APPLICATION NOTE

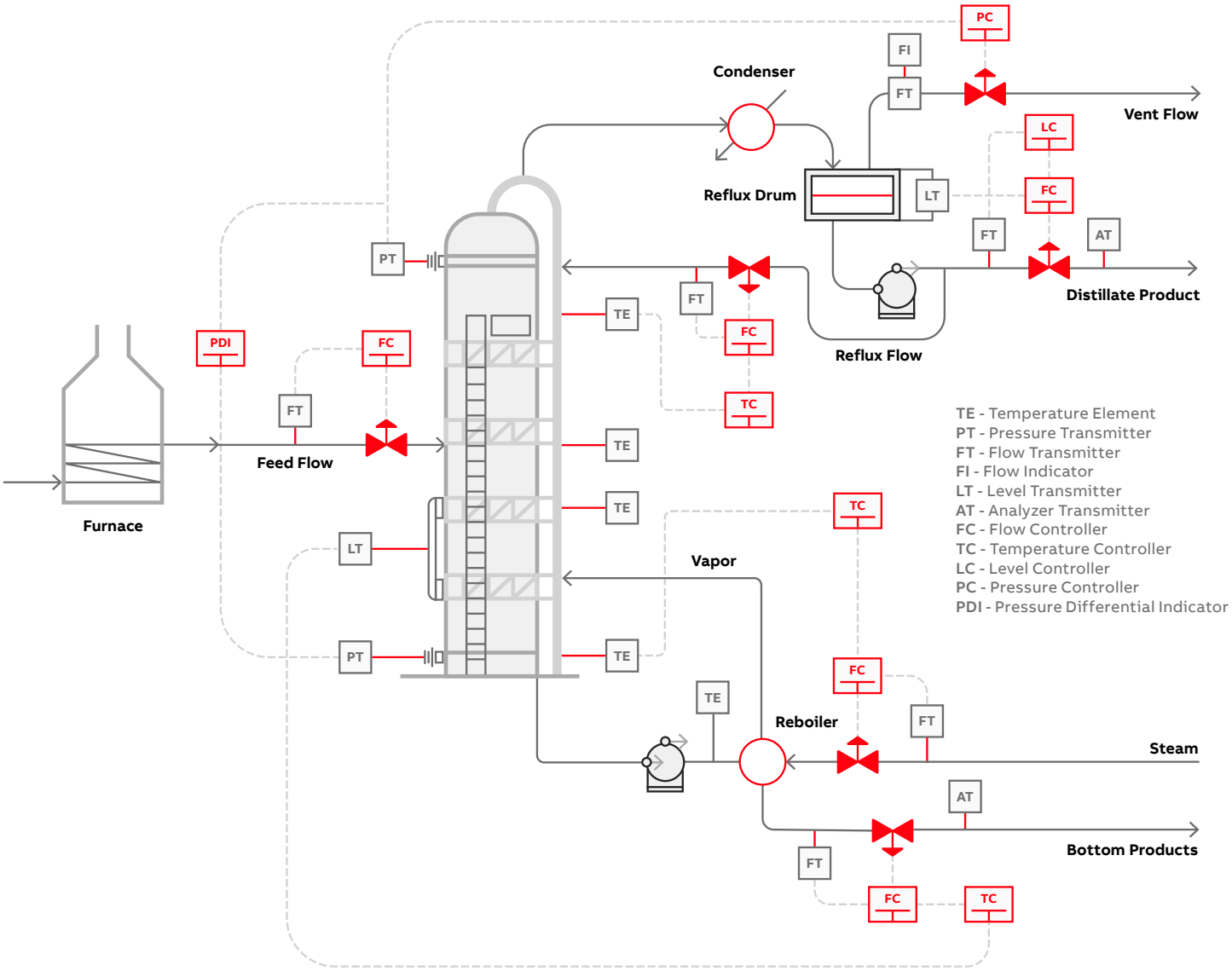
DISTILLATION TOWER OPERATION IN REFINERIES

INTRODUCTION

Distillation is a core separation process in oil refineries, used to fractionate crude or intermediate feedstocks into usable products such as naphtha, kerosene, diesel, and residue. The process involves thermal and phase separation steps that are highly sensitive to temperature, pressure, flow, and level changes.

Therefore, precise instrumentation is critical to ensuring safe, efficient, and stable operation. This application note outlines the key stages in a refinery distillation system like furnace, distillation column, reboiler, condenser, and reflux drum, and describes the specific types of instruments used at each step.

—
01 Distillation Column



CRUDE PREHEATING AND FURNACE OPERATION

In the crude oil distillation process, the preheating unit plays a vital role in preparing the feedstock for efficient separation in the atmospheric distillation column. This unit operates using a staged heating strategy that optimizes energy usage while ensuring the crude oil reaches the necessary temperature for vaporization and fractionation.

The preheating process begins when the crude oil enters a series of heat exchangers arranged in a train. Here, the relatively cold crude oil absorbs heat from hot streams already present in the refinery, such as diesel, naphtha, kerosene, and atmospheric residue. These hot product streams transfer their thermal energy to the incoming crude oil through shell-and-tube or plate-type exchangers, significantly raising the crude oil's temperature. This heat recovery approach minimizes the energy demand on downstream equipment and enhances overall thermal efficiency by utilizing process heat that would otherwise be lost.

The furnace then raises the temperature of the feed to approximately 340 to 400 °C (644 to 752 °F) in order to partially vaporize the hydrocarbon mixture

before it enters the distillation column. This high-temperature conditioning is essential to vaporizing the crude oil partially and ensuring effective phase separation once it enters the atmospheric distillation column.

The furnace outlet pressure typically ranges from 3 to 5 barg (approximately 45 to 75 psig), depending on the pressure of the downstream column and the feed resistance.

At this stage, temperature transmitters - typically thermocouples or resistance temperature detectors (RTDs) - are installed at the coil outlet and along different furnace zones. This ensures that the target temperature is reached without overheating.

CHALLENGE WITH DEGRADATION

As refinery infrastructure continues to age globally, the maintenance of thermowells, protective housings for temperature sensors, has become an increasingly difficult and costly task. Originally designed to withstand harsh process environments, many thermowells in older refineries now face degradation due to decades of exposure to high-pressure flows, corrosive chemicals, and thermal cycling. These conditions, combined with legacy installation methods such as welded-in designs, present a growing operational challenge.

THE SOLUTION

In response, ABB has introduced the NINVA™ TSP341-N, a non-invasive temperature sensor that offers a safer, lower-maintenance alternative suited to the complex needs of ageing assets.

SUCCESS CASE

Eliminating 'bad actor' thermowells in refinery

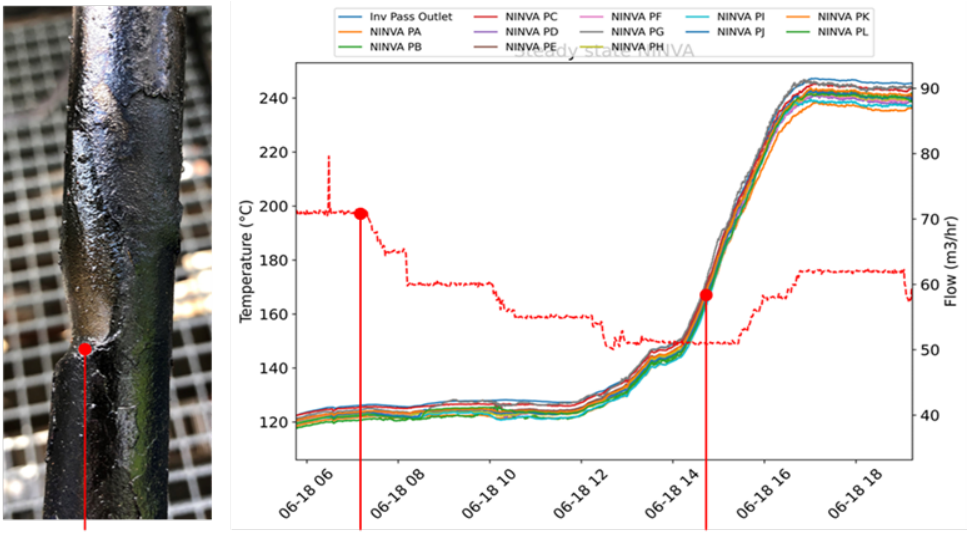
Challenge

- Thermowells were subject to erosion due to process cavitation and wear.
- Frequent replacements were necessary during turnarounds.
- A reproducible measurement approach was required across 14 parallel passes through the heater.

NINVA's value proposition

- Safety: Eliminates the risk of catastrophic failures, leaks, and structural weaknesses.
- Simplicity: Installation can occur without the need for complete shutdowns; some units were installed prior to shutdowns, while others were completed afterward.
- Performance: No compromise on response or repeatability.

NINVA™ has successfully replaced eroding thermowells in 14 passes of the crude oil preheater unit.



Example of cavitation wear on thermowells

Oil flow rate/pass

NINVAs™ on 14 Parallel passes showing measurement repeatability

—

02 Example for the NINVA™ application in the crude oil preheater unit

COMBUSTION CONTROL

Pressure transmitters are required for measuring fuel header and coil pressure in order to maintain safe and efficient combustion. If the sensors are not rated for the high-temperature or high-sulfur environment of furnace operation, they may degrade quickly. This can lead to inaccurate measurements, poor combustion control, or safety shutdowns.

THE SOLUTION

ABB offers the 266 Series and the newest P300 Series, which have a wide range of remote seals with capillaries made of different materials. ABB uses high-temperature oil as the filling fluid, which can withstand temperatures up to 400 °C. Our portfolio includes materials for wetted parts, such as Hastelloy C, Monel, Tantalum, and Duplex SS, which are corrosion-resistant. ABB can help you select materials to extend the lifetime of your instruments.

—
03 Pressure measurement remote and direct mount diaphragm seals

COMBUSTION IMPROVEMENT

Flowmeters, such as Coriolis or vortex meters, are used to monitor the flow rates of both the feed and the combustion fuel gas. These measurements are essential for ensuring a well-controlled process and a smooth flow of subsequent steps. For the highest accuracy in measuring the feed flow, Coriolis mass flowmeters are recommended.

THE SOLUTION

ABB's Coriolis flowmeter has an accuracy of 0.1 % of flow rate, onboard verification and diagnostics with the VeriMass option. VeriMass enables online health checks of the flowmeter and extended maintenance cycles, improving the efficiency of the maintenance team. Vortex or swirl flowmeters are state of the art for measuring the combustion fuel gas. The swirl principle provides excellent accuracy (±0.5 %) and repeatability (±0.2 %), with the lowest installation demands (inlet section: 3×DN, outlet section: 1×DN). This makes them ideal for existing brownfield installations that require updates for greater efficiency and transparency. Alternative measuring principles have high space requirements, making installation difficult in these environments.

—
04 ABB's CoriolisMaster flowmeter

FRACTIONATION IN THE DISTILLATION COLUMN

After leaving the furnace, the partially vaporized feed enters the distillation column, often at the flash zone located near the bottom third of the tower. The operating temperatures in the column typically range from 350 to 370 °C (662 to 698 °F) at the bottom and from 120 to 150 °C (248 to 302 °F) at the top. The pressure at the top of the column usually falls within 1 to 2 barg (15 to 30 psig), depending on the design of the condenser and the pressure control strategy.

FLOODING AND WEEPING PREVENTION

Pressure transmitters are strategically installed at various points along the distillation column, including the overhead vapor line, the reboiler section, and, occasionally, intermediate trays. They primarily function to monitor and regulate internal pressure, which influences the boiling points of the components being separated. Differential pressure transmitters assess pressure drop across trays, indicating conditions such as flooding or weeping. Improper placement, poor calibration, or selection without considering fluid characteristics can cause instruments to produce delayed or inaccurate signals, affecting product quality and process stability.

Despite their importance, pressure transmitters in distillation columns face several operational challenges. ABB addresses these **challenges** with advanced engineering **solutions** to ensure high performance and reliability:

HIGH TEMPERATURES AND PRESSURES

Distillation columns often operate under extreme thermal and pressure conditions. Measuring pressure at the top of the column is critical for controlling the pressure-temperature relationship and ensuring the effectiveness of overhead condensation. Transmitters must be able to resist signal drift, mechanical fatigue, and sensor failure. ABB's remote seal systems are designed with high-temperature silicone oil and can be paired with cooling towers specifically designed for applications exceeding 430 °C, ensuring stable performance in severe environments.

CORROSIVE AND CONTAMINATED MEDIA

Hydrocarbon vapors may contain aggressive substances, such as hydrogen sulfide (H_2S), or entrained liquids that can corrode sensor diaphragms. ABB offers a wide selection of corrosion-resistant materials, including Hastelloy and Monel, as well as protective coatings, to ensure long-term sensor integrity and process safety.

VAPOR-LIQUID INTERFACE INTERFERENCE

Pressure readings can be distorted when transmitters are exposed to fluctuating vapor-liquid phases. ABB mitigates this issue by offering remote diaphragm seals and impulse line configurations that isolate the sensor from direct contact with the process, ensuring more stable and accurate measurements.

PLUGGING OF IMPULSE LINES

Impulse lines can become clogged with viscous hydrocarbons or particulates, especially during process upsets. ABB recommends flush-mounted remote seals, heat tracing, and regular flushing protocols to maintain measurement reliability and reduce maintenance frequency.

CALIBRATION DRIFT AND SENSOR DEGRADATION

Long-term exposure to aggressive process conditions can lead to diaphragm wear and calibration drift. Maintaining the correct pressure is also vital for energy optimization. For example, reducing column pressure can lower the reboiler duty, thereby saving energy. Conversely, increasing pressure may enhance throughput, depending on the volatility of the components involved.

ABB's P-series transmitters are equipped with Digital Advanced Diagnostics, which continuously monitor sensor health, detect anomalies, and trigger predictive maintenance alerts. This minimizes downtime and ensures measurement accuracy.

—
05 Differential pressure transmitter with diaphragm seal PDD300

OVERFILLING OR DRY TRAYS PREVENTION

ABB's KM26 Magnetic Level Gauges, which are equipped with non-intrusive LMT200 magnetostrictive level transmitters, monitor the liquid level in the bottom section of the column. This prevents operational issues such as dry trays or overfilling.

THE SOLUTION

ABB offers the KM26 Magnetic Level Gauge with oversized chambers and guide rods that prevent entrained solids and heavy gas oil from impacting the float level, making it well-suited for this application. The KM26 operates with an internal magnetic float that is designed for specific process conditions, ensuring that the level of the magnetic field corresponds to the liquid level. The KM26 can easily handle the temperatures in this application, and it is offered with a high-visibility magnetic bar graph or shuttle indicator, which is magnetically coupled to the float, for local level validation. ABB offers insulation for the KM26 to prevent cold spots and minimize heat loss.

06 KM26 Magnetic Level Gauge with LMT200

To incorporate the level signal into a data collection system, it must be digitized. For this purpose, ABB offers the LMT200, which is externally mounted to a KM26 and detects the location of the magnetic float. The LMT200 has several probe options and can operate within these process temperatures. It is also available with HART, 4 to 20 mA, and Foundation Fieldbus communication protocols. ABB also offers the non-intrusive MS41 magnetic switch, which can easily be mounted on a KM26

Magnetic Level Gauge to provide a point-level signal. Its unique magnetic coupling action eliminates the need for seals, diaphragm springs, or torque tubes, as there is no physical contact with the process.
The MS41 is a vibration-resistant, hermetically sealed, DPDT switch with a compact design. It is suited for process temperatures ranging from -320 to 850 °F (-195 to 454 °C).

IMPROVED PRODUCT QUALITY AND PROCESS EFFICIENCY

Accurate and reliable flow measurement is critical in refinery distillation towers, where precise mass balance and process control directly impact product quality and process efficiency. ABB's FCB450 Coriolis mass flowmeters provide an ideal solution for such applications due to their capability to measure true mass flow directly, along with several operational advantages suited to the demands of refining environments.

Distillation processes rely on accurate mass flow data to maintain steady-state operation and ensure correct separation of components. Unlike volumetric flowmeters, which are subject to errors due to changes in fluid temperature and pressure.

THE SOLUTION

ABB Coriolis flowmeters are effectively applied at key measurement points within distillation towers, including feed inlet lines, reflux return paths, bottoms product withdrawal, and overhead product streams. At each of these locations, the meters contribute to more accurate flow control, better column efficiency, and improved mass balancing. For example, in the feed line to the column, mass flow and density measurement enables improved column feed consistency and provides early detection of composition shifts. In the reflux and overhead lines, precise mass measurement supports tighter control of separation performance and energy usage. Bottoms product flow monitoring benefits from reliable measurements under varying fluid viscosities and temperatures.

In addition to measuring mass flow, ABB Coriolis meters provide simultaneous measurements of density, temperature, and volume flow. These variables are critical for gaining real-time insight into processes, particularly when it comes to identifying compositional changes in distillation streams. Monitoring density in real time is especially beneficial for ensuring product quality and optimizing column performance under varying operating conditions.

ABB Coriolis flowmeters offer high accuracy, typically within ±0.1 % of rate, with exceptional repeatability. Their robust design, constructed from corrosion-resistant materials such as stainless steel or Hastelloy, enables long-term operation in high-temperature, high-pressure environments common to refinery units. Their immunity to flow profile disturbances allows flexible installation, even in space-constrained piping arrangements often found around distillation units. Additionally, ABB Coriolis meters are available with full hazardous area certifications (ATEX, IECEx, CSA, etc.), making them suitable for deployment in classified zones around distillation towers.

ABB's Coriolis instruments are equipped with VeriMass, a comprehensive diagnostic capability that assists in condition monitoring and process troubleshooting. These features include the detection of two-phase flow conditions, verification of installation integrity, and onboard self-diagnostics. Integration with industry-standard digital communication protocols (including HART, Foundation Fieldbus, PROFIBUS, and Modbus) facilitates seamless integration with distributed control systems and enables remote parameterization and monitoring.

Temperature measurement

Vapor rises through the column, condensing on trays or structured packing, while heavier liquid components descend. Accurate temperature measurement is essential for controlling the vapor–liquid equilibrium and determining product cut points. RTDs or thermocouples are installed at critical tray levels to monitor the internal temperature profile.

REBOILER

Prevent tube dry out or flooding

The reboiler generates vapor from the bottom product of the column to support the separation of heavier hydrocarbons. Reboiler outlet temperatures are typically in the range of 320 to 370 °C (608 to 698 °F), and the pressure closely matches that of the column bottom (usually 2 to 3 barg or 30 to 45 psig). The reboiler recirculates liquid from the bottom of the column, applies heat via steam or hot oil, and returns the vapor to the tower. High-temperature thermocouples or RTDs are used to accurately control the temperature by measuring the reboiler outlet temperature. Flowmeters, typically Coriolis, monitor the flow of the heating medium and the process side. If the heating medium is steam, a vortex or swirl meter can be used for monitoring and process control. Direct insertion magnetostrictive level transmitters maintain an appropriate liquid level in the reboiler circuit to prevent tube dry-out or flooding.

Using inadequate or incompatible instrumentation in the reboiler can lead to poor thermal control, reboiler damage, and unstable column performance.

THE SOLUTION

ABB's LMT100 Direct Insertion Magnetostrictive Transmitter can be installed in the reboiler. With a temperature rating of up to 426 °C (800 °F) and the ability to operate under pressure of up to 124 barg (2400 psig), the LMT100 is an ideal solution for this application. It is available with HART 4 to 20 mA and Foundation Fieldbus communication protocols for easy integration into DCS systems.

ABB will design a float specific to the process conditions of each application to ensure the highest measurement quality. When local visual indication is required, ABB offers the KM26 Magnetic Level Gauge solution with the non-intrusive LMT200 magnetostrictive level transmitter. ABB also offers the MS41 magnetic switch, which can easily be mounted on a KM26 Magnetic Level Gauge to provide a point-level signal. Its unique magnetic coupling action eliminates the need for seals, diaphragm springs, or torque tubes, as there is no physical contact with the process. The MS41 is a vibration-resistant, hermetically sealed, DPDT switch with a compact design. It is suited for process temperatures ranging from -320 to 850 °F (-195 to 454 °C).

—
07 LMT100 Direct Insertion Magnetostrictive Level Transmitter

—
08 MS41 Magnetic Level Gauge Switch

OVERHEAD CONDENSER

Vapor leaving the top of the column is routed to the overhead condenser, where it is cooled and condensed using either air or water as the cooling medium. The inlet vapor temperature to the condenser is typically between 120 and 150 °C (248 to 302 °F), and the outlet temperature after condensation ranges from 40 to 60 °C (104 to 140°F). Overhead pressure is usually controlled at 1 to 1.5 barg (15 to 22 psig).

Temperature transmitters monitor the condenser outlet temperature to ensure sufficient condensation, while differential pressure transmitters assess cooling water performance and detect fouling. Flowmeters, typically Vortex, are applied to both the cooling water and the condensate draw lines to control condenser efficiency and fluid balance. If sensors are incorrectly sized, located, or exposed to multiphase flow, measurement reliability is compromised. This can lead to poor reflux control and potential loss of light products or venting of valuable hydrocarbons.

—
09 Vortex flowmeters

EARLY DETECTION OF BLOCKED IMPULSE LINES

PLID is a built-in diagnostic feature available in ABB's 266 series smart pressure transmitters and the new P300 series. This function continuously monitors the dynamics of the pressure signal and detects abnormal behavior typically associated with blocked or restricted impulse lines. When an impulse line becomes plugged due to accumulated condensate, sulfur compounds, or solid residues, the pressure signal can become unresponsive, symmetrical, or artificially stable. PLID identifies these anomalies by analyzing the sensor's response pattern over time and triggers a diagnostic alert when the behavior matches known blockage signatures.

The PLID functionality in ABB pressure transmitters provides an intelligent and proactive approach to detecting impulse line blockage. Rather than relying solely on pressure values, PLID evaluates the dynamic characteristics of the signal, such as noise, symmetry, and rate of change. When it detects a potential plug, the transmitter generates a diagnostic alert via digital communication protocols such as HART or Foundation Fieldbus. This allows operators or asset management systems to take corrective action before the measurement error affects process performance.

ABB's PLID-equipped transmitters can be combined with diaphragm seals to further mitigate fouling risks by eliminating long impulse lines altogether. When used in overhead condenser applications, these transmitters ensure accurate and reliable pressure monitoring, reduce unplanned maintenance, and enhance plant availability.

—
10 Gauge pressure transmitter PGS300

REFLUX DRUM CONTROL

Optimizing condensation to improve process efficiency

The condensed liquid and any remaining vapor enter the reflux drum. There, the liquid separates and is either returned to the column as reflux or drawn off as the overhead product. Reflux drums typically operate at temperatures between 40 and 60 °C (104 and 140 °F) and pressures consistent with the overhead line, around 1 to 1.5 barg (15 to 22 psig).

In a typical overhead system, vapor exiting the distillation column is partially condensed in an overhead condenser. The resulting liquid-vapor mixture is then sent to the reflux drum. The temperature indicates whether proper condensation is occurring. If the temperature is too high, incomplete condensation can result in vapor carryover and losses of light-end products. If it is too low, excessive subcooling wastes energy and can overload downstream pumps and controls.

Precise and stable temperature feedback ensures the proper condensate-vapor balance, the correct reflux ratio, and the column's overall efficiency. Therefore, temperature measurement in this location must be accurate, responsive, and reliable over time.

—
11 TTH300 Temperature Transmitter

THE SOLUTION

The ABB's TTH300 is a high-performance, smart temperature transmitter that brings several advantages to reflux drum service:

- It provides exceptional measurement accuracy and stability, with a typical accuracy of ±0.05 °C when used with a calibrated PT100 RTD. This level of precision ensures tight control over reflux drum conditions and helps detect subtle shifts in condensation behavior that could indicate fouling in the overhead condenser or fluctuations in column overhead vapor composition.
- The TTH300 offers dual-sensor input capability, which is valuable in critical services like reflux drum monitoring. Dual sensors can be configured for redundancy, or to provide hot backup, enabling uninterrupted operation if one sensor fails. Additionally, the transmitter includes drift detection, comparing both sensors over time to identify early signs of sensor degradation - supporting predictive maintenance practices.
- It is also engineered for harsh refinery environments, with full compliance to hazardous area standards (ATEX, IECEx, FM, CSA) and robust protection against ambient temperature fluctuations, vibration, and corrosive atmospheres common in overhead and distillation zones.
- From a control system perspective, the TTH300 offers seamless integration via HART, FOUNDATION Fieldbus, PROFIBUS PA enabling live diagnostics and configuration through ABB's Field Information Manager or any asset management system. These diagnostics support improved reliability and quick troubleshooting without the need to physically access the transmitter in hard-to-reach reflux drum installations.

—
12 ABB's Temperature Portfolio

ABB offers a wide range of temperature sensors and transmitters, for the best accuracy, harsh environments and the highest safety standards

Prevent liquid film and false signals

There are a couple of methods for level control in the drum, each with its own advantages. They are preferred for their accuracy and ability to address changes in fluid density or dielectric constant.
For heavier products, it is important to carefully select the technology due to condensation.
Guided wave radar transmitters can generate false signals if condensation forms on the probe due to temperatures that cause condensation to form near the top of the tank.

THE SOLUTION

However, ABB's LWT series Guided Wave Radar with the LevelExpert™ algorithm can efficiently track levels through clutter. You do not need to be a radar expert to use this device. The expert is inside the device. Guided wave works very well for lighter products because there is no issue with condensation. The ABB LWT310 guided wave transmitter excels in this application with its multiple probe options and robust stainless steel or aluminum electronics housing.

13 LWT 310 Guided Wave Transmitter

For applications where guided wave radar technology is a constraint, the direct insertion ABB LMT100 magnetostrictive transmitter is a great option because it is unaffected by condensation.

The LMT100 can also be offered with an integrated temperature measurement option to compensate for any measurement and increase process efficiency.

ABB will design the magnetic float according to the specific process conditions to ensure maximum accuracy and reliability

SUSTAINABILITY AND ENVIRONMENTAL RESPONSIBILITY

In today's regulatory landscape, environmental sustainability is a strategic imperative, not an option. ABB is dedicated to minimizing its ecological footprint by innovating in the areas of energy efficiency, material circularity, and eco-conscious design.

A notable achievement is ABB's development of the first digital pressure transmitter with a Pre-EPD (Environmental Product Declaration - Type III). This third-party verified declaration provides transparency on the environmental impact of the P-series transmitters, including material sourcing, manufacturing practices, and end-of-life considerations. It empowers customers to make informed decisions aligned with their sustainability goals.

14 Digital Pressure Transmitter with an Enviromental Product Declaration

ABB Measurement & Analytics
For your local ABB contact, visit:
abb.com/contact

solutions.abb/instrumentation

AN/DISTILLATION_TOWER/101- EN REV.A 08.2025