

CONTROL STRATEGY & CONTROL PHILOSOPHY

Flash Dryer System – Modified Starch

1. PURPOSE AND SCOPE

This document defines the **complete Control Strategy and Control Philosophy** for the Modified Starch Flash Dryer system, based on the approved **P&ID** (5204-PR-DW-0001-02).

, explosion protection layout, rotating equipment monitoring, and expert operational comments.

The philosophy covers:

- Process control
- Equipment protection
- Explosion and mechanical safety interfaces
- Startup, shutdown, and emergency logic
- Instrumentation usage and redundancy
- Operator interaction philosophy

2. OVERALL CONTROL OBJECTIVES

The primary control objectives of the Flash Dryer system are:

1. Maintain final product moisture within specification.
2. Prevent product overheating and degradation.
3. Ensure continuous, stable solids conveying through the dryer.
4. Protect rotating and pressurized equipment.
5. Provide immediate safe response to explosion or mechanical failure.
6. Ensure compliance with ATEX / EN 14491 explosion protection requirements.

3. CONTROL SYSTEM ARCHITECTURE

- Control platform: **PLC**
- Control layers:
 - Regulatory control (PID / PI)

- Sequential control (step-based logic)
- Interlock and trip layer
- Operator HMI supervision
- Safety philosophy:
 - Hard interlocks in PLC
 - Fail-safe field devices
 - Interface with explosion protection devices

4. OPERATING MODES

Mode	Description
OFF	All equipment de-energized
START-UP	Automatic controlled startup sequence
NORMAL OPERATION	Fully automatic cascade-controlled drying
SHUTDOWN	Controlled drying and cooldown
EMERGENCY SHUTDOWN	Immediate protective shutdown
MAINTENANCE	Local / manual control with interlocks enforced

5. MAIN PROCESS CONTROL STRATEGY

5.1 Moisture-Based Cascade Control

The flash dryer operates under a **cascade control strategy**:

- **Master controller:** Online product moisture analyzer
- **Slave controller:** Exhaust air temperature controller
- **Manipulated variable:** Steam control valve to air heater

Control logic:

- The moisture controller adjusts the **setpoint of exhaust air temperature**.
- The temperature controller regulates steam flow to maintain that setpoint.

- If the moisture analyzer fails, the system automatically reverts to **temperature-only control**.

6. AIR SYSTEM AND FAN CONTROL

6.1 Dryer Fan Control (V6515)

Based on the P&ID, (5204-PR-DW-0001-02) the dryer fan is equipped with:

- VFD control
- Shaft speed measurement
- Bearing temperature monitoring
- Vibration monitoring
- Air velocity measurement at duct outlet

Control strategy:

- Fan speed is controlled to maintain required air velocity.
- Fan cannot start unless:
 - All downstream paths are open
 - Explosion vents are healthy
 - No active trip conditions exist

6.2 Fan Protection Interlocks

Protection	Action
High bearing temperature	Fan trip
High vibration	Fan trip
Overspeed	VFD trip
Loss of airflow	Heater trip ((TCV- S101)
Shaft speed mismatch	Alarm then trip

7. FEED SYSTEM CONTROL (STARCH CAKE FEEDER)

- Feed screw / feeder operates under mass measuring (WIC-B6200) control.
- Feed rate is interlocked with:
 - Fan running status
 - Heater availability
 - Cyclone and discharge readiness

If airflow or heating is lost:

- Feed is stopped immediately
- Purge sequence is initiated if allowed

8. HEATER AND STEAM CONTROL PHILOSOPHY

- Steam flow is modulated via control valve.
- Heater enable is permitted only if:
 - Fan is running
 - Minimum airflow is confirmed
 - No high temperature trip is active

Trips:

- High inlet air temperature (TIC-101) → Steam valve closed
- Fan trip → Steam valve closed (TCV- S101)
- Explosion signal → Steam valve closed

9. EXPLOSION PROTECTION AND BURST SENSOR LOGIC

9.1 Explosion Detection

The system includes multiple **Burst Sensors** XS-101 to XS-106 (Dryer Duct) + XS-F6506 to XS-F6511 (Cyclones) + XS-B6512 (Silo)) Installed on:

- Dryer duct
- Cyclone inlets
- Dry starch receiving silo

9.2 Explosion Response Strategy

Upon detection of burst / explosion signal:

Immediate actions:

1. Close steam control valve (TCV- S101& TCV- S102).
2. Stop product feed.
3. Maintain fan operation if mechanically allowed (post-explosion purge).
4. Generate latched alarm requiring manual reset.

Explosion events are treated as:

- **Non-auto-resettable trips**
- Root-cause investigation mandatory before restart

10. CYCLONE AND SOLIDS DISCHARGE CONTROL

- Cyclone discharge is via airlock/rotary valve.
- Rotary valves are interlocked with:
 - Fan operation
 - Cyclone pressure balance (controlled by level switches)
- Blockage detection results in:
 - Feed reduction
 - Alarm escalation
 - Controlled shutdown if unresolved

11. START-UP SEQUENCE (SUMMARY)

1. System permissive check.
2. Start dryer fan and verify airflow.
3. Enable heater and warm-up.
4. Start feed at minimum rate.
5. Enable cascade moisture control.
6. Ramp to normal production.

12. NORMAL SHUTDOWN SEQUENCE

1. Stop feed.
2. Continue drying until duct moisture clears.
3. Disable heater.
4. Cool-down with air.
5. Stop fan.

13. EMERGENCY SHUTDOWN (ESD)

Triggers:

- Emergency stop
- Explosion signal
- Fan trip
- Critical temperature or vibration

Actions:

- Immediate steam isolation
- Immediate feed stops
- Fan logic based on structural integrity status

14. ALARM PHILOSOPHY

- First-out alarm logic applied
- Priority-based alarms:
 - High: Safety / equipment damage
 - Medium: Process deviation
 - Low: Advisory
- All trips require manual reset

15. INTERFACE WITH MECHANICAL DESIGN

The control philosophy is directly aligned with:

- Explosion vent sizing and location

- Vacuum design limits
- Mechanical stress limits of ducting and cyclones
- Fan operating envelope

No control action allows operation beyond mechanical design limits.

In the following, we describe the dryer control philosophy in three steps.

STEP 1 – CAUSE & EFFECT MATRIX

1. PURPOSE OF CAUSE & EFFECT MATRIX

This Cause & Effect Matrix defines the **automatic protective and control responses** of the Flash Dryer system to abnormal process, mechanical, or safety events.

The matrix ensures:

- Consistent and predictable system behavior
- Protection of personnel and equipment
- Compliance with explosion safety standards
- Clear implementation guidance for PLC/DCS programming

2. PHILOSOPHY AND DESIGN BASIS

- All **Trips** are latched and require manual reset.
- Explosion-related causes have **highest priority**.
- Steam isolation is always **fail-safe closed**.
- Feed stoppage is **immediate** on loss of safe drying conditions.
- Fan operation after trip depends on **mechanical integrity and explosion logic**.

3. Cause & Effect Matrix

Symbol	Meaning	Description
✓	Action Executed	The specified action is automatically executed when the cause occurs

—	No Action	No automatic action is initiated
L	Latched Trip	A trip that remains active until manually reset by the operator after fault clearance and, where applicable, completion of maintenance or safety inspection
A	Alarm Only	An operator alarm without automatic shutdown or trip action; the process may continue to operate within safe limits

4. CAUSE & EFFECT MATRIX – MAIN PROCESS & SAFETY

4.1 Explosion & Fire Related Events

Cause	Feed Stop	Steam Valve Close	Fan Stop	Fan Continue (Purge)	Alarm	Trip
Burst Sensor – Dryer Duct	✓	✓	—	✓	✓	L
Burst Sensor – Cyclone Body	✓	✓	—	✓	✓	L
Burst Sensor – Exhaust Duct	✓	✓	—	✓	✓	L
Fire Detection (If Any)	✓	✓	✓	—	✓	L

Notes:

- Fan continues only if mechanical integrity is confirmed.
- Restart requires inspection and manual reset.

4.2 Air System & Fan Protection

Cause	Feed Stop	Steam Close	Fan Trip	Alarm	Trip
Fan Bearing High Temperature	✓	✓	✓	✓	L
Fan High Vibration	✓	✓	✓	✓	L
Fan Overspeed	✓	✓	✓	✓	L
Fan Motor Trip	✓	✓	✓	✓	L
Low Air Velocity in Duct	✓	✓	—	✓	A

4.3 Heater & Temperature Protection

Cause	Feed Stop	Steam Close	Fan Stop	Alarm	Trip
High Inlet Air Temperature	✓	✓	—	✓	L
High Exhaust Air Temperature	✓	✓	—	✓	L
Steam Supply Failure	✓	✓	—	✓	A
Condensate Backup High Level	✓	✓	—	✓	L

4.4 Feed System Abnormal Conditions

Cause	Feed Stop	Steam Close	Fan Stop	Alarm	Trip
Feeder Motor Trip	✓	—	—	✓	A
Feed Blockage	✓	—	—	✓	A
Loss of Airlock Rotation	✓	—	—	✓	L

4.5 Cyclone & Solids Discharge

Cause	Feed Stop	Steam Close	Fan Stop	Alarm	Trip
Cyclone High Differential Pressure	✓	—	—	✓	A
Rotary Valve Failure	✓	—	—	✓	L
Solids Backup High Level	✓	—	—	✓	L

4.6 Instrument & Control System Failures

Cause	Control Mode Change	Feed Stop	Alarm
Online Moisture Analyzer Failure	Temp Control Only	—	✓
Exhaust Temp Sensor Failure	Safe Steam Close	✓	✓
PLC / DCS CPU Fault	All Outputs Safe	✓	✓

5. RESET AND RESTART PHILOSOPHY

- Explosion-related trips **cannot be auto-reset**.
- Mechanical trips require maintenance clearance.
- Restart sequence must follow defined startup logic.
- First-out alarm is retained for diagnostics.

STEP 2 – DETAILED OPERATING SEQUENCES

Start-up, Normal Shutdown & Emergency Shutdown

1. PURPOSE OF THIS SECTION

This section provides a **detailed, step-by-step operational description** of:

- Start-up sequence
- Normal shutdown sequence
- Emergency shutdown sequence

The intent is to ensure:

- Safe and repeatable operation
- Clear understanding for operators and commissioning engineers
- Direct traceability to control logic and interlocks

2. GENERAL SEQUENCE PHILOSOPHY

- All sequences are executed automatically in **AUTO mode**.
- Each step requires defined **entry conditions, actions, and exit conditions**.
- Any critical trip overrides the active sequence and forces emergency logic.
- Operators can observe but not bypass sequence steps.

3. DETAILED START-UP SEQUENCE (AUTO MODE)

STEP SU-00 – System Standby

System State:

- All drives stopped

- Steam valve closed
- No active trips
- System in AUTO mode

Operator Action:

- Press “Start Flash Dryer” command

STEP SU-10 – Pre-Start Safety and Permissive Check

Control Actions:

- Verify all emergency stops are reset
- Confirm no explosion or fire trips active
- Check availability of:
 - Dryer fan
 - Steam supply
 - Condensate removal
 - Cyclones and rotary valves
- Verify instrument health (temperature, airflow, vibration)

If any permissive is not satisfied:

- Sequence is held
- Operator alarm generated

Exit Condition:

- All permissive = TRUE

STEP SU-20 – Dryer Fan Start and Stabilization

Control Actions:

- Start dryer fan via VFD
- Monitor:
 - Fan shaft speed
 - Bearing temperatures

- Vibration levels
- Air velocity in main duct

Interlocks:

- Heater and feed remain disabled

Exit Condition:

- Air velocity \geq minimum design value (e.g. 22 m/s)
- Fan parameters stable for defined time

STEP SU-30 – Heater Warm-Up Phase

Control Actions:

- Enable steam control valve
- Ramp inlet air temperature to warm-up setpoint
- Monitor exhaust air temperature

Protection:

- High temperature limits enforced
- Steam closed immediately on fan fault

Exit Condition:

- Exhaust air temperature reaches minimum drying threshold

STEP SU-40 – Feed System Initiation (Low Load)

Control Actions:

- Start rotary valves / airlocks
- Start feed system at minimum feed rate
- Maintain stable air temperature

Monitoring:

- Cyclone pressure balance
- Solids discharge continuity

Exit Condition:

- Stable exhaust temperature
- No abnormal vibration or pressure

STEP SU-50 – Ramp-Up to Normal Operation

Control Actions:

- Enable moisture-based cascade control
- Gradually ramp feed rate to production target
- Allow exhaust temperature setpoint to be adjusted by moisture controller

System State:

- Normal automatic operation achieved

4. NORMAL OPERATION MONITORING

During normal operation, the system continuously monitors:

- Product moisture
- Exhaust air temperature
- Air velocity
- Fan vibration and bearing temperature
- Cyclone pressure and discharge status

Any deviation results in alarms or controlled corrective action.

5. NORMAL SHUTDOWN SEQUENCE (CONTROLLED STOP)

STEP SD-10 – Feed Stop

Trigger:

- Operator stop command

Control Actions:

- Stop product feed immediately
- Maintain airflow and heating

STEP SD-20 – Drying and Duct Clearing Phase

Control Actions:

- Continue fan operation
- Maintain exhaust air temperature
- Allow remaining product to fully exit dryer and cyclones

Exit Condition:

- No solids detected in system
- Stable exhaust conditions

STEP SD-30 – Heater Shutdown

Control Actions:

- Close steam control valve
- Maintain airflow for cooldown

STEP SD-40 – Fan Cooldown and Stop

Control Actions:

- Continue fan until system temperature decreases to safe level
- Stop fan
- System returns to standby

6. EMERGENCY SHUTDOWN SEQUENCE (ESD)

6.1 Emergency Shutdown Triggers

Emergency shutdown is initiated by any of the following:

- Explosion / burst sensor activation
- Emergency stop pushbutton
- Fan critical trip (vibration, bearing temperature, overspeed)
- Heater critical overtemperature

6.2 Emergency Shutdown Actions (Immediate)

Upon ESD trigger, the following actions occur **without delay**:

1. Steam control valve closes (fail-safe)
2. Product feed stops

3. Moisture and temperature control loops disabled
4. Emergency alarms generated and latched

6.3 Fan Operation During Emergency

- If explosion detection is active:
 - Fan operation follows explosion venting and purge philosophy
- If mechanical trip:
 - Fan is stopped immediately

Fan behavior is defined by mechanical integrity status.

6.4 Post-Emergency State

- System remains locked in ESD state
- Manual inspection and clearance required
- Full start-up sequence mandatory for restart

7. SEQUENCE INTERRUPTION AND RECOVERY

- Any trip interrupts the active sequence.
- After fault clearance:
 - Operator must reset trips
 - System returns to STEP SU-00
- Partial sequence restart is not permitted.

8. INTERLOCK AND TRIP LOGIC (PSEUDO CODE)

8.1 Heater Enable Interlock

IF Fan Running = TRUE

AND Airflow_OK = TRUE

AND No_Active_Trips = TRUE

THEN

 Heater_Enable = TRUE

ELSE

```
    Heater_Enable = FALSE  
END_IF
```

8.2 Feed Enable Interlock

```
IF Fan_Running = TRUE  
AND Heater_Enabled = TRUE  
AND Exhaust_Temp_Stable = TRUE  
AND Explosion_OK = TRUE  
THEN  
    Feed_Enable = TRUE  
ELSE  
    Feed_Enable = FALSE  
END_IF
```

8.3 Explosion Trip Logic

```
IF Burst_Sensor_Activated = TRUE  
THEN  
    Steam_Valve = CLOSE  
    Feed_Enable = FALSE  
    Explosion_Trip = TRUE  
    Alarm_Latched = TRUE  
END_IF
```

8.4 Fan Protection Logic

```
IF Bearing_Temp_High OR Vibration_High OR Overspeed  
THEN
```

```
Fan_Trip = TRUE
Steam_Valve = CLOSE
Feed_Enable = FALSE
END_IF
```

8.5 Moisture Analyzer Failure Logic

```
IF Moisture_Analyzer_Fault = TRUE
THEN
    Moisture_Control = DISABLED
    Exhaust_Temp_Control = ENABLED
    Alarm = TRUE
END_IF
```

STEP 3 – ALARM, TRIP & OPERATOR ACTION PHILOSOPHY

1. PURPOSE OF THIS SECTION

This section defines the **alarm and trip philosophy** of the Flash Dryer system, including:

- Classification of alarms and trips
- Process rationale behind each protection
- Expected operator actions
- Clear distinction between alarms and shutdown events

The objective is to:

- Prevent unsafe operating conditions
- Protect equipment and product quality
- Avoid nuisance alarms
- Support efficient operator response

2. GENERAL ALARM PHILOSOPHY

2.1 Alarm Design Principles

- Alarms are generated only when **operator action is required**.
- Alarms are prioritized according to process risk.
- Alarms do **not automatically stop the plant**, unless escalated to a trip.
- Each alarm has:
 - Clear cause
 - Clear consequence
 - Defined operator response

2.2 Alarm Priority Classification

Priority	Description	Operator Response Time
High (H)	Immediate risk to safety or equipment	Immediate
Medium (M)	Risk to process stability or quality	Short term
Low (L)	Advisory or maintenance-related	When convenient

3. GENERAL TRIP PHILOSOPHY

- Trips result in **automatic shutdown actions**.
- Trips are **latched** and require manual reset.
- Trips override all operating modes.
- Explosion and fire-related trips have the **highest priority**.
- Trips always act in a **fail-safe manner**.

4. ALARM & TRIP CLASSIFICATION BY PROCESS AREA

4.1 Air System and Fan Protection

Alarms

Alarm	Priority	Process Meaning	Operator Action
Low Air Velocity	M	Risk of poor entrainment	Monitor, prepare for load reduction
Fan Bearing Temperature High	H	Mechanical degradation	Reduce load, prepare for shutdown
Fan Vibration High (Warning)	M	Early mechanical issue	Inform maintenance

Trips

Trip	Process Action
Fan Bearing Temperature High-High	Fan stop, steam close, feed stop
Fan Vibration High-High	Fan stop, steam close, feed stop
Fan Overspeed	Immediate fan trip

4.2 Heater and Thermal Protection

Alarms

Alarm	Priority	Meaning
Inlet Air Temperature High	H	Heater overload
Exhaust Air Temperature High	H	Product overheating risk
Condensate Level High	M	Heater efficiency loss

Trips

Trip	Process Action
Heater Overtemperature	Steam valve close
Condensate High-High	Steam valve close
Steam Supply Failure (Critical)	Controlled feed stop

4.3 Product Quality and Drying Performance

Alarms

Alarm	Priority	Meaning
Product Moisture High	M	Under-drying
Product Moisture Low	M	Over-drying
Moisture Analyzer Fault	M	Loss of quality feedback

Control Response (No Trip)

- Switch to exhaust temperature control
- Operator informed
- Production may continue at reduced performance

4.4 Feed System and Solids Handling

Alarms

Alarm	Priority	Meaning
Feed Blockage	M	Risk of unstable drying
Rotary Valve Speed Low	M	Solids backup risk
Cyclone Differential Pressure High	M	Fouling or overload

Trips

Trip	Process Action
Rotary Valve Failure	Feed stop
Solids High Level	Feed stop

4.5 Explosion and Fire Protection

Trips (Highest Priority)

Cause	Automatic Actions
Explosion / Burst Sensor Activation	Steam close, feed stop, alarms latched
Fire Detection	Steam close, feed stop, fan logic per design
Emergency Stop	Immediate ESD

Notes:

- Explosion-related trips are never bypassed.
- Restart requires mechanical inspection and management approval.

5. FIRST-OUT ALARM PHILOSOPHY

- The first detected trip or alarm is recorded as **First-Out**.
- Subsequent alarms are logged but do not mask the root cause.
- First-Out indication is clearly displayed to operators.

6. OPERATOR RESPONSE GUIDELINES

Alarm Response

Operators are expected to:

1. Identify alarm priority
2. Assess process trend
3. Take corrective action
4. Escalate to shut down if alarm persists

Trip Response

Operators must:

1. Acknowledge trip
2. Secure the system
3. Inform maintenance and supervision
4. Perform inspection
5. Reset only after clearance

7. ALARM RATIONALISATION PHILOSOPHY

- Each alarm is justified by a process risk.
- Duplicate alarms are avoided.
- Alarm limits are aligned with:
 - Equipment design limits
 - Product quality constraints
 - Safety margins

8. INTERFACE WITH FAT / SAT

During FAT and SAT:

- All alarms are tested for correct priority and message
- Trips are verified for correct actions
- Operator displays are validated for clarity