<table>
<tr><th>Control Objective & Consequences of Poor Control</th><th>Controlled Variable (cv)</th><th>Sensor type</th><th>Manipulated Variable (mv) (Actuator)</th><th>Disturbances</th><th>Maintenance Issues (Solutions)</th></tr>
<tr><td colspan="6">Nitration reactor (R101)</td></tr>
<tr><td>Objective: Maintain residence time to reach required yield and product selectivity.

Consequences: Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.</td><td>Residence time of reactor (R101)</td><td>Flowmeter</td><td>Volumetric flowrate of reactor inlet (Motor speed of pump P101)</td><td>• Feed and/or recycle flowrates.
• Pump (P101) not operating at set point leading to higher or lower inlet flowrate.
• Non-uniform mixing of reagents.</td><td rowspan="4">• Fooling and corrosion inside reactor affecting pressure drop, heat transfer rates and purity, especially caused by corrosive nitric acid (Periodic inspections with ultrasounds and cleaning, suitable choice of material).

• Fooling and corrosion outside reactor affecting heat removal efficiency (Periodic inspections and cleaning, suitable choice of material).

• Early catalyst deactivation caused by uncontrolled harsh conditions (Periodic inspection of control system and transmitter calibration).

• Leakage due to poor connection (Good sealing of the system, periodic inspections).

• Clogging of reactor and/or cooling system (Periodic cleaning).</td></tr>
<tr><td>Objective: Maintain optimum liquid level.

Consequences: Too high liquid holdup could lead to flooding.</td><td>Liquid level</td><td>Level transmitter</td><td>Volumetric flowrate of reactor outlet (FCV on 1-07)</td><td>• Pump (P101) operating above set point leading to higher inlet flowrate.</td></tr>
<tr><td>Objective: Maintain reactor temperature at 60°C.

Consequences: An increased in temperature can lead to the formation of hot spots and runaway reaction, especially for highly exothermic nitration. Too low reactor temperature results in lower conversion and poor product selectivity.</td><td>Reactor temperature</td><td>Temperature transmitters along the reactor</td><td>Volumetric cooling water flowrate through cooling jacket (FCV on W1-01)</td><td>• Variations in cooling water temperature.
• Pump for cooling system not operating at set point leading to higher or lower cooling water flowrate.
• Variation in liquid holdup in reactor.
• Temperature of the inlet feed to the reactor.
• Outside temperature.
• Speed of reaction rates.</td></tr>
<tr><td>Objective: Achieve specified nitrotoluene isomers selectivity.

Consequences: Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.</td><td>Outlet composition (1-07)</td><td>Composition analyser</td><td>Volumetric flowrate of nitric acid in M101 (FCV on 1-02)</td><td>• Reactor temperature impacting reaction rates and thus conversion plus selectivity.
• Recycle flowrate of nitric acid.</td></tr>
</table>

					• Precipitation of nitrotoluene due to uncontrolled temperature and pressure conditions (*Periodic inspection of control system and transmitter calibration*). • Actuators wear down (*FCV redundancies and frequent testing*).
2-Nitrotoluene reduction reactor (R201)					
Objective: Maintain residence time to reach required yield. **Consequences:** Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.	Residence time of reactor (R201)	Flowmeter	Volumetric flowrate of liquid reactor inlet (*Motor speed of pump P201*) → limiting reagent	• Feed and/or recycle flowrates. • Pump (P201) not operating at set point leading to higher or lower inlet flowrate.	• Fooling and corrosion inside reactor affecting pressure drop, heat transfer rates and purity (*Periodic inspections with ultrasounds and cleaning, suitable choice of material*). • Fooling and corrosion outside reactor affecting heat removal efficiency (*Periodic inspections and cleaning, suitable choice of material*). • Early catalyst deactivation caused by uncontrolled harsh conditions (*Periodic inspection of control system and transmitter calibration*).
Objective: Maintain optimum liquid level. **Consequences:** Too high liquid holdup could lead to flooding. Too low liquid level could lead to drying and explosion.	Liquid level	Level transmitter	Volumetric flowrate of reactor outlet (*FCV on 2-05*)	• Pump (P201) operating above or below set point leading to higher or lower liquid inlet flowrate. • Fan (F201) operating below or above set point leading to lower or higher gas flowrate.	
Objective: Maintain reactor temperature at 60°C. **Consequences:** An increased in temperature can lead to the formation of hot spots and runaway reaction, especially for	Reactor temperature	Temperature transmitters along the reactor	Volumetric cooling water flowrate through cooling jacket (*FCV on W2-01*)	• Variations in cooling water temperature. • Pump for cooling system not operating at set point leading to higher or lower cooling water flowrate.	

exothermic hydrogenation. Too low reactor temperature results in lower conversion and poor product selectivity.				• Pump (P201) and fan (F201) not operating at set point. • Temperature of the inlet feeds to the reactor. • Outside temperature. • Speed of reaction rates.	• Leakage due to poor connection (*Good sealing of the system, periodic inspections*). • Clogging of reactor and/or cooling system (*Periodic cleaning*). • Precipitation of nitrotoluene or o-toluidine due to uncontrolled temperature and pressure conditions (*Periodic inspection of control system and transmitter calibration*). • Actuators wear down (*FCV redundancies and frequent testing*).
Objective: Maintain reactor pressure at 5 atm and overcome reactor pressure drop. **Consequences:** Overpressure of the reactor can lead to vessel rupture and explosion. Too little pressure will decrease the flow in the reactor and thus conversion.	Pressure	Pressure transmitter	Fan speed (*F201*)	• Malfunction in fan. • Volumetric flowrate of H_2 and recycled H_2.	
Objective: Achieve required 2-nitrotoluene conversion to o-toluidine. **Consequences:** Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.	Outlet composition (2-05)	Composition analyser	Ratio of reactants (*cascaded to liquid flow control*)	• Reactor temperature impacting reaction rates and thus conversion plus selectivity. • Recycle flowrate of H_2.	
Oxidation reactors (R301, R401)					
Objective: Control residence time to reach required level of nitrotoluene oxidation. **Consequences:** Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.	Residence time of reactors (R301, R401)	Flowmeter	Volumetric flowrate of limiting reagent reactor inlet (*FCV on 3-13 and 4-07*)	• Pump (P501, P601) not operating at set point leading to higher or lower inlet flowrate. • Fan (F301, F401) not operating at set point leading to higher or lower inlet flowrate.	• Fooling and corrosion inside reactor affecting pressure drop, heat transfer rates and purity (*Periodic inspections with ultrasounds and cleaning, suitable choice of material*). • Fooling and corrosion outside reactor affecting heat removal efficiency
Objective: Maintain reactor temperature at 750K.	Reactor temperature	Temperature transmitters	Volumetric cooling water flowrate through cooling	• Variations in cooling water temperature.	

Consequences: An increased in temperature can lead to the formation of hot spots and runaway reaction, especially for exothermic hydrogenation. Too low reactor temperature results in lower conversion and poor product selectivity. The temperature must be kept above the boiling points of the reagents and products to ensure vapour phase reaction.		along the reactor	jacket (*FCV on W3-01, W4-01*)	• Pump for cooling system not operating at set point leading to higher or lower cooling water flowrate. • Fan (F301, F401, F302) not operating at set point. • Temperature of the inlet feeds to the reactor. • Outside temperature. • Speed of reaction rates.	(*Periodic inspections and cleaning, suitable choice of material*). • Early catalyst deactivation caused by uncontrolled harsh conditions (*Periodic inspection of control system and transmitter calibration*).
Objective: Maintain reactor pressure at 1 atm and overcome reactor pressure drop. **Consequences:** Overpressure of the reactor can lead to vessel rupture and explosion. Too little pressure will decrease the flow in the reactor and thus conversion.	Pressure	Pressure transmitter	Pressure control valve on air feed *(PCV on 3-22)*	• Volumetric flowrate to pump. • FCV opening. • Volumetric flowrate of air.	• Leakage due to poor connection (*Good sealing of the system, periodic inspections*). • Clogging of reactor and/or cooling system (*Periodic cleaning*).
Objective: Achieve required 4-nitrotoluene oxidation. **Consequences:** Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.	Outlet composition (3-14 and 4-08)	Composition analyser	Volumetric flowrate of air (*FCV on 3-23 or 4-02*)	• Reactor temperature impacting reaction rates and thus conversion plus selectivity.	• Precipitation of nitrotoluene or oxidation products due to uncontrolled temperature and pressure conditions (*Periodic inspection of control system and transmitter calibration*). • Actuators wear down (*FCV redundancies and frequent testing*).
Hydrogenation reactors (R501, R601)					
Objective: Maintain residence time to reach required yield.	Residence time of reactors (R501, R601)	Flowmeter	Volumetric flowrate of reactor inlet (*Motor*	• Pump (P501, P601) not operating at set point	• Fooling and corrosion inside reactor affecting

<table>
<tr>
<td>Consequences: Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.</td>
<td></td>
<td></td>
<td>speed of pump P501 and P601)</td>
<td>leading to higher or lower inlet flowrate.</td>
<td rowspan="5">pressure drop, heat transfer rates and purity (Periodic inspections with ultrasounds and cleaning, suitable choice of material).

• Fooling and corrosion outside reactor affecting heat removal efficiency (Periodic inspections and cleaning, suitable choice of material).

• Early catalyst deactivation caused by uncontrolled harsh conditions (Periodic inspection of control system and transmitter calibration).

• Leakage due to poor connection (Good sealing of the system, periodic inspections).

• Clogging of reactor and/or cooling system (Periodic cleaning).

• Precipitation of oxidation products and reduction products due to uncontrolled temperature and pressure conditions (Periodic inspection of</td>
</tr>
<tr>
<td>Objective: Maintain optimum liquid level.

Consequences: Too high liquid holdup could lead to flooding. Too low liquid level could lead to drying and explosion.</td>
<td>Liquid level</td>
<td>Level transmitter</td>
<td>Volumetric flowrate of reactor outlet (FCV on 5-09, 6-07)</td>
<td>• Pump (P501, P601) operating above or below set point leading to higher or lower liquid inlet flowrate.</td>
</tr>
<tr>
<td>Objective: Maintain reactor at room temperature.

Consequences: An increased in temperature can lead to the formation of hot spots and runaway reaction, especially for exothermic hydrogenation. Too low reactor temperature results in lower conversion and poor product selectivity.</td>
<td>Reactor temperature</td>
<td>Temperature transmitters along the reactor</td>
<td>Volumetric cooling water flowrate through cooling jacket (FCV on W5-01, W6-01)</td>
<td>• Variations in cooling water temperature.
• Pump for cooling system not operating at set point leading to higher or lower cooling water flowrate.
• Pump (P501, P401) not operating at set point.
• Temperature of the inlet feeds to the reactor.
• Outside temperature.
• Speed of reaction rates.</td>
</tr>
<tr>
<td>Objective: Maintain reactor pressure at 1 atm and overcome reactor pressure drop.

Consequences: Overpressure of the reactor can lead to vessel rupture and explosion. Too little pressure will decrease the flow in the reactor and thus conversion.</td>
<td>Pressure</td>
<td>Pressure transmitter</td>
<td>Pumping speed (Liquid pump P501, P601)</td>
<td>• Volumetric flowrate to pump.
• Inlet FCV opening.</td>
</tr>
<tr>
<td>Objective: Achieve required reduction.</td>
<td>Outlet composition (5-09, 6-07)</td>
<td>Composition analyser</td>
<td>Volumetric flowrate of formic acid (FCV on 5-03, 6-01)</td>
<td>• Reactor temperature impacting reaction rates and thus conversion plus selectivity.</td>
</tr>
</table>

Consequences: Insufficient conversion leading to sub-optimal downstream processing and thus process fails to meet product specifications.					*control system and transmitter calibration*). • Actuators wear down (*FCV redundancies and frequent testing*).
Decanter (S101, S302)					
Objective: Maintain liquid level in the decanter. **Consequence**: Too high level would reduce the cleanness of phase separation, valuable organics would be lost in aqueous stream. If level falls below the outlet port for the organics no product will be recovered.	Liquid level	Level transmitter	Outlet flowrate of aqueous stream *(FCV on 1-14)*	• Inlet flowrates	• Potential for acid based corrosion due to presence of dissolved nitric acid (S101). • Potential for acid based corrosion due to presence of 4-nitrobenzoic acid (S302) *(Regular ultrasound checks for corrosion during plant maintenance and shutdown).*
Packed distillation columns (S102, S103, S105, S201, S202, S203, S303, S501, S503, S504)					
Objective: Maintain composition of distillate to ensure production specs downstream are met. **Consequence**: Loss of column performance.	Tops composition	Composition analyser	Reflux ratio (*FCV on distillate stream*)	• Column pressure. • Reboiler duty. • Inlet flowrate, and inlet composition.	• Fouling on the column walls and on the packing could negatively impact column performance *(Periodic cleaning of column and replacement of packing after the recommended operational lifetime).* • Corrosion on the column walls due to organic (4-aminobenzoic acid and 4-nitrobenzoic acid) and
Objective: Maintain composition of bottoms to ensure production specs downstream are met. **Consequence**: Loss of column performance.	Bottoms composition	Composition analyser	Boil-up ratio (*FCV on bottoms stream*)	• Column pressure. • Reboiler duty. • Inlet flowrate, and inlet composition.	
Objective: Maintain column pressure at desired setpoint. **Consequence**: Variation in pressure stresses the mechanical integrity of	Column pressure	Pressure sensor	Cooling water flowrate in condenser (*FCV on cooling water inlet*)	• Temperature of cooling water. • Inlet flowrate, and inlet composition.	

the column, leading to safety issues and also changes the compositions of the distillate and bottoms streams, leading to loss of column performance.					inorganic acids (nitric acid). *(Regular ultrasound checks for corrosion during plant maintenance and shutdown).* • Wear and tear of insulation jacket around condenser and reboiler walls. *(Regular inspections to make sure insulation is functional and in good condition).*
Objective: Maintain desired temperature in the column **Consequence**: Temperature spikes can lead to variation in the boil-up vapour flowrate and composition, which would impact the composition of the top and bottom product. Column pressure would also be affected.	Temperature	Temperature sensor	Saturated steam flowrate in reboiler *(FCV on steam inlet to reboiler)*	• Temperature of steam. • Inlet flowrate, and inlet composition. • Column pressure.	
Objective: Maintain liquid level in the reboilers. **Consequence**: Too much liquid causes the reboiler and column to flood and reduces contact between vapour and liquid. Too little liquid causes the liquid entrainment by the gas. Both result in a loss of column performance.	Level	Level transmitter	Bottoms flowrate *(FCV on bottoms stream)*	• Reflux rate. • Inlet flowrate, and inlet composition. • Column pressure.	
Objective: Maintain liquid level in the reflux drum. **Consequence**: Too much liquid blocks the flow of gas and causes pressure buildup. Too little liquid reduces reflux to column and decreases column performance.	Level	Level transmitter	Tops flowrate *(FCV on tops stream)*	• Reflux rate. • Inlet flowrate, and inlet composition. • Column pressure.	
Melt Crystalliser (S104)					
Control Objective: Maintain slurry residence time. **Operational Consequences**:	Volumetric flowrate of crystalliser outlet	Flowmeter	Volumetric flowrate of crystalliser outlet (*FCV on 1-13*)	• Pump not operating at set point leading to higher or lower inlet flowrate.	• Fouling due to crystal buildup on the walls and the agitators.

Crystal growth and yield depends on the residence time in the crystalliser.				• Drastic change in crystal growth rate which affects the density and thus volumetric flowrate.	*(Periodic cleaning of the crystalliser with organic solvent. Also regular inspection of control system and sensor calibration to ensure control system is performing well)* • Corrosion on the column walls due to 4-nitrobenzoic acid (*Regular ultrasound checks for corrosion during plant maintenance and shutdown*) • Wear and tear of insulation around crystalliser, leading to heat loss. *(Regular inspections to make sure insulation is functional and in good condition)*
Control Objective: Control operating temperature of crystalliser. **Consequences**: Crystal growth is sensitive to temperature fluctuations, so product yield and purity will be affected if temperature spikes occur.	Temperature	Temperature sensor	Cooling water flowrate *(FCV on W1-03)*	• Cooling water temperature. • Inlet feed temperature. • Inlet feed flowrate (therefore heat capacity).	
Control Objective: Mechanical work to refrigerant. **Consequences**: Insufficient work to cool the refrigerant will not allow the cooling water to e sufficiently cool, leading to poor performance in crystalliser.	Mechanical work on P102	Work	Pump speed *(P102)*	• Temperature of cooling water.	
Control Objective: Control composition of crystalliser outlet **Consequences**: Changes in the amount of crystals forming would affect the yield of crystals and thus the downstream production rates of our products.	Composition of solid crystals at outlet	Solid composition analyser	Temperature *(Cascade control with temperature control)*	• Inlet feed composition. • Inlet feed flowrate (affecting residence time). • Inlet feed temperature.	
Solution Crystalliser (S601)					
Control Objective: Maintain slurry residence time. **Operational Consequences**: Crystal growth and yield depends on the residence time in the crystalliser.	Volumetric flowrate of crystalliser outlet	Flowmeter	Volumetric flowrate of crystalliser outlet (*FCV on 6-11*)	• Pump not operating at set point leading to higher or lower inlet flowrate. • Drastic change in crystal growth rate which affects the density and	• Fouling due to crystal buildup on the walls and the agitators. *(Periodic cleaning of the crystalliser with organic solvent. Also regular inspection of control*

				thus volumetric flowrate.	*system and sensor calibration to ensure control system is performing well)* • Corrosion on the column walls due to 4-nitrobenzoic acid (*Regular ultrasound checks for corrosion during plant maintenance and shutdown*) • Wear and tear of insulation around crystalliser, leading to heat loss. *(Regular inspections to make sure insulation is functional and in good condition)*
Control Objective: Control the cooling rate of crystalliser. **Consequences**: Crystal nucleation and growth is sensitive to cooling profile, so product yield and purity will be affected if temperature spikes occur.	Cooling rate	Thermocouple	Cooling water flowrate *(FCV on W6-03)*	• Cooling water temperature. • Inlet feed temperature. • Inlet feed flowrate (therefore heat capacity).	
Control Objective: Control composition of crystalliser outlet. **Consequences**: Changes in the amount of crystals forming would affect the yield of crystals and thus the downstream production rates of our products.	Composition of solid crystals at outlet	Composition analyser	Temperature *(Cascade control with temperature control)*	• Inlet feed composition. • Inlet feed flowrate (affecting residence time). • Inlet feed temperature.	
Hydraulic Wash Column (S106)					
Control Objective: Control flowrate of the melted crystal product. **Consequences**: Too low flowrate would mean a lower recovery of the product and difficulty in meeting the production specifications.	Melted crystal flowrate	Flowmeter	Outlet flowrate of crystals *(V301)*	• Inlet feed composition. • Inlet feed flowrate (affecting residence time in the column). • Pressure in the column	• Mechanical abrasion by solid crystals on the scraping knife at the bottom. *(Periodic cleaning of the wash column with organic solvent. Also regular inspection of knife)* • Clogging of filter tubes due to crystal deposits or impurities blocking pores.
Control Objective: Maintain pressure driving force in the column. **Consequences**: Too low pressure would allow the wash liquid (melted product flowing counter current to feed) to flow out of the	Pressure in the top of the column	Pressure sensor	Pump speed (P303, P301)	• Set point of pump is changed. • Ambient temperature (if crystals are not melted at the end, then resistance to flow will increase).	

column and be lost. Too high pressure would lead to the impure mother liquor reaching the end of the column, leading to impurities in the melted crystal product.				• Flowrate of feed from the crystalliser.	*(Periodic cleaning of the wash column with organic solvent. Also regular inspection of filter tubes, and pressure transmitters within the filter tube as a proxy for blocked pores)*
Control Objective: Maintain temperature of melted crystal product. **Consequences**: Too much heating is not economical, and too little heating will not melt sufficient crystals in the column. This will lead to a decrease in recovery of the pure crystal product.	Temperature of melted crystal product	Temperature sensor	Heat duty to heater H301	• Ambient temperature. • Feed temperature.	
Mixers (M101, M201, M501, M601)					
Control Objective: Maintain level of liquid in the tank. **Consequences:** If level is too high, there is risk of overfilling and backflow. If level is too low, risk of the agitator being damaged due to lack of resistance.	Level	Level transmitter	Outlet stream flowrate *(FCV in outlet stream)*	• Upstream disturbance to the inlet stream flowrates.	• Potential for acid based corrosion due to presence of organic (nitric acid in M101) and inorganic (4-nitrobenzoic acid in M401, formic acid in M501) acids. *(Regular ultrasound checks for corrosion during plant maintenance and shutdown).* • Potential for impeller damage due to corrosion *(Regular checks on impeller integrity during plant maintenance).*
Control Objective: Maintain ratio of feed streams entering tank. **Consequences:** If ratio is not controlled, operation of downstream units will be sub-optimal. Production rate of products will not be maximised.	Ratio of feed streams	Flowmeters	Feed stream flowrate *(FCV on larger feed stream)*	• Upstream disturbance to the inlet stream flowrates.	

					• Potential for mechanical components of impeller to degrade and result in loss of performance *(Regular tests on impeller performance during plant maintenance).*
Flash Units (S301, S401, S502)					
Objective: Maintain level of liquid in the tank. **Consequences:** If level is too high, would lead to flooding and the liquid spilling into the gaseous outlet. If level is too low, pressure in the flash might change and lead to poorer flash performance.	Level	Level transmitter	Outlet liquid flowrate *(FCV on 3-15, 4-10, 5-10)*	• Feed flowrate. • Stream inlet temperature. • Flash pressure.	• Potential for acid based corrosion due to acids. *(Regular ultrasound checks for corrosion during plant maintenance and shutdown).* • Wear and tear of insulation around flash, leading to heat loss. *(Regularly inspect integrity of insulation)* • Loose fittings around the flanges and ports of the vessel, leading to leakages of flammable gas and toxic liquids. *(Regularly inspect mechanical integrity of the joints)*
Objective: Maintain temperature of flash vessel. **Consequences:** Variations in temperature would lead to different equilibrium states in the flash, so product composition would vary and be sub-optimal to the design specification.	Temperature	Temperature sensor	Cooling water flowrate *(FCV on cooling water stream)*	• Ambient temperature. • Stream inlet temperature. • Stream inlet composition. • Cooling water temperature.	
Objective: Maintain pressure of flash vessel. **Consequences:** Variations in pressure would lead to different equilibrium states in the flash, so product composition would	Pressure	Pressure sensor	Outlet gas flowrate *(FCV on gas stream)*	• Ambient temperature. • Stream inlet temperature. • Stream inlet composition. • Cooling water temperature.	

vary and be sub-optimal to the design specification.					
Heat exchangers (C101, C102, C103, C201, C501)					
Objective: Maintain outlet temperature of process stream. **Consequences:** If outlet temperature is too high, process streams might force process units to operational limits and generally have decreased performance. Increased safety risk of thermal runaway in units with exothermic reactions.	Outlet temperature of process stream	Temperature sensor	Flowrate of cooling water *(FCV on cooling water inlet)*	• Inlet temperature of process stream. • Temperature of cooling water.	• Fouling due to deposition of impurities on walls *(Periodic cleaning and washing. Also regular inspection of inner parts during plant maintenance)* • Corrosion on the exchanger walls due to acidic chemicals (*Regular ultrasound checks for corrosion during plant maintenance and shutdown*) • Wear and tear of insulation around heat exchanger, leading to heat loss. *(Regular inspections to make sure insulation is functional and in good condition)*
Electric Heaters (H101, H201, H202, H301, H302, H303, H401, H402, H501, H601)					
Objective: Maintain outlet temperature of process stream. **Consequences:** If outlet temperature is too low, downstream process units will not operate at the designed specifications.	Outlet temperature of process stream	Temperature sensor	Electrical power to heater *(Electrical input to heater)*	• Inlet temperature of process stream. • Temperature of cooling water.	• Fouling due to deposition of impurities on walls *(Periodic cleaning and washing. Also regular inspection of inner parts during plant maintenance)*

					• Corrosion on the exchanger walls due to acidic chemicals (*Regular ultrasound checks for corrosion during plant maintenance and shutdown*) • Wear and tear of insulation around heat exchanger, leading to heat loss. *(Regular inspections to make sure insulation is functional and in good condition)*
Granulator (G201, G501)					
Objective: Maintain particle size distribution of product. **Consequences:** If grinding power is not consistent, the particle size distribution will not meet product specifications, and downstream transportation of solids might be more problematic.	Particle size distribution of product	Particle size analyser	Electrical power to granulator	• Particle size distribution in feed. • Feed flowrate.	• Loose fittings such as screws or grinders, leading to decreased performance. *(Regular maintenance checks for mechanical integrity of the unit and moving parts).* • Abrasion of solid particles on moving parts in the unit, leading to wear and tear of the unit. *(Regularly inspect unit during plant maintenance)*
Buffer Tanks (T101, T102, T301, T401, T501, T601)					
Objective: Maintain level of liquid in the tank.	Level	Level transmitter	Outlet liquid flowrate (FCV on outlet liquid flowrate)	• Feed flowrate.	• Potential for acid based corrosion due to acids.

Consequences: If level is too high, would lead to flooding and the liquid spilling into the gaseous outlet. If level is too low, pressure in the flash might change and lead to poorer flash performance.					*(Regular ultrasound checks for corrosion during plant maintenance and shutdown).* • Loose fittings around the flanges and ports of the vessel, leading to leakages of flammable gas and toxic liquids. *(Regularly inspect mechanical integrity of the joints)*