National Aeronautics and Space Administration

Miniature Efficient Heat Pump for Venus and Lunar Exploration

Principal Investigator: Weibo Chen (382); Co-Investigators: Luis Fonseca Flores (382), Jared Keller (382), Freddy Sevilla (382)

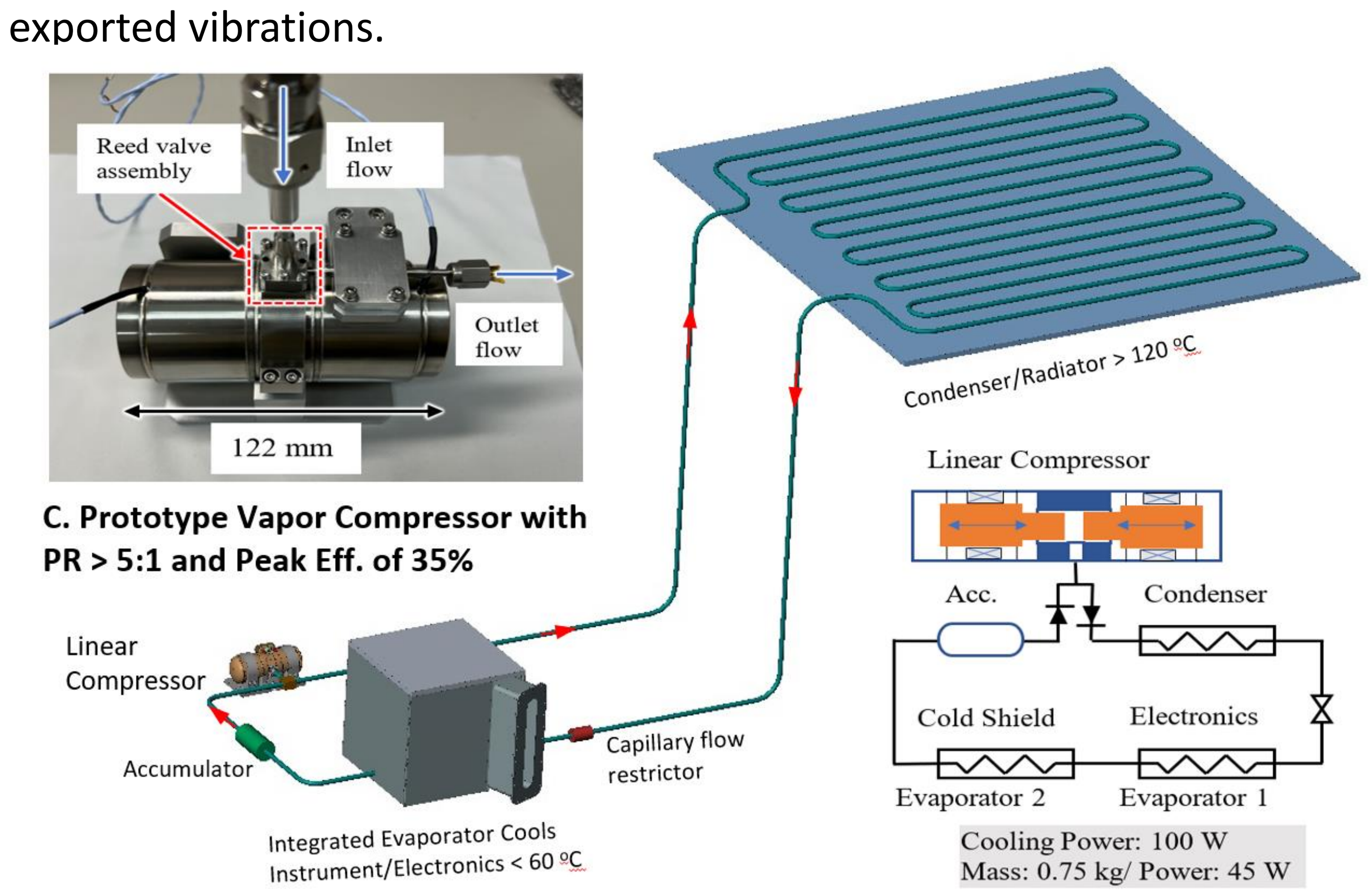
Program: FY22 R&TD Topics
Strategic Focus Area: Thermal control systems

Objectives

- Develop a miniature, efficient heat pump driven by a high-speed miniature linear compressor.
- High temperature lift (>50ºC) —allowing electronics and sensors to operate more than 50 ºC below the surrounding temperature.
- High heat rejection temperatures (>110ºC) —allowing instruments to operate in hot Venus atmosphere below the cloud.
- High efficiency – 2 W of cooling power per W of electrical power input (COP of 2).
- Lightweight, less than 0.75 kg for 100 W of cooling power
- Low exported vibrations (<0.3 N) to minimize jitters.

Background

- Environmental temperature during Venus balloon flight at altitudes of 45 km or lunar exploration at low latitude regions can be >110 ºC.
- Existing heat pumps cannot achieve comparable performance and can not meet Venus and lunar application needs.
- Provide new capability in terms of temperature lift, efficiency, size and mass, and exported vibrations.



A. Conceptual Heat Pump Integrated with Instrument B. Heat Pump Cycle Schematic

Figure 1. Compact Heat Pump to Enable Science Measurement in Extreme Thermal Environments

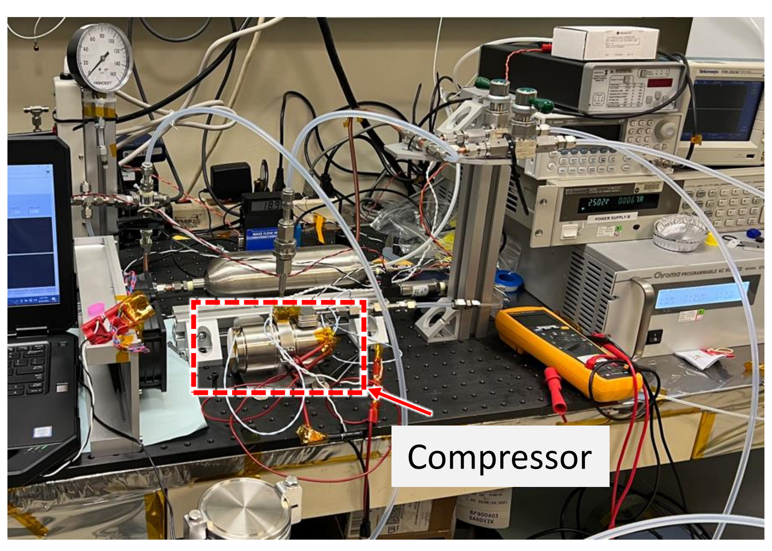


Figure 2. Closed Loop Vapor Compressor Test Setup

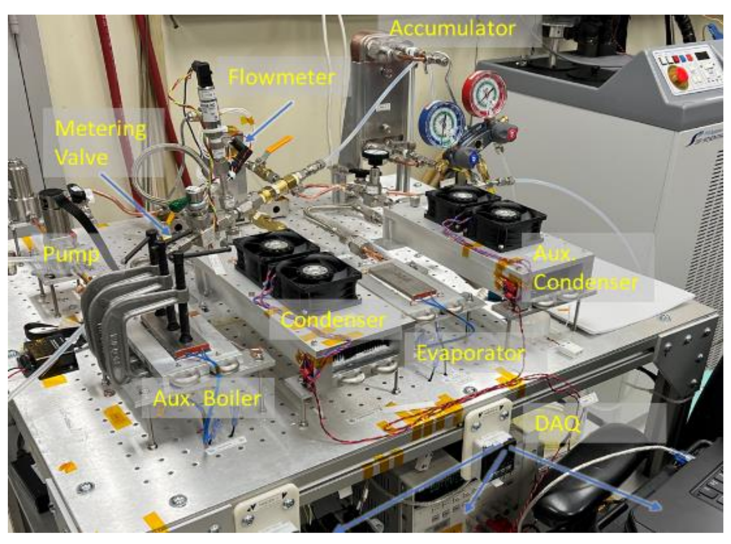


Figure 3. Separate Effects Test Loop with a Compressor Simulator

Approach

- Existing high speed linear compressor with dual-opposing pistons supported by flexure bearings for lightweight, low exported vibrations and reliable operation.
- Miniature, fast-response check valves with very small void volume, low leakage in "OFF" state and low resistance in "ON" state to enable efficient, reliable, high pressure ratio operation.

Results

- Successfully designed and fabricated a set of reed valves with a very small dead volume of <100 mm^3.
- Assembled compact DC flow compressor (1.6 kg) by integrating reed valve assembly with a commercial pressure wave generator.
- Demonstrated a peak isentropic efficiency of 35% at an compression ratio of 3.5:1 for gaseous nitrogen.
- Demonstrated an isentropic efficiency higher than 25% at compression ratio of 4: 1 for refrigerant R134a and an input power level of ~40 W for DC compressor.
- Demonstrated operation of a closed-loop heat pump with the DC compressor using R134a
- Demonstrated a compression ratio higher than 6.6:1 and no performance degradation after 5x10^6 cycles of operation.

Significance/Benefits to JPL and NASA

- Cross-cutting thermal management technology for NASA
  - Provide heat source by lifting heat from low to high temperatures,
  - Provide cooling for life support systems
- DC compressor is an enabling technology for critically needed Joule-Thomason 4 K cryocoolers for astrophysics missions
- The compact heat pump also has a wide range of terrestrial medical and commercial applications, such as safe transportation of temperature-sensitive medicines, vaccines, and bio samples in remote areas

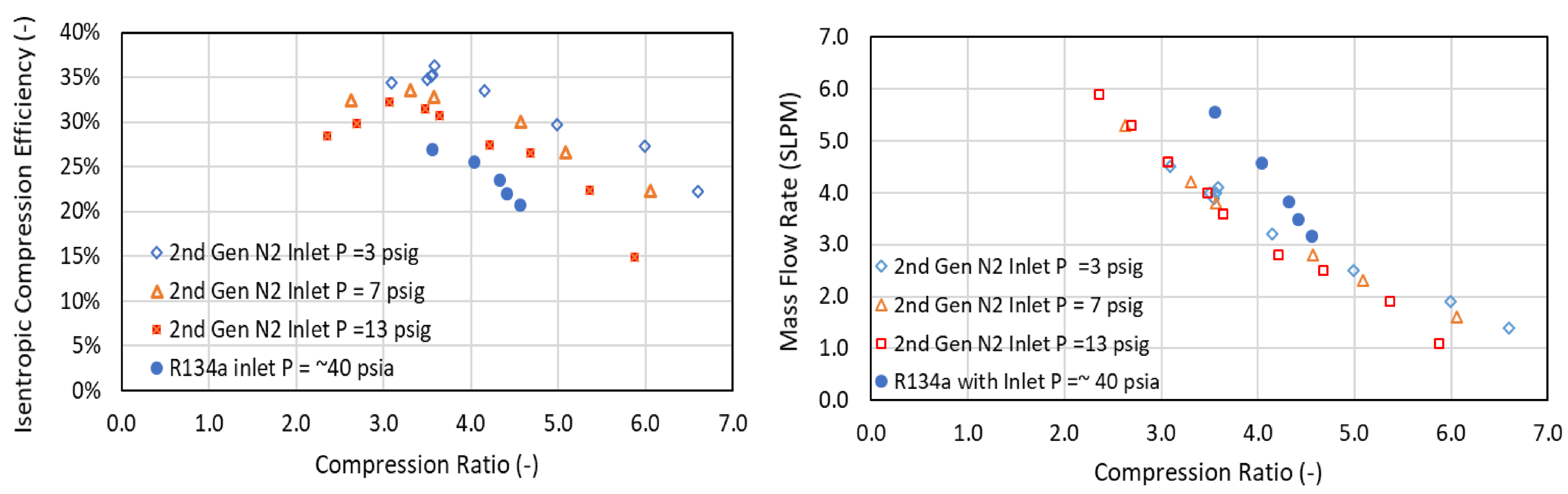


Figure 4. DC Compressor Efficiency and Flow Rate

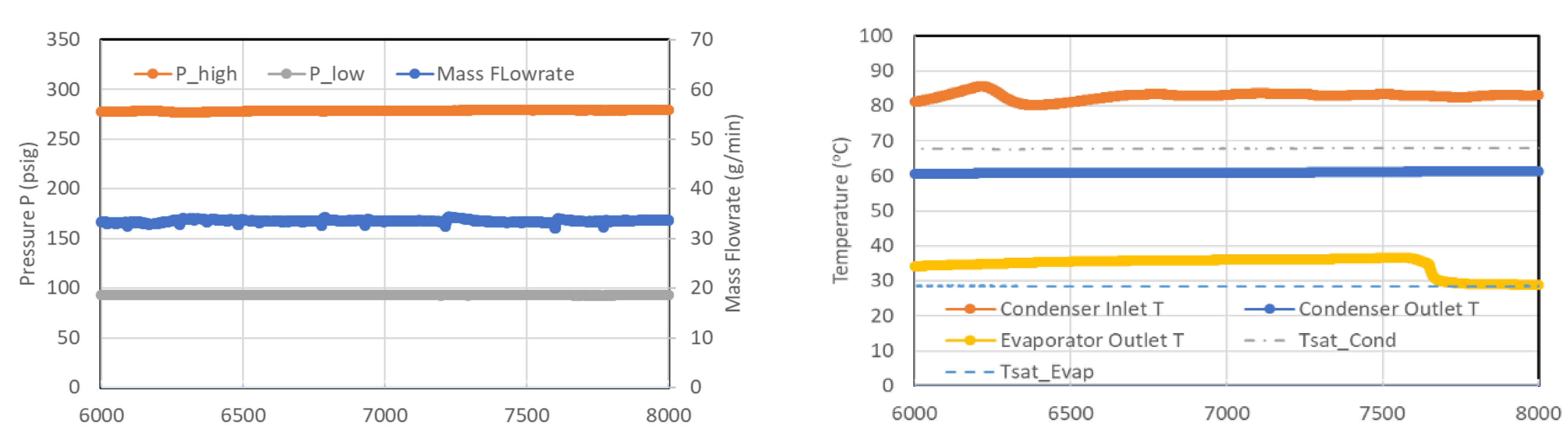


Figure 5. Pressure, Mass Flow Rate and Temperatures in Separate Effects Test Loop

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#22-4901
Poster Number: RPC#R21124

PI/Task Mgr. Contact Information:
Email: weibo.chen@jpl.nasa.gov

PI/Task Mgr Contact
Email: weibo.chen@jpl.nasa.gov