Physical Sciences

Fault-Tolerant Heat Exchanger

A single-point leak would not cause mixing of heat-transfer fluids.

Lyndon B. Johnson Space Center, Houston, Texas

A compact, lightweight heat exchanger has been designed to be fault-tolerant in the sense that a single-point leak would not cause mixing of heat-transfer fluids. This particular heat exchanger is intended to be part of the temperature-regulation system for habitable modules of the International Space Station and to function with water and ammonia as the heat-transfer fluids. The basic fault-tolerant design is adaptable to other heat-transfer fluids and heat exchangers for applications in which mixing of heat-transfer fluids would pose toxic, explosive, or other hazards: Examples could include fuel/air heat exchangers for thermal management on aircraft, process heat exchangers in the cryogenic industry, and heat exchangers used in chemical processing.

The reason this heat exchanger can tolerate a single-point leak is that the heat-transfer fluids are everywhere separated by a vented volume and at least two seals. The combination of fault tolerance, compactness, and light weight is implemented in a unique heat-exchanger core configuration: Each fluid passage is entirely surrounded by a vented region bridged by solid structures through which heat is conducted between the fluids. Precise, proprietary fabrication techniques make it possible to manufacture the vented regions and heat-conducting structures with very small dimensions to obtain a very large coefficient of heat transfer between the two fluids. A large heat-transfer coefficient favors compact design by making it possible to use a relatively small core for a given heat-transfer rate.

Characteristic		Non-Fault-Tolerant Design	Fault-Tolerant Design
Heat-Transfer Load	Design Point	14 kW	14 kW
	Pinch Point	25 kW	25 kW
Volume and Dimensions to Satisfy Pinch-Point Criterion		6.55 L 6.4 by 20.8 by 49.5 cm	2.5 L 9.1 by 12.7 by 21.6 cm
Mass (for Pinch-Point Criterion)		<12 kg	14.6 kg
Mass-Specific Heat Transfer	Design Point	>1.2 kW/kg	0.96 kW/kg
	Pinch Point	>2 kW/kg	1.7 kW/kg
Pressure	Maximum Allowable Working	3.7 MPa	3.7 MPa
	Proof	5.6 MPa	5.6 MPa
	Design/Burst	11.2 MPa	22.4 MPa
Pressure Drop on Primary (H_2O) Side at Mass Flow Rate of 380 g/s		19 kPa	19 kPa
Pressure Drop on Secondary (NH_3) Side at Flow Rate of 440 g/s		44.2 kPa	44.2 kPa

Design and Performance Characteristics of the fault-tolerant heat exchanger are shown alongside those of the prior non-fault-tolerant heat exchanger.

Calculations and experiments have shown that in most respects, the fault-tolerant heat exchanger can be expected to equal or exceed the performance of the non-fault-tolerant heat exchanger that it is intended to supplant (see table). The only significant disadvantages are a slight weight penalty and a small decrease in the mass-specific heat transfer.

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Atomic Clock Based on Opto-Electronic Oscillator

This apparatus would afford spectral purity plus long-term stability and accuracy.

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A proposed highly accurate clock or oscillator would be based on the concept of an opto-electronic oscillator (OEO) stabilized to an atomic transition. Opto-electronic oscillators, which have been described in a number of prior *NASA Tech Briefs* articles, generate signals at frequencies in the gigahertz range characterized by high spectral purity but not by long-term stability or accuracy. On the other hand, the signals generated by previously developed atomic clocks are characterized by long-term stability and accuracy but not by spectral purity. The proposed atomic clock would provide high spectral purity plus long-term stability and accuracy — a combination of characteristics needed to realize advanced developments in communications and navigation. In addition, it should be possible to miniaturize the proposed atomic clock.

When a laser beam is modulated by a microwave signal and applied to a photodetector, the electrical output of the photodetector includes a component at the microwave frequency. In atomic clocks of a type known as Raman clocks or coherent-population-trapping (CPT) clocks, microwave outputs are obtained from laser beams modulated, in each