Design of a Compressor Load Stand Capable of Supplying Two-Phase Refrigerant at Two Intermediate Pressures

Rui Gu, Margaret M. Mathison
Department of Mechanical Engineering
Marquette University
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- Load Stand Model
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**Introduction:** Conventional Vapor Compression Cycle

- Widely used in heating, refrigerating, and air-conditioning
- Performance improvements in components can be complex and costly

**Figure 1.** Conventional vapor compression cycle
Introduction: Multi-stage Vapor Compression Cycle

- Traditionally, economizing requires multi-stage compressors
- The cost has restricted the scope for implementation

**Figure 2.** Vapor compression cycle with two-stage compression and flash-tank economization.
Introduction: Vapor Compression Cycle with Injection

- Injection ports can be used to implement economization with less cost
- Provide the desired cooling effect

Figure 3. Vapor compression cycle with flash-tank economization and refrigerant injection
Load Stand Design: Schematic of Load Stand
Load Stand Design: Main Loop of Load Stand

Hot gas bypass
Load Stand Design: Injection Loops of Load Stand

Vapor injection lines

Liquid injection lines
Load Stand Model

- P-h diagram of load stand model with one injection port
Load Stand Model

Assumptions:

- Steady-state, steady flow conditions
- One-dimensional flow
- Isentropic compressor efficiency
- Instantaneous, adiabatic, isobaric mixing processes
- Isenthalpic throttling devices
- Negligible pressure drop through pipes
- Negligible heat transfer between the pipes and the ambient
- Negligible kinetic and potential energy changes
Minimum quality can be achieved under two cases:

- **Case 1:**
  \[ \dot{m}_{9-10} = 0 \]

- **Case 2:**
  \[ \dot{m}_{5-7} = 0 \]
Model Results: Impact of Evaporating Temperature

Figure 4. The dependence of minimum quality on evaporating temperature when refrigerant is injected at 1000 kPa with a mass flow rate ratio of 0.2, a superheat of 11°C, and saturated liquid at the condenser exit.
Model Results: Impact of Condensing Temperature

The transition occurs at lower evaporating pressures as the discharge pressure decreases.

Figure 5: The dependence of minimum quality on evaporating and condensing temperature when refrigerant is injected at 1000 kPa with a mass flow rate ratio of 0.2, a superheat of 11°C, and saturated liquid at the condenser exit.
**Model Results:** Impact of Injection Mass Fraction

![Graphs showing the dependence of minimum injection quality on evaporating temperature](image)

**Figure 6:** The dependence of minimum quality on injected mass fraction when refrigerant is injected at 1000 kPa with a superheat of 11°C and saturated liquid at the condenser exit. The injected mass flow rate ratio is (Left) 0.2, and (Right) 0.4.
Model Results: Impact of Injection Mass Fraction

- Minimum quality does not depend on the mass flow rate at small mass fractions
- Certain qualities cannot be reached regardless of injected mass fraction

Figure 7: Minimum quality versus injection pressure (640 kPa suction pressure with 11°C superheat, 2290 kPa discharge pressure, and 35°C condensing temperature with 0°C subcooling)
Model Results: Impact of Subcooling

Figure 8: Minimum quality versus injection pressure (640 kPa suction pressure with 11°C superheat, 2290 kPa discharge pressure, and 35°C condensing temperature).

(a) 0°C Subcooling  
(b) 5°C Subcooling
Model Results: Impact of Condensing Temperature

Figure 9: Minimum quality versus injection pressure (640 kPa suction pressure with 11°C superheat, 2290 kPa discharge pressure with 0°C subcooling)

(a) 35°C Condensing Temperature
(b) 24°C Condensing Temperature
Conclusions

• A load stand model was developed to guide its design and predict the minimum achievable injection quality

• The injection qualities are limited by:
  ➢ The enthalpy at the condenser exit at the lower injection mass flow rates
  ➢ The need to avoid “overcooling” the compressor with larger injection mass flow rates.

• Lower injection qualities can be achieved by:
  ➢ Increasing the degree of subcooling
  ➢ Decreasing the condensing temperature
Future Work

- Develop a two-phase injection model for a scroll compressor
- Validate the model using the load stand to perform experiments on a scroll compressor with multiport injection
- Carry out a parametric study on the compressor performance using the model


Reference