

Thermal Flowmeters

A practical guide to thermal flowmeters, covering the reader intent, the relationship to thermal flowmeters, key evaluation criteria, common risks, and the information the intended project audience should confirm before taking the next step.



levelmeter.org
Main topic: Main Page
<https://www.level-meters.com/>

In the landscape of industrial process control, the accurate measurement of gas flow is as critical as monitoring liquid levels in storage tanks. Thermal flowmeters, also known as thermal dispersion or thermal mass flowmeters, represent a sophisticated category of instruments designed primarily to measure the mass flow rate of gases. Unlike volumetric flowmeters, which require additional pressure and temperature compensation to determine mass, thermal flowmeters utilize the thermal properties of the fluid to provide a direct mass flow reading. This capability makes them indispensable in applications ranging from wastewater aeration to natural gas monitoring and nitrogen blanketing.

For engineers and facility managers evaluating comprehensive instrumentation packages—including the radar and ultrasonic sensors found on the Main Page—understanding how thermal flow technology integrates into a process is essential for achieving precise mass balance and operational efficiency.

| Measurement Principles of Thermal Flowmeters

Thermal flowmeters operate based on the principle of thermal dispersion or heat transfer. The fundamental physics dictates that a fluid moving past a heated surface will carry away heat. The rate of heat loss is directly proportional to the mass flow rate of the fluid. In industrial gas applications, this relationship is often described by King's Law, which relates the heat loss from a cylinder to the fluid velocity and density.

Most modern thermal flowmeters employ two Resistance Temperature Detectors (RTDs) as sensors. These sensors are typically housed within robust metal thermowells (often 316 Stainless Steel or Hastelloy) and inserted into the flow stream.

| 1. Constant Temperature Differential (CTD)

In this mode, the electronics provide power to one RTD (the active sensor) to maintain a specific, constant temperature difference above the second RTD (the reference sensor), which measures the ambient process temperature. As gas flows past the heated sensor, it carries heat away. To maintain the constant temperature differential, the instrument must increase the electrical power supplied to the heated sensor. This electrical power consumption is directly proportional to the mass flow rate of the gas.

| 2. Constant Current (CC)

In the constant current approach, a fixed amount of power is supplied to the heated sensor. As the flow rate increases, the cooling effect of the gas causes the temperature of the heated sensor to drop. The resulting temperature difference between the heated sensor and the reference sensor is measured. While effective, this method is less common in high-turndown industrial applications than the CTD method because it can be less sensitive at higher velocities.

Because these instruments measure heat transfer, they are naturally sensitive to the "mass" of the gas (the number of molecules passing the sensor) rather than the volume. This eliminates the need for separate pressure and temperature transmitters, simplifying the installation and reducing the potential for cumulative error.

| Industrial Applications and Use Cases

Thermal flowmeters are specialized tools, predominantly used for gas applications. Their design makes them particularly suited for specific industrial sectors:

Water and Wastewater Treatment: One of the most common uses is measuring aeration air. In biological treatment processes, precise control of air delivered to aeration basins is vital for microbial health and energy efficiency. Thermal flowmeters handle the low pressures and varying flow rates of aeration systems with high accuracy.

Oil and Gas: These meters are frequently used for flare gas monitoring, vapor recovery units (VRU), and natural gas distribution. Their ability to measure low-pressure gas and their high turndown ratio (often 100:1 or better) allows them to detect small leaks as well as high-volume relief events.

Chemical Processing: Nitrogen blanketing is a critical safety application where thermal flowmeters monitor the small amounts of inert gas used to prevent explosions in storage tanks. They are also used to monitor process gases like Hydrogen, Argon, and Carbon Dioxide.

Industrial Automation: Compressed air auditing is a major application. By measuring the mass flow of compressed air, plants can identify leaks and optimize compressor performance, leading to significant energy savings.

| Practical Selection Criteria

Choosing the right thermal flowmeter requires a detailed understanding of the process media and environmental conditions. Unlike level measurement instruments, which might be selected based on tank geometry, flowmeters are selected based on fluid dynamics.

| Selection Table: Key Evaluation Parameters

Parameter	Requirement/Consideration
Gas Composition	Must be known and constant. Changes in gas mix (e.g., CH ₄ vs. CO ₂) change the thermal conductivity.
Flow Range	Thermal meters excel at low velocities (down to 0.05 m/s or 10 SFPM).
Pipe Diameter	Insertion styles are used for pipes >50mm (2"); Inline styles for smaller diameters.
Process Temperature	Standard models handle up to 200°C (392°F); high-temp models up to 450°C (842°F).
Process Pressure	Typically rated up to 70 bar (1000 psi), though specific designs vary.
Accuracy	Generally $\pm 1\%$ of reading plus $\pm 0.5\%$ of full scale.

Insertion vs. Inline Designs

Insertion Flowmeters: These consist of a probe inserted through a flange or NPT fitting into the pipe. They are cost-effective for large ducts and pipes but require careful positioning to ensure the sensor sits at the point of average velocity (usually the center of the pipe).

Inline Flowmeters: These include a flow body or "spool piece" that is plumbed directly into the piping. Inline versions often include built-in flow conditioners to stabilize the flow profile, providing higher accuracy and repeatability in smaller lines (typically 6mm to 50mm).

Installation Considerations

To achieve the stated accuracy of a thermal flowmeter, the flow profile at the point of measurement must be fully developed and laminar. Turbulence caused by elbows, valves, or reducers can lead to significant measurement errors.

| Straight Run Requirements

As a general engineering rule, thermal flowmeters require a minimum of 10 to 20 diameters of straight pipe upstream and 5 diameters downstream. If the piping configuration includes multiple elbows in different planes or a partially open valve, the upstream requirement may increase to 40 diameters. In systems where space is limited, mechanical flow conditioners (perforated plates) can be installed to reduce these requirements.

| Orientation and Moisture

Thermal flowmeters should ideally be installed in a horizontal pipe. If moisture or condensate is present in the gas, the sensor should be mounted from the side (3 o'clock or 9 o'clock position) rather than the top. This prevents water droplets from pooling on the sensor head. It is important to note that thermal flowmeters cannot distinguish between the heat absorbed by a gas and the heat absorbed by a liquid droplet. Therefore, "wet" gas or entrained moisture will cause the meter to over-read significantly.

| Limitations and Risks

While highly versatile, thermal flowmeters are not universal solutions. Engineers must be aware of the following limitations:

1. **Gas Composition Sensitivity:** Because the meter is calibrated for a specific gas (e.g., 100% Nitrogen), any change in the gas composition will result in an error. If a process switches from Nitrogen to Argon, the meter must be re-calibrated or adjusted using conversion factors, as the thermal conductivity of these gases differs.
2. **Moisture and Condensation:** As mentioned, liquid droplets hitting the heated sensor cause a "spike" in the flow reading because liquids carry away much more heat than gases. They are not suitable for saturated steam or very wet biogas without proper moisture separation.

3. Coating and Fouling: If the gas contains particulates or oils that coat the sensor, the coating acts as an insulator. This slows the heat transfer and causes the meter to under-read. Regular cleaning is required in dirty gas applications.

4. High Velocity Limits: While excellent at low flows, thermal dispersion sensors can saturate at very high velocities where the cooling effect no longer increases linearly with flow.

| Integration with Level Measurement Systems

In many B2B industrial environments, flow measurement and level measurement are two sides of the same coin. For instance, in a chemical storage tank, a Welk radar level meter might monitor the volume of liquid remaining, while a thermal flowmeter monitors the Nitrogen used for blanketing the headspace.

Combining these data points allows for sophisticated mass balance calculations. If the level in a tank drops (indicating discharge) but the flowmeter shows no nitrogen inflow, it could indicate a vacuum safety risk or a failure in the blanketing system. For more information on the level sensors that complement these flow systems, you can [Review product options and application support on our Main Page](#).

| Frequently Asked Questions (FAQ)

Q: Do thermal flowmeters work on liquids?

A: While the principle of thermal dispersion can be used for liquids (often in flow switches), most industrial "thermal mass flowmeters" are specifically calibrated and designed for gas applications. Measuring liquid flow with this technology is difficult because liquids have much higher heat capacities and thermal conductivities than gases.

Q: Can I use a thermal flowmeter for steam?

A: Generally, no. Steam is often near its saturation point. Any condensate (water droplets) will cause erratic and highly inaccurate readings. Vortex flowmeters or Differential Pressure (DP) meters are typically preferred for steam.

Q: How often do thermal flowmeters need calibration?

A: In clean gas applications (like dry Nitrogen), a thermal flowmeter can maintain its calibration for several years. However, in regulated industries or dirty gas applications, annual calibration checks are recommended. Many modern units offer "in-situ" calibration validation, allowing technicians to verify the sensor's electronics and thermal response without removing it from the pipe.

Q: What is the difference between SCFM and ACFM?

A: ACFM (Actual Cubic Feet per Minute) is the volume of gas at the actual operating pressure and temperature. SCFM (Standard Cubic Feet per Minute) is the volume the gas would occupy at standard conditions (usually 14.7 psia and 60°F or 70°F). Thermal flowmeters naturally report in standardized units (SCFM or NCMH) because they measure mass.

| Conclusion

Thermal flowmeters provide a reliable, low-maintenance solution for gas mass flow measurement across a wide range of industrial sectors. By eliminating the need for separate temperature and pressure compensation, they offer a streamlined approach to process monitoring. When selected with a clear understanding of gas composition and installed with adequate straight pipe runs, they provide the precision necessary for modern industrial automation. For professionals managing complex fluid systems, pairing these flow instruments with the advanced level measurement technologies available on the Main Page ensures a robust and data-driven approach to facility management.