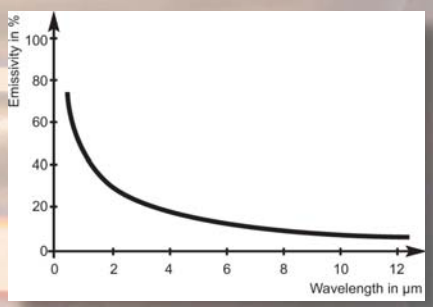
LUMASENSE TECHNOLOGIES

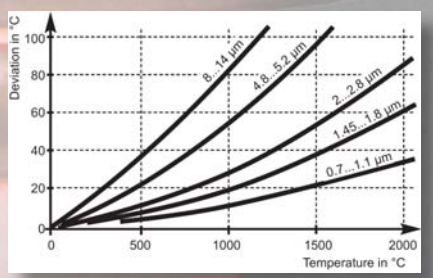
Application Note

Induction Hardening

Fixed IMPAC-pyrometer IS 140



Correlation between wavelength and emissivity for metals (Wien's law)



Measurement errors caused by incorrect selection of pyrometers. To demonstrate the temperature reading errors, the emissivity was incorrectly adjusted by 10%

The correct temperature is a critical factor in induction hardening. The resulting quality and durability of parts are influenced significantly by the temperature before quenching.

A good knowledge of all aspects of induction hardening helps avoid the above mentioned problem. The temperature measurement is easily handled by precise temperature measurement equipment and the use of pyrometers for non-contact temperature measurement has been proven to be successful for induction hardening applications.

Non-contact temperature measurement features the following advantages:

- Continuous monitoring of heating processes
- Continuous control of heating processes
- Fast temperature measurement
- Measurement of very small objects.
- Resistance to electromagnetic radiation interference
- Documentation of the measured values to monitor a defined quality standard.

For induction hardening, the capture of a temperature distribution of a larger area might be useful. This can be achieved by using a line camera or thermal imaging camera.

Principles of Pyrometry and Induction Hardening

In general, induction heating means hardening the surface of a part. Certain areas of a work piece are placed into an alternating electromagnetic field (induction coil). This results in the rapid heating of the metal part, typically to 900°C, followed by an immediate quenching process. The depth of penetration, consequently the thickness of the hardened layer, is determined by the power consumption and the frequency applied to the inductor.

Every body emits electromagnetic radiation (infrared radiation) in a broad spectral range. A pyrometer uses this emitted radiation to assess the temperature of this body. Every material, however, radiates individually. The standard of this specification is called emissivity.

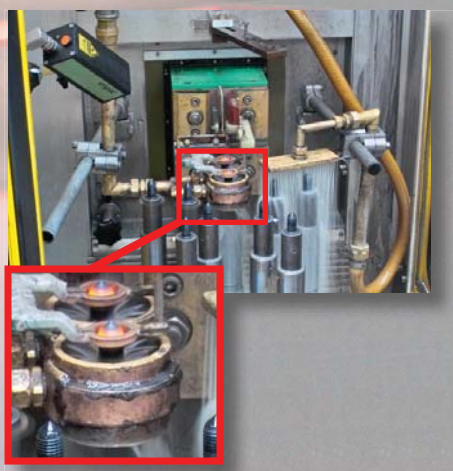
The emissivity of metal is dominant at short wavelengths and decreases at broad-band radiation. That is why metal should be measured by pyrometers working at short wavelengths. The graph to the left shows the typical correlation (Wien's law).

If this correlation is disregarded and the wrong type of pyrometer is used, the accuracy of the temperature measurement drops significantly.

The graph to the left shows five pyrometers detecting different wavelengths of the radiation emitted by a metal part. The pyrometer working at the shortest wavelength produces the smallest measurement errors.

The IS 5 (left) standard pyrometer with fixed optics and ISR 12-LO (right) ratio pyrometer with fiber-optic cable

The IS 5 (left) standard pyrometer with fixed optics and ISR 12-LO (right) ratio pyrometer with fiber-optic cable



Pusher feed hardening of a special screw

Selection of the Suitable Pyrometer

The choice of a suitable pyrometer depends on several aspects:

- The pyrometer should be applicable for metals
- The measurement range of the pyrometer should cover the temperature range of the hardening process
- The spot size of the pyrometer should match at least the size of the target
- The measurement distance to the target selects the correct optic of the pyrometer
- The response time of the pyrometer should match the process speed

Severe conditions motivate the use of so called ratio pyrometers or fiber-optic pyrometers.

Ratio-pyrometers are recommended for the following conditions:

- The spot size of the pyrometer is larger than the target
- The emissivity of the target changes during measurement
- The measurement is affected by ambient conditions e.g., airborne particles

Fiber-optic pyrometers feature a small, remote optical head, which is connected via a fiber-optic cable to the transducer.

The advantages of the fiber-optics are:

- Fiber-optics and fiber optic cable are non-sensitive to electromagnetic radiation
- The fiber-optic can be installed directly onto the inductor and moves along with the inductor in the process
- Fiber-optics can be used where the geometry does not allow standard sensors

Application: Classic Process of Hardening

In the classical process of hardening, neither the inductor nor the target are moved while heating. Consequently it is quite easy to measure the temperature with a fixed standard pyrometer.

The use of pyrometers is recommended for the following reasons:
To ensure the optimized hardening of the metal surface, the part has to be heated rapidly for a defined period of time to the correct temperature. The resulting quality and durability of parts is influenced significantly by the temperature before being quenched. For this application, IMPAC pyrometers IS5, IS12, IA140, IGA5, IGA12, and IGA140 are best suited.

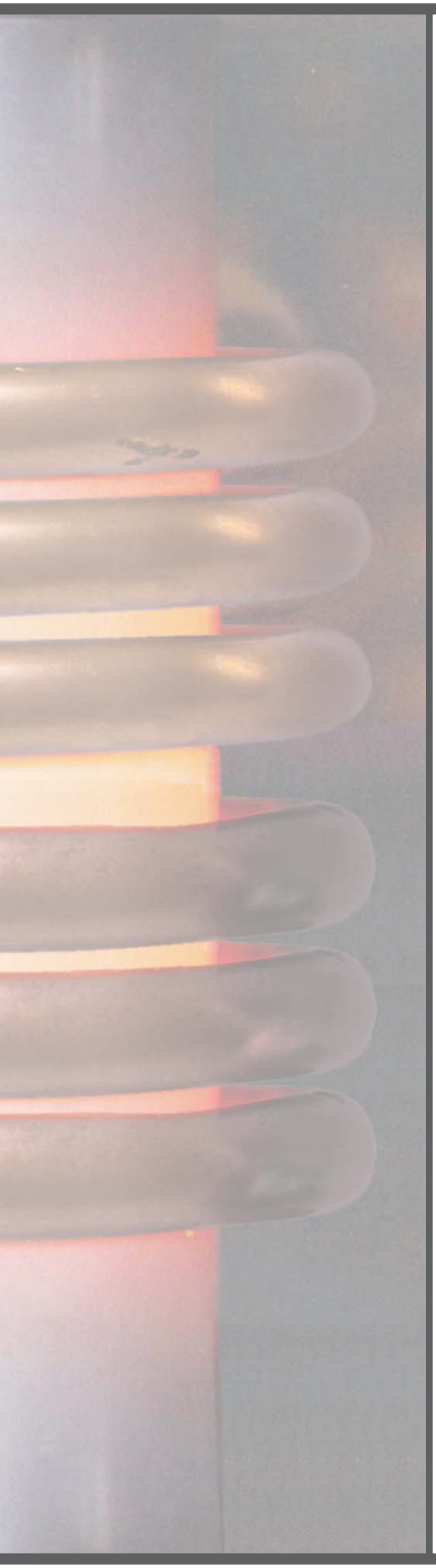
When dealing with adverse conditions, such as small targets, unfavorable atmospheres or electromagnetic fields, the ration pyrometers ISQ5, ISQ5-LO, ISR12-LO, and IGAR12-LO offer the best solutions. These are available with or without fiber-optics.

Application: Pusher Feed Hardening

In the pusher feed hardening process, the inductor and quenching equipment are moved along the metal part. For some heating processes, it is sufficient to measure the temperature of a metal part with a fixed pyrometer, such as IS5, IS12, IS, 140, IGA5, IGA12, or IGA140.

In this process the temperature is measured at one reference point of the metal part before the inductor hides it and disables the measurement. See the example image to the left.

If the temperature needs to be measured by moving along the target, the pyrometer can be mounted on the inductor. In most cases, a fiber-optic pyrometer



IA5-LO or IGA5-LO is used for this situation. The optical head is small, lightweight and easy to mount.

For applications where there are target size, emissivity and atmospheric obstruction problems, a ratio-pyrometer, such as IAQ5-LO, ISR12-LO, or IGAR12-LO, should be used.

Application: Tempering

Induction hardening can leave parts in a potentially brittle condition due to the high surface stresses caused by the rapid heating process. To remove these stresses, the parts go through a tempering process. This process requires the part to be heated to a lower temperature and then be allowed to cool naturally.

For accurate temperatures at these lower temperatures, the IMPAC IP140 pyrometer is recommended.

Advantages of IMPAC Pyrometers

IMPAC specializes in all areas of non-contact temperature measurement and provides system solutions, solutions for industries and specialized solutions.

IMPAC pyrometers excel in following aspects:

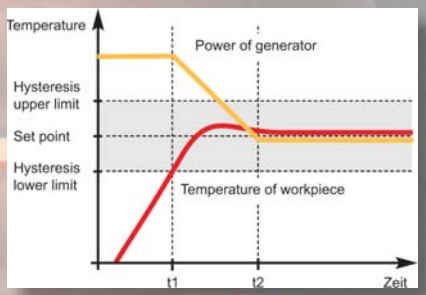
- Highest quality standards
- Fast response time (fast moving objects can be measured)
- Accurate measurements
- Broad measurement ranges
- Precise measurement with negative influences, e.g. water vapor or dust
- Full digital signal conditioning
- Ease of use
- Automatic process controls

For more than 50 years, our customer base has benefited from consistent high quality, reliability and the attractive price-value ratio of IMPAC pyrometers.

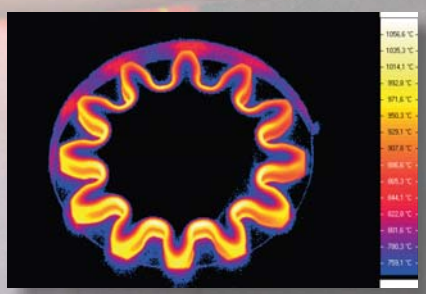
	Type	Temperature Range (°C)	Response Time (ms)	Min. Spot Size (mm)	Optics	Display
Standard Pyrometer	IS 5	650 to 3.0	2	0.5	fixed	-
	IS 5-LO	650 to 3.0	2	0.45	fiber optic	-
	IS 12	550 to 2.5	1	0.2	focusable	yes
	IS 140	550 to 3.3	1	0.35	focusable	-
	IGA 5	250 to 3.0	2	0.5	fixed	-
	IGA 5-LO	300 to 3.0	2	0.45	fiber optic	-
	IGA 12	300 to 1.8	1	0.2	focusable	yes
	IGA 140	250 to 2.5	1	0.35	focusable	-
	IP 140	50 to 1.3	1.5	0.25	focusable	-
Ratio Pyrometer	ISQ	600 to 3.0	10	1.5	fixed	-
	ISQ 5-LO	700 to 2.5	10	0.45	fiber optic	-
	ISR 12-LO	600 to 3.3	2	0.45	fiber optic	yes
	IGAR 12-LO	300 to 2.2	2	0.45	fiber optic	yes

IMPAC pyrometers represent cutting edge quality in technology and workmanship

DA 6000-C



Automatic temperature control using a proportional controller



Thermal image of a gear wheel

Special Solution: Automatic Process Control

Of great importance for induction heat treating is the extremely short time it takes to get a metal part to the target temperature and to hold it constant. To control heating processes very quickly, controllers as well as pyrometers are required.

In order to meet this challenge, IMPAC has designed the DA 6000-C digital indicator with a high speed proportional controller for temperature control.

The DA 6000-C analyzes the measured data of the pyrometer and controls the heating process. The proportional controller provides a very fast cycle time of 1ms and is ideally suited for induction heating applications.

The graph to the left shows how this p-controller works. The desired set point and the width of the control span (hysteresis) is adjustable using the parameters of the DA 6000-C. Moreover, the power of the generator can be controlled.

Special Solution: Line-Cameras and Thermal-imaging

Besides single point measurement by pyrometers, IMPAC also offers the measurement of temperature distribution in parts using portable thermal imagers.

Possible applications include:

- Optimization of the magnetic field of an inductor by logging the temperature data of a target.
- Optimization of temperature gradients, e.g. of a gear wheel between the tooth tip and tooth base
- Detection of the optimal spot for a single point measurement by pyrometers
- Logging of image sequences at high speed, e.g, 60Hz, for later analysis of individual frames (pictures)
- The ability to check if targets which have been heated up in parallel show identical temperature patterns

Special Solution: Software

IMPAC offers software for visualization, data logging and analysis for various products.

- **InfraWin:** the standard software shipped with all digital pyrometers from IMPAC. Additionally, all IMPAC pyrometers utilise the Universal Pyrometer Protocol (UPP). This enables seamless integration of pyrometers into existing user software.
- **MultiTemp:** software for combining the data-logging of several pyrometers. Temperatures are visualized, logged and can be analyzed from a central computer. All parameters of all attached pyrometers are adjustable.

IMPAC can also supply software solutions to meet individual customer-specific software requests.

Individual Application Solutions

IMPAC's experienced staff will answer any questions and provide individual solutions based on our technologies.

Additional information, including product datasheets, application brochures, news, etc., can be found on our website or obtained by contacting a LumaSense sales representative.

LumaSense Technologies

Americas and Australia
Sales & Service
Santa Clara, CA
Oakland, NJ
Ph: +1 800 631 0176
Fax: +1 408 727 1677

Europe, Middle East, Africa, Asia Sales & Service
Frankfurt, Germany

Ph: +49 69 97373 0
Fax: +49 69 97373 167

India
Sales & Support Center
Mumbai, India

Ph: +91 22 67419203
Fax: +91 22 67419201

China
Sales & Support Center
Shanghai, China

Ph: +86 20 3468 3518
Fax: +86 20 3468 3566

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