

<b>Node ID</b>	1
<b>Design Intent</b>	To transfer methanol and o-nitrotoluene feed from mixer M201 to R201. The stream passes through a heat exchanger to be heated up from 326 K to 333 K before entering R201. To transfer hydrogen from storage tank to R201 with the aid of F201a/F201b To reduce o-nitrotoluene to o-toluidine in R201 at 333 K, 5 atm

Row ID	Parameter	Deviation	Causes	Consequences	Existing Safeguards	Recommendations
<b>Methanol / ONT feed</b>						
1.1	Flow	No flow into P201a	Blockage in V206	C1: P201a runs dry and overheats/cavitates, leading to pump damage C2: Reactor R201 shutdown resulting in production loss C3: Overheating of H202 leading to fire	S1: Regular alarm FAL 211 informs operator S2: Executive alarm FZALL205 triggers interlock I2 to shutdown reactor R201 S3: Overheating of P201a results in executive alarm TZAHH206 and interlock I2 S4: TIC212 controls H202 temperature S5: Flow diverted to P201b via V208 to continue operation S6: Regular alarm FAL 202 informs operator	R1: Regular inspection of valve R2: Procedure for operators to manually divert flow to backup pump P201b R3: Training of operators
1.2	Flow	No flow into P201b after flow redirected from P201a	Blockage in V208	C1: P201b runs dry and overheats / cavitates, leading to pump damage Refer to 1.1 C2-3	Refer to 1.1 S1, S2, S4, S6	R1: Install executive alarm TZAHH to P201b
1.3	Flow	No flow out of P201a	- Blockage in V207 - P201a malfunction	C1: overpressure in P201a, leading to pump damage C2: Piping rupture Refer to 1.1.C2-3	Refer to 1.1	R1: Install additional pressure sensor associated with regular and executive alarms
1.4	Flow	No flow out of P201b	- Blockage in V209 - P201b malfunction	C1: overpressure in P201b, leading to pump damage C2: Piping rupture Refer to 1.1 C2-3	Refer to 1.2	R1: Install additional pressure sensor associated with regular and executive alarms
1.5	Flow	No flow to R201	Blockage in H202	Refer to 1.1 C2-3	S1: FT202 downstream controls P201a/b speed via FIC202 S2: FT205 upstream triggers FZALL 205 and I2 S3: Regular alarm FAH 202 informs operator	R1: Regular inspection of equipment and cleaning to remove fouling
1.6	Flow	No flow to V206	Blockage in SOV-201	Refer to 1.1 C1-3 and 1.2 C1	Refer to 1.1 S1-4, S6	R1: Regular inspection of valve and interlock control system
1.7	Flow	More flow to R201	FIC202 set point too high in error	C1: P201a/b overheat, leading to pump damage C2: line temperature drops as H202 unable to supply sufficient heat, leading to loss of production	S1: Regular alarm FAH 211 informs operator S2: Overheating of P201a results in executive alarm TZAHH206 and interlock I2 S3: Regular alarm FAH 202 informs operator	R1: Install executive alarm FZAHH on flow to R201 after pump P201a/b
1.8	Flow	Less flow to R201	FIC202 set point too low in error	Refer to 1.1 C1-3 and 1.2 C1	Refer to 1.1 S1-4, S6	R1: Install executive alarm FZALL on flow to R201 after pump P201a/b
1.9	Flow	Less flow to P201a	Partial failure of V206	Refer to 1.1	Refer to 1.1	Refer to 1.1
1.10	Flow	Less flow to P201b	Partial failure of V208	Refer to 1.2	Refer to 1.2	Refer to 1.2
1.11	Flow	Less flow out of P201a	- Partial failure of V207 - Malfunction of P201a	Refer to 1.3	Refer to 1.3	Refer to 1.3
1.12	Flow	Less flow out of P201b	Partial failure of V209 Malfunction of P201b	Refer to 1.4	Refer to 1.4	Refer to 1.4
1.13	Temperature	High temperature in R201	TIC212 set point too high in error	C1: High temperature flow into R201 leading to thermal runaway and explosion with possible harm to humans and the environment C2: H202 overheats	S1: Regular alarm TAH212 informs operator S2: Executive alarm TZAHH204 triggers interlock 1 to turn off H202 and shutdown reactor R201	R1: Install additional alarm TZAHH on inlet streams to reactor
1.14	Temperature	High temperature in R201	TT212 erroneously reads low	Refer to 1.13	Refer to 1.13 S2	Refer to 1.13

1.15	Temperature	High temperature in R201	Malfunction of H202	Refer to 1.13 C1	Refer to 1.13	Refer to 1.13
1.16	Temperature	Low temperature in R201	TIC212 set point too low in error	C1: Reactor R201 operating in suboptimal conditions leading to loss of production	S1: Regular alarm TAL212 informs operator	Refer to 1.13
1.17	Temperature	Low temperature in R201	TT212 erroneously reads high	Refer to 1.16	Refer to 1.16	Refer to 1.13
1.18	Temperature	Low temperature in R201	Malfunction of H202	Refer to 1.16	Refer to 1.16	Refer to 1.13
1.19	Pressure	Low pressure in R201	FIC202 set point too low in error	Refer to 1.8	N/A	Refer to 1.4
1.20	Pressure	Low pressure in R201	Malfunction of P201a	Refer to 1.3	Refer to 1.1 S5	Refer to 1.1 R1, R3
1.21	Pressure	Low pressure in R201	Malfunction of P201b	Refer to 1.4	Refer to 1.2	Refer to 1.4
1.22	Pressure	High pressure in R201	Malfunction of P201a	Refer to 1.3	Refer to 1.1 S5	Refer to 1.3
1.23	Pressure	High pressure in R201	Malfunction of P201b	Refer to 1.4	Refer to 1.2	Refer to 1.4
1.24	Pressure	High pressure in R201	Pump P201a blockage	Refer to 1.3	Refer to 1.1 S5	Refer to 1.3
1.25	Pressure	High pressure in R201	Pump P201b blockage	Refer to 1.4	Refer to 1.2	Refer to 1.4
1.26	Pressure	High pressure in R201	FIC202 set point too high in error	Refer to 1.7	Refer to 1.7	Refer to 1.7
<b>Hydrogen feed and recycle</b>						
1.27	Flow	No flow to V202	Blockage in V210	C1: F201a overheats leading to gas explosion Refer to 1.16	S1: PT203 could suggest no flow and trigger PAL201 S2: Regular alarm FAL 203	R1: Add FI to FT206 and FIC controlling F201a/b
1.28	Flow	No flow to V210	Blockage in SOV-202	Refer to 1.27	S2: Regular alarm FAL 203	Refer to 1.27
1.29	Flow	No flow into F201a	Blockage in V202	Refer to 1.27	Refer to 1.29	Refer to 1.27
1.30	Flow	No flow into F201b after flow redirected from F201a	Blockage in V203	C1: F201b overheats leading to gas explosion Refer to 1.16	S1: PIC201 S2: Regular alarm FAL 203	Refer to 1.27
1.31	Flow	No flow out of F201a	-Blockage in V204 -Fan F201a malfunction	Refer to 1.27	S1: FT206 sensor would detect no low S2: FT203 sensor would detect no low S3: Regular alarm FAL 203	Refer to 1.27
1.32	Flow	No flow out of F201b	-Blockage in V205 -Fan F201b malfunction	Refer to 1.30	Refer to 1.31	Refer to 1.27
1.33	Flow	No flow to R201	Blockage in H201	C1: Overheating of H201 leading to explosion Refer to 1.12 C2	Refer to 1.32	Refer to 1.27
1.34	Flow	More flow through F201a/b	PIC201 set point too high in error	Refer to 1.1 C2 and 1.27 C1	S1: FT206 triggers executive alarm FZAHH206 S2: Regular alarm FAH 203	Refer to 1.27
1.35	Flow	Less flow to V210	Partial blockage in SOV-202	Refer to 1.16	Refer to 1.34	Refer to 1.27
1.36	Flow	Less flow to V202	Partial blockage in V210	Refer to 1.16	Refer to 1.34	Refer to 1.27
1.37	Flow	Less flow to R201	PIC201 set point too low in error	Refer to 1.27	Refer to 1.34	R1: Install additional FZAHH in the hydrogen inlet to the reactor after H201
1.38	Flow	Less flow to F201a	Partial failure of V202	Refer to 1.27	Refer to 1.34	Refer to 1.27
1.39	Flow	Less flow into F201b after flow redirected from F201a	Partial failure of V204	Refer to 1.30	Refer to 1.34	Refer to 1.27
1.40	Flow	Less flow out of F201a	- Partial failure of V203 - Fan F201a malfunction	Refer to 1.27	Refer to 1.34	Refer to 1.27

1.41	Flow	Less flow out of F201b	- Partial failure of V205 - Fan F291b malfunction	Refer to 1.30	Refer to 1.34	Refer to 1.27
1.42	Flow	Less flow out of H201	Partial blockage of H201	Refer to 1.33	Refer to 1.34	Refer to 1.27
1.43	Flow	Misdirected flow at V210	Under-/over-pressure in feed/recycle streams entering valve	R1: Excess H <sub>2</sub> gas released via recycle stream purge leading to explosion	S1: FIC207 regulates flow through purge	R1: install non-return valves on feed & recycle streams entering valve R2: install PCV between SOV-202 and 3-way valve; move PT203 & PIC203 to here to control new PCV. SP of PIC203 should be MV of PIC201
1.44	Flow	No flow through recycle purge	- Blockage in FCV-202 - FT207 reads erroneously high - FIC207 set point low in error	Refer to 1.16	N/A	R1: Install regular and executive alarms on recycle controller FIC207
1.45	Flow	Less flow through recycle purge	Refer to 1.44	Refer to 1.16	N/A	Refer to 1.45
1.46	Flow	More flow through recycle purge	- FT207 reads erroneously low - FIC207 set point high in error	Refer to 1.16, 1.43	N/A	Refer to 1.45
1.47	Temperature	High temperature in H201	TIC213 setpoint too low in error	C1: High temperature flow into R201 leading to thermal runaway and explosion with possible harm to humans and the environment C2: H201 overheats	S1: Regular alarm TAH211 informs operator	Refer to 1.13
1.48	Temperature	High temperature in H201	TT213 erroneously reads low	Refer to 1.47	S1: Controller TIC213 controls cooling water flow	Refer to 1.13
1.49	Temperature	High temperature in H202	Malfunction of H202	Refer to 1.47	Refer to 1.47	Refer to 1.13
1.50	Temperature	Low temperature in H202	Malfunction of H202	C1: Reactor R201 operating in suboptimal conditions leading to loss of production	S1: Regular alarm TAL211 informs operator	Refer to 1.13
1.51	Temperature	Low temperature in H202	TT212 erroneously reads high	Refer to 1.50	Refer to 1.50	Refer to 1.13
1.52	Temperature	Low temperature in H202	TIC212 setpoint too high in error	Refer to 1.50	Refer to 1.50	Refer to 1.13
1.53	Pressure	High pressure in F201a/F201b	PT 203 erroneously reads low	C1: Overheating of F201a leading to gas explosion C2: Reactor R201 operating in suboptimal conditions leading to loss of production	S1: Executive alarm PZAHH205 triggers interlock I4 S2: Regular alarm PAH202 S3: Additional inputs from PIC202 to PIC201 acting on fan speed	R1: Install additional pressure sensor associated with regular and executive alarms as backup
1.54	Pressure	High pressure in F201a/F201b	PIC203 set point too high in error	Refer to 1.53	Refer to 1.53	Refer to 1.53
1.55	Pressure	High pressure in F201a/F201b	PT 202 erroneously reads low	Refer to 1.53	Refer to 1.53	Refer to 1.53
1.56	Pressure	High pressure in F201a/F201b	PIC202 set point too high in error	Refer to 1.53	S1: Regular alarm PAH201 Refer to 1.53	Refer to 1.53
1.57	Pressure	High pressure in F201a	Blockage in V203	Refer to 1.30	Refer to 1.30	Refer to 1.53
1.58	Pressure	High pressure in F201a	Fan F201a malfunction	Refer to 1.34	S1: PT 202 triggers PAH 202	
1.59	Pressure	High pressure in F201b	Fan F201b malfunction	Refer to 1.34	N/A	
1.60	Pressure	Low pressure in F201a/F201b	PT 203 erroneously reads high	Refer to 1.50	S1: Additional inputs from PIC202 to PIC201 acting on fan speed S2: Regular alarm PAL202	R1: Install additional PZALL executive alarm to alert operators when pressure is low
1.61	Pressure	Low pressure in F201a/F201b	PIC203 set point too low in error	Refer to 1.50	Refer to 1.60	Refer to 1.60
1.62	Pressure	Low pressure in F201a/F201b	PT 202 erroneously reads high	Refer to 1.50	Refer to 1.60	Refer to 1.60
1.63	Pressure	Low pressure in F201a/F201b	PIC201 set point too low in error	Refer to 1.50	S1: Regular alarm PAL201 Refer to 1.60	Refer to 1.60

1.64	Pressure	Low pressure in F201a	Fan F201a malfunction	Refer to 1.27	Refer to 1.60	Refer to 1.60
1.65	Pressure	Low pressure in F201b	Fan F201b malfunction	Refer to 1.30	Refer to 1.60	Refer to 1.60
<b>Cooling water feed</b>						
1.66	Flow	No flow of cooling water into R201	Blockage in FCV-201	C1: Overheating of R201, leading to fire and explosion	S1: Low flow results in executive alarm FZALL204 and interlock I1 S2: Regular alarm FAL 201 informs operator	R1: Regular inspection of valve
1.67	Flow	Low flow of cooling water into R201	Partial blockage in FCV-201	Refer to 1.66	Refer to 1.66	Refer to 1.66
1.68	Flow	Low flow of cooling water into R201	FT201 erroneously reads high	Refer to 1.66	Refer to 1.66 S1	Refer to 1.66
1.69	Flow	Low flow of cooling water into R201	FIC201 set point too low in error	Refer to 1.66	Refer to 1.66	Refer to 1.66
1.70	Flow	High flow of cooling water into R201	FT201 erroneously reads low	C1: Reactor R201 operating in suboptimal conditions leading to loss of production	N/A	R1: Install executive alarm FZAHH to FT204
1.71	Flow	High flow of cooling water into R201	FIC201 set point too high in error	Refer to 1.70	N/A	R1: Install regular alarm FAH201 Refer to 1.70
1.72	Temperature	Low temperature in cooling water	TT203 erroneously reads high	Refer to 1.70	S1: additional inputs from TIC201 and TIC202 to FIC201 controlled by TIC203	R1: Install executive alarm TZALL205 to TT205
1.73	Temperature	Low temperature in cooling water	TIC203 set point low in error	Refer to 1.70	Refer to 1.72	R1: Install regular alarm TAL203 Refer to 1.72
1.74	Temperature	Low temperature in cooling water	TT202 erroneously reads high	Refer to 1.70	S1: additional inputs from TIC201 and TIC203 to FIC201 controlled by TIC202	R1: install executive alarm TZALL adjacent to TT202
1.75	Temperature	Low temperature in cooling water	TIC202 set point low in error	Refer to 1.70	Refer to 1.74	R1: Install regular alarm TAL202 Refer to 1.74
1.76	Temperature	High temperature in cooling water	TT203 erroneously reads low	Refer to 1.66	S1: High temperature results in executive alarm TZAHH205 and interlocks I1 S2: additional inputs from TIC201 and TIC202 to FIC201 controlled by TIC203	R1: install executive alarm TZAHH adjacent to TT203
1.77	Temperature	High temperature in cooling water	TIC203 set point high in error	Refer to 1.66	S1: Regular alarm TAH203 informs operator Refer to 1.72	R1: install regular alarm TAH203 Refer to 1.76
1.78	Temperature	High temperature in cooling water	TT202 erroneously reads low	Refer to 1.66	S1: additional inputs from TIC201 and TIC203 to FIC201 controlled by TIC202	R1: install executive alarm TZAHH adjacent to TT202
1.79	Temperature	High temperature in cooling water	TIC202 set point high in error	Refer to 1.66	Refer to 1.78	R1: install regular alarm TAH202 Refer to 1.78
<b>Reactor R201</b>						
1.80	Level	High level in R201	FIC202 set point too high in error	C1: Liquid enters gas recycle stream; damage to fans and danger to workforce through leakage via purge, resulting in production loss	S1: Regular alarm LAH208 informs operator S2: High level results in executive alarm LZAHH 201 and interlocks I3 to open reactor liquid bleed SOV-203	R1: Install LIC-208 to feed into FIC-209
1.81	Level	High level in R201	Blockage of FCV-203	Refer to 1.80	Refer to 1.80	Refer to 1.80
1.82	Level	High level in R201	Failure of SOV-203 opening	Refer to 1.80	Refer to 1.80	Refer to 1.80
1.83	Level	High level in R201	FIC-209 set point too low	Refer to 1.80	Refer to 1.80	Refer to 1.80
1.84	Level	Low level in R201	FIC202 set point too low in error	C1: Gas enters liquid product stream, resulting in production loss	S1: Regular alarm LAL208 informs operator	R1: Install executive alarm LZALL201 to LT201 Refer to 1.80
1.85	Level	Low level in R201	FIC-209 set point too low	Refer to 1.84	Refer to 1.84	Refer to 1.84
1.86	Level	Low level in R201	Incorrect closure of SOV-203	Refer to 1.84	Refer to 1.84	Refer to 1.84
1.87	Level	Low level in R201	PIC201 set point too high in error; overpressure of gas forces liquid out of reactor	Refer to 1.84	Refer to 1.84	Refer to 1.84
1.88	Temperature	Low temperature in R201	TT201 erroneously reads high	Refer to 1.70	S1: additional inputs from TIC202 and TIC203 to FIC201 controlled by TIC201	R1: Install executive alarm TLALL204 to TT204
1.89	Temperature	Low temperature in R201	TIC201 set point low in error	Refer to 1.70	S1: Regular alarm TAL201 informs operator Refer to 1.70	Refer to 1.70

1.90	Temperature	High temperature in R201	TT201 erroneously reads low	C1: Overheating of R201, leading to fire and explosion	S1: High temperature results in executive alarm TZAHH204 and interlocks I1 to open reactor liquid bleed SOV-203 S2: additional inputs from TIC202 and TIC203 to FIC201 controlled by TIC201	R1: Install additional alarm to TAH201
1.91	Temperature	High temperature in R201	TIC201 set point high in error	Refer to 1.90	S1: Regular alarm TAH201 informs operator Refer to 1.90	Refer to 1.90
1.92	Pressure	High pressure in R201	PT201 erroneously reads low	C1: Reactor R201 operating in suboptimal conditions leading to loss of production	S1: High pressure results in executive alarm PZAHH204 and interlocks I1 to open reactor gas and liquid bleeds SOV-204 and SOV-203 S2: Additional inputs from PIC202 and PIC203 to PIC201 mitigate effect of bad data from PT 201 S3: PRV-1 releases over-pressure	R1: Regular inspection of pressure units
1.93	Pressure	High pressure in R201	PIC201 set point high in error	C1: Overpressure of R201, leading to fire and explosion with possible harm to humans and the environment	S1: Regular alarm PAH201 informs operator Refer to 1.92	Refer to 1.92
1.94	Pressure	High pressure in R201	Bed blockage in reactor R201	Refer to 1.93	Refer to 1.92	Refer to 1.92
1.95	Pressure	High pressure in R201	Blockage in FCV-202	Refer to 1.93	Refer to 1.92	Refer to 1.92
1.96	Pressure	Low pressure in R201	PT201 erroneously reads high	C1: Reactor R201 operating in suboptimal conditions leading to loss of production	S1: Additional inputs from PIC202 and PIC203 to PIC201 mitigate effect of bad data from PT 201	R1: Install executive alarm PZALL204 to PT204
1.97	Pressure	Low pressure in R201	PIC201 set point low in error	Refer to 1.96	S1: Regular alarm PAL201 informs operator Refer to 1.96	Refer to 1.96
1.98	Composition	More (condensable vapours) in R201	Higher reactor R201 temperature	Refer to 1.43, 1.70	S1: AT204 sensor and AIC204 controller S2: TIC201 controls reactor temperature	R1: Ensure AT204 installed as close to reactor as possible to minimise lag in measured variable
1.99	Composition	Other than specified setpoint	- AT202 reads erroneous value - AT203 reads erroneous value - AIC203 set point incorrect	Incorrect feed ratio leading to off specification product	N/A	R1: install AT + AAL/AAH downstream of reactor to monitor product stream composition R2: install AIC to feed into FIC202
1.100	Composition	Other than specified setpoint	- AT204 reads erroneous value - AIC204 set point incorrect	Refer to 1.16	N/A	R1: install AT + AAL/AAH adjacent to 3 way valve