarm on LI 5204	HTAS
16	66	Consider adding high alarm on LI 5204 **(previosly added, see action no. 65)**	HTAS
16	67	Check set pressure of PSAH 5207 to prevent release of liquid from PV 5207 B (static head)	HTAS
17	68	Consider adding high alarm on LI 5271	HTAS
17	69	Consider deviation alarm on FIC 5441	HTAS
17	70	Check design temperature of reboiler E5003 (dry running)	HTAS
17	71	Consider adding high alarm on LI 5271 **(previosly added, see action no. 68)**	HTAS
17	72	Consider deviation alarm on FIC 5441 **(previously added see action no. 69)**	HTAS
18	73	Install blinds at individual inlet to polishers.	HTAS
18	74	Consider installing common PI and PG on inlet to polishers	HTAS
19	75	Consider installing a three way control	HTAS

		valve on the return line to ensure direct connection to at least one tank	
19	76	Consider installing common PI with high alarm on discharge line of pump P5008	HTAS
19	77	Consider thermal expansion valve on run down line (note on PID)	HTAS
19	78	Consider separate breather valves on tank TK5002 1/2	HTAS
19	79	Check PSV 5400, 5417 layout to avoid static pressure build up	HTAS
20	80	PSV 5450 to be designed for gas break through from D1001	HTAS
20	81	Consider changing manual drain valve from KO D1001 from 2” to 1”	HTAS
20	82	Consider installing separate shut off valve at low level in D1001	HTAS
20	83	PID to be updated to actual pump type (reciprocating pump)	HTAS
20	84	Consider adding high alarm on TI 5443	HTAS
20	85	Check PSV 5450 layout to avoid static pressure build up	HTAS
23	86	Ensure design temperature of the coils take reduced process gas flow into account	HTAS
23	87	Consider opening of false air damper at low pressure	HTAS
23	88	Assure correct installation of atmospheric leg at pressure instruments according to HTAS hook up drawing J24	MEKPCO
24	89	Add high alarm on AI 2479 **(previosly added see action 28).**	HTAS
24	90	Ensure piping layout is in accordance with PIDs (no pockets)	MEKPCO

24	91	Consider if PSV 2014 is necessary	HTAS
24	92	Consider if local analysis point on in-coming O2 line is possible from safety point of view	HTAS
24	93	MEKPCO should supervise detailed design of piping layout according to HTAS requirements as indicated on the PIDs **(is added, see action no. 37).**	MEKPCO
24	94	Ensure correct opening sequence of valve in detailed operating manual	MEKPCO
24	95	Alternatively change system to monel	HTAS
28	96	Consider adding low alarm on TIC 2360	HTAS
28	97	Consider high alarm on TI 2355 and TI 2356 **(previously added, see action no. 40)**	HTAS
28	98	Correct FLO instead of FLC on PV 2363 **(previously added, see action no. 43)**	HTAS
28	99	Consider LO on block valves before automatic vents **(previously added, see action no. 44)**	HTAS
28	100	Consider adding low alarm on TIC 2360 **(previously added, see action no. 96)**	HTAS
28	101	Consider adding low alarm on TIC 2360 **(previously added, see action no. 96)**	HTAS
29	102	Consider adding high alarm on TI 7021	HTAS
29	103	Consider adding low alarm on TI 7021	HTAS
30	104	Consider adding high alarm on PT 7003 or PT 7004	HTAS
30	105	Consider adding low alarm on PT 7003 or PT 7004	HTAS
30	106	Consider adding high alarm on TI 7007	HTAS
30	107	Consider adding low alarm on TI 7007	HTAS

30	108	Consider adding low alarm on TI 7007 **(previously added, see action no 107)**	HTAS
31	109	Consider adding low alarm on PI 7034	HTAS
31	110	Consider adding high alarm on PI 7034	HTAS
31	111	Consider adding high alarm on TI 7031	HTAS
32	112	Consider adding high alarm on PIC 7056	HTAS
32	113	Consider adding high alarm on TI 7056, 7052, 7053	HTAS
32	114	Consider adding low alarm on TIC 7052, 7053	HTAS
33	115	Check PSV for R3001 tube rupture case	HTAS
34	116	Regular inspection of level gauge on D7002 during operation	MEKPCO
35	117	Consider adding high alarm on PI 2150	HTAS
35	118	Consider increasing design temperature on H2 recycle header to 200 C corresponding to C2002 discharge temperature	HTAS
35	119	Consider adding high alarm on PI 2150 **(previously added, see action no 117)**	HTAS
36	120	Consider installing pressure compensated trip on low flow FSAL 2582	HTAS
37	121	HTAS do not recommend block valves around PSVs without interlock	HTAS
37	122	Implement mechanical interlock between isolating valves on PSV during detailed engineering (API 520)	MEKPCO
37	123	Add note on PIDs regarding mechanical interlock	HTAS
37	124	Consider sprinkler system on major vessels	MEKPCO/detailed engineering
37	125	Assure incorporation in detailed operating manual and maintenance procedure	MEKPCO/detailed engineering