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**Analisis Eksperimental Pengaruh Variabel Beban Termal dan Perubahan Setpoint Suhu terhadap Kinerja
Sistem Transportation Refrigeration Unit (TRU) Elektrik**
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Universitas Gadjah Mada, 2026 | Diunduh dari http://etd.repository.ugm.ac.id/

INTISARI

Transportation Refrigeration Unit (TRU) elektrik merupakan salah satu teknologi penting dalam sistem rantai dingin yang berperan menjaga kualitas produk selama proses distribusi dengan konsumsi energi yang lebih ramah lingkungan dibandingkan TRU berbahan bakar diesel. Namun, kinerja sistem TRU elektrik dipengaruhi oleh besarnya beban termal yang harus diserap serta pengaturan *setpoint* suhu operasi. Oleh karena itu, penelitian ini bertujuan menganalisis secara eksperimental pengaruh variasi tingkat beban termal dan *setpoint* suhu terhadap kinerja sistem TRU elektrik berdasarkan laju pelepasan kalor, daya kompresor, konsumsi energi, Coefficient of Performance (COP), dan karakteristik distribusi temperatur ruang muat.

Penelitian dilakukan menggunakan TRU elektrik tipe Hwasung HT-500 ESC satu fasa dengan media uji berupa air sebagai simulasi beban termal. Variabel penelitian terdiri atas tiga tingkat beban, yaitu 0%, 50% (12,5 L), dan 100% (25 L), serta tiga *setpoint* suhu, yaitu −2°C, −5°C, dan −7°C sehingga diperoleh sembilan kombinasi pengujian. Setiap pengujian berlangsung selama 20 jam. Parameter temperatur diukur menggunakan sensor RTD PT100 berbasis ESP32, sedangkan parameter kelistrikan direkam menggunakan powermeter Modbus RS485. Data yang diperoleh selanjutnya digunakan untuk menghitung laju pelepasan kalor, konsumsi energi, daya kompresor rata-rata, dan COP.

Hasil penelitian menunjukkan bahwa peningkatan beban termal dan penurunan *setpoint* suhu menyebabkan laju pelepasan kalor, daya kompresor, dan konsumsi energi meningkat, sedangkan nilai COP cenderung menurun. Laju pelepasan kalor tertinggi sebesar 1,634 kW diperoleh pada kondisi beban 100% dengan *setpoint* −7°C, sedangkan COP tertinggi sebesar 1,79 dicapai pada kondisi beban 50% dengan *setpoint* −2°C yang menunjukkan kondisi operasi paling efisien. Konsumsi energi kompresor maksimum sebesar 23,77 kWh terjadi pada kondisi beban 100% dan *setpoint* −7°C. Selain itu, profil temperatur produk menunjukkan fase plateau di sekitar 0°C sebagai indikasi pelepasan kalor laten selama proses pembekuan. Penelitian ini memberikan dasar empiris mengenai pengaruh beban termal dan *setpoint* suhu terhadap kinerja TRU elektrik yang dapat digunakan sebagai acuan dalam pengoperasian sistem yang lebih efisien serta mendukung pengembangan transportasi berpendingin yang berkelanjutan.

Kata kunci: *Transportation Refrigeration Unit* (TRU) elektrik, beban termal, tingkat pengisian air, suhu target, konsumsi energi, daya kompresor, *Coefficient of Performance* (COP).

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ABSTRACT

Electric Transportation Refrigeration Units (TRUs) play an essential role in cold chain logistics by maintaining product quality during distribution while offering a more environmentally friendly alternative to conventional diesel-powered refrigeration systems. However, the performance of electric TRUs is strongly influenced by the applied thermal load and operating temperature *setpoint*. Therefore, this study aims to experimentally investigate the effects of thermal load variation and temperature *setpoint* on the performance of an electric TRU in terms of heat removal rate, compressor power, energy consumption, Coefficient of Performance (COP), and cargo-space temperature distribution.

The experiments were conducted using a single-phase Hwasung HT-500 ESC electric TRU with water employed as a simulated thermal load. Three loading levels were investigated, namely 0%, 50% (12.5 L), and 100% (25 L), combined with three temperature *setpoint*s of −2°C, −5°C, and −7°C, resulting in nine operating conditions. Each experiment was carried out for 20 hours. Temperature data were continuously recorded using PT100 RTD sensors integrated with an ESP32-based data acquisition system, while electrical parameters were measured using a Modbus RS485 power meter. The acquired data were subsequently analyzed to determine the heat removal rate, compressor energy consumption, average compressor power, and COP.

The results indicate that increasing the thermal load and lowering the temperature *setpoint* increase the heat removal rate, compressor power, and energy consumption while reducing the COP. The highest heat removal rate of 1.634 kW was obtained at 100% load with a −7°C *setpoint*, whereas the highest average COP of 1.79 was achieved at 50% load with a −2°C *setpoint*, indicating the most energy-efficient operating condition. The maximum compressor energy consumption of 23.77 kWh occurred at 100% load and a −7°C *setpoint*. Furthermore, the product temperature profile exhibited a plateau around 0°C, indicating latent heat removal during the freezing process. The findings provide empirical insight into the influence of thermal load and temperature *setpoint* on electric TRU performance and may serve as a reference for improving operational energy efficiency and supporting the development of sustainable refrigerated transportation systems.

Keywords: electric *Transportation Refrigeration Unit* (TRU), thermal load, target temperature, heat removal rate, energy consumption, compressor power, coefficient of performanc