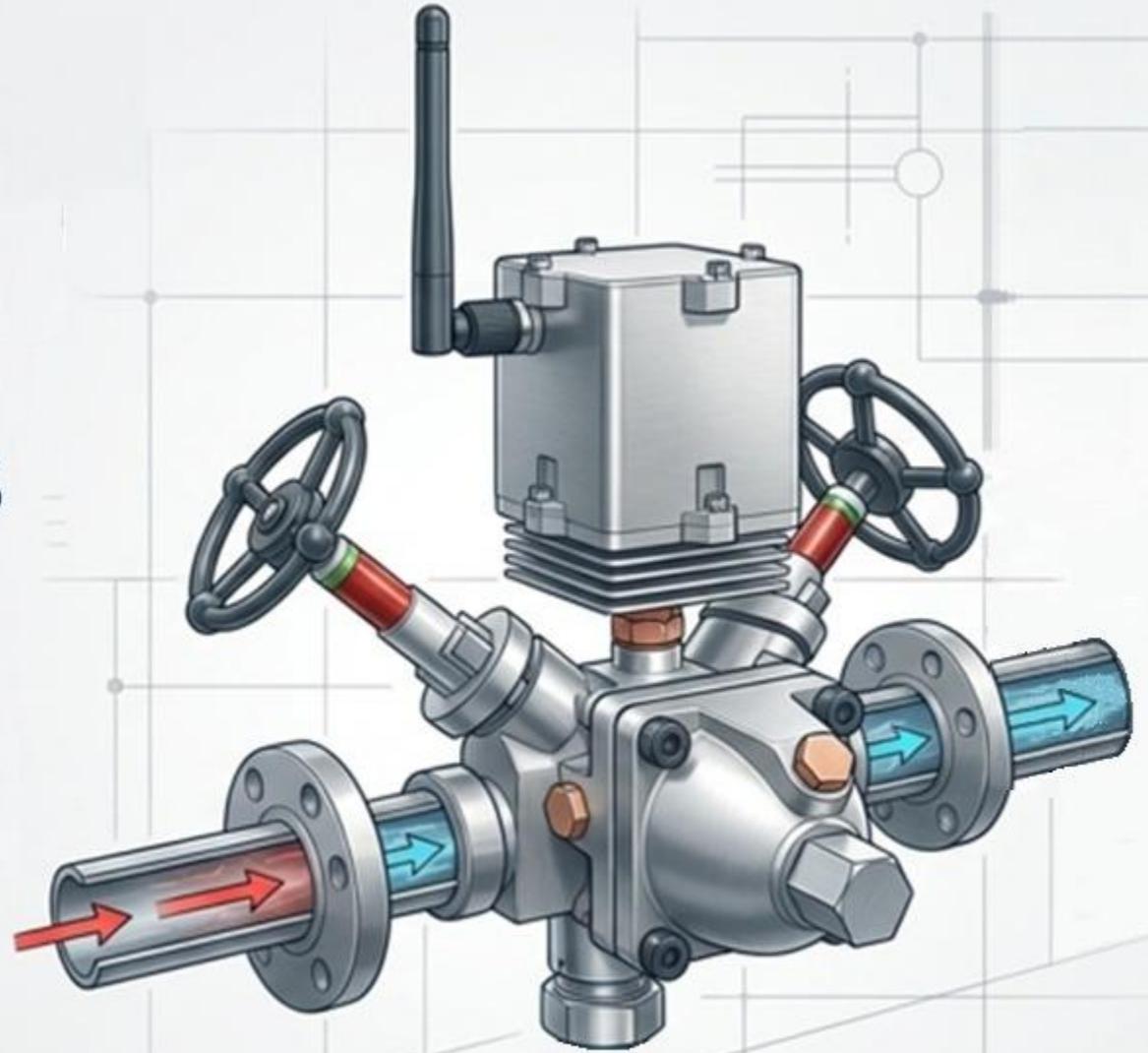# Steam Manual: Energy Efficiency and Smart Steam Traps

Optimizing the use of steam in modern industry to reduce operational costs and CO_2 emissions.

Based on the technical work of Vicente Blázquez Navarro (Aeronautical Engineer and Founder of BiTherm).
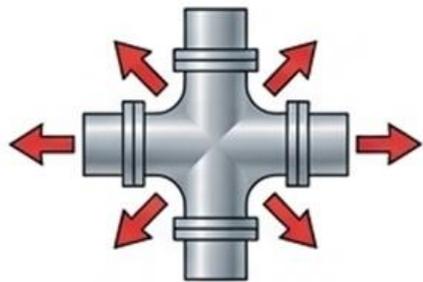
Industrial Steam's Triple Challenge

Efficiency

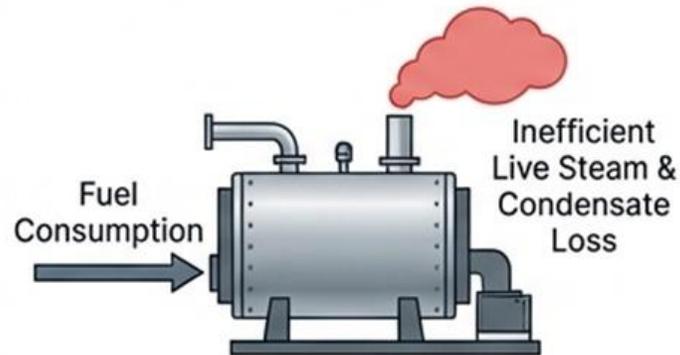Steam transfers massive amounts of energy, but traditional systems operate with hidden systemic losses.
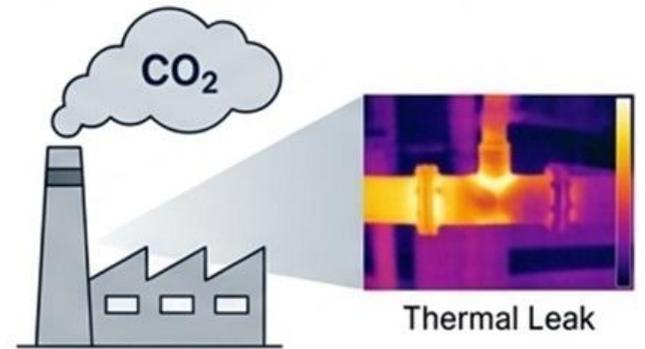
Systemic Losses

Costs

Live steam loss and inefficient condensate handling exponentially increase boiler fuel consumption.

Fuel Consumption
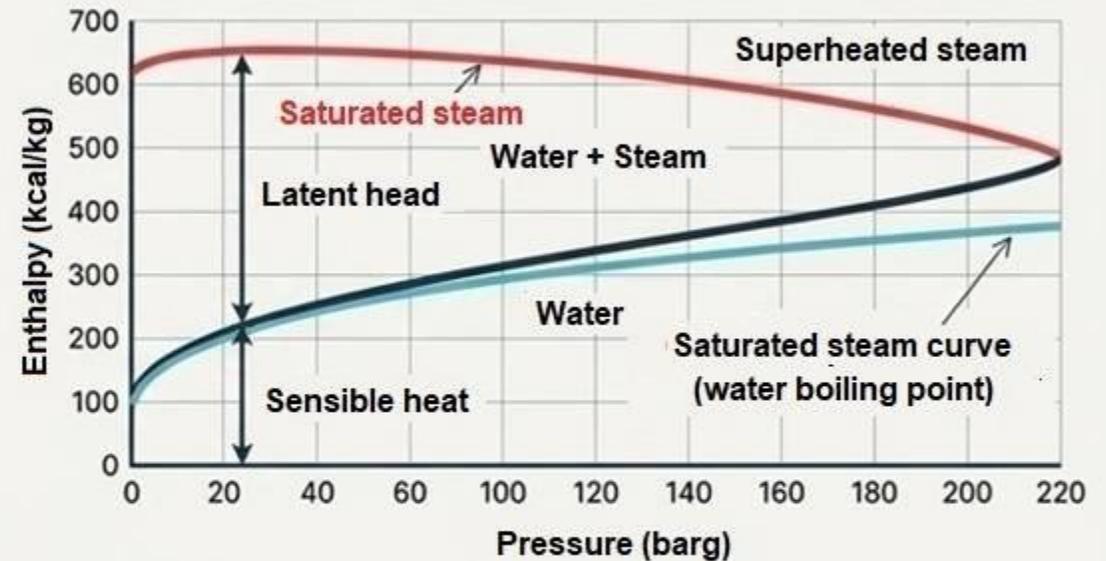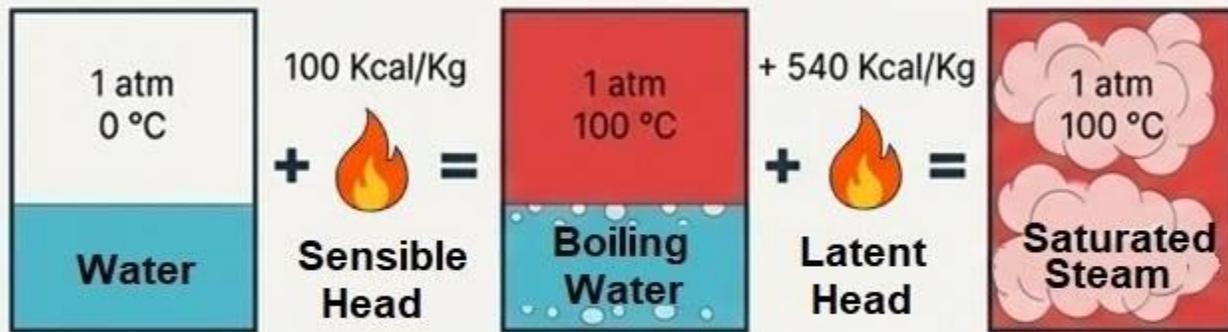
Inefficient Live Steam & Condensate Loss

Emissions

Every unmodulated thermal leak translates directly into an unnecessary increase in atmospheric CO_2 emissions.

CO_2

Thermal Leak

Key Takeaway: Optimizing the steam system is no longer a simple maintenance task; it is the pillar of industrial profitability and sustainability.

The Physics of Thermal Efficiency: Sensible Heat vs Latent Heat

1 atm
0 °C

Water

+ 🔥 =

100 Kcal/Kg

Sensible Head

1 atm
100 °C

Boiling Water

+ 🔥 =

+ 540 Kcal/Kg

Latent Head

1 atm
100 °C

Saturated Steam

Chart: Enthalpy (kcal/kg) vs Pressure (barg)

Superheated steam

Saturated steam

Water + Steam

Latent head

Water

Sensible heat

Saturated steam curve (water boiling point)

Sensible heat:
Raises the temperature of liquid water up to its boiling point.

Latent heat:
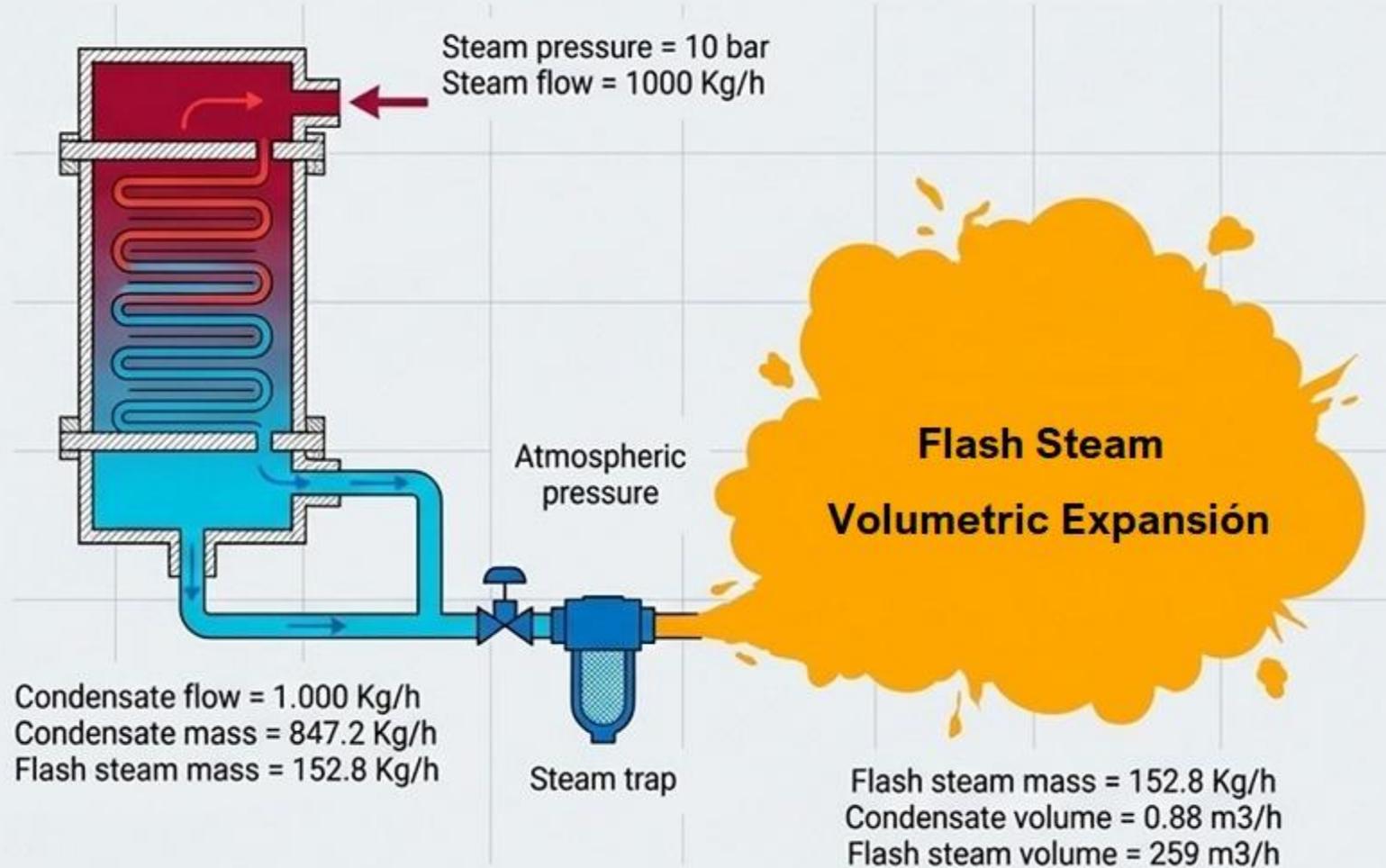Energy absorbed or released during the phase change (water steam) at constant temperature.

Golden Rule of Efficiency:
The **lower the steam pressure**, the **greater the amount of latent heat released**.

Key Principle: The objective of an efficient network is to use steam at the **lowest possible pressure** (while guaranteeing heat transfer) and evacuate condensate while retaining its residual energy.

The Hidden Enemy: Flash Steam

Generated spontaneously at the trap outlet due to a pressure drop in hot condensate (release of excess enthalpy).

Steam pressure = 10 bar
Steam flow = 1000 Kg/h

Atmospheric pressure

Flash Steam

Volumetric Expansión

Condensate flow = 1.000 Kg/h
Condensate mass = 847.2 Kg/h
Flash steam mass = 152.8 Kg/h

Steam trap

Flash steam mass = 152.8 Kg/h
Condensate volume = 0.88 m3/h
Flash steam volume = 259 m3/h

The Volumetric Asymmetry
(Example: 10 bar discharging to 1 bar)

Mass: Flash steam represents only 15.28% of the mass.

15.28%	84.72%

Volume: It occupies an astounding 99.66% of the total flow volume.
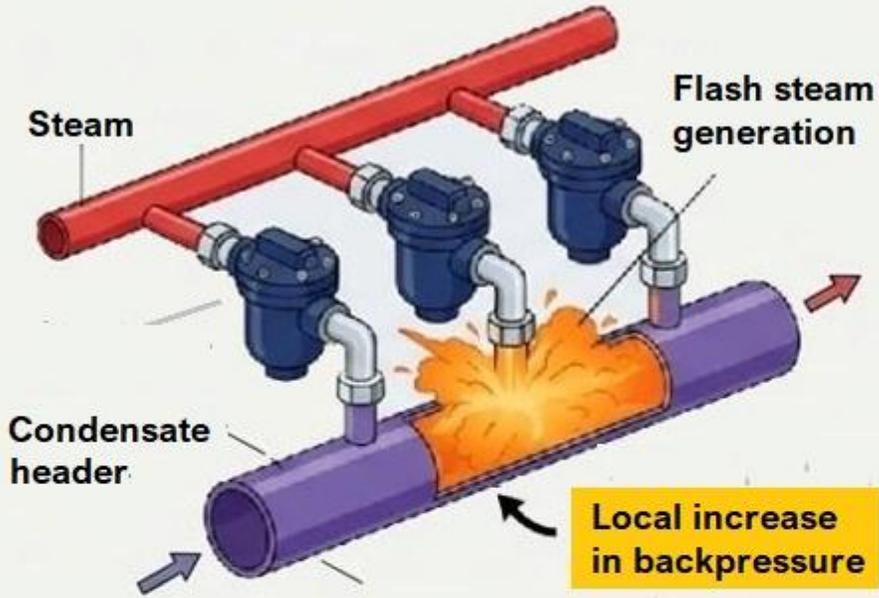
99.66%

0.34%

Condensate + Flash steam

Live steam

Physically identical to live steam. Visually impossible to distinguish with the naked eye.

Destructive Effects of Uncontrolled Flash Steam

Steam

Flash steam generation

Condensate header

Local increase in backpressure

HYDRAULIC WATER HAMMER

Excesive speed of steam relative to water

Pipe bending

Instant flow obstruction

THERMAL WATER HAMMER

Steam buble implosion

Steam Trap

Poorly constructed drip well
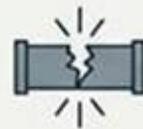
Operational Chaos (Backpressure)

- The immense volume of flash steam pressurizes return headers.

- It reduces available differential pressure, choking and flooding neighboring traps.
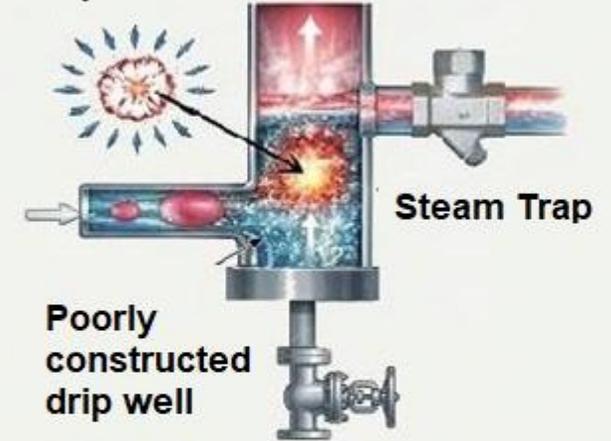
Mechanical Damage

Hydraulic Water Hammer:
Water waves block pipes due to velocity differences.

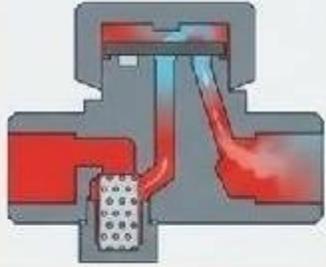**Thermal Water Hammer:**
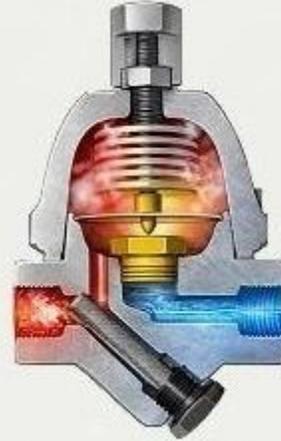Violent implosions of steam bubbles within condensate.

Environmental Loss

- Impossible to recover condensate.

- Continuous venting to the atmosphere wastes direct energy and treated water.

Technological Evolution of Steam Traps

- Cyclical live steam leaks
- No energy control
- Excessive flash steam

- Perfect energy control
- Steam flash reduction

IoT MONITORIZACIÓN

- Decarbonization
- Reliability
- Efficiency
- RCM Maintenance

On/Off Valve (Past)
(Past)

- **Definition:** Automatic valve sensitive only to physical state (liquid vs gas).

- **Problem:** No thermal control and prone to large steam losses.

Energy Control Valve
(Present)

- **Definition:** Thermostatic regulator that modulates flow based on temperature and residual energy (sensible heat).

Smart Steam Trap
(Current Standard)

- **Definition:** Monitored control valve capable of **real-time self-diagnosis** for **RCM maintenance** (Reliability-Centered Maintenance).

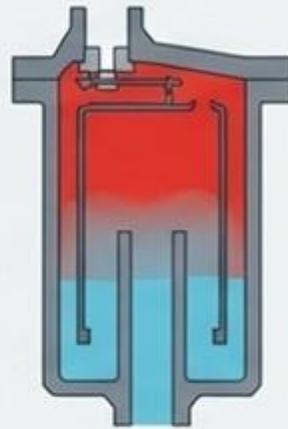# Traditional Technologies: Limits of Density and Velocity Designs
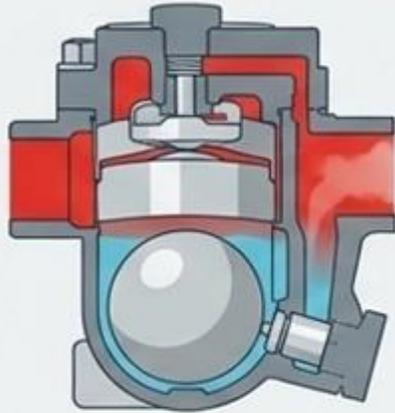
Mechanical Traps (Float & Inverted Bucket)

- **Mechanism:** Buoyancy (density-sensitive).

- **Deficiencies:** Bulky, pressurize the return line, no temperature control, low efficiency.

## Thermodynamic disc steam trap

- **Mechanism:** Bernoulli principle (velocity-sensitive)

- **Deficiencies:** Violent cyclic discharge with live steam leak. If backpressure exceeds 60%, the trap fails open and spreads the problem across the network.

Conclusion: These technologies are incompatible with modern demands for Energy Efficiency and Emission Reduction.

# The Paradigm Shift: Thermostatic Control
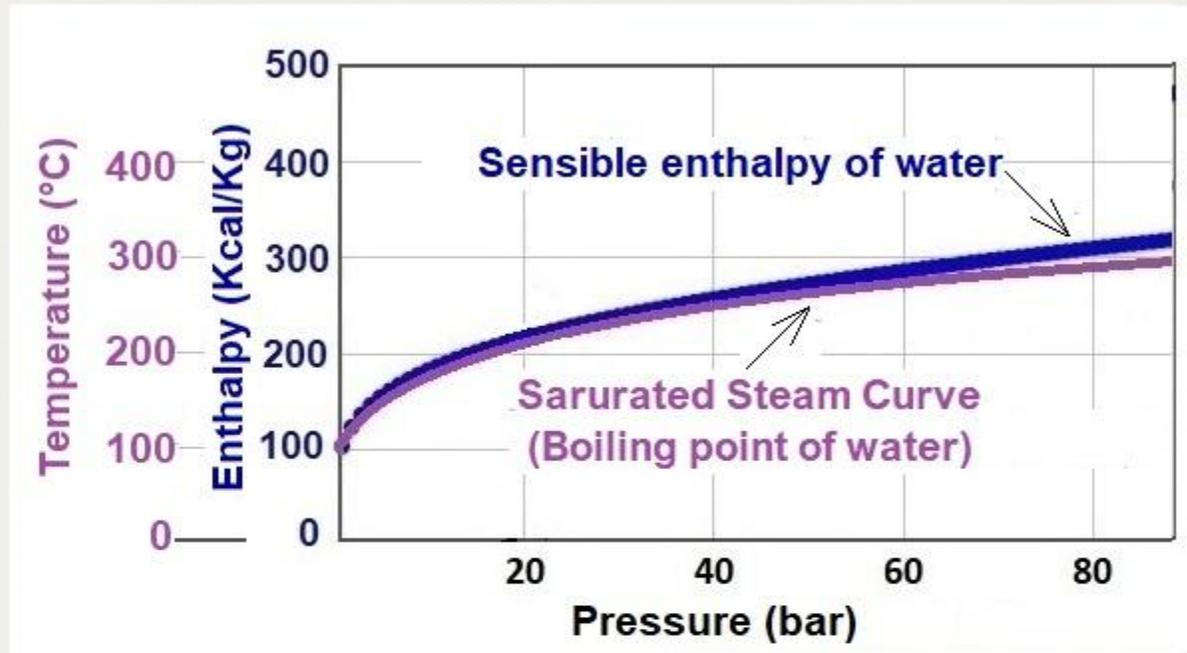
Central Concept:
The energy of condensate at steam saturation temperatura (sensible enthalpy of water, kcal/kg) is approximately equal to the **boiling temperature of water (°C)**.

Conclusion: Controlling condensate temperature = Regulating condensate energy.

Application: Thermostatic trap = Condensate energy regulator.

The Classical Bimetallic Steam Trap and Its Achilles Heel

P1

P1

P1

P2

Expansion chamber

Nozzle

P3

Bimetal regulator

Valve plug

"Y" Filter
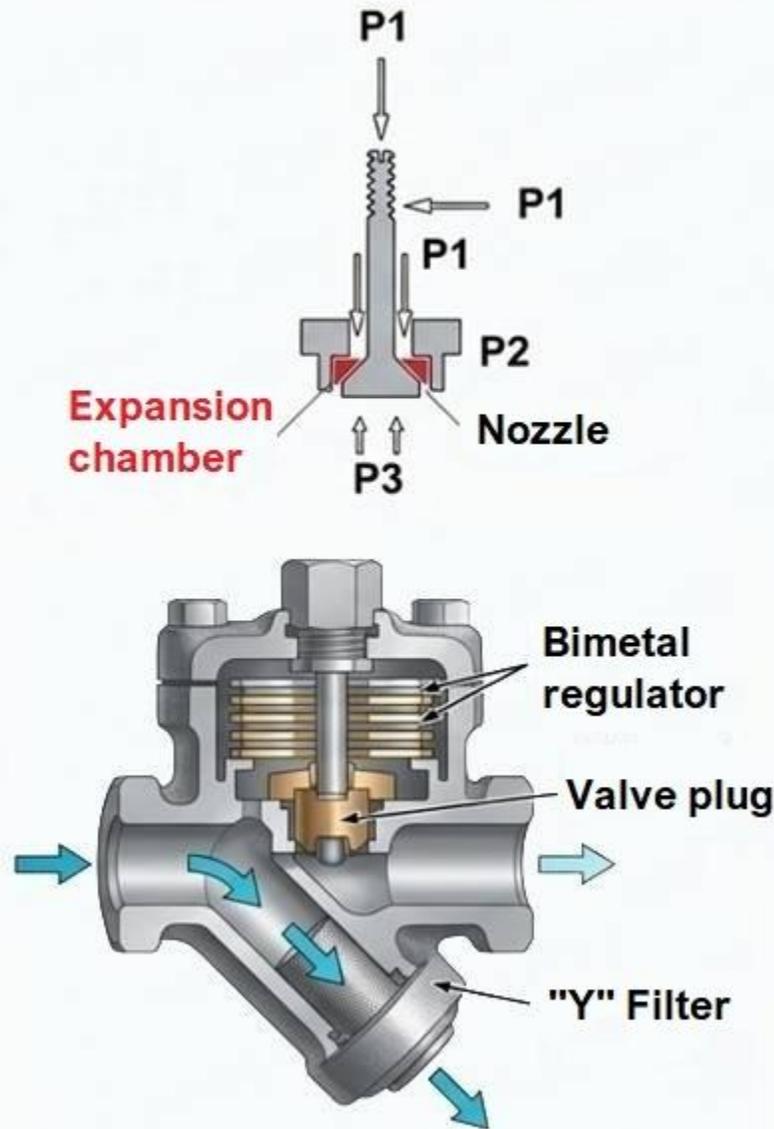
Mechanism:

Bimetallic plates pull the cone upward to close the valve as temperature increases.

Two Critical Physical Limitations:

1. Differential Pressure Valve:

Steam pressure tends to open the valve. The thermostat must fight against system pressure, limiting its operating range.

2. Flash Steam Erosion:

Closing occurs on the outlet side. The high-velocity two-phase flow (condensate + flash steam) acts like a **sandblasting jet**, rapidly destroying the sealing cone.

Result:

- Perfect dynamic modulation and **no cold blocking**.

- It requires frequent replacement of internal parts with service interruptions.

The Optimal Solution: Bithermostatic Bimetallic Steam Trap

**Innovation 1: Dual Antagonistic Thermostat**

Upper thermostat (closing) Lower single-leaf thermostat (opening). Result: Perfect dynamic modulation and **no cold blocking**.

Innovation 2: Balanced Pressure Valve

Fully submerged in condensate. Pressure forces result **= zero**. Immune to return line backpressure.
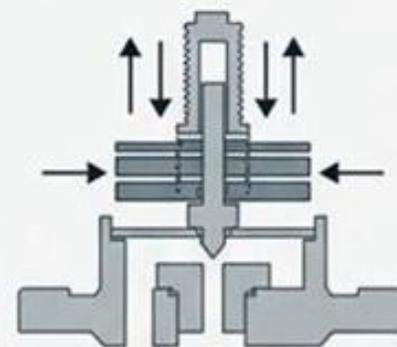
Innovation 3: Long Service Life (No Erosion)

Closing occurs on the **inlet side** (low velocity).The cone is not impacted by destructive flash steam.
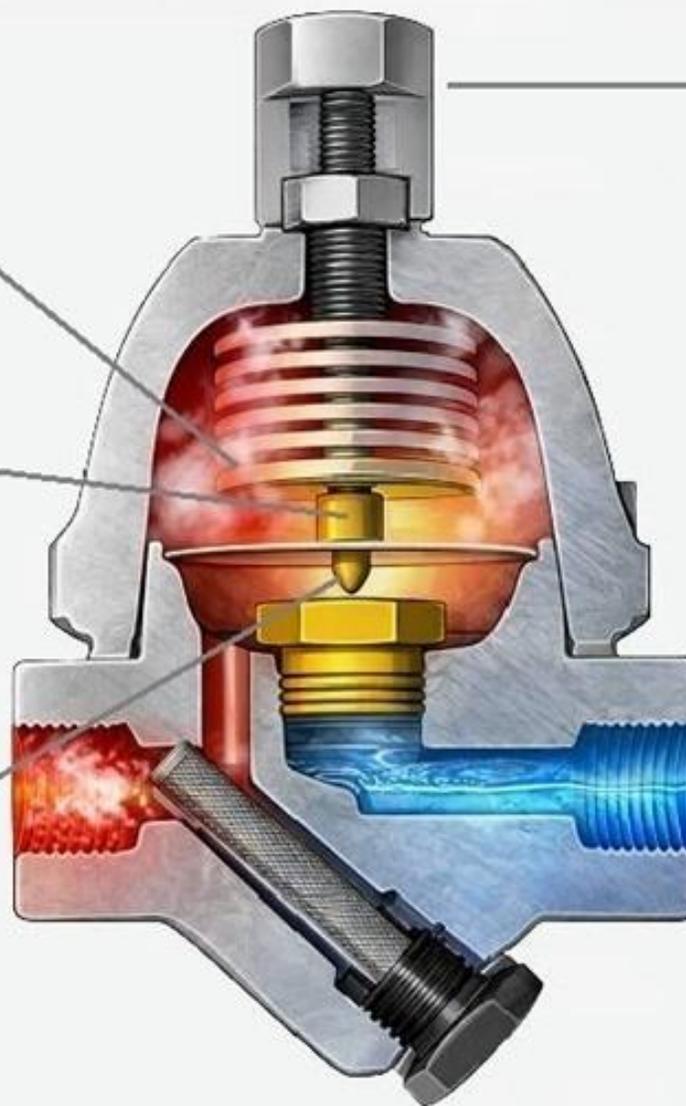
Innovation 4: External Adjustment Without Shutdown

External adjustment mechanism allowing discharge temperature changes **without stopping the process**.

Valve cone guided on both ends.

Technical Battle: Classical vs BiThermostatic

	Classical	**Bithermostatic**	
Operational Flexibility	Requires service interruption	Online adjustment without shutdown (Excellent)	✓
Valve Type (The key factor)	Differential pressure (backpressure sensitive)	Balanced pressure (immune to backpressure)	✓
Wear and Service Life	Cone eroded by flash steam (frequent replacement)	Cone guided both ends, erosion isolated. Lifetime tripled, no spare parts	✓

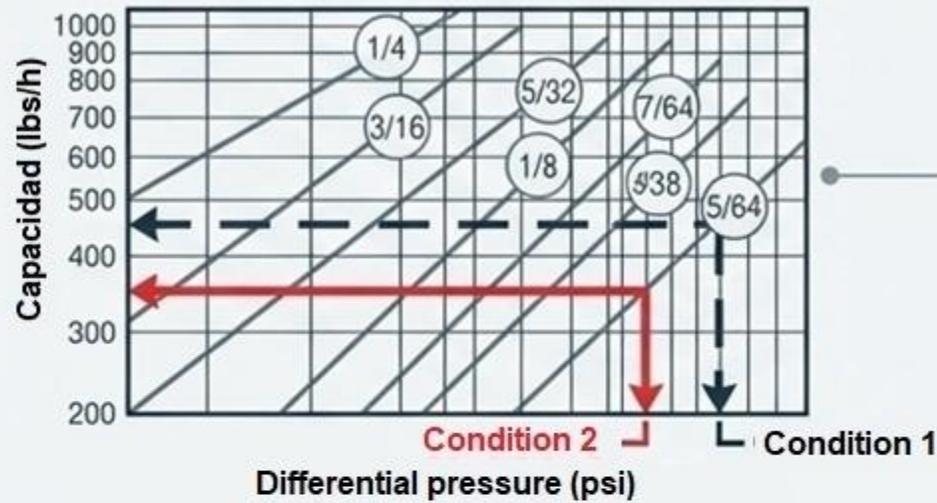## Anti-Blocking Mechanisms (Bithermostatic Exclusive)

Integrated Y-filter   <>   Full-port valve   <>   1 mm anti-dirt spacer washers

Dynamic Behavior: Capacity vs Backpressure

Capacity curve - inverted bucket trap


Capacity curve - bithermostatic steam trap

The Problem with Cyclic Traps (e.g. Inverted bucket):

- If backpressure rises suddenly, discharge capacity drops sharply and the trap floods and **cools the process**.

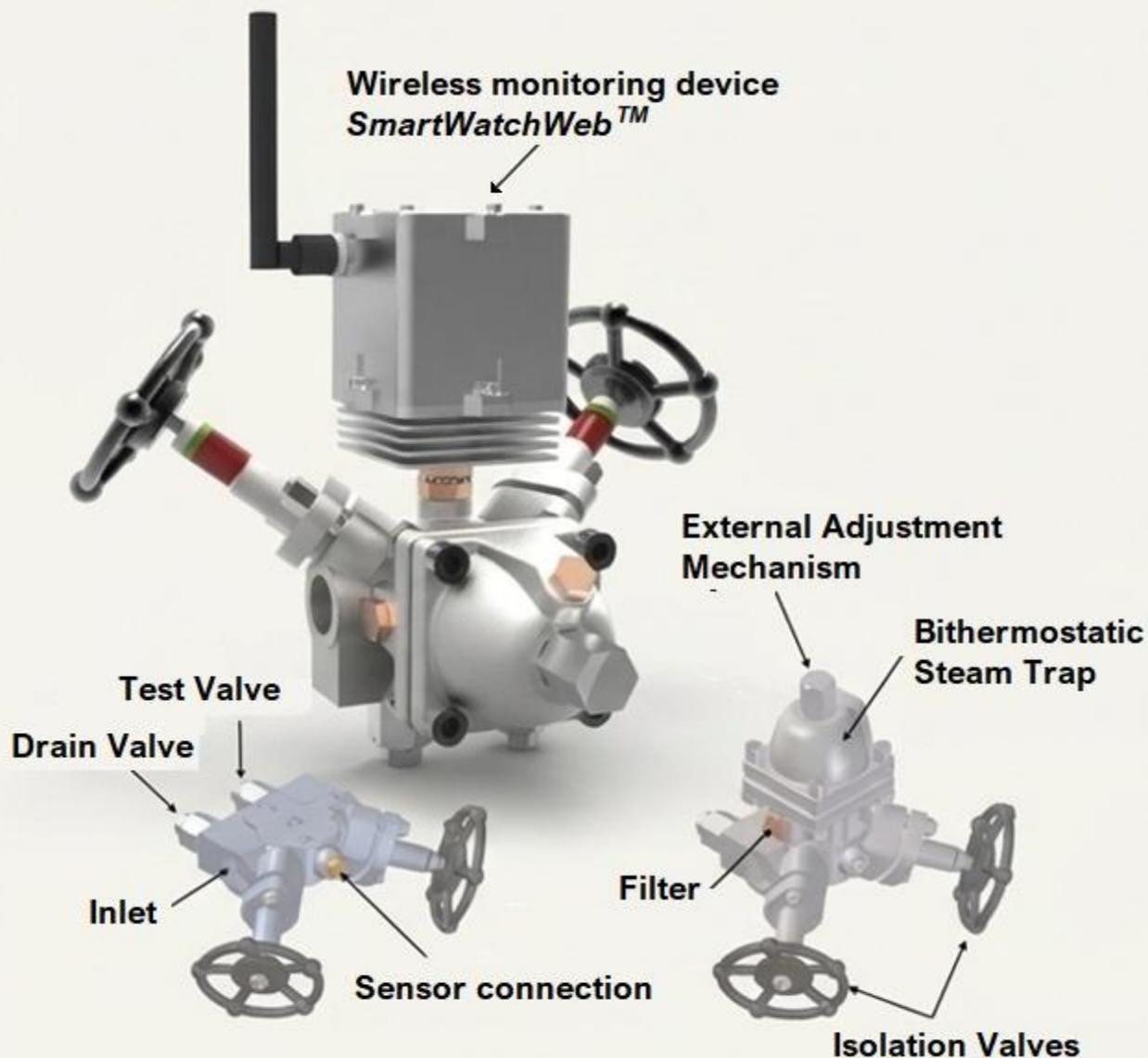## The Bithermostatic Response (Dynamic Balance):

- Because it is a **balanced pressure valve** and **temperature-modulating**: If backpressure increases:

- Condensate is temporarily retained, but after cooling a few degrees it jumps to a **higher capacity curve** (e.g. $\Delta T=10°C \rightarrow \Delta T=15°C$).
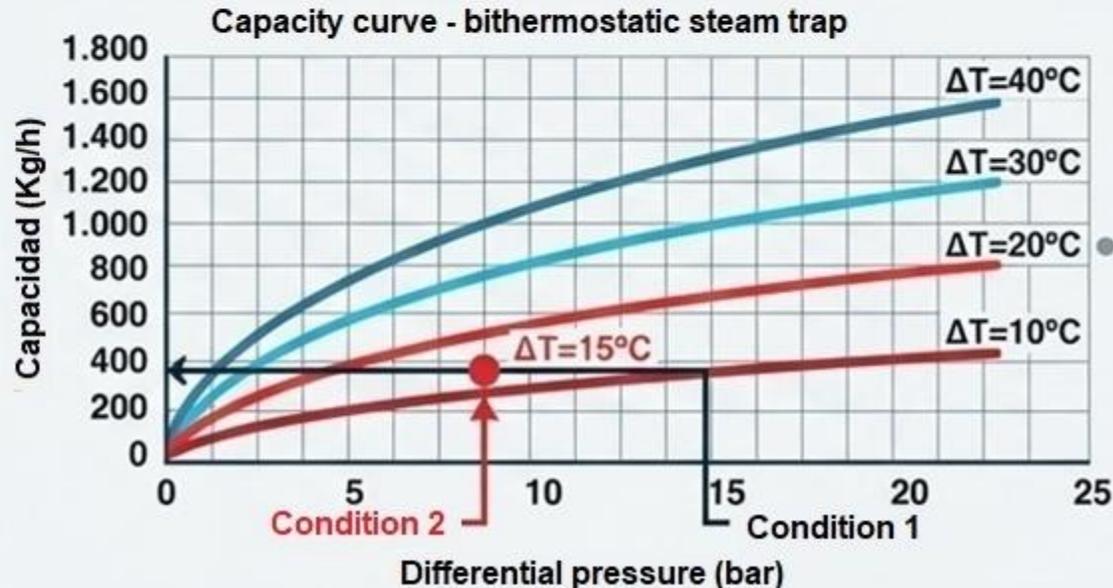
Result:

Capacity automatically adapts in real time to restore flow without collapsing the line.

The Future of Maintenance: Smart Steam Traps

Wireless monitoring device *SmartWatchWeb™*

External Adjustment Mechanism

Bithermostatic Steam Trap

Test Valve

Drain Valve

Inlet

Sensor connection

Filter

Isolation Valves

Concept

Transition from empirical diagnostics to **global IoT monitoring**.

SmartWatchWeb™

Advanced algorithms that distinguish with absolute precision between:

- Normal discharge / Live steam leaks (failure) / Cold

- Real-time data transmisión (LoRaWAN / NB-IoT)

Financial Impact (LDAR)

SmartWatchWeb technology allows the implementation of **L**eak **D**etection **& R**epair Methodology (fast repair in service thanks to the external adjustment mechanism).

Demonstrated Result

Reduction in steam consumption greater than 8% in large-scale steam networks.

Conclusion: The 21st Century Energy Control Valve
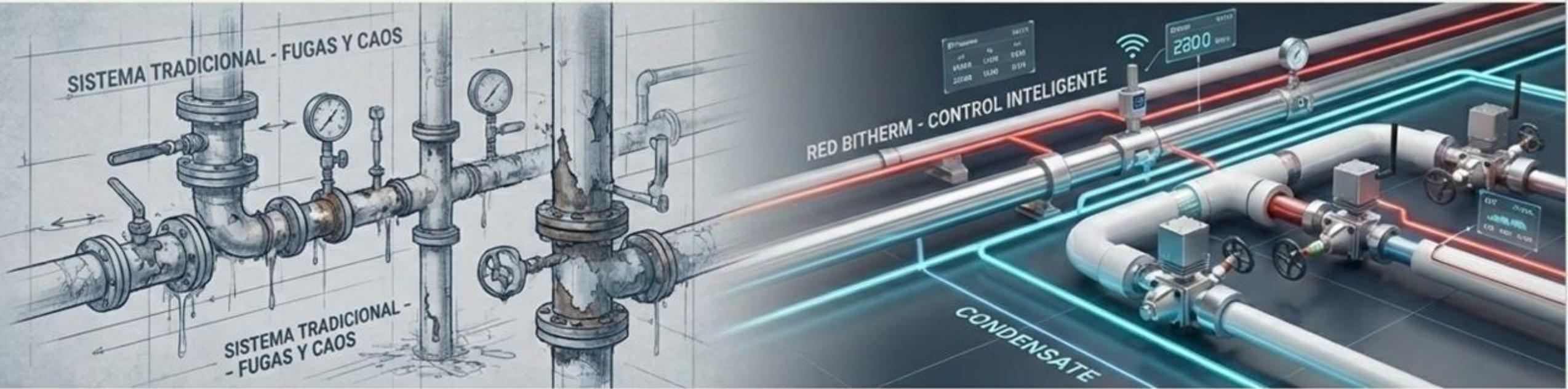
- Flash steam is unavoidable, but controlling it through **temperature modulation** is the key to preventing collapse of the return network.

- Mechanical and thermodynamic steam traps generate systemic inefficiencies, backpressure, increased CO_2 emissions.

- The **bithermostatic bimetallic steam trap** eliminates erosion wear, ignores backpressure, and allows online adjustment without stopping production.

- **Smart Steam Traps (IoT):** The modern standard for auditing, controlling, and guaranteeing **more than 8% energy savings.**

bithermostatic

Efficient steam management is **not about draining water.**
It is about **precisely managing thermal energy.**