

Manual for un-cooled Suction Pyrometer

Standard industrial, mobile/travel and miniature version



Mobile/travel version

Introduction

In this manual is the industrial standard suction pyrometer (page 4) and the miniature suction pyrometer (page 8) for laboratory scale gas temperature measurements described.

Measurement of the local gas temperature in boilers and flames by thermocouples is affected by thermal radiation heat transfer between the thermocouple, flame and walls. It is in theory possible to correct temperature readings, but it is difficult in practise as many parameters must be known, e.g. emissivity and geometry of thermocouple and combustion chamber, but also detailed information about gas composition, flow velocities and temperatures in system is needed.

A well established way to improve accuracy of local gas temperature measurements by a thermocouple is to use a suction pyrometer, where the thermal heat transfer by thermal radiation is reduced by radiation shields around the thermocouple tip. In the standard suction pyrometer the thermocouple, protected from chemical attack by sheath, is surrounded by two concentric radiation shields. The gases are drawn between the shields and over the sheath with high velocity (usually min. 150 m/s) so that the equilibrium thermocouple temperature is nearly that of the gases without the need for correction. Standard suction pyrometers exist in many versions, e.g. high temperature water-cooled suction pyrometer with platinum-rhodium thermocouple (flames) or with type K and N thermocouple up to typical 1100°C and 1300°C, respectively.

Read the manual carefully before using the suction pyrometer

Table 1 Pyrooptic manufacture many type of probes for gas temperature measurements. The list is notcomplete, e.g. custom version.

Туре	Features	Pros and Cons
Un-cooled suction pyrometer	Low cost. Simple, 2 shields, type N or K thermocouple. Injector use 5-7 bars compressed air.	Max. 1100-1300°C. 10s – 100 s response time. Risk of bending of horizontal long probe at high temperature. Particles in flow might block suction flow after 5-120 minutes.
Steam cooled suction pyrometer	Low/moderate cost. Cooling by water injected with compressed air. 5-7 bars. 10 liter water gives cooling for approx. 10 minutes. Injector use 5-7 bars compressed air.	Max. 1300°C. 10s – 100 s response time. Long probe at high temperature. Particles in flow might block suction flow after 5-120 minutes. No condensation in probe, i.e. extended operation time.
Water-cooled suction pyrometer	Moderate cost. 3 ceramic shields + platinum thermocouple. Cooling water 5-50 l/min. Injector use 5-7 bars compressed air.	Up to 9 m long probes. 30s – 120 s response time. Useful for flame measurements <1650°C. Particles in flow might block suction flow after 5-120 minutes. Condensation in probe, i.e. limited operation time (special design option to avoid problem).
IR temperature probe	Moderate cost. Gas temperature from CO ₂ band at 4.3µm. Cooling water 5-50 l/min. Small purge flow used to protect lens, approx. 4 l/min.	Up to 9 m long probes. 10-30 ms response time. Useful for flame measurements. No upper temperature limit. Faster measurements as no time needed to stabilize temperature reading.
FTIR fibre-optic probe	 High cost. Gas temperature from CO₂ band at 4.3μm. Advanced options: Radiative heat flux measurements, Fast gas concentration measurements. Cooling water 5-50 l/min. Small purge flow approx. 4 l/min. Cooling water 5-50 l/min. Small purge flow used to protect lens, approx. 4 l/min. 	Up to 9 m long probes. Miniature and large scale probes. Fast response time. Useful for flame measurements. No upper temperature limit. Faster measurements as no time needed to stabilize temperature reading

The Un-cooled standard Industrial Suction Pyrometer

Mounting of suction pyrometer:

- 1) Mount injector on ½" 2 m long stainless steel (SS) tube. The injector suck hot gas from tip of probe through ½" SS tube and blow it out at end of injector.
- 2) Insert 6 mm stainless steel diameter tube through injector into ½" tube (figure 4). In mobile version is it necessary to mount 6 mm tubes together with adaptor (M6 thread) and insert from front part (possible due to cone inside fitting).
- 3) Insert type N or K thermocouple through small stainless steel tube (6x1 mm diameter). Avoid bends on thermocouple as it will be hard to push in. A few oil droplets might help if thermocouple is hard to push through the small SS tube, but a straight thermocouple is the best way. The small 6 mm SS tube protects the thermocouple and insure inner ceramic shield cannot move backwards. Tip of thermocouple must stick approx. 15 cm out from ½" SS tube.
- 4) Mount small inner ceramic tube at probe tip with thermocouple inside. Tip of thermocouple must be approx. 1 2 cm behind opening of inner ceramic shield (positions shown in figure 2).
- 5) Fix position of the small 6 mm SS tube at injector by fitting (do not tighten too hard as it will be difficult to re-use parts) and bend thermocouple slightly to mark correct position of thermocouple tip in inner ceramic shield.
- 6) Mount outer ceramic shield with cement/"GUN GUM", see figure 3. End of outer ceramic shield should stick 1.5-2 cm inside ½" SS tube. Use "cement/"GUN GUM" to created a gas tight seal between outer ceramic shield and the ½" SS tube to insure hot gas is only sucked in through hole in tip of outer ceramic shield (highest possible velocity of gas inside ceramic tubes and therefore best convection between gas and thermocouple. The cement will dry after 10-30 minutes in air or insert it carefully without suction for a short time in boiler (approx. 30 s).
- 7) Prepare compressed air for injector. Note, use 5-10 bar pressure for best and most accurate gas temperature measurement. Inspect vacuum at hole tip of ceramic shield with a finger.
- 8) Connect thermocouple to thermometer. A 3-10 m long compensation cable can be inserted to avoid thermometer hanging behind suction pyrometer. Turn on thermometer: type N or K thermocouple must be selected (set at delivery, but any other thermocouples might be used instead, e.g. type B).
- 9) Mark ½" SS tube or note distance from hole in outer ceramic shield to injector for later use, i.e. position of temperature measurement. Point of temperature measurement is at hole in ceramic shield.
- 10) Insert suction pyrometer into hot gas flow. Turn on pressurized air to injector and wait approx. 1 minute for temperature reading to stabilize. Move suction pyrometer to next measurement point and wait approx. 1 minute for stable temperature reading (un-stable temperature reading can be caused by process fluctuations).
- 11) Inspect vacuum at hole in tip of ceramic shield with a finger when suction pyrometer is cooled down after use to ensure measurements taken are accurate.



Figure 1 Mounted 2m (78.7") un-cooled suction pyrometer. Right: 15 mm outer ceramic shield with 10 mm hole for suction of hot gas. Left: injector driven by compressed air 7-8 bar. Temperature of type N thermocouple is read by calibrated handheld temperature instrument.



Figure 2 Illustration of recommended position of thermocouple (below), inner ceramic shield (middle) and outer ceramic shield with hole for suction of hot gas. Scale in cm $(1^{"} = 2.54 \text{ cm})$ at top of each image. A: side hole in outer shield with closed end, B: open end shield.



Figure 3 Left: Fix outer ceramic shield at tip of $\frac{1}{2}$ " tube with fixing cement "GUN GUM". "GUN GUM" is product usually used for repair of car exhaust pot, but work fine for suction pyrometers for temperature up to 1100-1200°C. "GUN GUM" should insure a gas tight seal between $\frac{1}{2}$ " tube and outer ceramic shield. Wash finger or better use gloves to avoid contact with GUN GUM. Right: a wire (heating element wire) with bended ends can be used to hold inner ceramic tube (open ends) from falling out in vertical orientation of suction pyrometer.



Figure 4 Mark thermocouple position by a minor bend to ensure tip of thermocouple is at the right position.



Figure 5 Optimum position of injector tip is 10-15 mm from the inlet of injector cone as shown in picture.



Figure 6 Gas velocity in ceramic tip in test at ambient temperature. The actual gas velocity at hot conditions will be much higher as the velocity scale with the ideal gas law, i.e. the hot gas is cooled down on the way to the injector and in the injector.

Miniature Suction Pyrometer

The miniature un-cooled suction pyrometer is designed for gas temperature measurements at temperatures up to 1250°C with a type N thermocouple surrounded by 2 ceramic radiation shields. The suction pyrometer is designed with a diameter of only 12.0 mm for typical laboratory scale measurements. The first 400 mm front part (ceramic tubes + thermocouple) is uncooled whereas the last part with stainless steel tubes (316) is air cooled. The injector driven by compressed air ensure suction of gas at high speed around tip of thermocouple and cooling air for the stainless-steel tubes.

The miniature un-cooled suction pyrometer (figure 7) is assembled from 5 parts, figure 8. First, the thermocouple is inserted through fitting of adaptor part (see details in figure 9). The thermocouple is pushed forward gently until approx. 20 mm of the tip is outside the tip of the 8-9 mm diameter stainless steel tube. Straighten the thermocouple and do not make any sharp bends. The inner ceramic shield (3-5 mm ceramic tube wrapped with Kanthal A1 1 mm wire, max. 1400°C) is then inserted into the adaptor part via the opening of the 8-9 mm diameter stainless steel tube and with the thermocouple inside the 3-5 mm ceramic tube. The Kanthal wire is used to centre the inner ceramic tube. The end of the ceramic tube with approx. 45° cut should face towards and touch the adaptor part (create a flow through tube). Next, insert thermocouple further until it is feed through the inner ceramic tube and pull it 10 mm backwards to obtain approx. 10 mm distance from tip of thermocouple behind tip of the inner ceramic tube to shield the thermocouple from thermal radiation. Finally mount outer ceramic shield and fix it by the 12 mm Swagelok fitting. Only hand tighten the 12 mm Swagelok fitting, i.e. it will be easy to disassemble it again. Mount hose with 6mm injector nozzle and connect to compressed air (use tools to fix injector nozzle).



Figure 7 Miniature suction pyrometer fully assembled. The suction pyrometer is cooled by ambient air through the 4 holes at the 12 mm Swagelok fitting. The injector is typical rotated with the injector pointing upwards (tubing from ground).



Figure 8 1: Injector in stainless steel (316), 2: Adaptor part for thermocouple with 8/9 mm SS tube, 3: 12.0 mm SS tube with outer ceramic shield (8/10 mm), 4: inner ceramic shield with Kanthal A1 wire (375 mm) and 5: thermocouple type N 1.5 mm diameter x 1 m.



Figure 9 Upper left picture: Insert thermocouple with fitting through adaptor part and be careful not to make any bends on thermocouple. Upper right picture: Mount inner ceramic shield with tilted cut towards the adaptor part and push it gently into the 8/9 mm SS tube. Lower left picture: Mount outer ceramic shield and only hand tighten the 12 mm Swagelok fitting. Lower right picture: Be careful not to break fragile ceramic tubes, i.e. do not bend or hit ceramic tubes. The inner ceramic tube can be used broken as the thermocouple hold pieces together.

SAFETY Miniature Suction Pyrometer

RISK of burns – hot metal and ceramics

Harmful gases from incomplete combustion

Noise due to injector operation

Be aware that the uncooled suction becomes very hot at operation and the risk of burns. Hold hot suction pyrometer at a cool part, i.e. hose with 6 mm injector nozzle, and use tool to hold at the hot part. The suction pyrometer cools quickly down if the compressed air is not turned off. Place the suction pyrometer on insulation or metal to cool fully down after use.

Be aware of harmful gases can be sucked out, i.e. CO from zone in flame with incomplete combustion. Evaluation risk and take precautions before starting measurements, e.g. remove gases by ventilation, CO alarm, etc. Smoke or soot can activate fire alarms.

Lifetime of thermocouple will be significantly reduced at temperature levels of 1300°C. Outer metal shield of thermocouple becomes brittle after use at high temperature due to oxidation, i.e. avoid bending thermocouple after use to extend lifetime.



Figure 10 Calculated gas velocity at 1000°C in ceramic tip of miniature suction pyrometer based on flow measurements at ambient temperature for a 12-mm diameter and 850 mm long suction pyrometer. The recommended operation pressure is 6 bars or higher to obtain a sufficient cooling air flow at high gas temperatures.

Recommended tools

Ruler (e.g. 2 m) Pen to mark suction pyrometer Wrench Pipe wrench Cable strips PVC tape (to seal GUN GUM can) Clamp or similar to hold hot part of suction pyrometer Tool for removing broken outer shield glued to ½" SS tube

Safety

Read this manual before use of the suction pyrometer.

The un-cooled suction pyrometer is build to be inserted into hot gas flow at temperature up to max 1300°C. Hot gas is extracted through ½" tube by injector and suction pyrometer becomes very hot. Do not touch the suction pyrometer during measurements or after it is taken out before it is cooled down. Wear fire safe cloth (e.g. cotton) and insulated gloves when handling the hot suction pyrometer.

HOT SUCTION PYROMETER - RISK OF SKIN BURNS

Be aware of harmful gases as the hot gas extracted from e.g. boiler and flames is blow out from injector, e.g. gas might contain CO if combustion process is not fully completed. Do not use the suction pyrometer in small enclosure or rom if gas contains harmful gases.





Figure 11 Hold un-cooled suction pyrometer with tool and rear part of injector at inlet of pressurized air and wearing gloves when it is hot.

Temperature measurement and uncertainty

The use of a suction pyrometer can reduce measurement errors on hot gas temperature significantly. Errors of 50-250°C can be seen using a simple thermocouple in hot gas flows. Just try to measure the flame temperature of a candle light (approx. 1250°C true gas temperature) or compare reading of an old oxidized and new shinny thermocouple in a gas flame surrounded with cold or no walls.

Uncertainty depends on many factors:

- Correct high velocity of gas in shields (sufficient pressure to drive injector, blocking by particles,...),
- Broken shields during measurements,
- Sufficient time to stabilize temperature reading (e.g. 1-2 minutes for industrial type).
- Measurement uncertainty on raw temperature measurement
- High gas flow rate in inner AND outer shields

The suction pyrometer can be delivered with calibrated thermometer and N thermocouples and certificate. It is recommended to mark all instruments, cables and thermocouples with ID labels, i.e. it is possible to perform a calibration afterwards although calibration before is recommended (if sensor is broken).

Case story: Thermometer was calibrated accredited with both thermocouples at 0.0°C and 1100.7°C. Only minor correction was observed at 0.0°C (from -0.1°C to -0.4°C) whereas temperature correction at 1100°C was +4°C.

Use the correct type of compensation cable (e.g. type N, K, S and B) to connect thermometer with thermocouple. Ensure that thermometer is set to correct type of thermocouple.

Total uncertainty on suction pyrometer measurements are normally below 10°C, but can vary depending on measurement conditions (fluctuations, instable process, problems with blocking of ceramic shield by particles in gas, etc.). Too low suction flow is usually the reason of bad measurements with a suction pyrometer. It is important that the gas flow velocity is high in all shields around the thermocouple to lower uncertainties.

Increase life time of suction pyrometer

Life time of suction pyrometer can be extended if it is used with care. However, even with care it is sometime hard to measure for more than ½ - 1 day without repair. Typically, the ceramic tip is blocked by particles or is broken due to handling of the suction pyrometer.

- a) Avoid bending the first part of the thermocouple as it becomes fragile after use. Eventually, store used thermocouple (TC) in straight tube or store suction pyrometer carefully. Store TC in a tube or coiled without sharp bending.
- b) Direct hole in outer ceramic shield opposite to flow direction if gas is particle loaded. This will mostly extend operation time significantly before gas flow through ceramic shields is blocked by particles.
- c) Avoid to insert an un-cooled suction pyrometer horizontal more than 1-1,5 m if temperatures are very high. ½" SS tube with bend due to its own weight, eventually, rotate suction pyrometer sometimes to keep it straight. A water or steam cooled suction pyrometer is needed for measurement over longer distances (up to 9 m) at very high temperatures. "GUN GUM" must be replaced by a ceramic cement in high temperature flame measurements.
- d) Avoid mechanical shocks or hitting the measurement port with ceramic shield of suction pyrometer. Ceramics becomes fragile after use.

Measurements with a suction pyrometer can sometimes be a hard job when measurement conditions are tough, e.g. in flames with high gas temperature and with high load of molten particles. Another way to measure gas temperature under very difficult conditions is to use a water-cooled probe measuring gas temperature with an IR-sensor from the thermal radiation from CO_2 band at 4.3 μ m. The IR-sensor can be used for many hours/days as a small purge flow keeps lens of the IR-sensor clean, contact Pyrooptic for more details about IR methods.

List of delivery (standard industrial version)

- 1) 1 piece complete un-cooled suction pyrometer with SS (316) injector
- 2) 1 piece temperature instrument /thermometer and printed manual (if ordered)
- 3) 3 pieces' type N or K thermocouples 1.5 mm diameter
- 4) Calibration certificate on temperature instrument and thermocouples (if ordered)
- 5) Cement "GUN GUM" for mounting of outer ceramic shield
- 6) 3 set of ceramic shields, i.e. inner shield 7 mm diameter and outer shield 15 mm diameter
- 7) Manual of suction pyrometer
- 8) Spare set of stainless steel tube, i.e. 6.0x1.0 mm tube and ½" tube (type 316)
- 9) Spare fitting parts in plastic bag
- 10) 3/5/10 m type N or type K compensation cable



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