ACTIVELY COOLED VENUS LANDER INSTRUMENT PAYLOAD USING A MULTI-CASCADE REFRIGERATION CYCLE.

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Introduction:

Landing and operating on the surface of Venus has been a tremendous challenge that includes ten mission failures and only eight successes since 1962. Venus surface knowledge is limited due to the minimal operational time provided by past thermal system technology. The existing state-of-the-art established by previous Russian Venus landing missions included demonstrated survivability durations which serve as benchmarks for this effort. The Russian missions Venera 13 circa 1981 [1] and Venera 14 circ 1982 [2] are the longest lived mission lasting 127 minute. A New Frontiers finalist for 2011 [3], Surface and Atmosphere Geochemical Explorer (SAGE) proposed a Venus surface design life of up to 3 hours. This timeline is ineffective to fully leverage the in-situ geochemistry and surface mineralogy tools and research for a Venus mission. Short-lived mission durations on the surface of Venus are due to extreme environments, where the temperature is 740 K (467 °C, 872 °F) with a pressure of 9.3 MPa (1348.8 psi). To this end, the current paper outlines an active instrument cooling payload concept utilizing a multi-cascaded refrigeration cycle application to Venus lander missions. The proposed cascaded hybrid refrigeration system [1], if successful would enable future science instruments to survive this harsh environment for durations spanning days, weeks, and perhaps months to exercise the In-Situ geochemistry and mineralogy research of the Venus surface. This paper present the systems level integration of a novel refrigeration system into a Venus payload architecture that will allow future science instrument and electronics to survive the harsh surface environment with operational time measured in weeks instead of minutes. Figure 1 shows the concept of an active instrument cooled payload within the framework of a conceptual Venus lander. Figure 1 shows the lander with an upper Power Bay and a lower Volume Bay. The Power Bay is populated biwth with Radioisotope Thermoelectric Generators (RTG) and/or Fuel cells, or perhaps another Direct Energy Conversion technology such as Li-CO2 batteries. The power from the Power Bay is used to provide power to cool a Volume Bay were payload (including seismic instruments and/or drills, etc.) may be housed. The cascaded refrigeration cycle discussed in this paper is housed in the Power Bay and is used to maintain the electronics in the Volume Bay at a prescribed temperature.

Figure 1. Proposed Venus Lander Configuration (background apadted from [5])

Figure 2 shows the components of the proposed active cascaded refrigeration system which are housed in the Power Bay.

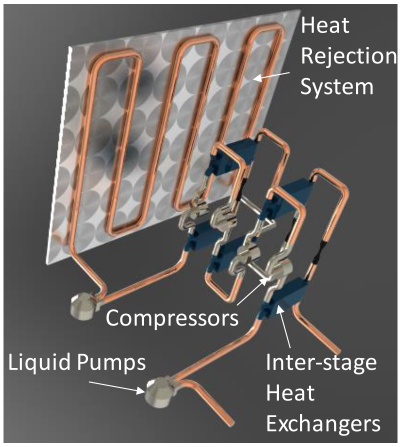

Figure 2. Multicascade Active Refrigeration Payload Cooling System

Figure 2 shows the varioius components of the active cooling system including the liquid feed pumps, the interstage heat exchangers, the refrigerant compressors, and the heat rejection system. The technology goals of the current paper are vital to the development of a significantly increased science payload life for an in-situ Venus mission. The expectation to have long duration surface investigations on Venus depends on the ability to protect instruments and electronics from the external 740K temperature. The proposed refrigeration system can extend life cycle of lower or high temperature electronics. To date, technology advancements in high temperature electronic components has been made. But, with the addition of our proposed active cooling, these components can operate for extended periods of time on the surface of Venus. The paper will outline the development of a hybrid, cascade refrigeration system. The system is cascaded into four stages, with the working fluids 1) NH3, 2) Transcritical CO2, 3) Supercritical CO2, and 4) Methyl Linoleate (MLL) Fatty Acid Methyl Ester (FAME). The MLL-FAME working fluid is a biofuel usually obtained from vegetable oils and presently uncharacterized for this application. It will be used in the topping cycle and will experience the highest temperature at 773K (500°C,932°F). The system is expected to lift 250W of thermal energy while maintaining a payload environmental temperature of 180°C. The use of a refrigeration system still requires that electronic components operate at elevated temperatures but not at 740K (467 °C, 872 °F). The novel thermal system provides a realistic achievable goal and operational middle ground for both electronics and thermal system technology advancements. The paper will focus on the following aspects: (a) optimization of the cycle for input power and heat lift (b) thermodynamic characterization of the MLL-FAME working fluid, and (c) life-cycle testing of the MLL-FAME working fluid to establish the thermodynamic integrity of the fluid at operating temperatures. Preliminary findings of the system performance will be included in the paper. Finally, subsystem component specification requirements for the compressor, pumps, and heat exchangers, and key working fluid/gas parameter are driven by their Technology Readiness Level (TRL). advancement for key subsystem components. The paper will outline the current TRL of the proposed cascaded refrirgeraion cycle and highlight the level of research and development needed to see the concept to fruition.

References:

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