HAZOP STUDY

Finish Section

Hazard and Operability Study

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⚠ *This document is a preliminary HAZOP worksheet for workshop review. Actions identified herein are recommendations only and must be validated by a qualified multi-disciplinary HAZOP team.*

1. Purpose & Scope

This Hazard and Operability (HAZOP) Study examines the Finish Section of the coating line, systematically evaluating each process input for potential deviations from design intent and the hazards, operability problems, and quality consequences that may result.

The study applies structured guideword analysis to the following process nodes:

- Node 1 — Coil feed via Finish Oven and Finish Section (material, tension, alignment, temperature)
- Node 2 — Clean Water supply via Finish Water Quench (flow, pressure, temperature, quality)
- Node 3 — Compressed Air supply via Finish Air Knife (flow, pressure, air quality)
- Node 4 — Natural Gas supply via Finish Oven Zone 1, Zone 2, and Zone 3 Gas Valves (flow, pressure, combustion, ignition, ventilation)

The scope covers deviations from all relevant process variables — not solely those with installed instrumentation — to ensure a comprehensive hazard identification.

2. Methodology

The HAZOP methodology follows IEC 61882:2016 (Hazard and Operability Studies — Application Guide). For each node, a set of process parameters is identified and each parameter is examined against a structured set of guidewords to generate credible deviations.

2.1 Guidewords Applied

Guideword	Definition
NONE	Complete negation of the intent — no flow, no signal, no activity
MORE	Quantitative increase beyond design intent — higher flow, pressure, temperature, speed
LESS	Quantitative decrease below design intent — lower flow, pressure, temperature, speed
AS WELL AS	Qualitative increase — additional component, phase, or activity not intended
PART OF	Qualitative decrease — only part of the intended action occurs (partial flow, partial coverage)
REVERSE	Logical opposite of intent — reverse flow, backflow, reverse rotation
OTHER THAN	Complete substitution — wrong material, contaminated medium, different utility
EARLY / LATE	Timing deviation — action occurs before or after intended time

2.2 Risk Rating

Each deviation is assigned a qualitative Severity (SEV) and Likelihood (LIK) rating, from which an overall Risk level is derived. Ratings reflect the situation with existing safeguards in place.

Rating	Description
H – High	Significant impact; immediate or likely consequence; uncontrolled hazard
M – Medium	Moderate impact; possible with existing controls; requires monitoring
L – Low	Minor impact; unlikely or adequately controlled; review only

Risk matrix: H+H or H+M → HIGH risk. H+L, M+M, M+H → MEDIUM risk. M+L, L+x → LOW risk.

3. System Description

The Finish Section is the final process zone of the coating line, responsible for curing applied coatings to the required specification (Peak Metal Temperature — PMT) and then rapidly cooling the coated strip prior to recoiling.

Key process inputs and their design intent are summarised below:

- Coil (via Finish Oven & Finish Section): Steel strip travels through the finish oven at controlled speed and tension to achieve the required coating cure. The strip must be correctly threaded, aligned, and tensioned throughout.
- Clean Water (via Finish Water Quench): Following the oven, the hot strip passes through a water quench to rapidly reduce strip temperature to safe handling levels. Adequate flow, pressure, and water quality are essential.
- Compressed Air (via Finish Air Knife): After the water quench, an air knife removes residual surface water from the strip prior to recoiling. Correct air pressure and clean, dry air are required for effective wiping.
- Natural Gas (via Finish Oven Zone 1, Zone 2, and Zone 3 Gas Valves): Three independently controlled gas valve zones provide heat to the finish oven. The three-zone arrangement allows a controlled temperature profile along the oven length to achieve the required PMT curve.

4. Assumptions & Limitations

- This worksheet is intended as a pre-study input for a facilitated HAZOP workshop. All findings must be reviewed and validated by the full multi-disciplinary team.
- The analysis considers all plausible process variables, including those without installed instrumentation, to ensure completeness.
- Existing safeguards listed represent typical industry practice and/or probable controls; their actual presence must be confirmed during the workshop.
- Interactions between simultaneous failures (common cause failure) have not been fully explored in this preliminary study.
- Downstream consequences are assessed to the immediate downstream process step only; further propagation should be reviewed during the workshop.
- Applicable standards include but are not limited to: IEC 61882, EN 746-2 (Industrial thermoprocessing equipment — Safety requirements for combustion and fuel handling systems), IGE/UP/1, and AS/NZS 4645 (Gas distribution networks).

5. HAZOP Worksheet

SEV = Severity | LIK = Likelihood | RISK: H = High (red), M = Medium (amber), L = Low (green) | Ratings reflect condition WITH existing safeguards in place.

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
Node 1 Coil Feed (Finish Oven & Finish Section)	Coil Feed(Material)	**NONE**	No coil present / coil runout	Coil exhausted; coil break upstream; threading failure; upstream jam	Finish oven runs empty (risk of overheating components); air knife and water quench operate on nothing; production loss	Coil end detector / proximity sensor; upstream tension monitoring; operator HMI alarm	Install/verify coil runout sensor with automatic oven burner shutdown. Add alarm to control system.	H	M	H
	Coil Feed(Material)	**LESS**	Reduced coil speed / slow feed	Drive speed reduction; slippage on pinch rolls; tension imbalance; coil set/camber	Prolonged dwell time in oven — overheating, discolouration, mechanical damage; poor coating adhesion	Line speed encoder; tension roll feedback; operator speed HMI	Verify speed feedback loop is closed-loop. Set low-speed alarm with automatic oven temperature trim.	M	M	M
	Coil Feed(Material)	**MORE**	Excessive coil speed	Drive overspeed; control loop failure; incorrect recipe loaded	Insufficient oven dwell time — under-cure of coating; inadequate quench cooling; coating quality failure	Overspeed trip; encoder feedback; recipe interlocks	Confirm max-speed trip setpoint is validated. Add quality sampling at line speed extremes.	M	L	L
	Coil Feed(Alignment)	**OTHER THAN**	Coil mis-track / lateral wander	Edge guide failure; camber in strip; worn steering rolls; incorrect entry guide setting	Strip contacts oven walls or air knife; damage to strip edge; potential fire from contact with burner zone; equipment damage	Edge guides; steering roll control; strip edge sensors; operator visual inspection	Install automatic steering control if not present. Add edge-contact alarm with line stop.	H	M	H
	Coil Feed(Tension)	**MORE**	Excessive strip tension	Drive synchronisation fault; brake drag; coil set tight	Strip stretching, necking or break; coil snap causing whip hazard; line stoppage	Tension roll load cells; drive synchronisation control; tension limits in PLC	Review tension control limits and high-tension trip setpoints. Conduct personnel exclusion zone audit.	H	L	M
	Coil Feed(Tension)	**LESS**	Loss of strip tension / slack loop	Drive fault; loop accumulator overflow; speed mismatch	Strip sag contacts oven floor/burners — fire risk; uneven heating; strip marking	Loop sensors; tension feedback; auto-speed adjustment	Verify loop pit sensors are functional and interlock with oven burner safety shutoff.	H	M	H

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
	Coil Feed(Temperature — entry)	MORE	Strip enters oven at higher than expected temperature	Upstream process heat not dissipated; ambient high temperature	Over-cure of coating in oven; peak metal temperature (PMT) exceeded; coating defects	Entry temperature monitoring (pyrometer); oven zone temperature control	Add entry strip temperature pyrometer. Interlock with Zone 1 gas valve modulation.	M	L	L
Node 2 Clean Water (Finish Water Quench)	Flow	NONE	No water flow to quench	Supply pump failure; isolation valve closed (administrative error); pipe blockage; burst main upstream; control valve failure (fail-closed)	Strip exits oven uncooled — elevated strip temperature; risk of burning operators/equipment downstream; coating damage; fire risk from hot strip contact with flammable materials	Flow switch / flow transmitter on quench supply; operator visual check; low-flow alarm on HMI	Install automatic line stop interlock on loss of quench flow. Verify control valve fail-safe position. Add dual-redundant flow monitoring.	H	M	H
	Flow	LESS	Reduced water flow	Partial blockage (scale, debris); control valve partially closed; supply pressure drop; pump wear; partially closed isolation valve	Inadequate strip cooling; PMT remains elevated; downstream handling risk; coating quality failure	Flow transmitter with low-flow alarm; pressure gauge on supply; operator patrol	Set low-flow alarm at 80% of nominal. Schedule regular strainer/filter maintenance.	M	M	M
	Flow	MORE	Excessive water flow	Control valve failure (fail-open); manual over-ride; supply pressure surge	Flooding of section floor — slip hazard; water ingress to oven zone; steam generation near hot strip (burn hazard); water carryover to air knife section	High-flow alarm; drain design capacity; bunded floor	Review drain capacity vs max possible flow. Add high-flow alarm. Assess steam generation risk near oven exit.	M	L	M
	Pressure	MORE	Excessive supply pressure	Pressure regulator failure; surge from supply main; PRV failure	Mechanical damage to quench nozzles/manifold; water spray reaching electrical equipment or hot oven surfaces; operator safety risk	Pressure relief valve on supply; pressure transmitter; nozzle rated pressure	Install and test PRV on quench water supply. Verify nozzle manifold rated to max supply pressure.	H	L	M
	Pressure	LESS	Low supply pressure	Pump failure; supply main restriction; filter blocked	Poor quench spray coverage; inadequate cooling of strip edges; uneven cooling	Pressure transmitter; low-pressure alarm	Add low supply pressure alarm with operator alert. Consider duty/standby pump arrangement.	M	M	M

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
					causing flatness defects					
	Quality(Contamination)	**OTHER THAN**	Water contaminated (oil, chemicals, biological growth)	Cross-connection with non-potable/process lines; heat exchanger leak; supply tank contamination; legionella growth in stagnant sections	Coating contamination affecting adhesion/appearance; corrosion of quench manifold; health risk to operators (Legionella); product quality failure	Water quality testing (periodic); backflow preventer; dedicated supply line labelling	Implement water quality monitoring programme. Install backflow preventer. Review pipework for dead-legs prone to stagnation.	**H**	**L**	**M**
	Temperature	**MORE**	Quench water temperature too high	Supply water pre-heated (long stagnant pipe run in hot area); recirculated water without cooling; seasonal supply temperature rise	Reduced cooling efficiency; strip exits at higher temperature; downstream handling risk	Water temperature monitoring; recirculation system (if used)	Install water temperature sensor on quench supply. Set high-temperature alarm. Review pipe routing through hot zones.	**M**	**M**	**M**
	Position /Direction	**REVERSE**	Backflow of quench water into oven zone	Pressure reversal; pump stops while oven still hot; no check valve	Water/steam in oven — damage to burners and refractory; rapid thermal shock to strip; potential explosion risk	Check valve on quench supply; physical separation between oven exit and quench header	Verify check valve is installed and functional. Add physical drip shield/baffle between oven exit and quench zone.	**H**	**L**	**M**
Node 3 Compressed Air (Finish Air Knife)	Flow / Supply	**NONE**	No compressed air to air knife	Compressor failure; isolation valve closed; major air line rupture; control valve failure (fail-closed); air receiver empty	Air knife inoperative — excessive water carryover on strip surface; poor coating quality; water enters downstream processes; coating delamination	Air pressure switch on knife header; HMI alarm; compressor duty/standby arrangement	Install air knife supply pressure transmitter with low-pressure line stop interlock. Verify compressor standby changeover is automatic.	**H**	**M**	**H**
	Pressure	**LESS**	Low air pressure at knife	Compressor capacity insufficient; excessive demand elsewhere on ring main; air leak in line; filter/dryer blockage; control valve set incorrectly	Insufficient wiping — residual water on strip; uneven coating weight; surface defects	Pressure transmitter on knife manifold; low-pressure alarm; pressure regulator	Set low-pressure alarm at 90% of minimum acceptable setpoint. Audit air ring main for competing demand during production.	**M**	**M**	**M**

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
	Pressure	MORE	Excessive air pressure at knife	Pressure regulator failure; manual over-ride of regulator; pressure transient from compressor	Excessive wiping — coating thinning beyond specification; mechanical damage to strip (scoring, edge lift); noise hazard above safe levels	Pressure relief valve; pressure regulator; high-pressure alarm	Install and test PRV on knife manifold. Add high-pressure alarm. Conduct noise level survey at max design pressure.	M	L	L
	Air Quality(Moisture)	OTHER THAN	Wet / moisture-laden air	Air dryer failure; dryer bypass open; condensation in receiver; cold weather condensation in lines	Water in air stream introduced to coated strip — surface contamination; coating adhesion failure; corrosion of knife internals	Air dryer with dew-point monitor; moisture separator/drain traps; periodic drain purge	Install dew-point sensor downstream of dryer with high-moisture alarm. Implement auto-drain trap maintenance schedule.	M	M	M
	Air Quality(Oil contamination)	OTHER THAN	Oil-contaminated compressed air	Compressor oil seals worn; coalescing filter failure or not installed; wrong compressor oil grade used	Oil deposition on strip — coating adhesion failure; product contamination; potential fire if oil contacts hot surfaces	Coalescing oil filter; oil detector; regular filter maintenance	Install coalescing filter upstream of air knife and implement filter change schedule. Conduct oil content testing quarterly.	H	L	M
	Temperature(Air)	MORE	High air temperature delivered to knife	Compressor aftercooler failure; hot pipe routing; no inter-stage cooling	Hot air accelerates coating cure unevenly; thermal shock to quenched strip; potential coating surface defects	Air temperature monitoring; aftercooler; line routing away from heat sources	Monitor compressed air temperature at point of use. Add high-temperature alarm if temperature exceeds process limits.	L	L	L
	Position /Angle	OTHER THAN	Air knife lip misaligned or at wrong angle	Mechanical loosening from vibration; incorrect setup after maintenance; wear of adjustment mechanism	Non-uniform wiping across strip width; coating weight variation; edge defects; possible strip marking	Mechanical locking of knife position; setup procedure and check sheet	Implement knife position verification in pre-production checklist. Add position indicator marks on knife adjustment mechanism.	M	M	M
	Air Supply(Reversal)	REVERSE	Air flows back from knife toward supply line	Pressure surge on shutdown; no check valve; control valve fails open during compressor shutdown	Process contaminants (moisture, coating particles) back-fed into air ring main; damage to instrumentation upstream	Check valve on air knife supply; isolation on shutdown procedure	Verify check valve installed on knife branch. Include isolation step in shutdown procedure.	L	L	L

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Gas Flow(All Zones)	**NONE**	Complete loss of gas supply to oven	Main gas supply isolation; meter/regulator failure; emergency shut-off activation; utility supply interruption; manual valve inadvertently closed	Loss of all oven heat; under-cured coating; production loss; cold oven relight procedure required (risk of gas accumulation if relight not controlled)	Gas pressure transmitter on main supply header; HMI alarm; emergency shutoff valve (ESDV); low-pressure trip	Verify ESDV is functional and tested regularly. Formalise oven relight procedure (purge before re-ignition). Add low-gas-pressure line stop.	H	M	H
	Gas Flow(Zone 1)	**NONE**	No gas to Zone 1 only	Zone 1 gas valve (solenoid/actuated) fails closed; zone valve actuator failure; instrumentation fault causing spurious trip	Zone 1 cold — uneven heating profile along oven length; under-cure at strip entry; potential condensation of coating on cold zone surfaces	Zone gas pressure switch; burner management system (BMS) flame supervision; HMI zone alarm	BMS to alarm and record individual zone shutdowns. Review zone valve maintenance schedule.	M	M	M
	Gas Flow(Zone 2)	**NONE**	No gas to Zone 2 only	Zone 2 gas valve fails closed; solenoid coil burnout; PLC output fault	Loss of mid-oven zone — peak metal temperature (PMT) not achieved; product quality failure	BMS zone monitoring; Zone 2 temperature alarm on HMI	Ensure BMS individual zone fault alarms are configured and tested. Review PLC output diagnostics.	M	M	M
	Gas Flow(Zone 3)	**NONE**	No gas to Zone 3 only	Zone 3 gas valve fails closed; mechanical fault; incorrect setpoint	Strip exits oven below required PMT; coating under-cure; potential rework/scrap	Exit zone temperature monitoring; BMS alarm	Install exit strip temperature pyrometer (if not present). Interlock with quality reject system.	M	M	M
	Gas Pressure	**MORE**	Excessive gas pressure to burners	Pressure regulator failure (fail-open); upstream pressure surge; bypass valve left open	Burner over-firing — strip overheating; PMT exceeded; coating burnoff/fire; burner damage; risk of oven structural damage	Gas pressure relief valve (PRV/slam-shut valve); high-pressure trip; BMS high-temperature alarm; pressure transmitter	Confirm slam-shut valve is set and tested at correct maximum pressure. Annual PRV inspection required.	H	L	M
	Gas Pressure	**LESS**	Low gas pressure to burners	Supply restriction; regulator set too low; filter blocked; high demand elsewhere on site ring main; gas	Burner flame unstable or lifts off — risk of unburnt gas accumulation; incomplete combustion (CO	Low-gas-pressure trip in BMS; flame supervision (UV/ionisation); CO detector in oven area	Verify low-gas-pressure trip setpoint is appropriate. Confirm CO detectors are installed and calibrated annually.	H	M	H

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
				supply pressure varies (utility)	generation); process temperature low					
	GasCompositio n	**OTHER THAN**	Gas composition outside specification (calorific value variation, inerts, LPG mix)	Utility supply changes (network gas blending); switching between gas supplies	Burner performance changes — under or over-heating; burner instability; flame instability; combustion tuning out of specification	Utility contractual quality specification; burner manufacturer limits	Notify gas supplier of process sensitivity. Consider gas calorific value meter on main supply. Establish re-commissioning protocol on gas supply changes.	**M**	**L**	**L**
	Gas Leak(Unignited)	**OTHER THAN**	Unignited gas release (inside or outside oven)	Valve stem seal failure; flange leak; flexible hose failure; stress corrosion of gas pipework; valve body crack	Explosive atmosphere formation; risk of explosion / fire; personnel injury or fatality; property damage	Gas detector in oven enclosure; BMS ESDV; regular pipework inspection; hot-work permit system	Install combustible gas detector(s) in oven enclosure with automatic ESDV shutoff. Implement gas pipework inspection programme per IGE/UP/1 or equivalent.	**H**	**L**	**H**
	Ignition	**NONE**	Burner fails to ignite on startup	Ignition electrode failure; no spark; gas valve not open; low gas pressure; wet electrode	Unburnt gas accumulates in oven — risk of explosive ignition on next attempt; production delay; CO risk	BMS ignition trial with flame supervision; purge cycle before re-attempt; ignition fault alarm; lockout after set attempts	Verify BMS purge cycle time and retry lockout are per manufacturer specification and applicable code (e.g. EN 746-2). Document in maintenance schedule.	**H**	**M**	**H**
	Ignition	**MORE**	Delayed / late ignition (gas accumulates before ignition)	Weak spark; partial electrode fouling; gas valve slow to open	Hard light-off / explosion risk in oven; burner damage; potential oven structural damage; personnel risk	BMS maximum ignition trial time limit; purge cycle; flame supervision lockout	Include electrode condition check in planned maintenance. Review BMS ignition trial time limits.	**H**	**L**	**M**
	CombustionAir (Ratio)	**LESS**	Insufficient combustion air (rich mixture)	Combustion air fan failure; damper failure; air filter blocked; incorrect burner tuning	Incomplete combustion — CO and soot production; carbon deposition on strip and oven; fire/explosion risk; health hazard to personnel	Combustion air pressure/flow monitor; CO analyser in flue; BMS air proving switch; emission monitoring	Install combustion air proving switch on each burner as BMS input. Schedule annual combustion analysis / flue gas testing.	**H**	**M**	**H**

Node / System	Parameter	Guide-word	Deviation	Possible Causes	Consequences	Existing Safeguards	Recommended Actions	SEV	LIK	RISK
	CombustionAir (Ratio)	**MORE**	Excess combustion air (lean mixture)	Air damper set too high; fan over-speed; incorrect tuning	Flame instability or flame-out; NOx emission increase; increased fuel consumption; poor oven temperature uniformity	Burner tuning procedure; air-to-gas ratio control	Schedule periodic burner tuning. Monitor fuel consumption as leading indicator of combustion inefficiency.	L	M	L
	OvenTemperature(Zone Control)	**MORE**	Oven zone over-temperature	Temperature controller failure (output high); thermocouple fault (reading low — controller compensates); gas valve stuck open; control loop tuning fault	Strip overheating — coating burnoff; fire risk from coating vapours; PMT exceeded; strip mechanical property degradation; oven refractory damage	Over-temperature alarm and independent high-temperature trip (separate from control TC); BMS; relief damper	Verify independent high-temperature safety trip is on a separate thermocouple to the control thermocouple. Test annually.	H	M	H
	OvenTemperature(Zone Control)	**LESS**	Oven zone under-temperature	Gas valve under-firing; thermocouple reading high (controller reduces output); heat loss via oven door/seals; cold strip load	Under-cure of coating; product quality failure; may not be detected until downstream inspection	Low-temperature alarm per zone; thermocouple calibration schedule; strip exit pyrometer	Implement periodic thermocouple calibration. Add strip exit temperature monitoring as independent quality check.	M	M	M
	OvenVentilation(Fume Extraction)	**LESS / NONE**	Reduced or no fume extraction from oven	Extraction fan failure; damper closed; duct blockage by condensed coating vapours	Accumulation of solvent vapours and coating combustion products inside oven — fire/explosion risk; VOC emission to workplace; personnel health risk	LEV fan status monitoring; duct temperature; solvent vapour detector in oven atmosphere; explosion relief panels	Interlock oven operation with fume extraction fan running confirmation. Schedule duct inspection for condensate blockage.	H	M	H

6. Summary of High-Risk Items

The following deviations were assessed as HIGH risk (with existing safeguards in place) and are prioritised for immediate action:

Node	Deviation	Key Consequence	Recommended Action
Node 1 Coil Feed (Finish Oven & Finish Section)	No coil present / coil runout	Finish oven runs empty (risk of overheating components); air knife and water quench operate on nothing; production loss	Install/verify coil runout sensor with automatic oven burner shutdown. Add alarm to control system.
Node 1 Coil Feed (Finish Oven & Finish Section)	Coil mis-track / lateral wander	Strip contacts oven walls or air knife; damage to strip edge; potential fire from contact with burner zone; equipment damage	Install automatic steering control if not present. Add edge-contact alarm with line stop.
Node 1 Coil Feed (Finish Oven & Finish Section)	Loss of strip tension / slack loop	Strip sag contacts oven floor/burners — fire risk; uneven heating; strip marking	Verify loop pit sensors are functional and interlock with oven burner safety shutoff.
Node 2 Clean Water (Finish Water Quench)	No water flow to quench	Strip exits oven uncooled — elevated strip temperature; risk of burning operators/equipment downstream; coating damage; fire risk from hot strip contact with fl…	Install automatic line stop interlock on loss of quench flow. Verify control valve fail-safe position. Add dual-redundant flow monitoring.
Node 3 Compressed Air (Finish Air Knife)	No compressed air to air knife	Air knife inoperative — excessive water carryover on strip surface; poor coating quality; water enters downstream processes; coating delamination	Install air knife supply pressure transmitter with low-pressure line stop interlock. Verify compressor standby changeover is automatic.
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Complete loss of gas supply to oven	Loss of all oven heat; under-cured coating; production loss; cold oven relight procedure required (risk of gas accumulation if relight not controlled)	Verify ESDV is functional and tested regularly. Formalise oven relight procedure (purge before re-ignition). Add low-gas-pressure line stop.
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Low gas pressure to burners	Burner flame unstable or lifts off — risk of unburnt gas accumulation; incomplete combustion (CO generation); process temperature low	Verify low-gas-pressure trip setpoint is appropriate. Confirm CO detectors are installed and calibrated annually.
Node 4 Natural Gas (Finish Oven Zone	Unignited gas release (inside or outside oven)	Explosive atmosphere formation; risk of explosion / fire; personnel injury or fatality; property damage	Install combustible gas detector(s) in oven enclosure with automatic ESDV shutoff. Implement gas pipework inspection programme per IGE/UP/1 or equivalent.

1, 2 & 3 Gas Valves)			
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Burner fails to ignite on startup	Unburnt gas accumulates in oven — risk of explosive ignition on next attempt; production delay; CO risk	Verify BMS purge cycle time and retry lockout are per manufacturer specification and applicable code (e.g. EN 746-2). Document in maintenance schedule.
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Insufficient combustion air (rich mixture)	Incomplete combustion — CO and soot production; carbon deposition on strip and oven; fire/explosion risk; health hazard to personnel	Install combustion air proving switch on each burner as BMS input. Schedule annual combustion analysis / flue gas testing.
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Oven zone over-temperature	Strip overheating — coating burnoff; fire risk from coating vapours; PMT exceeded; strip mechanical property degradation; oven refractory damage	Verify independent high-temperature safety trip is on a separate thermocouple to the control thermocouple. Test annually.
Node 4 Natural Gas (Finish Oven Zone 1, 2 & 3 Gas Valves)	Reduced or no fume extraction from oven	Accumulation of solvent vapours and coating combustion products inside oven — fire/explosion risk; VOC emission to workplace; personnel health risk	Interlock oven operation with fume extraction fan running confirmation. Schedule duct inspection for condensate blockage.

7. Document Control & Sign-Off

This document is issued as a draft for workshop review. The following sign-off is required prior to issuing as a controlled document:

Role	Name	Signature	Date
HAZOP Facilitator			
Process Engineer			
Safety Engineer			
Operations Manager			
Approving Authority			

— End of Document —