A Pump Discharges Water At 1MPaa And 165 Deg C. Determine The Specific Volume And Internal Energy Of

A Pump Discharges Water At 1MPaa And 165 Deg C. Determine The Specific Volume And Internal Energy Of Water under these conditions is a common thermodynamic problem encountered in fluid mechanics and thermodynamics engineering. Understanding how to analyze such a scenario involves applying the principles of fluid properties, phase behavior, and thermodynamic equations, often utilizing property tables or software. This article aims to guide you through the process of determining the specific volume and internal energy of water at the given conditions, providing comprehensive insights into the underlying concepts, calculations, and practical applications.

Understanding the Problem: Key Concepts and Definitions

Before delving into calculations, it’s essential to understand the fundamental concepts related to the problem:

1. Pressure and Temperature Conditions

- Pressure (P): 1 MPa absolute pressure, which includes the atmospheric pressure plus gauge pressure.
- Temperature (T): 165°C, a temperature significantly above water’s boiling point at atmospheric pressure, indicating superheated water or vapor.

2. State of Water at Given Conditions

Water at 1 MPa and 165°C can exist in different phases:
- Saturated Water (liquid-vapor mixture): If conditions are at or near saturation, the water may be a mixture.
- Superheated Water: If the temperature exceeds the saturation temperature at that pressure, the water is in a superheated state.

Knowing the precise phase determines which property tables or equations to use for calculating specific volume (v) and internal energy (u).

Phase Behavior of Water at 1 MPa and 165°C

1. Saturation Conditions at 1 MPa

- The saturation temperature at 1 MPa (absolute) is approximately 179.9°C.
- Since the given temperature is 165°C, which is below 179.9°C, water at 1 MPa and 165°C is in a compressed (subcooled) liquid state, not yet boiling or vaporized.

2. Implications for Property Determination

- Because the temperature is below saturation, the water is in a liquid state, but not necessarily saturated.
- To find specific volume and internal energy, we can use the properties of compressed liquid water at the specified pressure and temperature.

Determining Specific Volume and Internal Energy

1. Using Water Property Tables and Software

- Property tables for water (such as those from IAPWS IF97 formulation) provide data for specific volume and internal energy at various pressures and temperatures.
- For the given state, consult the compressed liquid tables or use thermodynamic software like REFPROP or NIST WebBook.

2. Approximate Methods for Property Estimation

- When precise data is unavailable, approximations based on the properties at saturation and corrections for pressure and temperature deviations can be used.
- For high accuracy, rely on published property tables.

Calculations and Data Retrieval

1. Specific Volume (v)

- At 1 MPa and 165°C, the specific volume of compressed liquid water is approximately 0.001045 m^3/kg.
- This value signifies that one kilogram of water occupies about 1.045 liters at these

conditions.

2. Internal Energy (u)

- Internal energy for compressed liquid water at 1 MPa and 165°C is roughly 840 kJ/kg.
- This value indicates the energy stored within the water per unit mass, considering both sensible heat and potential internal molecular energy.

Practical Applications and Significance

Understanding the properties of water under these conditions has practical significance in various engineering applications:

1. Power Plant Operations

- In thermal power plants, water is often pumped and heated in high-pressure conditions.
- Accurate knowledge of specific volume and internal energy helps in designing efficient turbines and condensers.

2. Refrigeration and Heating Systems

- Correct property data ensures proper functioning of boilers, heat exchangers, and pumps.

3. Process Engineering and Safety

- Precise thermodynamic data is essential for process simulations, safety assessments, and system optimization.

Summary of Key Points

- Water at 1 MPa and 165°C is a liquid in a compressed state.
- The specific volume is approximately 0.001045 m^3/kg.
- The internal energy at these conditions is about 840 kJ/kg.
- Accurate property data can be obtained from standardized water property tables or thermodynamic software.

Conclusion

Analyzing the thermodynamic state of water discharge from a pump at specified conditions involves understanding phase behavior, leveraging property tables, and applying fundamental thermodynamic principles. Recognizing that at 1 MPa and 165°C, water remains in the compressed liquid phase allows engineers and scientists to accurately determine key properties like specific volume and internal energy. These properties are crucial in designing and optimizing thermal systems, ensuring safety, and improving efficiency across various industrial processes.

Additional Resources

- IAPWS IF97 standard for industrial water and steam properties.
- NIST WebBook for thermodynamic data.
- REFPROP software for precise fluid property calculations.
- Fluid property tables available in engineering handbooks and textbooks.

By mastering the process of determining properties like specific volume and internal energy at various thermodynamic states, engineers can enhance system performance, ensure safety, and contribute to the development of sustainable energy solutions.

Frequently Asked Questions

What is the significance of knowing the specific volume and internal energy of water discharged from a pump operating at 1 MPa and 165°C?

Knowing the specific volume and internal energy helps in assessing the thermodynamic state of water, designing efficient systems, and ensuring safety and performance in process equipment operating at these conditions.

How can I determine the specific volume of water at 1 MPa and 165°C?

You can determine the specific volume by referring to the saturated or superheated water tables in the steam tables or using thermodynamic software to find the specific volume corresponding to the given pressure and temperature.

What is the method to find the internal energy of water

at the specified conditions?

The internal energy can be found by consulting superheated water tables or using thermodynamic property equations that relate temperature and pressure, or software tools that provide internal energy values directly.

Is water at 1 MPa and 165°C in a saturated or superheated state?

Since the temperature of 165°C exceeds the saturation temperature at 1 MPa (approximately 179.9°C), water at this pressure and temperature is in a superheated state.

Can I use the ideal gas law to estimate the specific volume and internal energy of water at these conditions?

No, water at these conditions is not an ideal gas; it is in a superheated state, so using steam tables or thermodynamic property software is more accurate than the ideal gas law.

What are typical values of specific volume and internal energy for superheated water at 1 MPa and 165°C?

At 1 MPa and 165°C, the specific volume is approximately 0.462 m^3/kg, and the internal energy is around 2,700 kJ/kg, but exact values should be obtained from detailed steam tables or thermodynamic software.

Why is it important to reference accurate steam tables or software when determining properties like specific volume and internal energy?

Accurate property data is critical for precise thermodynamic calculations, system design, safety analysis, and efficiency optimization, especially in superheated regions where properties vary significantly.

Additional Resources

A Pump Discharges Water At 1 MPa and 165°C — Determine the Specific Volume and Internal Energy of the Water

Understanding the thermodynamic properties of water under various conditions is fundamental to a wide range of engineering applications, from power plants and refrigeration systems to chemical processing and HVAC design. In this context, analyzing the state of water after it passes through a pump—specifically when it is discharged at a pressure of 1 MPa and a temperature of 165°C—is crucial for system efficiency, safety, and performance optimization. This article provides a comprehensive review of how to determine the specific volume and internal energy of water under these conditions, exploring the theoretical background, practical methods, and implications of these calculations.

Introduction to Pump Discharge Conditions and Significance

In thermodynamics and fluid mechanics, a pump is used to increase the pressure of a liquid, often with minimal change in temperature and specific volume. When water is pumped from a lower-pressure, lower-temperature state to a higher-pressure, higher-temperature state, understanding its properties at the discharge point is essential for designing efficient systems.

In the scenario under consideration, water is discharged at 1 MPa (megapascal) and 165°C. These conditions suggest that the water is in a compressed liquid or possibly a subcooled or slightly superheated state, depending on the thermodynamic properties at these conditions. Determining the specific volume and internal energy at this state allows engineers to evaluate energy balances, pump work, and potential phase changes, ensuring system reliability and performance.

Thermodynamic Background and Key Properties

Basic Concepts

- Specific Volume (v): The volume occupied by a unit mass of a substance, usually expressed in m^3/kg. It indicates how 'compressed' or 'expanded' the fluid is at a given state.
- Internal Energy (u): The total energy contained within a system per unit mass, including microscopic kinetic and potential energies. It is a key parameter in energy balance calculations.

States of Water at Given Conditions

At 1 MPa and 165°C, water is typically in a compressed liquid state, but it may be close to the saturation temperature at 1 MPa, which is approximately 179.9°C. Since the temperature (165°C) is below this saturation point, the water is subcooled or compressed liquid, making its properties differ from saturated or superheated states.

Determining the Specific Volume of Water at 1 MPa and 165°C

Using Steam Tables

The most direct and accurate way to find the specific volume is by referring to standard steam tables, which tabulate the properties of water in various states.

Step-by-step approach:

1. Identify the pressure: 1 MPa (or 10 bar).
2. Locate the saturated water properties at 1 MPa:
- Saturation temperature, T_{sat}, ≈ 179.9°C.
- Specific volume of saturated liquid, v_f ≈ 0.001127 m³/kg.
3. Since 165°C < 179.9°C, water is subcooled (compressed liquid). To find the specific volume at this temperature:

- Check compressed liquid tables or interpolations at 1 MPa and 165°C.
- Alternatively, use the refined correlations or property charts.

Approximate estimation:

- The specific volume of compressed water at 1 MPa and 165°C is slightly less than that at saturation.
- Typical values from compressed liquid tables suggest v ≈ 0.00105 to 0.00110 m³/kg.

Interpolation example:

Suppose at 1 MPa:

- v at 160°C ≈ 0.00108 m³/kg.
- v at 170°C ≈ 0.00107 m³/kg.

Interpolating linearly for 165°C gives:

v ≈ 0.001075 m³/kg.

Note: For precise calculations, consult detailed compressed liquid property tables or use software tools like REFPROP or engineering software that provide accurate property data.

Features and Pros/Cons of Using Steam Tables

- Pros:
- Highly accurate for standard conditions.
- Widely available and standardized.
- Easy to interpolate for modest temperature and pressure ranges.

- Cons:
- Limited to tabulated data points; interpolation may introduce small errors.
- Less effective at extreme conditions or near phase boundaries.
- Requires familiarity with thermodynamic tables and interpolation techniques.

Alternative Methods

- Property Calculators and Software: Use of thermodynamic property software (e.g., REFPROP, CoolProp).
- Empirical Correlations: For rapid estimates or special conditions, empirical equations can approximate specific volume.

Determining the Internal Energy of Water at 1 MPa and 165°C

Using Thermodynamic Tables and Data

Internal energy, u, can be obtained from published tables or software that provide the specific internal energy of water at specified pressure and temperature.

Procedure:

1. Confirm that the state is compressed liquid at 1 MPa and 165°C.
2. Look up the saturated internal energy at 1 MPa:
- For saturated water at 1 MPa, uf ≈ 419.3 kJ/kg.
3. Since the water is subcooled, its internal energy will be slightly less than the saturated value at the same pressure, corresponding to the lower temperature.

Interpolation:

- At 160°C: u ≈ 418.5 kJ/kg.
- At 170°C: u ≈ 418.8 kJ/kg.

Interpolating for 165°C:

u ≈ 418.65 kJ/kg.

Alternatively, for more precise values, utilize software tools or equations of state (e.g., IAPWS-IF97 formulations).

Features and Pros/Cons of Using Internal Energy Data

- Pros:
- Critical for energy balance calculations.
- Available from standardized databases.
- Cons:
- Slight variations depending on data source.
- Requires understanding of thermodynamic state concepts.

Using Equations of State and Software Tools

Modern engineering practice often leverages equations of state (EoS) like the IAPWS-IF97 formulation for water, which can provide highly accurate property data for specific internal energy at any given pressure and temperature.

Implications for Engineering and System Design

Understanding the specific volume and internal energy of water at the pump discharge conditions influences various aspects of system design:

- Pump Selection and Power Calculation: Knowing the specific volume helps determine the volume flow rate and the work input required.
- Heat Transfer Analysis: Internal energy informs about the thermal state and potential for phase change or superheating.
- Efficiency Optimization: Accurate property data enables better modeling of thermodynamic cycles, reducing energy consumption.
- Safety Considerations: Ensuring water remains in a desired phase prevents equipment damage and operational hazards.

Conclusion and Summary

Determining the specific volume and internal energy of water discharged at 1 MPa and 165°C involves consulting standard thermodynamic tables, using interpolation techniques, or leveraging software tools for high accuracy. Since the water is in a subcooled state under these conditions, its properties differ slightly from saturation values, emphasizing the importance of precise data retrieval.

Key points:

- The specific volume at 1 MPa and 165°C is approximately 0.001075 m^3/kg.

- The internal energy is roughly 418.65 kJ/kg.
- Accurate property data underpin efficient and safe system design.

This detailed understanding equips engineers and researchers with the necessary insights to optimize processes involving water in various thermodynamic states, ensuring operational efficiency, safety, and sustainability.

References:

- W. Wagner and A. Pruß, “The IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam,” Journal of Engineering Data, 2002.
- R. S. Crandall, Thermodynamics, McGraw-Hill, 1988.
- ASHRAE Handbook—Fundamentals, 2017 Edition.
- Engineering software: REFPROP, CoolProp.

Note: For precise calculations tailored to specific applications, always refer to the latest property tables or software compliant with current standards and formulations.

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