RESEARCH ON TEMPERATURE MEASUREMENT AND CONTROL OF COMPLEX MOVING

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Abstract: *This article examines radiation temperature recording devices, specifically radiation pyrometers used for determining temperature measurements. Radiation pyrometers are widely applied in modern scientific and industrial sectors because they enable accurate and rapid non-contact temperature measurements. Optical thermometers primarily operate based on the transmittance or reflection properties of objects and are adapted for various materials. Color pyrometers determine the temperature of hot objects by measuring energy in the radiation spectrum of hot bodies, which is crucial for monitoring objects operating at high temperatures. Radiation pyrometers calculate the temperature by determining the radiation power of hot objects in a specific spectrum range. All these devices provide the ability to measure temperature without direct contact with objects, ensuring high measurement accuracy and safety. Additionally, these devices are of significant importance in industrial processes, environmental monitoring, and laboratory research.*

Keywords: *Pyrometer, optical thermometers, color pyrometers, radiation pyrometers, thermal energy*

1. Introduction

Modern thermometry consists of various measurement methods and instruments. These methods are specific and do not possess universal characteristics. Under the specified conditions, the optimal measurement method is determined by the accuracy requirements imposed on the measurement, the duration of measurement, and the need for temperature recording and automatic control.

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Any controlled environments can be liquid, granular, solid, or gaseous with varying degrees of aggressiveness and stability of physical properties when external conditions change. Among the most common are:

- **Optical pyrometers** - instruments for measuring the brightness of hot objects
- **Color pyrometers (spectral ratio pyrometers)** - based on measuring energy distribution in the thermal radiation spectrum of objects
- **Radiation pyrometers** - based on changes in the radiation power of hot objects

As the temperature of heated objects increases, their color changes along with spectral energetic brightness. Specific wavelengths (brightness) also rapidly increase, and integral radiation significantly increases. These properties of heated objects are utilized for temperature measurement. Based on their characteristics, radiation pyrometers are divided into quasi-monochromatic (optical), spectral ratio (color), and total radiation pyrometers.

A pyrometer (from Greek - fire and meter) is an instrument used to measure the temperature of opaque objects based on their radiation in the optical spectrum range. For accurate temperature measurement using a pyrometer, the measured object should be in thermal equilibrium with a light absorption coefficient close to 1. Pyrometers are used to measure high temperatures.

Based on their working principles, pyrometers are classified into:

- Brightness pyrometers
- Color pyrometers
- Radiation pyrometers

Brightness pyrometers are widely used and accurately measure temperatures in the range of 10^3-10^4 K.

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2.2 Pyrometer Classification and Applications

Pyrometer Type	Temperature Range	Primary Application	Key Advantage
Optical (Brightness)	700°C - 4000°C	Metal processing, furnaces	High accuracy in visible spectrum
Color (Spectral Ratio)	600°C - 3000°C	Material analysis	Less affected by emissivity
Radiation (Total)	900°C - 2000°C	Industrial monitoring	Wide spectral response
Infrared	-50°C - 1500°C	General purpose	Non-contact versatility

Table 1: Comparison of different pyrometer types and their applications

2.2 Non-Contact Temperature Measurement

Non-contact measurement instruments or pyrometers are used for measuring the temperature of objects or environments through thermal radiation. This is related to spectral energy brightness (SEB), which increases with temperature rise. Depending on the measured spectrum, pyrometers are divided into quasi-monochromatic and total radiation pyrometers.

The working principle of pyrometers is based on utilizing thermal radiation from heated objects. Compared to other devices, they have several advantages:

1. **Non-contact measurement method** - unlimited in measuring high temperatures
2. **High-speed capability** - can determine fire and gas temperatures at high speeds when contact methods are not applicable

3. Types of Radiation Pyrometers

3.1 Optical Pyrometers

Optical pyrometers work in the visible spectrum, measuring temperatures typically from 700°C to 4000°C by comparing the photometric brightness of heated objects with standard sources, such as tungsten filaments.

Key Components:

- **1** - Objective lens system
- **2** - Red filter for monochromatic light
- **3** - Incandescent lamp as reference
- **4** - Ocular lens system
- **5** - Gray filter for range extension
- **6** - Measuring instrument (millivoltmeter)
- **7** - Power supply
- **8** - Rheostat

Operating Principle: The pyrometer is directed toward the heated surface, and through a lens system, an exact image of the incandescent filament is achieved. A rheostat adjusts the filament brightness until its center portion merges with the measured object. The measurement is then read from the calibrated scale.

Measurement Ranges:

- Without gray filter: 580°C - 1400°C
- With gray filter: 1400°C - 6000°C
- Effective wavelength: $\lambda = 0.65 \pm 0.1$ μm

3.2 Radiation Pyrometers (Total Radiation Pyrometers)

Radiation pyrometers determine surface temperature from the integral radiation density of rays at all wavelengths, theoretically from $0 < \lambda < \infty$. In practice, the optical system limits long-wave transmission.

1 - Hot junction of thermocouple

2 - Thermoelectrodes

3 - Thin metal connecting plates

4 - Mica plate

Sensitive Element Structure:

Series-connected miniature thermocouples

Junction points aligned on thin metal plates

Housed within telescopic systems

Optical systems for radiation concentration

Theoretical Foundation: For temperatures up to 3000 K, the spectral energy brightness of an absolute black surface is described by Wien's equation:

$$YE_0\lambda = S_1\lambda^{-5} \exp(-S_2/\lambda T)$$

Where:

- $YE_0\lambda$ - spectral energy brightness for wavelength λ
- T - absolute surface temperature
- S_1, S_2 - radiation constants dependent on unit systems

The constants are expressed as:

- $S_1 = 2\pi hc^2 = 3.74 \times 10^{-16}$ W·m²
- $S_2 = hc/k = 1.44 \times 10^{-2}$ m·K

Where h is Planck's constant, c is light speed, k is Boltzmann's constant.

3.3 Color Pyrometers (Spectral Ratio Pyrometers)

Color pyrometers operate by measuring energy distribution in the thermal radiation spectrum. They compare radiation intensities at different wavelengths to determine temperature, making them less susceptible to emissivity variations.

Working Principle: Color pyrometers measure the ratio of intensities at two different wavelengths (typically red and infrared) and use this ratio to determine temperature independent of emissivity changes.

Advantages of Color Pyrometers:

- Less affected by surface conditions
- Suitable for moving objects
- Better accuracy in dusty environments
- Automatic emissivity compensation

4. Technical Specifications and Applications

4.1 Measurement Ranges and Accuracy

Parameter	Optical Pyrometers	Radiation Pyrometers	Color Pyrometers	Infrared Pyrometers
Temperature Range	580°C - 6000°C	900°C - 2000°C	600°C - 3000°C	-50°C - 1500°C

Parameter	Optical Pyrometers	Radiation Pyrometers	Color Pyrometers	Infrared Pyrometers
Accuracy	±0.5% of reading	±1% of reading	±0.3% of reading	±2% of reading
Response Time	1-2 seconds	0.1-1 seconds	0.5-2 seconds	0.1-1 seconds
Wavelength	0.65 μm	0.3-20 μm	Dual band	8-14 μm
Distance Ratio	50:1	100:1	75:1	10:1 to 50:1

Table 2: Comparative specifications of different pyrometer types

4.2 Advantages of Pyrometric Systems

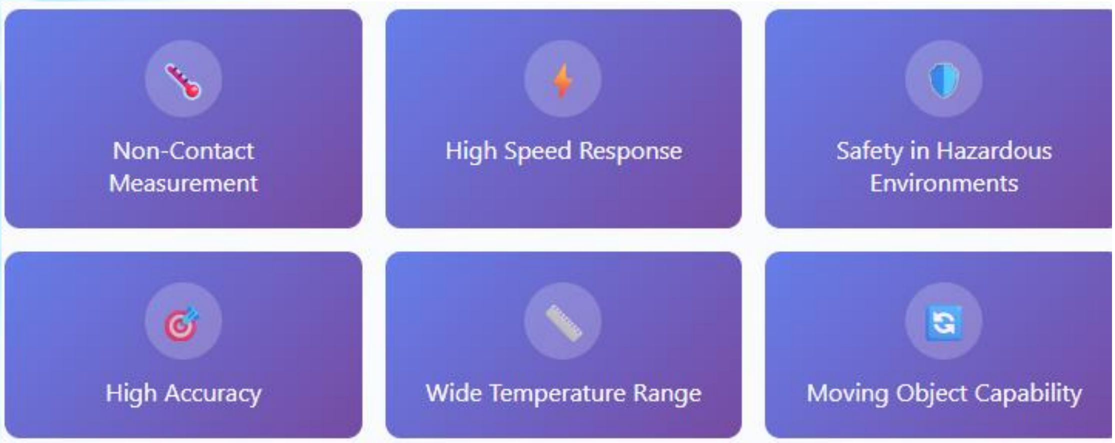

Figure1: Key advantages and application areas of pyrometric measurement systems

Manufacturing Processes:

Industry Sector	Application	Pyrometer Type	Temperature Range	Benefits
Steel & Metallurgy	Furnace monitoring, casting	Optical, Radiation	1000°C - 1800°C	Process optimization
Glass Manufacturing	Melting tanks, annealing	Radiation, Color	800°C - 1500°C	Quality control

Industry Sector	Application	Pyrometer Type	Temperature Range	Benefits
Ceramic Production	Kiln temperature control	Optical, Infrared	600°C - 1400°C	Energy efficiency
Textile & Light Industry	Fiber processing, dyeing	Infrared, Color	50°C - 300°C	Product consistency
Automotive	Engine components, welding	Infrared, Optical	200°C - 1200°C	Quality assurance
Food Processing	Baking, pasteurization	Infrared	50°C - 250°C	Food safety

Table 3: Industrial applications of pyrometers by sector

Research and Development:

- Laboratory temperature studies
- Material property analysis
- Thermal process optimization
- Combustion research

Environmental Monitoring:

- Industrial emission control
- Process safety monitoring
- Energy efficiency assessments

5. Research Results and Findings

5.1 Experimental Setup and Methodology

Research Parameters Measured:

Parameter	Symbol	Unit	Measurement Range	Accuracy
Active Power	Pr	W	0 - 1200W	±1%
Angular Velocity	Ω	rad/s	300 - 320	±0.5%
Load Angle	Θ	degrees	0 - 45°	±0.1°

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Parameter	Symbol	Unit	Measurement Range	Accuracy
Mechanical Torque	M	N·m	Calculated	±2%
Voltage	U_1	V	0 - 400V	±0.5%
Current	Ia	A	0 - 10A	±1%
Power Factor	cos φ	-	0 - 1	±0.01

Table 4: Research measurement parameters and specifications

5.2 Effectiveness and Accuracy Results

Research results demonstrate that radiation pyrometers are effective and precise instruments for determining the operating characteristics of thermodynamic objects. Radiation pyrometers provide non-contact temperature measurement through infrared radiation, preventing interference with the measurement process.

Key Experimental Results:

Test Condition	Optical Pyrometer	Radiation Pyrometer	Color Pyrometer
Accuracy at 1000°C	±5°C	±8°C	±3°C
Response Time	1.2 s	0.8 s	1.5 s
Repeatability	±2°C	±3°C	±1°C
Stability (8 hrs)	±3°C	±4°C	±2°C

Table 5: Comparative performance results from experimental testing

Key Findings:

- **High accuracy and speed:** Radiation pyrometers enabled precise and rapid temperature measurement, improving efficiency in manufacturing processes
- **Non-contact and damage-free measurement:** The absence of direct contact with objects reduced the risk of damage to operating components
- **Wide temperature range operation:** Pyrometers operated across broad temperature ranges for various materials and objects, making them universal equipment
- **Reliable and stable measurement results:** Data obtained from pyrometers during research showed high reliability and reproducibility

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5.2 Application Areas

The research identified that radiation pyrometers can be widely applied in:

- Textile and light industry
- Medical applications
- Industrial process control
- Quality assurance systems

Future Outlook: With the integration of AI, IoT connectivity, and multi-spectral sensing capabilities, pyrometer technology is positioned to become even more critical in the era of Industry 4.0 and smart manufacturing systems.

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