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Author(s): Cassingham, Nathan John

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Optical Pyrometer Temperature Measurements Through Different Atmospheres

Nathan Cassingham

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Introduction

- Quick intro into optical pyrometers and how they work.
- Scope of work and test setup for measuring temperature through different atmospheres.
- Results from temperature measurements
- Further work to be performed
- Conclusions

Basics of Optical Pyrometry

- Early optical pyrometers utilized a disappearing filament technique.
 - Thermal radiation from objects used to determine the temperature.
 - The hotter the object the shorter the wavelength.

Ancient Optical Pyrometer

Temperature, °C	Color
550	
630	
680	
740	
770	
800	
850	
900	
950	
1000	
1100	
1200	
1300	

Incandescent temperature scale

- Stefan-Boltzmann Law

$$F = \epsilon \sigma T^4$$

- F (Flux) = P (power)/ A (Area)
- ϵ = emissivity
- σ = constant = $5.67 \times 10^{-8} \text{ J}/(\text{s} \cdot \text{m}^2 \cdot \text{K}^4)$
- T Kelvin

One Color vs Two Color Optical Pyrometers

- Single Color (previous slide)
 - Dependent on object emissivity
 - Shorter wavelengths reduce the effect of emissivity errors for metals
 - Variety of pyrometers for specific applications
 - Often used for low temperature measurements
 - Measures the average temperature within the field of view (spot size)
 - Target must completely fill the field of view
 - Field of view is proportional to the distance to the target
 - Affected by obstructed windows or contaminated atmospheres
- Two Color
 - Independent of the emissivity of the target
 - Can measure the average, mean, or peak temperature within the field of view
 - Tolerates up to 95% blockage of the target
 - Unaffected by contaminants within the field of view (i.e. dirty windows)
 - Unaffected by moving targets within the field of view
 - Lowest temperature measurement is between 300-700 °C

Scope of Work: Devise Under Test

- Temperature measurements of a black body source through different atmospheres.
 - This system will measure temperature of a target through multiple medias.
 - Windows
 - Atmosphere
 - Optical Pyrometer will provide signal for temperature control of the system during production.

Verification of Optical Pyrometer Measurements

Comparing temperature output of two pyrometers

- Black Body Furnace ($\varepsilon = 99.5\%$)
- Atmosphere Chamber
- Verified calibration of the black body furnace with a certified Type B TC
- Old vs New pyrometer differences

Black Body Furnace Calibration

Furnace Temp (°C)	Type B TC (°C)	Type B TC (mV)	ΔT (°C)
750	766	2.9	16
800	816	3.27	16
850	864	3.66	14
900	917	4.1	17
950	969	4.55	19
1000	1021	5.02	21
1050	1073	5.52	23
1100	1124	6.01	24
1150	1175	6.53	25
1200	1225	7.05	25
1250	1275	7.58	25
1300	1327	8.14	27
1350	1378	8.71	28
1400	1429	9.28	29
1450	1480	9.87	30
1500	1532	10.47	32
1550	1582	11.05	32
1600	1635	11.59	35

Temperature differences between the black body furnace (BBF) set point and measured temperature with a calibrated type B thermocouple (TC).

- Correction factor for adjusting temperature of the BBF.

$$y = 1.0227x - 2.3922$$

Temperature Measurements Through Air

- Emissivity corrected temperature (T_e) measurements taken through air with no atmosphere chamber show a decrease in ΔT with an increase in temperature up to ~ 1325 °C. After which, there is a steady increase in ΔT .
- Region of interest for material processing is a temperature between 1300 °C and 1600 °C.

Avg. temp measurements through air (no chamber) of the black body furnace from 6 tests and associated difference in temperature to the corrected furnace.

Emissivity measurements for 9 measurements through air. The average of the 9 measurements at each temperature interval is the black circles and solid black line.

Temperature Measurements Through Different Atmospheres

Atmosphere-Chamber Filled with Air

- Emissivity measurements through different atmospheres show no significant differences between the atmospheres as measured through the atmosphere chamber.
- All measurements show an emissivity averaging ~86 for all measurements through the atmosphere chamber.

- Measurements show good agreement between the old and new pyrometers for measured temperatures within the region of interest.
- Difference between measured and corrected black body furnace (BBF) is much higher than measurements without an atmosphere-chamber.
 - Data suggests glass windows in the system will have a large effect on temperature measurements.

Emissivity with Atmosphere-Chamber

Temperature Measurements Continued

Glass of the atmosphere-chamber has a much larger effect on temperature measurements than the atmosphere itself.

Argon may have a slight effect on temperature measurements; however, the difference is not significant.

Old pyrometer measurements show good agreement to the new pyrometer.

Old pyrometer ΔT calculations show good agreement to the new pyrometer calculations within the region of interest (1300-1600 °C).

No significant differences between measurements of different atmospheres.

Pyrometer alignment and window composition appear to have more of an effect on temperature measurements than the atmosphere.

Next Steps

- Further testing of temperature measurements with glovebox laminated glass.
 - Yield information on how the laminated glass affects the temperature measurements compared to the different glass composition of the atmosphere-chamber window used on each end of the atmosphere-chamber in this study.
- Further testing using a fused quartz window vs the borosilicate glass window (this study) to determine how differences in glass composition effect temperature measurements.
 - Information gathered will provide a calibration offset if needed.

Conclusions

- Measurements taken with the atmosphere-chamber can be significantly affected by the alignment of the pyrometer and transparent media between the pyrometer and the target.
- The atmosphere within the atmosphere-chamber does not significantly affect the temperature measurements.
- Further testing will be performed to determine how the glass used in the production system affects temperature measurements.

Thank you for your time!

Any Questions?