impac®
Spezialist für
berührungslose Temperaturmessung

VDE-zertifiziert ISO 9001 IMPAC Electronic

User Manual

Infratherm Pyrometer
IN 5 · IN 5/5

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Contents

Congratulations on choosing the IMPAC pyrometer. You are now the owner of a compact infrared non-contact thermometer, which combines efficiency and excellence for optimal temperature measurements.

Please read this manual carefully before installing this pyrometer. It contains all the necessary information to set up and operate the new IMPAC pyrometer.
Should you require further assistance, please call our customer service hotline in Germany (+49) (0) 69 9 73 73-190.

IMPAC has been developing and manufacturing non-contact temperature measurement instruments since 1958 and has more than 60 000 pyrometers and systems installed worldwide.

IMPAC Electronic GmbH

1. Scope of delivery

– Pyrometer with optics (IN 5: a = 100, 300 or 800 mm. IN 5/5: a = 100, 300 or 1200 mm)

Please Note: A connecting cable is not included with the instrument and should be ordered separately **(see 8. Order numbers)**.

2. Special features Infratherm IN 5; IN 5/5

– Suitable for measuring objects with non-metallic surfaces (IN 5) and metals which are painted or oxidised or glass surfaces (IN 5/5)
– Measures temperature ranges between -32 and 900 °C (IN 5); between 100 and 2500 °C (IN 5/5)
– Two wire technique
– Analog output 4 - 20 mA
– Digital linearization guarantees accuracy up to 0.6 % of the measured value
– Readings are unaffected by the relative humidity or the amount of CO_2 in the air
– Stainless steel housing
– Adjustable emissivity from 0.20 to 1.00 (20 - 100 %) in 0.01 (1 %) steps
– Adjustable response time from 0.08 to 5 sec

Safety warning:

Caution!
Do not clean the lens with liquids containing acids or solvents

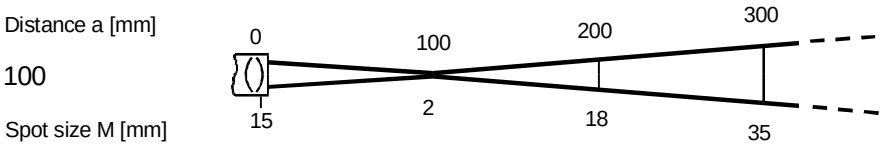
3. Optics

The pyrometer is available with various optical profiles. Select the optics that are most appropriate for your application from the optical profiles shown below. The optics must be chosen when ordering the instrument, and cannot be changed once installed.

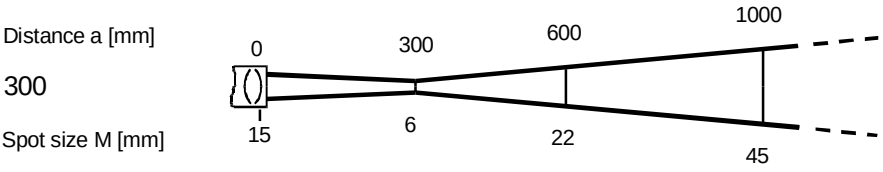
A pyrometer operates passively. It receives heat radiation, from the measured object, which passes through the lens and is then converted to an electrical signal. The measured object may be at any distance from the pyrometer! However, the farther the measured object is from the pyrometer, the larger the area (*spot size*) that will be measured by the pyrometer. The object (or the area on the object) that you want to measure has to be as big (or bigger) than the pyrometer's *spot size*, for that distance.

The following drawings show the pyrometer's *spot sizes* (minimum required sizes for the measured object) and the focal distances, in relation to the distance from the pyrometer. The *spot size* at a distance of 0 mm (a = 0) is 15 mm (M = 15) or 10 mm (M = 10 at the IN5/5, MB 25), which is the diameter of the aperture behind the lens.

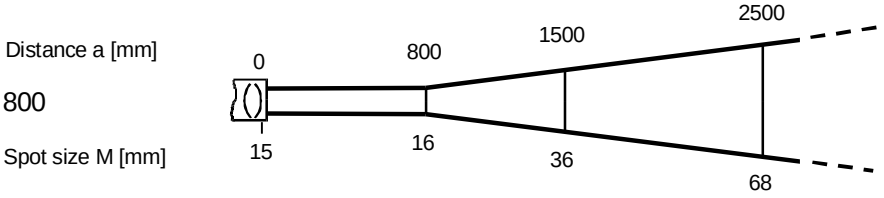
IN 5; Optics 100



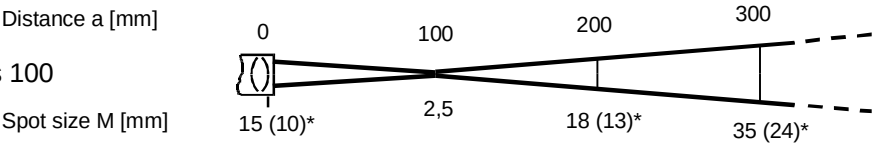
IN 5; Optics 300



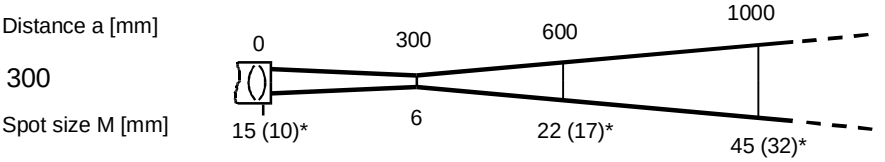
IN 5; Optics 800



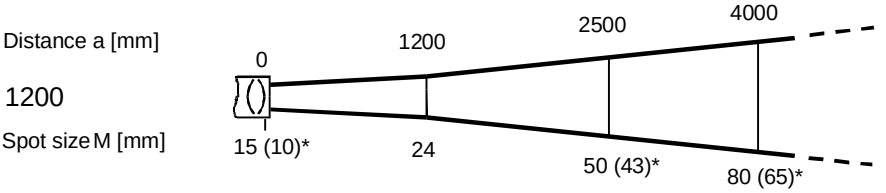
IN 5/5; Optics 100



IN 5/5; Optics 300



IN 5/5; Optics 1200



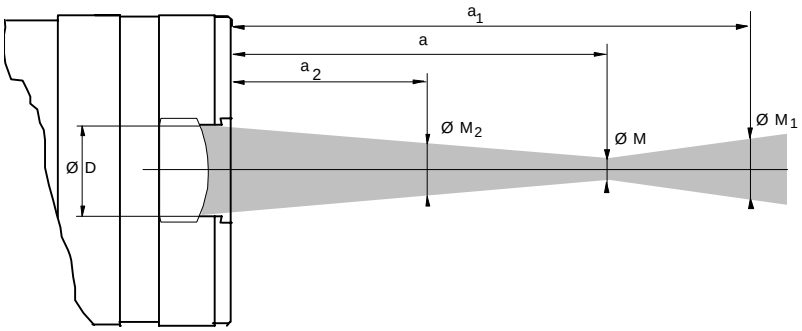
* MB 25 at the IN 5/5

Note: Please note that the optical profiles show nominal dimensions. The spot size diameter or the focal distance may be slightly different due to *lens tolerances.*

The *optical profiles* show that the *spot size* M varies with the distance from the pyrometer.
Spot sizes for intermediate distances, that are not shown on the optical profiles, may be calculated using the following formula, where:

D = 15 mm (10 mm at IN 5/5, MB 25) (the aperture diameter)
a = the nominal distance (from the optical profiles)
M = the nominal spot size (from the optical profiles)

$$M_2 = \frac{a_2}{a}(M - D) + D \qquad M_1 = \frac{a_1}{a}(M + D) - D$$



4. Technology

4.1. Technical description

All objects whose temperature are above absolute zero (-273.15 ºC / -459.67 ºF) emit heat. Most of this heat is emitted as infrared (IR) radiation.

IMPAC pyrometers are measuring instruments, which receive heat radiation through the optics and focus it on a detector. The detector converts it into an electric signal. This signal is digitally linearized and converted into a standard analog output signal.

For best accuracy, the correct optical filter with the appropriate spectral range must be selected for the the type of material that is being measured. For example, select the IN 5 with the 8 to 14 µm spectral range for measuring non-metallic surfaces or the IN 5/5 with the narrow 5.14 µm nominal bandwidth for measuring glass surfaces.

An integrated micro-controller performs all calculations and digital processing.

4.2. Technical data

Temperature ranges:	IN 5: 0 to 100 °C 0 to 200 °C 0 to 300 °C 0 to 400 °C 0 to 500 °C 0 to 900 °C - 32 to + 50 °C IN 5/5: 100 to 600 °C 200 to 800 °C 100 to 1300 °C 400 to 2500 °C (custom temperature ranges for either instrument are available on request)
Data handling:	Digital
Spectral response:	IN 5: 8 to 14 µm (for all general applications on non-metallic surfaces and metals which are painted or oxidised) IN 5/5: 5.14 µm (narrow band, for glass surfaces)
Optics:	IN 5: Germanium (Ge) Lens IN 5/5: Zinc Sulfide (ZnS) Lens
IR-detector:	Silicon (Si)-based thermopile
Power supply:	24 V DC (10 to 30V) ripple must be less than 0.5 V
Analog output:	4 - 20 mA, direct current, linear resolution: 2880 steps
Load:	max. 700 Ω at 24 V (max. 100 Ω at 12 V)
Emissivity:	user-adjustable from 0.20 - 1.00 in steps of 0.01
Response time t_{90}:	user-adjustable from 0.08 to 5 sec

Accuracy:

Dependent on object temperature T and ambient temperature T_u

(ε = 1, t_{90} = 1 sec):

IN 5

T \ Tu	15 to 30 °C	0 to 15 °C or 30 to 63 °C
0 to 300 °C	0.6 % of measured value in °C or 1 °C *)	1 % of measured value in °C or 1.5 °C *)
300 to 900 °C	1 % of measured value in °C	1.3 % of measured value in °C
-32 to 0 °C	1.5 °C	2 °C

IN 5/5

T \ Tu	15 to 30 °C	0 to 15 °C or 30 to 63 °C
100 to 1300°C	0.6 % of measured value in °C or 2 °C *)	1 % of measured value in °C or 3 °C *)
1300 to 1800°C	0.8 % of measured value in °C	1.2 % of measured value in °C
1800 to 2500°C	1 % of measured value in °C	1.4 % of measured value in °C

*) whichever value is greater. The instrument must be at a constant ambient temperature for a minimum of 15 minutes

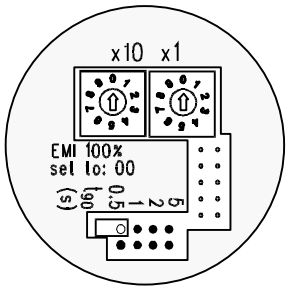
Repeatability:	IN 5; IN 5/5: 0.3 % of measured value in °C or 0.6 °C *) *) whichever value is greater. The instrument must be at a constant ambient temperature for a minimum of 15 minutes
Noise Equivalent Temperature Difference (NETD):	0.2 K (σ = 1) measured temperature = 23 °C, t_{90} = 80 ms and ε = 1 0.05 K (σ = 1) measured temperature = 23 °C, t_{90} = 1 sec and ε = 1
Ambient temperature:	0 to +70 °C (IN 5/5, MB 25: 0 to 63 °C)
Storage temperature:	-20 to +70 °C
Enclosure rating:	IP 65 (DIN 40050)

Weight:	400 g
Dimensions:	111 mm x 49,5 mm (l x d)
Housing:	Stainless steel
Operating position:	Any

CE Approval / EMV tests:	Satisfies EU regulations for electromagnetic immunity (industry norm)

5. Instrument settings

5.1. Controls



The *controls* are located under the rear cover of the pyrometer and can be accessed by removing the rear cover. To remove the rear cover unscrew both rear screws and take the cover off, making sure it remains straight (without bending or twisting it).

Caution: **Disconnect the cable before opening the cover. Reconnect only when assembly is complete!**

When reassembling the cover, insert it carefully into the guide pins and then fasten it with the screws. The connector cable can now be plugged in.

5.2. Emissivity (EMI)

5.2.1. Explanation

The temperature of a given object can only be measured correctly if its exact emissivity ε (Epsilon) is known and the pyrometer is set up accordingly. The emissivity is the ratio between the level of radiation from an object and the level of radiation from a black body radiator at the same temperature. Different materials have different emissivities ranging between 0 and 1.00 (or 0% and 100%).

A value of ε = 1 means that the material absorbs all incoming radiation acting like a black body (a perfect absorber and perfect emitter). Materials which reflect more radiation have a lower emissivity and the emissivity control of the pyrometer needs to be adjusted accordingly. Emissivity values of common materials are listed in table **5.2.2. Emissivities of common materials.**

Note: The minimum emissivity setting for the pyrometer is 0.20 (20 %)!

One way to determine an accurate emissivity value for a material is to make a comparison measurement. This can be done as follows:

1. Measure the surface temperature of the object using a contact thermometer (e.g. Tastotherm MP2000 with a suitable probe) and, at the same time, measure the temperature using the pyrometer. Adjust the emissivity control until the pyrometer displays the same temperature as the thermometer.
2. If possible, coat a portion of the object with dull black paint or carbon soot. Paint and carbon soot have high emissivities (0.95) and take on the same temperature as the object. Measure the temperature of the painted area with the emissivity control set to 95 %. Then measure the temperature of an adjacent unpainted area of the object and adjust the emissivity until the pyrometer displays the same temperature.

5.2.2. Emissivities of common materials

Object	ε (at 8 to 14 µm)
"Black body furnace"	1.00
Human skin	0.98
Black dull varnish	0.95
Carbon soot	0.95
Wood	0.8 - 0.92
Paper	0.92 - 0.95
Asphalt	0.85
Glass/Quartz glass	0.72 - 0.87
Textile	0.75 - 0.95
Graphite	0.75 - 0.92
Cement	0.9
Water	0.95

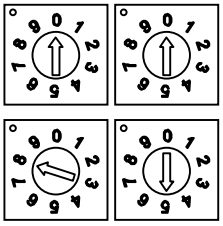
Object	ε (at 8 to 14 µm)
Brickwork Fire clay Rubber Porcelain Ceramics Varnish Plaster Oil paint	0.85 - 0.95
Steel (oxidized)	0.6 - 0.8
Steel (smooth)	0.1 - 0.3
Aluminium (smooth)	0.02 - 0.15
Aluminium (anodized)	0.9

Object	ε (at 5.14 µm)
Glass/Quartz glass	0.97

5.2.3. Set up examples for IN 5; IN 5/5

ε = 1.00

ε = 0.85



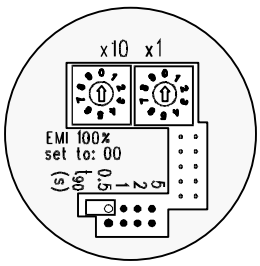
Adjust both switches (EMI) as shown in the example on the left.

Emissivity ε can be adjusted between 0.20 and 1.00 in steps of 0.01.

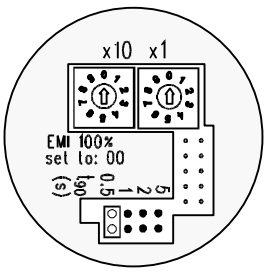
Note: If the emissivity is set to a value below 0.2 the instrument will automatically utilize an emissivity value of 1. The setting 00 is interpreted as ε = 1.00!

5.3. Response time t_{90}

The response time t_{90} is the time interval from the start of measurement up to the respective change in the output signal (4 - 20 mA) which is the time taken to reach 90 % of the recorded temperature difference.
The response time is changed by adjusting the jumper position. In the open position shown in the diagram on the left, the response time is 0,08 s.
For alternative settings (t_{90} = 0,5 s, 1 s, 2 s or 5 s) select the respective jumper position (see diagram on the right).



Example: t_{90} = 0,08 s



Example: t_{90} = 0,5 s

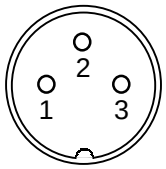
Longer response times are useful when measuring objects with fluctuating temperatures.

Settings at delivery:
ε = 1; t_{90} = 0.08 s

6. Electrical installation

The Infratherm IN 5 and IN 5/5 is powered by 24 V DC (10 to 30 V DC). When connecting the device to the power supply ensure correct polarity. The *power consumption* (in this case 4 - 20 mA) is also the measuring signal.
To meet the electromagnetic requirements (EMV), a shielded connecting cable must be used. The shield of the two wire connecting cable is usually only connected on the pyrometer side. If the connecting cable is extended, the extension cable also needs to be shielded. Do not connect the shield to the power source side (control cabinet), to avoid ground loops.

6.1. Connector assignment



Pyrometer plug (connector):
3 pole Flange plug

Pin 1	(white)	+24 V (10 V to 30 V)
Pin 2	(brown)	0 V
Pin 3	(black)	shield

6.2. Display devices

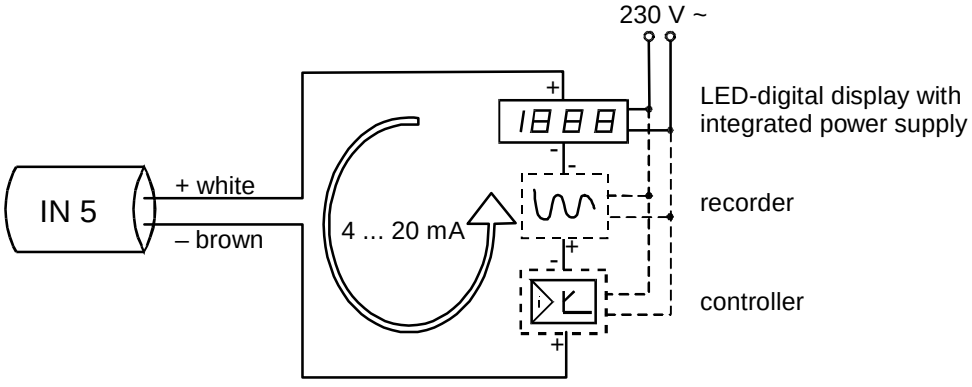
To display the temperature, IMPAC offers display devices with integrated power supplies for two-wire pyrometers as accessories. **(see 8. Order numbers)**

- (DA 4000-N): display only
- (DA 4000): DA 4000-N with 2 limit switches
- (DA 6000): With 2 limit switches, maximum value storage and R S232 or RS 485 interface

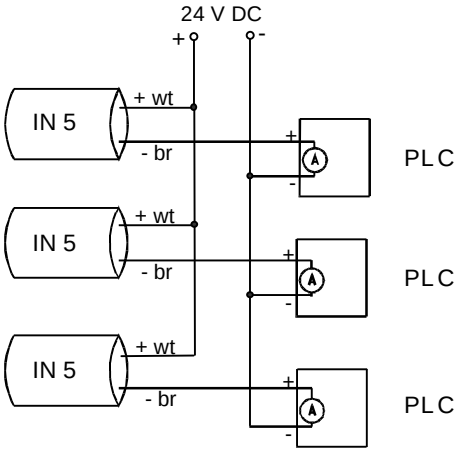
display device type DA 4000

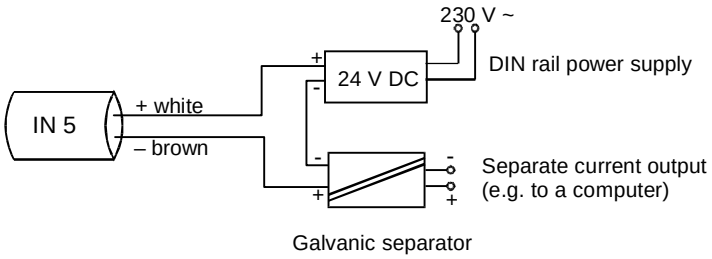
6.3. Connection schematic for display devices

The DA 4000, DA 4000-N and DA 6000 LED display devices have an integrated 24 V power supply for two-wire instruments. If an RS 232 interface is required then the DA 6000 display must be used.



6.3.1. Examples of the IN 5 with peripheral devices

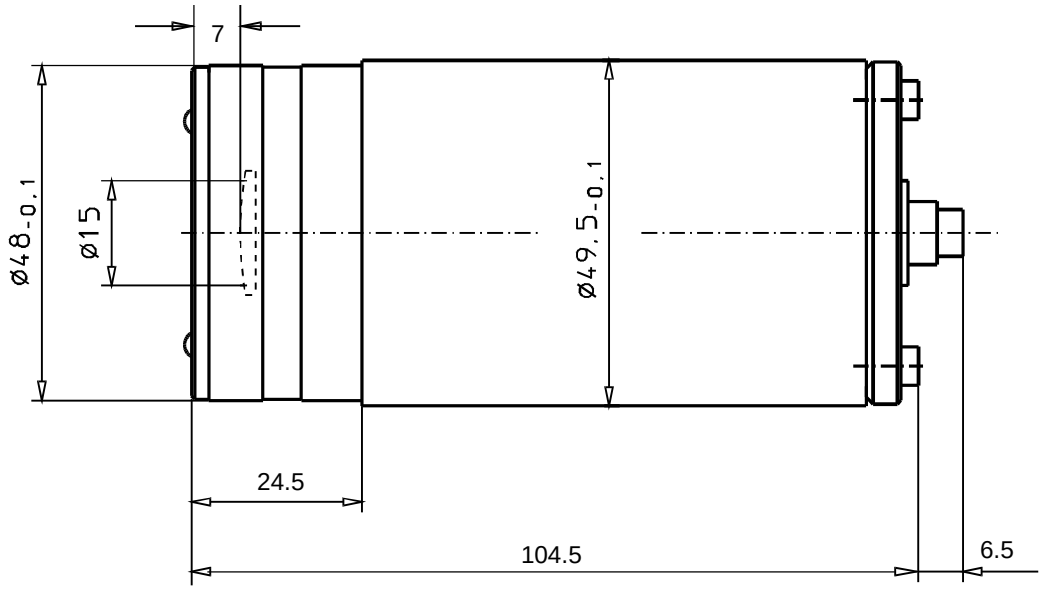




Note: Additional instruments with current input e.g. a recorder **(see 8. Order numbers)** or a controller can be connected to the display in series as shown above.

7. Mechanical installation

7.1. Device dimensions IN 5; IN 5/5

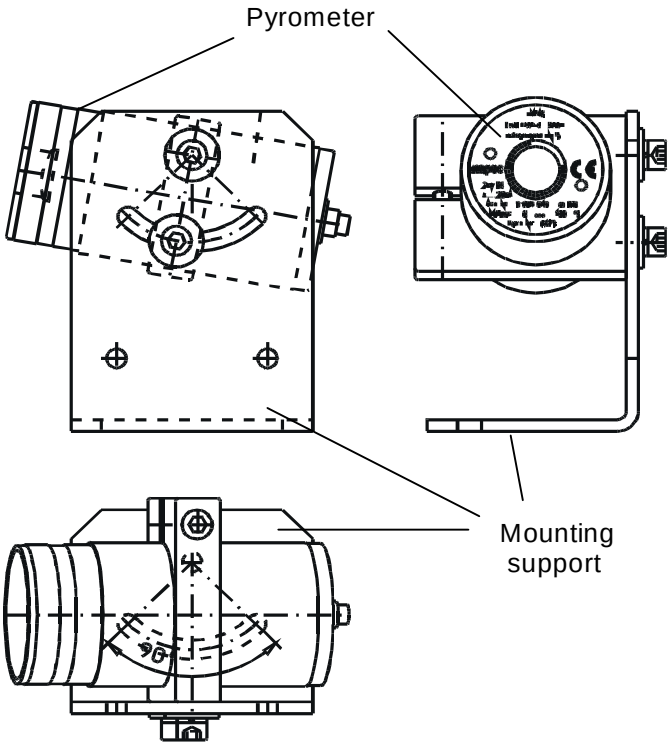


Robust mounting accessories for installation of the Infratherm IN 5 or IN 5/5 are described and depicted in the following section, along with the article numbers (**see** also **8.2.1. Mechanical accessories**).

7.2. Adjustable mounting support with 2 axes

The standard mounting support is made from stainless steel. It can be independently adjusted in the horizontal or vertical directions (± 45º).

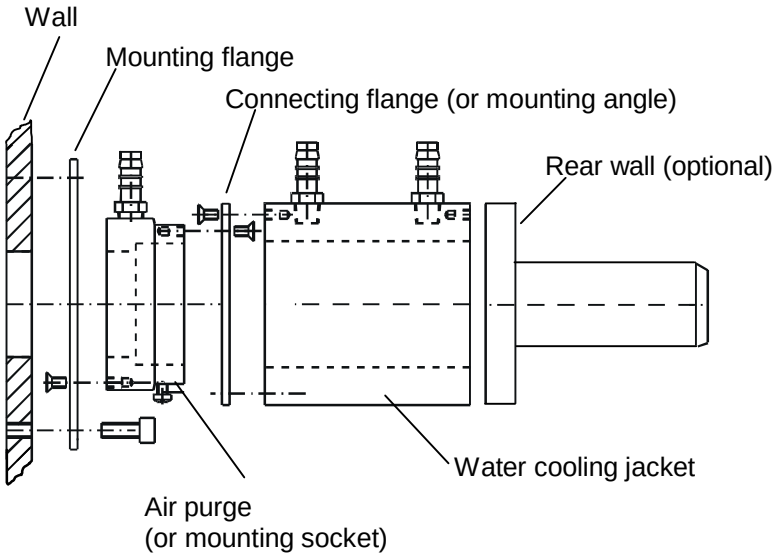
Note: This mounting support cannot be used with the water cooling jacket.



7.3. Water cooling jacket (standard) / Air purge

The standard *water cooling jacket* is designed to protect the pyrometer in hot environments with ambient temperatures above 70 °C (or 63 °C at the IN 5/5, MB 25). With this cooling jacket, the pyrometer may be operated at ambient temperatures up to 170 °C when using a cooling water temperature of 17 °C and a cooling water flow rate of 0.4 l/min.

The *air purge* protects the lens of the pyrometer against dust, humidity and other suspended matters by blowing air away from the lens in a cone-shaped air stream.



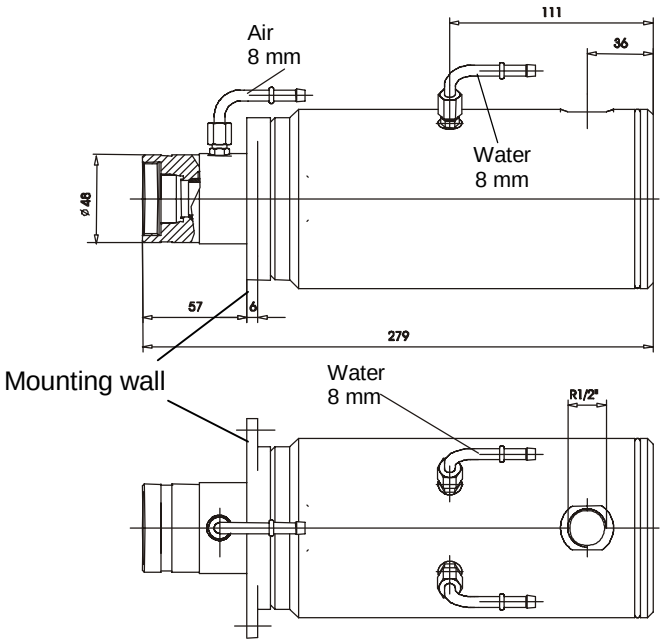
Note: Both parts are also available separately!

Mounting instructions: Depending on intended use, additional parts may necessary for proper mounting:

- The water cooling jacket requires an attachment device such as:
  - a mounting flange with air purge or mounting socket (not in drawing) and connecting flange.
  - or a mounting angle with air purge or mounting socket. (The air purge can also be used alone in connection with the pyrometer.)
- The mounting flange can be used instead of the connecting flange (or mounting angle); the mounting angle can also be used instead of the mounting flange.
- The rear cover (with cable duct) serves as an additional temperature protection.

7.4. Water cooling jacket
(heavy duty) with
integrated air purge

The heavy duty water cooling jacket protects the pyrometer in extremely hot ambient temperatures. It is completely closed and is equipped with a long air purge tube to protect the lens. With the heavy duty cooling jacket, the pyrometer may be operated at ambient temperatures up to 280 °C when using a cooling water temperature of 14 °C and a cooling water flow rate of 2 l/min. Max. water pressure is 6 bar.

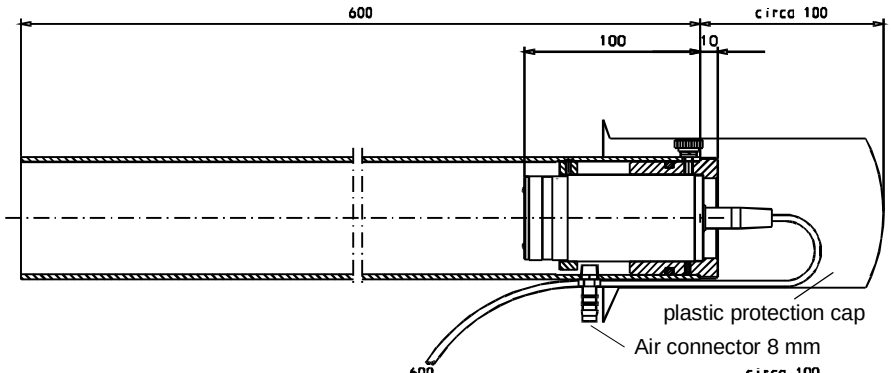


Note: The maximum possible ambient temperature is dependant on the temperature and flow rate of the cooling water. All maximum temperatures stated are for reference and need to be verified according to the specific conditions. Ensure that the cooling water is at the correct temperature at all times. If the cooling water is too cold, condensation can build up inside the device, which will prevent proper functioning of the pyrometer. When using the pyrometer in very low ambient temperatures, proper operation can be achieved by using heated throughput water.

Note on air purge: The required airflow rate is approximately 25 - 30 l/min (1.5 - 1.8 m³/h) at approx. 0.2 - 0.5 bar. Please use clean, dry air (oil and dust free) only!

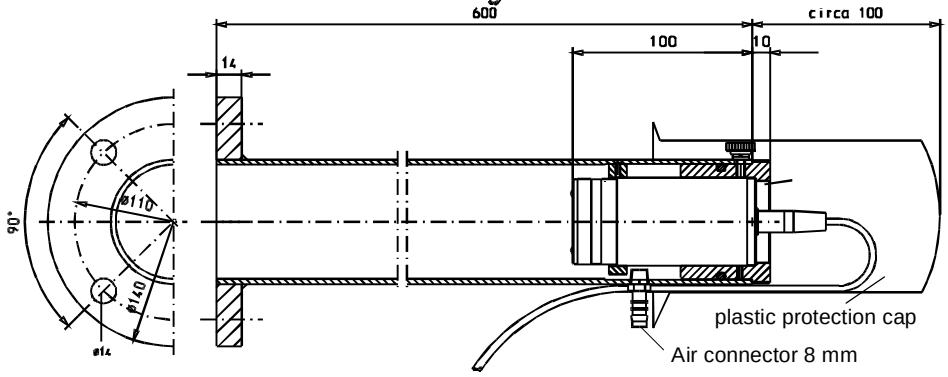
7.5. Mounting tube

The *mounting tube* protects the lens of the pyrometer from dirt. There is also an 8 mm diameter connector.



7.6. Flange tube

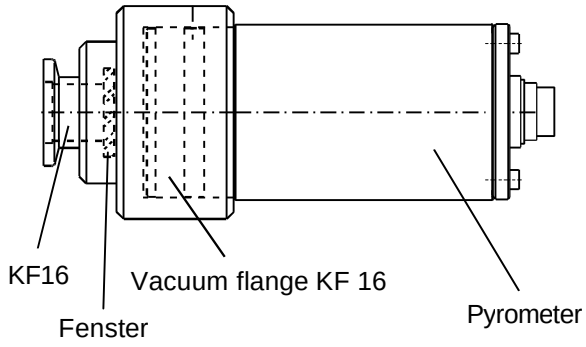
The flange tube is a mounting tube with a weldable flange.



Note on mounting tube: The air volume required for the mounting tube is approximately 50 - 60 l/min (3.0 - 3.6 m³/h) at approx. 0.4 - 1 bar.

7.7. Vacuum flange

The vacuum flange separates the pyrometer from the process area. The pyrometer can be easily removed, without an interruption to the process (furnace or vacuum).
The decrease in radiation, due to the window's transmission, can be compensated by reducing the emissivity setting by the appropriate factor.



Window material:

- IN5:
  ZnSe
  Transmission:
  71 %
- IN 5/5:
  CaF_2
  Transmission:
  94 %

7.8. Avoiding reading errors caused by faulty assembly

To avoid reading errors, please note the following points when mounting the pyrometer:

1. The diameter of the measuring object cannot be smaller than the pyrometer's *spot size* (see **3. Optics**).
2. A source of radiation behind or around the measuring object can influence the result. If the object is transparent or partly transparent another material behind the object could transmit its radiation to the pyrometer as well. In this case the location of the pyrometer should be changed, or, if the background radiation remains constant it can be compensated for by changing the emissivity setting respectively.
3. Please take into account that radiation from other hot parts around the measured object can be reflected by it and influence the result. If the measured object has a low emissivity, the temperature measured will be mainly that of the reflected object not from the intended measured object itself. To prevent environmental radiation from reaching the spot area, a mounting tube should be used. The mounting tube should be placed as near as possible to the measured object so that the tube's shadow blocks out all the environmental radiation.

8. Order numbers for IN 5 or IN 5/5 instruments incl. optics

Order numbers IN 5 8 to 14 µm	Messbereich
3 869 010	0 to 100 °C
3 869 020	0 to 200 °C
3 869 030	0 to 300 °C
3 869 040	0 to 400 °C
3 869 050	0 to 500 °C
3 869 090	0 to 900 °C
3 869 100	- 32 to + 50 °C

Order numbers IN 5/5 5.14 µm	Messbereich
3 869 110	100 to 600 °C
3 869 120	200 to 800 °C
3 869 130	100 to 1300 °C
3 869 140	400 to 2500 °C

Custom ranges available upon on request.

The *optics* must be specified when ordering
IN 5: a = 100, 300 or 800 mm;
IN 5/5: a = 100, 300 or 1200 mm

Note: The length of the measuring area does not affect the accuracy of the pyrometer, but does affect the resolution of the analog output (2880 steps for the range 4 - 20 mA).

8.1. Ordering example for IN 5

3 869 040	IN 5, Temperature range 0 to 400 °C Optics a = 300 mm
3 820 560	Connecting cable 5 m length

8.2. Accessories

8.2.1. Mechanical accessories:

Order No.:	Accessory:
3 834 210	Mounting bracket (adjustable)
3 835 160	Air purge
Water cooling system (combination):	
3 837 080	Standard water cooling jacket for ambient temperatures up to 170 °C
3 846 100	Mounting tube
3 835 080	Mounting angle
3 835 070	Connecting flange
3 835 160	Air purge
3 835 090	mounting socket
3 835 110	Rear wall for cooling jacket
3 837 230	Water cooling jacket (heavy duty) with integrated air purge for ambient temperatures up to 280 °C
3 846 120	Flange tube
3 846 620	Vacuum flange KF16 with CaF_2–window for IN 5/5
3 846 630	Vacuum flange KF16 with ZnSe-window for IN 5
3 846 650	Spare window CaF_2 Ø 25x3 with Viton-O-ring
3 846 660	Spare window ZnSe Ø 25x3 with Viton-O-ring

8.2.2. Electrical Accessories:

Order No.:	Accessory:
3 820 210	Connection cable 2 m long
3 820 560	Connection cable 5 m long
3 820 570	Connection cable 10 m long
3 820 580	Connection cable 15 m long
3 820 590	Connection cable 30 m long
3 820 280	Connection cable 2 m long, temperature resistant up to 200 °C, (Silicone)
3 890 600	Power supply for DIN rail mounting (230 V AC into 24 V DC)
3 890 960	Power supply for DIN rail mounting (115 V AC into 24 V DC)
3 890 610	Galvanic separator for DIN rail mounting (no extra power supply necessary)
3 890 640	DA 4000-N: LED-Digital display with integrated 2 wire supply
3 890 650	DA 4000: like DA 4000-N, but additionally with 2 limit switches
3 890 520	DA 6000: analog input and 2 limit switches, RS 232-interface
3 890 530	DA 6000: analog input and 2 limit switches, RS 485-interface
3 890 660	IP 65-front cover for LED digital display
3 863 010	Converter IW 5-C (4 - 20 mA into 0 - 20 mA)

9. Further information

9.1. Maintenance

The pyrometer has no internal parts which have to be cleaned. The lens can be cleaned with compressed air which is dry and free of oil. If the lens requires more thorough cleaning, use a soft, dry cloth such as that used to clean camera objectives.

Caution: Do not clean or touch the lens with acidic or solvent liquids!

The Ge lens of the IN 5 has an anti-reflective coating which appears slightly colored.
Be extremely careful - this layer can easily be rubbed off - this will greatly affect the measuring results!

9.2. Packing instructions

To transport or store the instrument, please use the original box or a box padded with sufficient shock-absorbing material. For storage in humid areas or shipment overseas, the device should be placed in welded foil (ideally along with silicon gel) to protect it from humidity .

9.3. Warranty

All series 5 instruments from IMPAC Electronic GmbH have a warranty of two years from the invoice date. This warranty covers manufacturing defects and faults which arise during operation only if they are the result of defects caused by IMPAC Electronic GmbH. User-induced faults are not covered with this warranty.

9.4 Limit of Liability

IMPAC Electronic GmbH is not liable for any damages that arise from the use of any examples or processes mentioned in this manual.

9.4. Copyright

10. Glossary

Absolute zero	-273.15°C (-459.67 ºF), lowest possible natural temperature. No molecular activity occurs.
Absorption	Transfer of energy to a material by means of wave radiation or particle radiation. Reception of energy (light, heat), gases or liquids.
Air purge	Accessory to keep dust and dirt away from the optics
Aperture	Optical diameter of the stop of an objective
Black body	A body that absorbs all incoming radiation at all wavelengths and that emits the maximum possible radiation at all wavelengths for its temperature (has an emissivity value of 1 at all wavelengths)
Black body furnace	Radiates almost like an ideal black body. Needed for calibrating and testing infrared pyrometers
Calibration	Comparison of the pyrometer to international temperature standards and adjustment so that it measures accurately in accordance to the temperature standards
Certificate	Document on the conformity of the calibration accuracy
Contact thermometer	Temperature measuring device which measures an object's temperature by contact, for example thermocouples or resistance thermometers
Cooling jacket	Accessory for using the pyrometer at high ambient temperatures
Detector	Receptor for radiation. Changes heat radiation into an electrical signal
Emissivity	Ratio of the radiation emitted by a surface to that emitted by a *black body* at the same temperature
Infrared (IR)	Electromagnetic waves that are invisible and have longer wavelengths than red light in the visible spectrum. Wavelengths between 0.78 and 1000 µm.
Instrument temperature compensation	Automatic compensation for the temperature change of the pyrometer due to a change in the ambient temperature
Interface	RS 232, RS 485, digital output for communication between pyrometer and computer or bus
Lens tolerance	Production-determined spread of focal length and centering
Limit switches	Relays that switch at predefined temperatures. i.e. high/low alarm (located in the power supply or digital display)
Linearization	A function of the signal processing performed by the microprocessor in a pyrometer. Establishes the proportionality between the measured temperature and the output signal
Maximum measuring range limit	Upper limit of the measuring range (highest measurable temperature for the pyrometer)

Minimum measuring range limit	Lower limit of the measuring range (lowest measurable temperature for the pyrometer)
Measuring distance	Distance between the measured object and the lens of the pyrometer
Measuring uncertainty	Most probable deviation between displayed and true temperature
Objective	Optical system which consists of lenses or mirrors and which forms the object's image on the detector of the pyrometer
Pyrometer	Instrument for non-contact temperature measurement (radiation thermometer)
Rate of reflection	Ratio of reflected intensity to incident intensity
Reflection	Return of radiation rays at the border between two materials, may be directed or diffuse
Repeatability	The uncertainty with which a measured value may be reproduced under constant conditions (same instrument, same environmental conditions)
Soot	black carbon in powder form (residue of incomplete burning of organic substances) has very high emissivity
Spectral range	The wavelength range within the electromagnetic spectrum used by the pyrometer
Spectrometer	Measuring device which determines the radiation intensity in relation to the wavelength
Spot size	Area on the object from which the pyrometer receives the temperature radiation
Temperature	Corresponds to the average molecular velocity inside the material, measured in Kelvin, °Celsius or °Fahrenheit K = °C + 273.15 °C = 0.555 (°F - 32) °F = 1.8 °C + 32
Test certificate	Certificate stating the accuracy of a measuring device in relation to known standards
Wavelength	Property of electromagnetic waves, corresponding to the color of light for the visible part of the electromagnetic radiation
Window	Special glass plate, for protection of the pyrometer against hazardous materials, which allows the pyrometer to measure a process (through the window)

11. Subject index

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