To What Temperature Would 10 Lbm Of A Brass Specimen At 25C (77F) Be Raised If 65 Btu Of Heat Is Supplied?

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Understanding how heat affects the temperature of materials is fundamental in various engineering and scientific applications. When a specific amount of heat is supplied to a material like brass, predicting the resulting temperature change involves concepts from thermodynamics, specific heat capacity, and material properties. This article explores the detailed process of calculating the temperature increase of a brass specimen when a known quantity of heat is added, providing a comprehensive understanding suitable for students, engineers, and enthusiasts alike.

Fundamental Concepts in Heat Transfer and Material Properties

Before delving into calculations, it's essential to understand some key concepts:

Heat (Q)

- Defined as energy transferred between systems due to temperature difference.
- Measured in units like joules (J), calories (cal), or British thermal units (Btu).
- In this context, the heat supplied is 65 Btu.

Specific Heat Capacity (c)

- The amount of heat required to raise the temperature of a unit mass of a substance by 1°C (or 1K).
- Usually expressed in units of Btu/lbm·°F, J/kg·K, or cal/g·°C.
- For brass, the typical specific heat capacity at room temperature is approximately 0.380 Btu/lbm·°F.

Mass (m)

- The amount of material in consideration, measured in pounds mass (lbm) here.

- Given as 10 lbm in this problem.

Temperature Change (ΔT)

- The increase in temperature resulting from heat input.
- Calculated via the relationship involving heat, mass, and specific heat capacity.

Calculating the Temperature Rise of Brass Specimen

The fundamental formula linking these quantities is:

$$
Q = m \times c \times \Delta T
$$

Where:
- Q is the heat supplied,
- m is the mass,
- c is the specific heat capacity,
- ΔT is the temperature change.

Rearranged for ΔT:

$$
\Delta T = \frac{Q}{m \times c}
$$

Given data:
- $Q = 65\, \text{Btu}$
- $m = 10\, \text{lbm}$
- $c = 0.380\, \text{Btu/lbm·°F}$

Substituting:

$$
\Delta T = \frac{65\, \text{Btu}}{10\, \text{lbm} \times 0.380\, \text{Btu/lbm·°F}} = \frac{65}{3.8} \approx 17.11\, °F
$$

This calculation indicates that supplying 65 Btu of heat increases the temperature of the brass specimen by approximately 17.11°F.

Determining the Final Temperature

The initial temperature of the brass specimen is given as 25°C, which converts to Fahrenheit:

$$
T_{initial} = 25°C \times \frac{9}{5} + 32 = 77°F
$$

Adding the temperature change:

$$
T_{final} = T_{initial} + \Delta T = 77°F + 17.11°F \approx 94.11°F
$$

To express this in Celsius:

$$
T_{final} = (T_{final} - 32) \times \frac{5}{9} \approx (94.11 - 32) \times \frac{5}{9} \approx 62.11 \times \frac{5}{9} \approx 34.50°C
$$

Result: The brass specimen's temperature would rise from 25°C to approximately 34.5°C after receiving 65 Btu of heat.

Additional Considerations and Assumptions

While the calculation provides a straightforward estimate, several factors can influence the actual temperature change:

1. Uniform Temperature Distribution

- Assumes heat is evenly distributed throughout the specimen.
- In practice, thermal conductivity and geometry may cause temperature gradients.

2. Constant Specific Heat Capacity

- Assumes that the specific heat capacity remains constant over the temperature range.
- In reality, specific heat can vary slightly with temperature.

3. No Heat Losses

- The calculation neglects heat losses to the environment through conduction,

convection, or radiation.
- Actual temperature rise may be less if heat dissipates during transfer.

4. Material Homogeneity

- Assumes the brass specimen is homogeneous and isotropic.

Understanding Brass Properties for Accurate Calculations

Brass is an alloy primarily composed of copper and zinc, with properties that can vary depending on composition. Its thermal properties, including specific heat capacity, are well documented:

- Average Specific Heat Capacity: 0.380 Btu/lbm·°F
- Density: approximately 0.304 lbm/in³
- Thermal Conductivity: varies between 90-130 W/m·K, affecting heat transfer rates but not the static temperature calculation.

Knowing these properties enables engineers to design systems involving brass components more accurately, such as heat exchangers, cookware, or structural elements.

Practical Applications of This Calculation

Understanding the temperature change resulting from heat addition is vital in numerous practical scenarios:

- Manufacturing Processes: Heat treatment of brass components requires precise temperature control.
- Thermal Management: Designing systems where brass parts are exposed to heat sources.
- Material Testing: Evaluating how brass responds to thermal loads.
- Engineering Design: Ensuring safety margins by predicting temperature rises during operation.

Conclusion

In summary, when 65 Btu of heat is supplied to a 10 lbm brass specimen initially at 25°C (77°F), the temperature is expected to increase by approximately 17.11°F, raising the final temperature to about 94.11°F or roughly 34.5°C. This calculation hinges on the fundamental thermodynamic relationship between heat, mass, specific heat capacity, and temperature change. While idealized, such calculations are instrumental in engineering design, material science, and thermal management, providing crucial insights into how materials respond to thermal energy input.

Key Takeaways:

- The specific heat capacity of brass is approximately 0.380 Btu/lbm·°F.
- The temperature increase can be reliably estimated with the heat transfer formula.
- Real-world applications require considering heat losses and property variations for more precise predictions.

By understanding these principles, engineers and scientists can better predict material behavior under thermal loads, ensuring safety, efficiency, and longevity in their designs and processes.

Frequently Asked Questions

What is the temperature increase of a 10 lb brass specimen when 65 Btu of heat is supplied at 25°C?

The temperature increase can be calculated using the formula $\Delta T = Q / (m\ c)$. For brass, with a specific heat capacity of approximately 0.380 Btu/lb·°F, the temperature rise is $\Delta T = 65$ Btu / (10 lb 0.380 Btu/lb·°F) ≈ 17.11°F. Therefore, the final temperature is approximately 77°F + 17.11°F ≈ 94.11°F, or about 34.5°C.

How do you determine the final temperature of a brass specimen after heating with a known amount of heat?

You determine the temperature change using $\Delta T = Q / (m\ c)$, where Q is the heat supplied, m is the mass, and c is the specific heat capacity. Adding ΔT to the initial temperature gives the final temperature.

What is the initial temperature in Celsius and Fahrenheit of the brass specimen before heating?

The initial temperature is 25°C, which is equivalent to 77°F.

What is the specific heat capacity of brass used in this calculation?

The specific heat capacity of brass is approximately 0.380 Btu/lb·°F.

If the heat supplied is increased, how does that affect the final temperature of the brass specimen?

Increasing the amount of heat supplied will proportionally increase the temperature rise, resulting in a higher final temperature.

Can the temperature rise be calculated directly from the heat supplied and the initial conditions?

Yes, using the formula $\Delta T = Q / (m c)$, where Q is the heat supplied, m is the mass, and c is the specific heat capacity.

What units are used in calculating the temperature increase in this problem?

The heat is in Btu, the mass in pounds (lb), and the specific heat in Btu/lb·°F, leading to a temperature change in Fahrenheit degrees.

Is the temperature increase in Celsius or Fahrenheit in this calculation?

Since the specific heat is given in Btu/lb·°F and heat in Btu, the temperature change is calculated in Fahrenheit degrees; convert to Celsius if needed.

How would the calculation change if the initial temperature was given in Fahrenheit instead of Celsius?

The calculation remains the same, but ensure consistent units; the initial temperature in Fahrenheit would be used directly, and the temperature rise in Fahrenheit degrees added to find the final temperature.

What is the approximate final temperature of the brass specimen in Celsius after receiving 65 Btu of heat?

The temperature increases by approximately 17.11°F (about 9.5°C), so the final temperature is roughly 34.5°C.

Additional Resources

Understanding the Temperature Rise of Brass When Heated with a Given Quantity of Heat

When exploring the thermal response of materials, particularly metals like brass, it's essential to understand the relationship between the heat supplied, the material's properties, and the resulting temperature change. This analysis discusses the scenario: "To what temperature would 10 lbm of a brass specimen at 25°C (77°F) be raised if 65 Btu of heat is supplied?" This question involves principles of thermodynamics, specific heat capacity, and material properties.

In this comprehensive review, we'll delve into the fundamental concepts, step-by-step calculations, and practical considerations to understand how heat transfer affects the temperature of a brass specimen.

Fundamental Concepts of Heat Transfer and Material Properties

Before attempting any numerical calculation, it’s critical to understand the basic principles involved:

Heat and Its Units

- Heat (Q): The transfer of thermal energy from one system to another due to a temperature difference.
- Units of heat in this context:
- British thermal unit (Btu): The amount of heat required to raise the temperature of one pound of water by 1°F.
- Conversion note: 1 Btu ≈ 1055 joules (J).

Specific Heat Capacity

- Definition: The amount of heat required to raise the temperature of a unit mass of a substance by 1°C or 1°F.
- Units: Usually expressed as J/(kg·K) or Btu/(lbm·°F).

Mass and Material Composition

- The mass of the specimen influences the total heat needed for a specific temperature change.
- Brass is an alloy primarily composed of copper and zinc, with typical properties influencing its specific heat capacity.

Properties of Brass Relevant to Thermal Calculations

The properties of brass vary based on composition, but typical values are:

- Density: Approximately 8.4 g/cm³ (or 0.304 lb/in³).
- Specific Heat Capacity: Ranges from 0.380 to 0.460 J/(g·K). For calculation purposes, a typical value is:

- Specific heat (c): ~0.380 J/(g·K)

- In Btu units: approximately 0.092 Btu/(lbm·°F).

- Thermal Conductivity: About 100 W/(m·K), but less relevant in this static heat capacity calculation.

These properties enable us to determine how much heat is necessary to raise the temperature of the specimen by a certain amount.

Step-by-Step Calculation: Determining the Temperature Rise

The core of this problem involves applying the fundamental heat transfer equation:

$$
Q = m \times c \times \Delta T
$$

where:

- Q = heat supplied (in Btu),
- m = mass of the specimen (in lbm),
- c = specific heat capacity (in Btu/(lbm·°F)),
- ΔT = temperature change (in °F).

Rearranged to find the temperature change:

$$
\Delta T = \frac{Q}{m \times c}
$$

Converting Known Quantities

Given data:

- $Q = 65\, \text{Btu}$,
- $m = 10\, \text{lbm}$,
- $c \approx 0.092\, \text{Btu/(lbm·°F)}$.

Calculate:

$$
\Delta T = \frac{65\, \text{Btu}}{10\, \text{lbm} \times 0.092\, \text{Btu/(lbm·°F)}}
$$

Numerical Calculation

Performing the calculation:

$$
\Delta T = \frac{65}{10 \times 0.092} = \frac{65}{0.92} \approx 70.65\, °F
$$

This indicates that the specimen's temperature would increase by approximately 70.65°F.

Determining the Final Temperature

- Initial temperature: 25°C (77°F).
- Temperature increase: approximately 70.65°F.

Converting the initial temperature for clarity:

- Initial temperature: 25°C = 77°F.

Adding the temperature rise:

$$
T_{final} = T_{initial} + \Delta T = 77°F + 70.65°F \approx 147.65°F
$$

In Celsius:

$$
T_{final} = \frac{(147.65 - 32)}{1.8} \approx 64.25°C
$$

Final temperature: approximately 147.65°F or 64.25°C.

Practical Considerations and Assumptions

While the calculation appears straightforward, several real-world factors might influence the actual temperature change:

Uniform Heating Assumption

- The calculation assumes uniform heat distribution throughout the specimen.
- In practice, temperature gradients may develop, especially in larger or differently shaped objects.

Heat Losses

- The model neglects heat losses due to conduction, convection, or radiation.
- In real scenarios, some heat may dissipate to the surroundings, leading to a lower actual temperature increase.

Material Purity and Alloy Composition

- Variations in the alloy composition can slightly alter specific heat capacity.
- For precise calculations, the exact material composition should be considered.

Material State and Mechanical Constraints

- The temperature increase may cause thermal expansion, stress, or phase changes if the temperature reaches critical points.
- Brass has a melting point around 900°C (1652°F), so a temperature of about 147.65°F is well below melting, but other phase considerations might be relevant in specific contexts.

Additional Insights and Broader Context

To deepen understanding, it is useful to explore related concepts:

Heat Capacity and Specific Heat in Engineering

- The heat capacity of a material is proportional to its mass.
- The specific heat capacity is a material property, essential for designing heating or cooling processes.

Energy Efficiency and Safety

- Knowing how much heat is required to raise the temperature helps in optimizing energy use.
- Ensuring the specimen does not reach temperatures that could compromise its structural integrity or cause safety hazards.

Application in Manufacturing and Material Testing

- Precise temperature control is vital in processes like annealing, welding, or testing material properties.
- The calculation informs engineers about the energy requirements for thermal treatments.

Summary of Key Points

- Supplied heat: 65 Btu.
- Mass of brass: 10 lbm.
- Approximate specific heat capacity of brass: 0.092 Btu/(lbm·°F).
- Calculated temperature rise: approximately 70.65°F.
- Final temperature: approximately 147.65°F (64.25°C).

This calculation provides a practical and theoretical understanding of how heat impacts the temperature of a brass specimen.

Conclusion

Understanding the temperature increase of a brass specimen when heat is supplied involves a combination of thermodynamic principles, material properties, and practical considerations. By applying the basic heat transfer equation, we find that supplying 65 Btu to 10 lbm of brass initially at 25°C (77°F) results in a temperature rise of approximately 70.65°F, reaching a final temperature of roughly 147.65°F.

This insight is valuable in various engineering applications, from manufacturing processes to material testing, where precise thermal management is essential. While the calculation simplifies real-world complexities, it provides a solid foundation for further analysis and practical decision-making.

In essence, the key takeaway is the importance of knowing specific heat capacities and heat quantities to predict and control temperature changes in materials effectively.

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