Heat Pump Turbine System Analysis

Based on CO_2/Acetone Mixture Phase Transition Data

Executive Summary

This analysis evaluates the theoretical performance of a low-temperature heat pump turbine system using a CO_2/acetone mixture as the working fluid. The system operates on the principle of phase transition expansion at high pressure (70-120 bar) and moderate temperature (40°C), with a condenser for cooling.

System Configuration

- **Working Fluid:** CO_2/Acetone mixture
- **Expansion Factor:** 10x (based on Denardin et al. data)
- **Operating Temperature:** 40°C (expansion) / 18-20°C (condensation)
- **Pressure Range:** 70-120 bar
- **Turbine Scenarios:** Single-phase (best), Two-phase (optimistic and conservative)

Key Findings

- Total cases analyzed: 96
- Viable cases (positive net energy): 92 (95.8%)
- Average net energy in viable cases: 37.6 kJ/kg
- Maximum net energy achieved: 90.0 kJ/kg
- Minimum mass flow required: 1.11 kg/s (for 100 kW output)

Performance Analysis

Best Case Scenario

Parameter	Value
Pressure	80 bar
COP	10.0
Gross energy	92.3 kJ/kg

Electrical output	69.2 kJ/kg
Heat pump input	9.2 kJ/kg
Net energy	60.0 kJ/kg
Required mass flow	1.67 kg/s

COP 7.0 Cases

Pressure	Gross Energy	Electrical Output	Heat Pump Input	Net Energy	Mass Flow
70 bar	80.8 kJ/kg	60.6 kJ/kg	11.5 kJ/kg	49.0 kJ/kg	2.04 kg/s
80 bar	92.3 kJ/kg	69.2 kJ/kg	13.2 kJ/kg	56.0 kJ/kg	1.78 kg/s
100 bar	115.4 kJ/kg	86.5 kJ/kg	16.5 kJ/kg	70.1 kJ/kg	1.43 kg/s
120 bar	138.5 kJ/kg	103.8 kJ/kg	19.8 kJ/kg	84.1 kJ/kg	1.19 kg/s

Analysis Plots

Heat Pump Turbine Analysis Plots

Conclusions

The analysis shows that the heat pump turbine system using CO_2/acetone mixture is theoretically viable in most operating conditions, with 95.8% of cases producing positive net energy. Higher pressures and COP values generally improve system performance, with the best case achieving 60.0 kJ/kg net energy at 80 bar and COP 10.0.

The minimum mass flow requirement of 1.11 kg/s for 100 kW output demonstrates the system's potential for practical power generation, though real-world implementation would need to address challenges related to two-phase flow handling and heat exchanger design.

Analysis based on Denardin et al. (2013) "Phase transition and volume expansion in CO_2-expanded liquid systems"

Report generated on 2025-11-17