Technology Focus: Test and Measurement

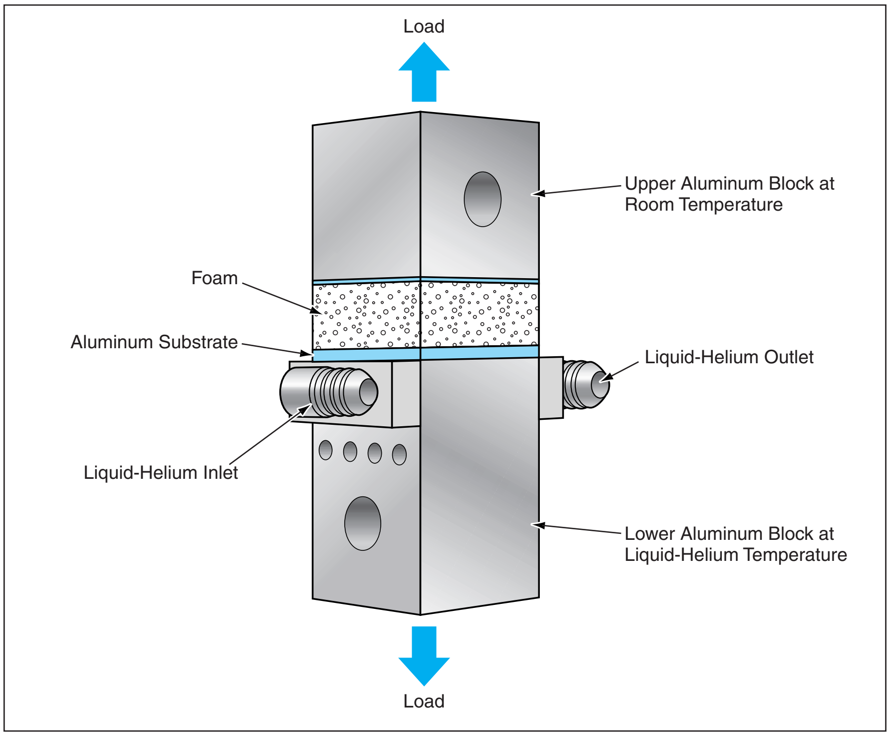
Cryogenic Temperature-Gradient Foam/Substrate Tensile Tester

Tensile strengths are measured under more nearly realistic conditions.

Marshall Space Flight Center, Alabama

The figure shows a fixture for measuring the tensile strength of the bond between an aluminum substrate and a thermally insulating polymeric foam. The specimen is meant to be representative of insulating foam on an aluminum tank that holds a cryogenic liquid. Prior to the development of this fixture, tensile tests of this type were performed on foam/substrate specimens immersed in cryogenic fluids. Because the specimens were cooled to cryogenic temperatures throughout their thicknesses, they tended to become brittle and to fracture at loads below true bond tensile strengths.

The present fixture is equipped to provide a thermal gradient from cryogenic temperature at the foam/substrate interface to room temperature on the opposite foam surface. The fixture includes an upper aluminum block at room temperature and a lower aluminum block cooled to –423 °F (≈–253 °C) by use of liquid helium. In preparation for a test, the metal outer surface (the lower surface) of a foam/substrate specimen is bonded to the lower block and the foam outer surface (the upper surface) of the specimen is bonded to the upper block.



This **Test Fixture** applied both a tensile load and a through-the-thickness temperature gradient to the foam/substrate specimen.

In comparison with the through-the-thickness cooling of immersion testing, the cryogenic-to-room-temperature thermal gradient that exists during testing on this fixture is a more realistic approximation of the operational thermal condition of sprayed insulating foam on a tank of cryogenic liquid. Hence, tensile tests performed on this fixture provide more accurate indications of operational bond tensile strengths. In addition, the introduction of the present fixture reduces the cost of testing by reducing the amount of cryogenic liquid consumed and the time needed to cool a specimen.

This work was done by Christophe Vailhe of Lockheed Martin for **Marshall Space Flight Center**. *Further information is contained in a TSP (see page 1).*
MFS-31672

Flight Test of an Intelligent Flight-Control System

A neural network helps to optimize handling qualities.

Dryden Flight Research Center, Edwards, California

The F-15 Advanced Controls Technology for Integrated Vehicles (ACTIVE) airplane (see figure) was the test bed for a flight test of an intelligent flight control system (IFCS). This IFCS utilizes a neural network to determine critical stability and control derivatives for a control law, the real-time gains of which are computed by an algorithm that solves the Riccati equation. These derivatives are also used to identify the parameters of a dynamic model of the airplane. The model is used in a model-following portion of the control law, in order to provide specific vehicle handling characteristics. The flight test of the IFCS marks the initiation of the Intelligent Flight Control System Advanced Concept Program (IFCS ACP), which is a collaboration between NASA and Boeing Phantom Works.

The **F-15 ACTIVE Airplane** is a test bed for advanced flight-control systems.

The goals of the IFCS ACP are to (1) develop the concept of a flight-control system that uses neural-network technology to identify aircraft characteristics to provide optimal aircraft performance, (2) develop a self-training neural network to update estimates of aircraft properties in flight, and (3) demonstrate the aforementioned concepts on the F-15 ACTIVE airplane in flight. The activities of the initial IFCS ACP were divided into three Phases, each devoted to the attainment of a different objective. The objective of Phase I was to develop a pre-trained neural network to store and recall the wind-tunnel-based stability and control derivatives of the vehicle. The objective of Phase II was to develop a neural network that can learn how to adjust the stability and control derivatives to account for failures or modeling deficiencies. The objective of Phase III was to develop a flight control system that uses the neural network outputs as a basis for controlling the aircraft. The flight test of the IFCS was performed in stages. In the first stage, the Phase I version of the pre-trained neural network was flown in a passive mode. The neural network software was running using flight data inputs with the outputs provided to instrumentation only. The IFCS was not used to control the airplane. In another stage of the flight test, the Phase I pre-trained neural network was integrated into a Phase III version of the flight control system. The Phase I pre-trained neural network provided real-time stability and control derivatives to a Phase III controller that was based on a stochastic optimal feedforward and feedback technique (SOFFT). This combined Phase I/III system was operated together with the research flight-control system (RFCS) of the F-15 ACTIVE during the flight test. The RFCS enables the pilot to switch quickly from the experimental-research flight mode back to the safe conventional mode.

These initial IFCS ACP flight tests were completed in April 1999. The Phase I/III flight test milestone was to demonstrate, across a range of subsonic and supersonic flight conditions, that the pre-trained neural network could be used to supply real-time aerodynamic stability and control derivatives to the closed-loop optimal SOFFT flight controller. Additional objectives attained in the flight test included (1) flight qualification of a neural-network-based control system; (2) the use of a combined neural-network/closed-loop optimal flight-control system to obtain level-one handling qualities; and (3) demonstration, through variation of control gains, that different handling qualities can be achieved by setting new target parameters. In addition, data for the Phase-II (on-line-learning) neural network were collected, during the use of stacked-frequency-sweep excitation, for post-flight analysis. Initial analysis of these data showed the potential for future flight tests that will incorporate the real-time identification and on-line learning aspects of the IFCS.

The majority of the design for this work was performed by Ron Davidson of Boeing Phantom Works and John T. Bosworth, Steven R. Jacobson, and Michael P. Thomson of **Dryden Flight Research Center***, and Charles C. Jorgensen of Ames Research Center. For further information, contact the Dryden Commercial Technology Office at (661) 276-3689.*
DRC-01-35

Slat Heater Boxes for Thermal Vacuum Testing

These devices are superior to infrared lamps for controlling sink temperatures.

Lyndon B. Johnson Space Center, Houston, Texas

Slat heater boxes have been invented for controlling the sink temperatures of objects under test in a thermal vacuum chamber, the walls of which are cooled to the temperature of liquid nitrogen. A slat heater box (see Figure 1) includes a framework of struts that support electrically heated slats that are coated with a high-emissivity optically gray paint. The slats can be grouped together into heater zones for the purpose of maintaining an even temperature within each side.

The sink temperature of an object under test is defined as the steady-state temperature of the object in the vacuum/radiative environment during the absence of any internal heat source or sink. The slat heater box makes it possible to closely control the radiation environment to obtain a desired sink temperature.

The slat heater box is placed inside the cold thermal vacuum chamber, and the object under test is placed inside (but not in contact with) the slat heater box. The slat heaters occupy about a third of the field of view from any point on the surface of the object under test, the remainder of the field of view being occupied by the cold chamber wall. Thus, the radiation environment is established by the combined effects