Q2 SERIES: BEYOND THE FLAME
Burner management in Hi-Temp and Flameless mode

1. Introduction

When the temperature of an industrial furnace exceeds the auto-ignition threshold of the fuel, operating conditions change relative to conventional operation: the flame supervision logic can be adapted to the new operating mode, and flameless mode operation becomes possible.

2. Auto-ignition

As the temperature in an industrial furnace rises, the auto-ignition threshold of the fuel is reached. Beyond this limit:

- **Spontaneous Ignition:** The fuel reacts upon contact with the hot gases and refractory walls without the need for ignition devices.

- **HTM Definition:** This physical condition identifies the High Temperature Mode (HTM).

Safety and Logical Relevance
In HTM regime, the nature of flame supervision changes radically:

- **Loss of Sensor Relevance:** Although UV or ionization sensors may still detect a signal, their logical function lapses. Any momentary signal interruptions do not constitute a hazard, as re-ignition is guaranteed by the chamber temperature.

- **Regulatory Compliance:** The UNI EN ISO 13577 standard incorporates this principle.

- **Mandatory Requirement:** Bypass is permitted only if the system has a certified furnace temperature measurement that constantly confirms that the safety threshold is exceeded.

3. Flameless Combustion

Flameless combustion is an advanced oxidation process based on the mixing of reactants with recirculated flue gases prior to the reaction.

- **Dilution:** reduces local oxygen concentration and equalizes temperature.

- **Absence of flame:** there is no flame front; combustion is distributed throughout the chamber.

- **Requirements:** furnace temperature above the auto-ignition threshold and high-velocity injection to circulate flue gas.

Operational Benefits
The adoption of this technology delivers tangible benefits on multiple fronts:

- **Environmental:** drastic reduction in NOx emissions.

- **Quality:** greater thermal uniformity, which improves the final product and preserves refractory materials.

- **Acoustic:** significant reduction in combustion noise.

Supervision and Safety
A critical aspect of plant management concerns the control systems:

- **Irrelevance of standard sensors:** in flameless mode, sensors do not detect a flame signal.

- **Justified bypass:** it is the temperature that guarantees continuous oxidation.

3.1. REGENERATIVE BURNERS

Flameless mode becomes essential in high-efficiency regenerative systems for the following reasons:

- **Efficiency vs. Emissions:** regenerative burners achieve high efficiencies by preheating combustion air using flue gas heat. However, in conventional mode, the hot air would cause adiabatic temperature peaks with excessive NOx production.

- **The Solution:** flameless mode eliminates these thermal peaks through reactant dilution, making high energy savings compatible with environmental limits.

4. FLAME SUPERVISION

Standards EN 298 and UNI EN ISO 13577-2 require continuous flame supervision to ensure the operational safety of burners:

- **Low Temperature:** safety relies on physical sensors (ionization electrodes or UV cells). At this stage, absence of signal triggers immediate shutdown to prevent unburned fuel accumulation.

- **High Temperature:** once the chamber exceeds the auto-ignition temperature of the fuel, safety no longer depends on the sensor, but on the thermal condition itself.

4.1. OPERATIONAL BENEFITS IN HTM

Switching to HTM (High Temperature Mode) allows optimization of service continuity:

- **Process Continuity:** Untimely shutdowns or lockouts caused by momentary sensor signal instabilities are avoided.

- **Spontaneous Reignition:** The presence of a temperature above the auto-ignition limit guarantees fuel oxidation, making direct flame detection unnecessary.

4.2. REGULATORY REQUIREMENTS

Managing high temperature mode involves an articulated set of safety standards:

EN 298	Automatic burner control systems for burners and appliances burning gaseous or liquid fuels.
UNI EN ISO 13577-2	Industrial furnaces and associated equipment - Safety Part 2: Combustion and fuel handling systems.
UNI EN ISO 13577-4	Industrial furnaces and associated equipment - Safety Part 4: Protective systems.
EN 13611	Safety and control devices for burners and gas appliances burning gaseous and/or liquid fuels - General requirements.
EN 14597	Temperature control devices and temperature limiters for heat generating systems.
IEC 61508	Functional safety of electrical, electronic and programmable electronic safety-related systems.

5. Q2

Q2 is a device that manages the entire burner cycle and adapts to different operating modes without hardware modifications, simply by changing the configuration:

- **Versatility:** manages gas burners (single-stage, multi-stage, modulating), oil, and hydrogen.

- **High Temperature:** natively integrates HTM.

- **Continuous operation:** can remain on indefinitely, eliminating cyclical interruptions that cause production losses, both in low temperature and HTM/flameless mode.

- **Advanced self-diagnostics:** certification guarantees that the electronics perform safety checks in real time, without the need for periodic maintenance shutdowns.

5.1. HIGH TEMPERATURE MODE

Q2 activates HTM when it receives a safety signal (external STL) confirming that the auto-ignition threshold has been exceeded.

- **What changes:** no lockout on flame loss, ignition spark is not required.

- **Cool-down:** when the temperature drops below the threshold, the behavior can be selected:
  o Transition to one of the 3 low-temperature stages, restoring supervision.
  o Burner shutdown.

- **Dual Safety:** for greater protection against possible failures, confirmation of the physical signal from the controller (STL) with consent via fieldbus (PLC) can be enabled.

Important: Q2 does not perform direct furnace temperature measurements. The responsibility for the correctness and reliability of the HTM enable signal rests entirely on the certified external safety loop (STL + wiring + sensor).

5.2. FLAMELESS

Flameless mode is an extension of HTM that requires dedicated functions:

- **Staged Injection**: The Q26 and Q28 models manage up to 4 gas valves, allowing the operation of each valve to be defined to optimize the internal recirculation required for flameless mode.

- **Automatic Transition:** Q22, Q26 and Q28 manage standard start-up at low temperature, transition to flameless, and return to low temperature.

5.3. REGENERATIVE BURNERS

- **Operation:** A pair of Q2 units manages the regenerative cycle natively.

- **Supervisor Role:** The external system (PLC/DCS) is responsible solely for switching between the two burners, defining run and pause times.

- **Connectivity:** Control can be implemented either through traditional electrical wiring (using the QIO module) or through fieldbus.

5.4. HTM ENABLING

HTM enabling (High Temperature Mode) is a critical safety function. Incorrect activation in the absence of auto-ignition conditions poses an immediate explosion risk. For this reason, risk analyses (HAZOP/LOPA) typically require a SIL 2 reliability level (per IEC 61508).

Requirements for Achieving SIL 2

To ensure compliance with SIL 2 level, the measurement architecture must meet the following minimum performance requirements:

- **Failure Probability:** A PFH_D (Probability of Dangerous Failure per Hour) between 10^{-7} e 10^{-6} applicable in High Demand mode, consistent with the continuous nature of the HTM function.

- **Safe Failure Fraction:** SFF (Safe Failure Fraction) ≥ 90%.

- **Fault Tolerance:** HFT ≥ 1 (Hardware Fault Tolerance), dual channel with cross-diagnostics.

- **Life Cycle:** Hardware and firmware development certified by third-party bodies.

Analysis of "Method A" per UNI EN ISO 13577-4

The UNI EN ISO 13577-4 standard describes Method A as an approach based on components compliant with their respective product standards, without the obligation to calculate overall SIL/PL. However, its application to the HTM function in an industrial context has significant technical limitations, particularly in **High Demand** mode applications (**where the safety function is exercised frequently or operates continuously**):

1. **Inadequacy in High Demand**: Method A does not include the calculation of PFH_D (probability of dangerous failure per hour), which is the fundamental metric for functions such as HTM operating in continuous mode, where the flame supervision bypass is permanently active.

2. **Absence of guarantees on SFF and HFT**: the approach is limited to the compliance of individual components and does not impose requirements on the system architecture. This makes it impossible to demonstrate the achievement of an SFF ≥ 90% and an HFT ≥ 1 fault tolerance, which are essential parameters for the safety of the HTM function.

3. **Inconsistency with Risk Analysis**: if the risk analysis requires a SIL 2 integrity level for the HTM enabling function, Method A does not provide the necessary analytical tools to validate the safety function, making it unverifiable against the project requirements.

Architecture and Separation Principle

To ensure the integrity of the function, the measurement of physical quantities (temperature, pressure, flow rate) must follow the separation principle:

- **External Measurement Unit:** Must be a dedicated device, SIL-certified for the required PFH_D value, which processes and validates the signal.

- **BMS (Burner Management System):** Operates exclusively on already-validated digital signals from the external device certified for use as STL.

5.5. REGULATORY COMPLIANCE

Analysing Q2 against the standards cited above:

EN 298	Product standard: compliant and certified.
UNI EN ISO 13577-2	Plant safety requirements: compliant.
UNI EN ISO 13577-4	Plant safety requirements: compliant.
EN 13611	Construction requirements: compliant (referenced by EN 298).
EN 14597	Product standard: applies to the external STL device.
IEC 61508	SIL3 certified for safety functions including indirect HT supervision.

6. FAQ

Are HTM and flameless the same thing?
No, these are distinct concepts. HTM (High Temperature Mode) is a safety condition linked exclusively to furnace temperature: when this exceeds the auto-ignition threshold, the system allows bypassing flame supervision (UV/ionization).
Flameless is instead a specific combustion regime (distributed oxidation without a flame front) that can only occur in HTM, but it is not the only way to operate in that state.

Can you switch to HTM without operating in Flameless mode?
Yes. A burner can operate in high temperature mode maintaining a conventional flame "attached" to the burner's head and detectable by sensors. In this case, although direct supervision is technically bypassed thanks to HTM, the combustion regime is not flameless.

How does the burner start-up sequence work?
Q2 manages two distinct start-up sequences depending on the furnace conditions at the time of ignition.
If the furnace is cold — i.e., the STL has not yet provided consent — Q2 executes the conventional start-up sequence with ignitor activation and flame signal verification via UV sensor or ionization electrode. If no flame is detected within the configured safety time, a lockout or re-ignition attempt will occur according to the configuration settings.
If instead the STL consent is already present at the time of start-up — typical case of a hot furnace restart — after any pre-purge, Q2 enters HTM directly: the pre-ignition spark phase is suppressed, as the furnace temperature guarantees fuel auto-ignition, and the flame signal verification logic is not applied.

How does the transition between low temperature and flameless mode occur?
Switching to HTM occurs automatically as soon as the external safety instrument detects that the auto-ignition threshold has been exceeded; an additional consent from the supervisor (PLC/DCS) via fieldbus may be required if that option is enabled.
Since the direct transition from conventional flame to flameless mode is not physically feasible, the Q2 system offers two options.
The first option uses stage 5 as an intermediate transition phase, during which all gas valves are closed for a predefined interval to extinguish the flame; subsequently, the system moves to stage 6, reopening only the valves configured for flameless mode, thereby avoiding a complete burner shutdown.
The second option, more conservative, involves a complete burner shutdown with execution of the full stop and restart sequences, including any leak tests and purge phases. Upon restart, the STL consent is already active and therefore the system enters HTM directly without activating the ignitor.
The return from high temperature mode is always managed automatically by the Q2 system which, upon loss of the safety signal, immediately adopts the configured behavior, transitioning to a low temperature stage with restoration of flame supervision, or proceeding to a controlled shutdown.

Is Q2 compatible with any STL on the market?
Yes, Q2 guarantees full compatibility with any external safety device, regardless of the manufacturer, provided it generates a digital fail-safe signal compliant with standard EN 14597. The specific choice of instrument (whether JUMO, WIKA, Honeywell, ABB or other brands) remains a free decision of the plant designer, who must however ensure that the entire safety loop — including sensor, STL and wiring — meets the SIL2 level required for the HTM enabling function per IEC 61508. Should optional fieldbus enabling also be activated, the system will require an additional confirmation from the external supervisor to authorize high temperature operation.

Is an external supervision system (PLC/SCADA) required to use Q2 in HTM?

No. Q2 is designed to manage high temperature mode based on the digital signal from the external safety instrument (STL). Fieldbus consent from the supervisor is a purely optional function that the designer can decide to activate to increase system robustness.

What happens if the external STL fails?

The EN 14597 certified STL is designed with fail-safe logic: in case of sensor failure (thermocouple break, short circuit, signal loss) consent is withdrawn and Q2 returns to low temperature mode adopting the behavior configured by the designer: transition to a low temperature stage with reactivation of UV/ionization supervision, or controlled burner shutdown.

In a plant with multiple burners, does each Q2 require its own STL?

It depends on the furnace geometry. If the temperature is uniform throughout the volume, multiple Q2 units can share the same STL signal. If thermally non-uniform zones exist, each zone must have an independent measurement. The architectural choice is the responsibility of the plant designer.

Does the SIL3 certification of Q2 also cover the HTM function?

Yes. The SIL3 certification of Q2 includes the management of HTM as a safety function, including indirect flame supervision activated by the signal from the external STL (PFH$_D$ 2.59×10^{-9} 1/h, SFF 98.97%).

Q2 performs this function correctly with the certified reliability level, provided that the enabling signal comes from an adequate external loop.

The essential point is that the SIL3 certification of Q2 concerns what Q2 does with the received signal — not the quality of the signal itself. The temperature measurement function, which produces that signal, falls within the scope of the STL.

Does it make sense to integrate analog safety measurements directly into a BMS?

Although the integration of analog safety measurements into a BMS is explicitly permitted by UNI EN ISO 13577-4 (Method A) without the obligation of specific SIL certification, this choice is often technically and economically disadvantageous compared to dedicated alternatives.

A correct implementation in fact imposes strict hardware requirements for each analog input bound to safety functions, mandatorily requiring galvanic isolation from the rest of the circuit, independent power supply for the 2 sensor inputs and periodic diagnostic systems to guarantee fail-safe behavior.

This complexity generates high costs without matching the reliability of an external SIL 2 certified safety instrument (STL), designed according to rigorous HAZOP/LOPA risk analyses. Furthermore, the use of an external STL allows monitoring of homogeneous thermal zones serving multiple burners simultaneously, drastically simplifying the plant architecture and ensuring a clear separation of functional responsibilities.

In summary, the integration of analog inputs linked to safety-relevant functions, even if correctly implemented, guarantees lower performance compared to a dedicated external solution.

You can find more information about Q2 here:
www.burner-control.com

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