DESIGN AND DEVELOPMENT OF SHUTTLE GET-AWAY-SPECIAL EXPERIMENT G-0074

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Abstract

This paper describes a McDonnell Douglas Astronautics Company (MDAC) sponsored Get-Away-Special (GAS) experiment to investigate more versatile, lower cost surface tension propellant acquisition approaches for future satellite and spacecraft propellant tanks. The experiment, designated G-0074, is designed to demonstrate a propellant off-load capability for a full-tank gallery surface tension device, such as that employed in the Shuttle Reaction Control Subsystem (RCS), and demonstrate a low-cost refillable trap concept that could be used in future orbit maneuver propulsion systems for multiple engine restarts. The experiment consists of a Plexiglas test tank, movie camera and lights, auxiliary liquid accumulator, control electronics, battery pack, and associated valving and plumbing. The test liquid is Freon 113, dyed blue for color movie coverage. The fully loaded experiment weighs 106 pounds and will be installed in a NASA five-cubic-foot flight canister. Vibration tests, acoustic tests, and high and low temperature tests were performed to qualify the experiment for flight. The experiment will be delivered to NASA-Kennedy Space Center (KSC) on 9 June 1984 and is scheduled to be flown on the STS-41-F mission on 23 August 1984.

I. Introduction

The G-0074 GAS experiment has been part of an on-going research and development effort at MDAC to evaluate advanced surface tension propellant acquisition concepts. Initial planning for the experiment was begun in 1981 and a NASA Payload User's agreement was signed in April 1982.

The objective of the experiment is to demonstrate an off-load capability for a full-tank propellant acquisition system, a capability that does not exist with current full-tank surface tension devices such as the Shuttle RCS propellant acquisition system (Fig. 1). In the acquisition system shown in Fig. 1, the gallery legs must be kept full of propellant to ensure gas-free propellant delivery to the engines. This is not possible when the tank is launched with a partial propellant load because, uncovered, the forward gallery leg screens are not able to retain propellant during launch acceleration. The G-0074 experiment is designed to solve this problem by demonstrating passive gallery fill following orbit insertion. In addition, it will demonstrate a passive refillable trap concept that could be used in an orbit maneuver propulsion system to provide multiple engine restart capability.

The following paragraphs describe the design and operation of the experiment and tests performed to qualify the experiment for flight environments.

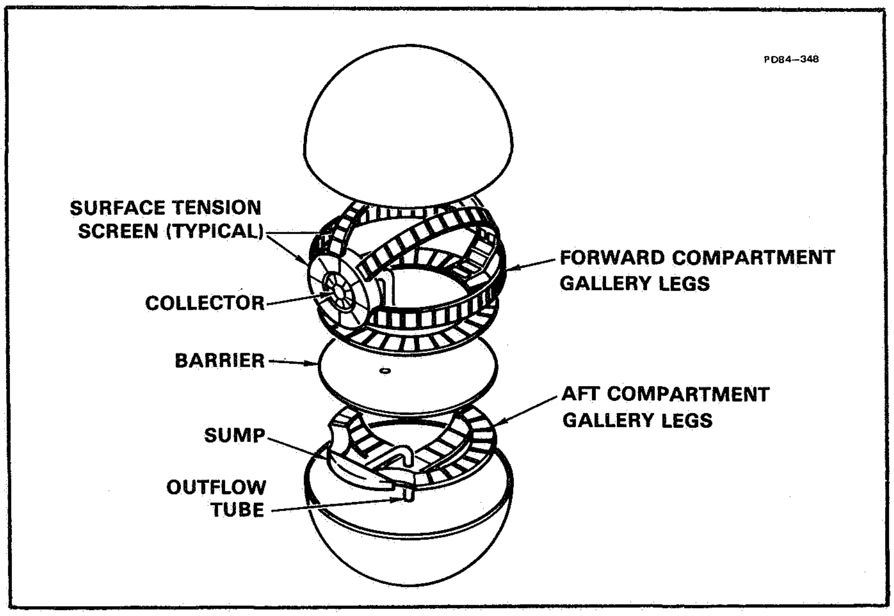

Fig. 1 Shuttle RCS Propellant Acquisition Device

II. Design and Operation

The complete flight payload (Fig. 2) consists of a Plexiglas test tank, movie camera and lights, auxiliary liquid accumulator, control electronics, battery pack, and associated valving and plumbing. The entire payload with support structure will be installed within a NASA-supplied, five-cubic-foot flight canister. The payload support structure is a 6061-T6 aluminum frame assembly that is cantilevered from a mounting plate at the top of the canister and supported laterally by four "bumpers" at its opposite end.

The test tank (Fig. 3) is a bolted assembly consisting of a cylindrical Plexiglas section, an aluminum forward dome, and an aluminum aft end plate. The tank is divided into forward and aft compartments by an internal Plexiglas bulkhead. The three gallery legs in the forward compartment are made of Plexiglas to allow visual (movie) evaluation of passive gallery fill. Each gallery leg has a flat, stainless steel screen surface along its outer face (adjacent to the tank wall) and a vent screen inside the forward vent baffle assembly. The internal bulkhead assembly contains a tapered Plexiglas vent stack to provide an exit passage for entrapped gas during passive fill of the aft trap compartment. The vent stack is covered by two perforated plate discs at its forward end. Gallery leg dimensions, screen mesh sizes, and perforated plate hole sizes are presented in Table I. The variation in shape, cross section, and screen mesh for the three gallery legs will allow us to acquire parametric data.

The tank operating sequence is shown in Fig. 4. The tank will be launched with a partial liquid load (Freon 113) in the forward compartment and a nearly empty aft compartment. During the zero-g interval following main engine cutoff, the three gallery legs will fill by capillary pumping. The baffle assembly at the forward end of the tank keeps the gallery vent screens dry until the gallery fill process is complete.

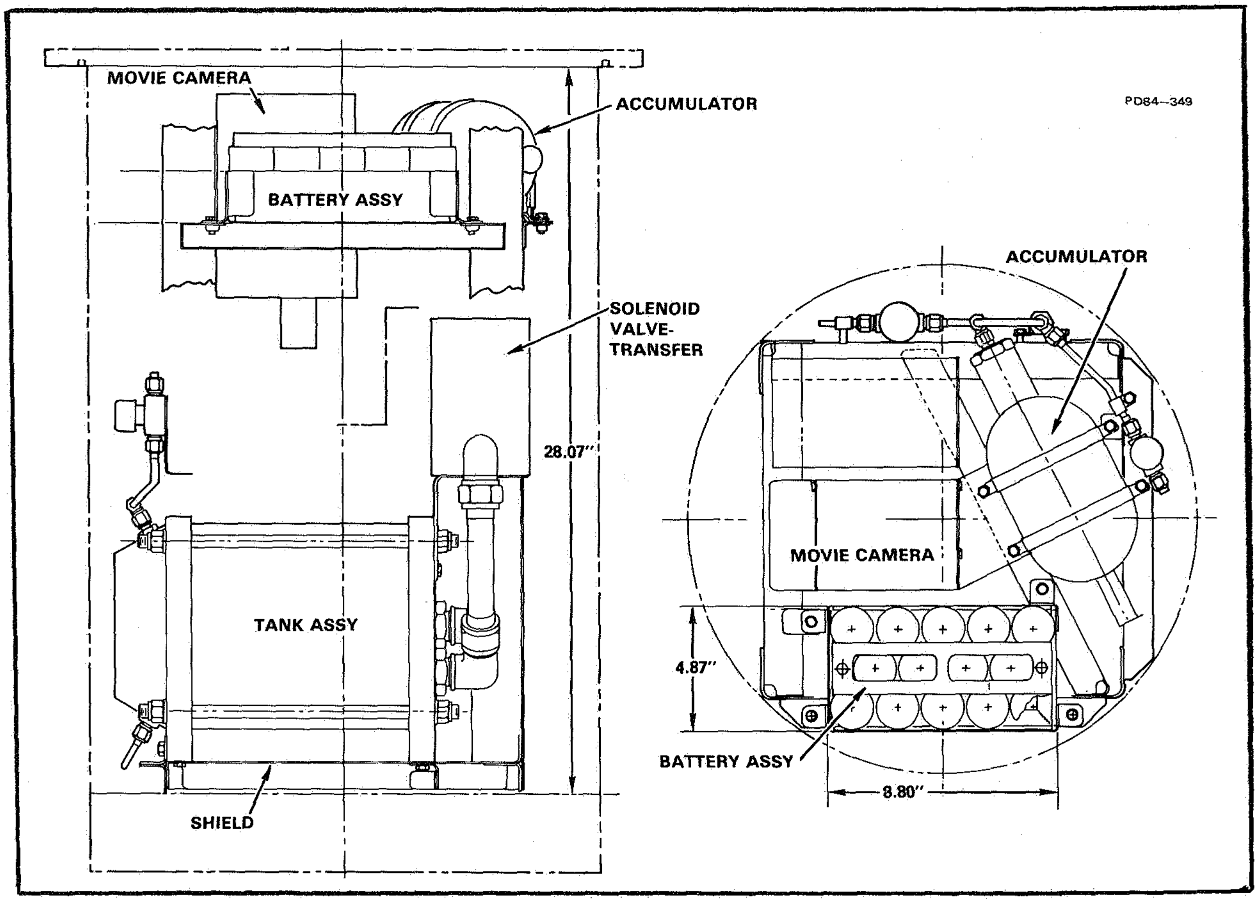

Fig. 2 Experiment Layout

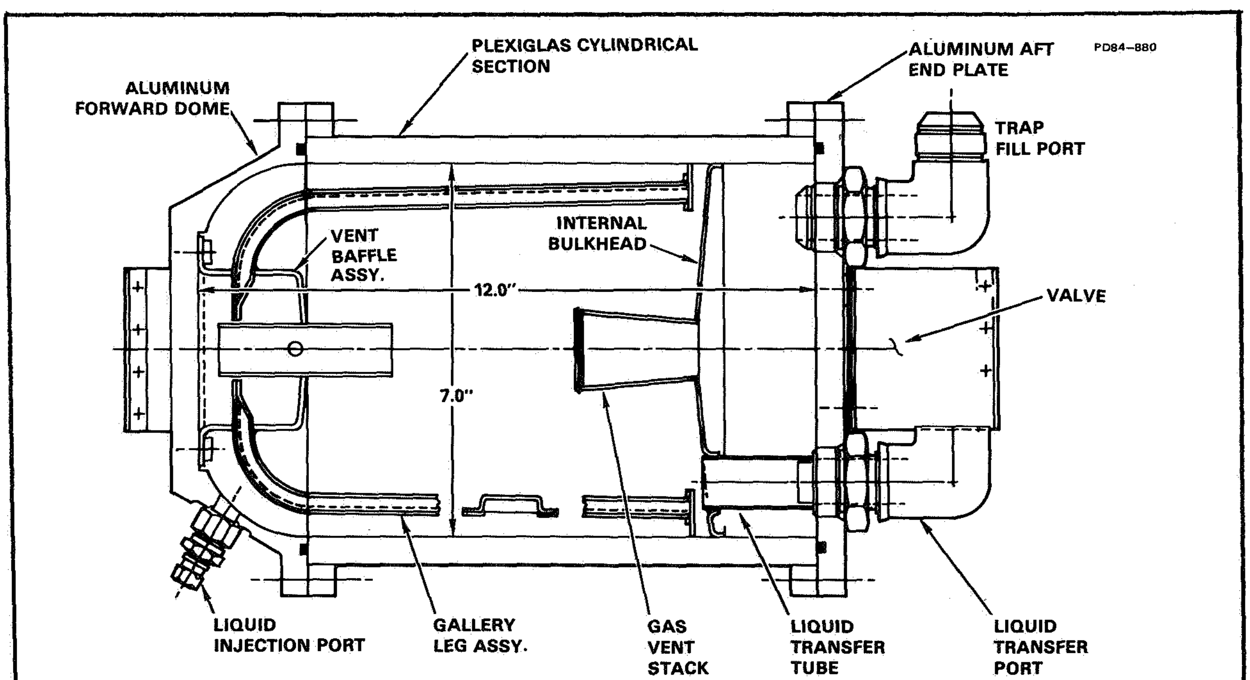

Fig. 3 Plexiglas Test Tank

Table I Gallery Leg and Vent Stack Perforated Plate Geometry

PD84-350

GALLERY LEG DESIGN CHARACTERISTICS:

	SHAPE	CROSS SECTION	GALLERY SCREEN MESH	VENT SCREEN MESH
GALLERY LEG NO. 1	RECTANGULAR	0.25 IN. x 1.00 IN.	150 x 150 PSW(1)	150 x 150 PSW
GALLERY LEG NO. 2	RECTANGULAR	0.25 IN. x 1.00 IN.	30 x 250 TDDW(2)	30 x 250 TDDW
GALLERY LEG NO. 3	TRAPEZOIDAL	0.25 IN. HIGH; 0.25 IN. & 1.00 IN. BASES	30 x 250 TDDW	30 x 250 TDDW

(1) PSW – PLAIN SQUARE WEAVE
(2) TDDW – TWILLED DUTCH DOUBLE WEAVE
} ALL SCREEN MATERIAL IS STAINLESS STEEL

VENT STACK PERFORATED PLATE HOLE SIZES:

	HOLE DIAMETER, IN.	% OPEN AREA
LOWER PLATE (1.0 IN. DIAMETER)	0.125	30%
UPPER PLATE (1.0 IN. DIAMETER)	0.250	30%

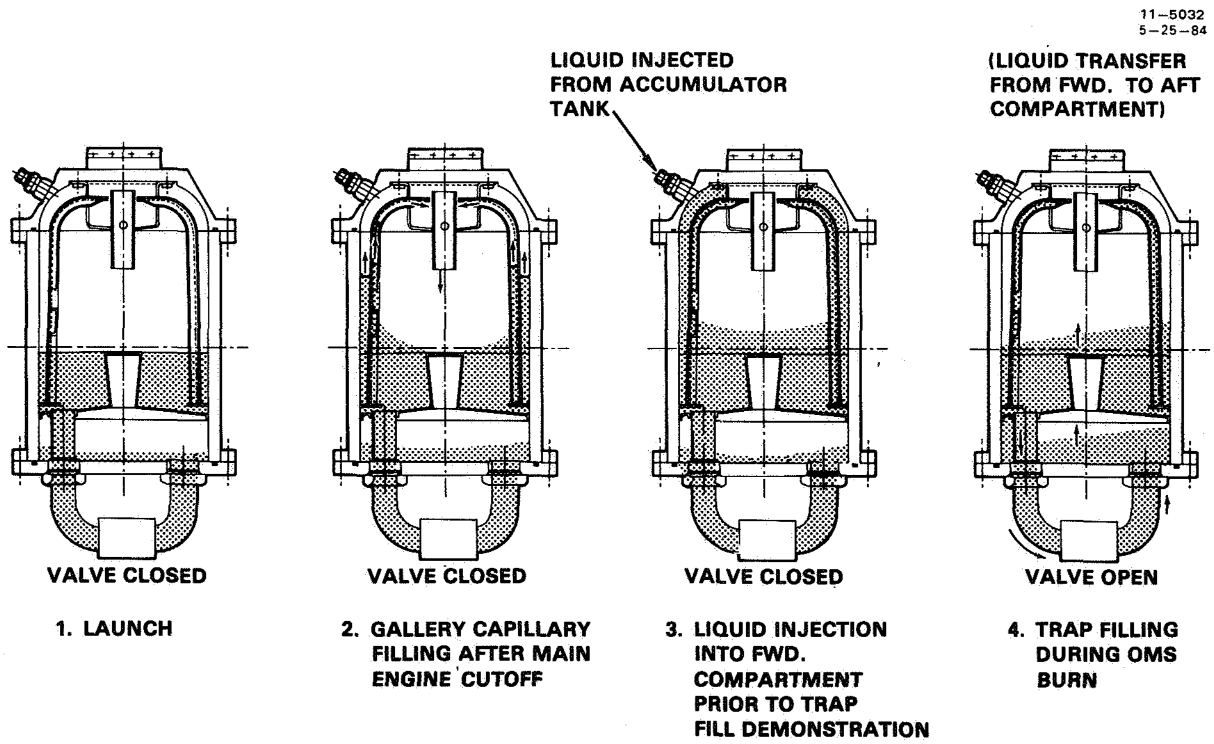

Fig. 4 Experiment Operating Sequence

The principle of gallery capillary pumping is illustrated in Fig. 5. The pressure, P_1, in the bulk liquid is higher than that in the gallery leg, P_2, for the common ullage pressure, P_a. The pressure differential (P_1 - P_2) results from differences in the meniscus radii at these locations in a low-g environment. As a result, liquid is pumped through the gallery leg in order to achieve a minimum free-energy position. During the gallery fill process the gas within the gallery legs is vented to the tank through the vent screens at the top of the gallery legs. The gallery fill rate is retarded by pressure losses due to liquid flow into the gallery legs, frictional and dynamic pressure losses due to liquid flow within the gallery legs, and pressure losses due to gas flow leaving the gallery legs. Predicted gallery fill times are shown in Fig. 6 as a function of gallery fill length. For the design gallery fill length of 6 inches, the maximum fill time (10.3 seconds) occurs for the rectangular leg with 30 x 250 twilled dutch double weave (TDDW) screen.

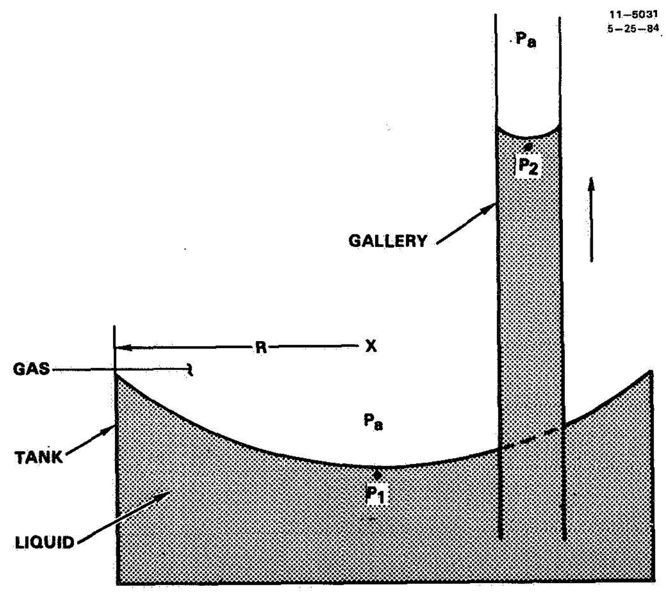

Fig. 5 Gallery Leg Capillary Pumping

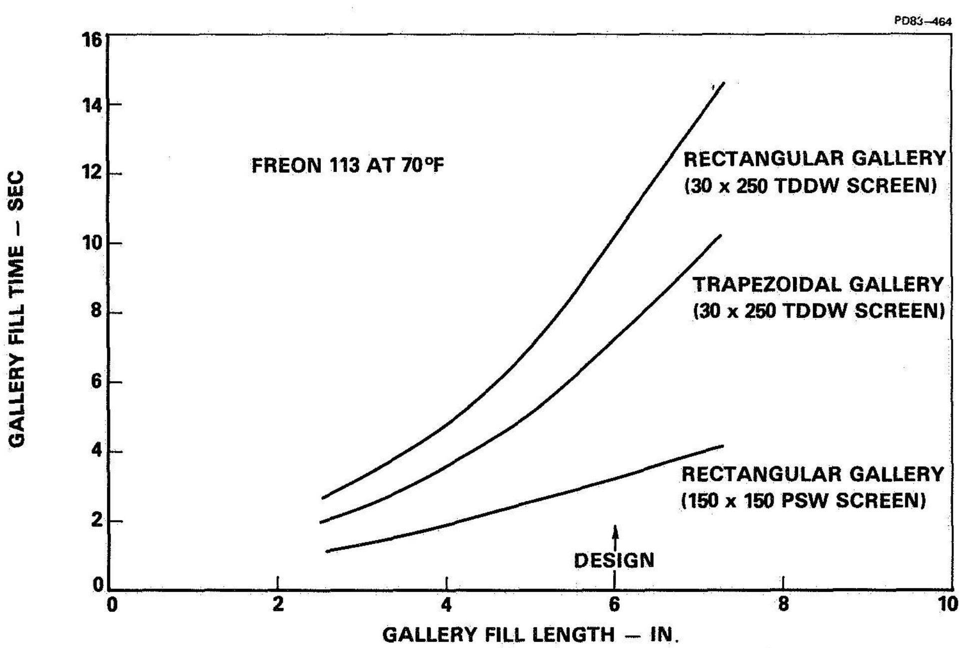

Fig. 6 Gallery Leg Fill Time

After the first Orbital Maneuvering Subsystem (OMS) burn, additional Freon 113 will be injected into the tank forward compartment from an auxiliary positive displacement accumulator in preparation for the trap filling experiment (Fig. 4). The trap filling experiment will be performed during the second OMS engine firing. The transfer valve at the tank outlet will be signalled open to allow liquid flow from the forward to aft compartment. During the burn, gas inside the aft compartment will be expelled through the vent stack perforated plates by the hydrostatic pressure imposed across the entrapped gas bubble, allowing the aft compartment to fill. The aft compartment fill rate is retarded by liquid flow pressure losses through the transfer line and valve and by gas flow pressure losses through the vent stack perforated plates. Predicted trap fill times are shown in Fig. 7 as a function of OMS acceleration level. For an OMS acceleration of 0.04 g's, the aft compartment fill time is approximately 30 seconds.

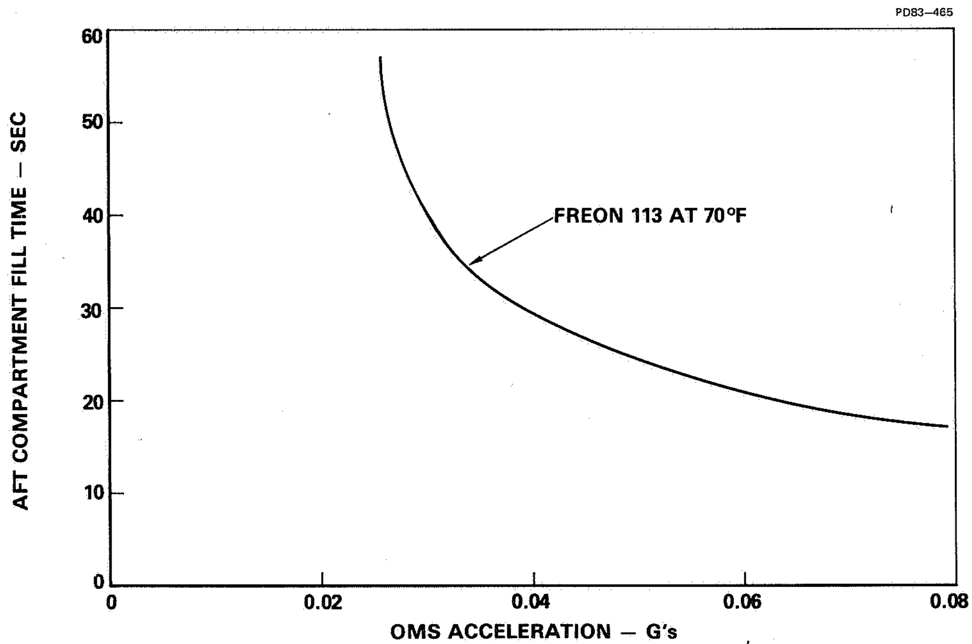

Fig. 7 Aft Compartment Fill Time

The experiment is controlled by an electronics package consisting of acoustic switches and timing circuits. At lift-off, the experiment will be activated using redundant acoustic switches that sense main engine ignition. The switches activate timing circuits that perform three functions: (1) turn on lights and camera for three minutes at main engine cutoff to monitor gallery leg filling; (2) activate a solenoid valve to inject liquid from the accumulator into the test tank in preparation for the trap refill experiment; and (3) turn on lights and camera and activate the test tank transfer valve for the trap refill experiment during the second OMS burn. A photograph of the acoustic switches and timing circuits is shown in Fig. 8 and photographs of the assembled experiment are presented in Fig. 9.

III. Testing

Environmental testing was performed to qualify the experiment for flight. The testing consisted of high and low temperature operating tests, vibration tests and acoustic tests.

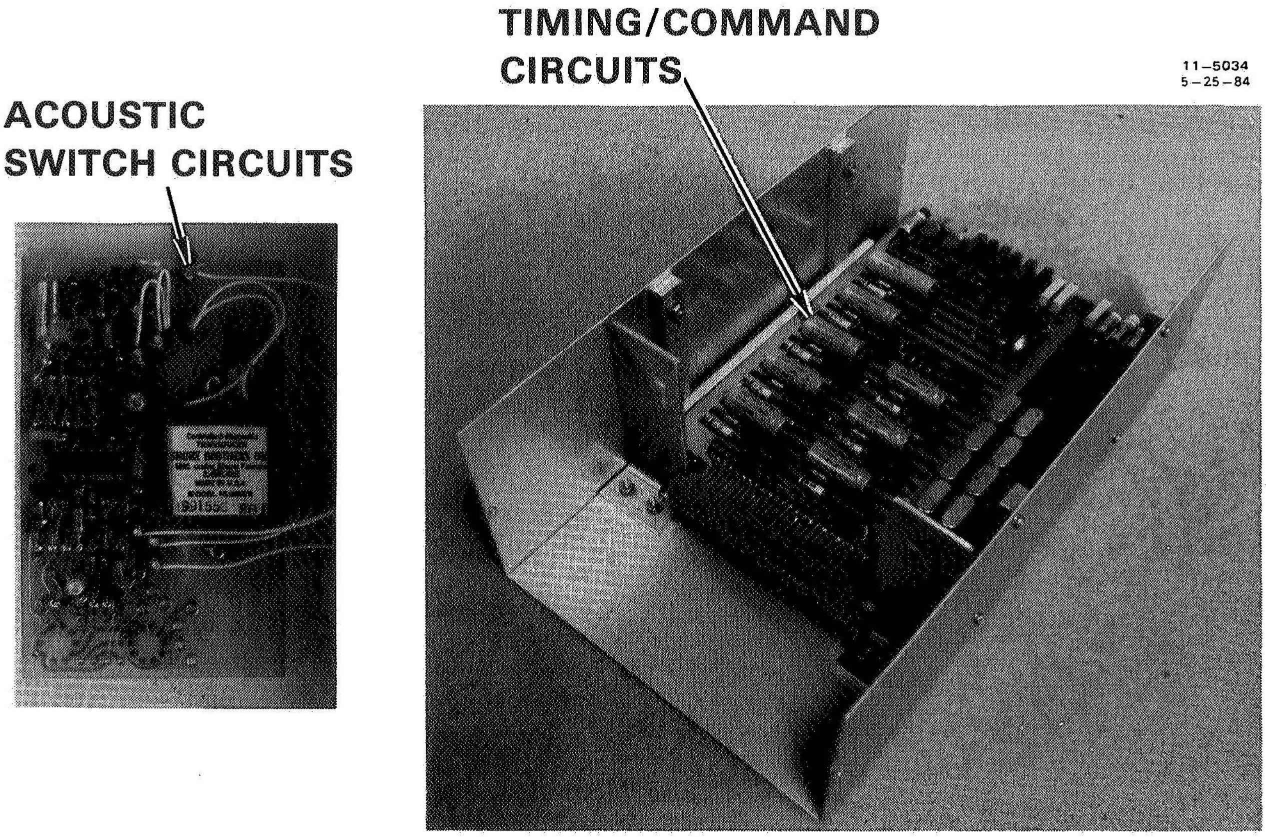

Fig. 8 Experiment Electronics

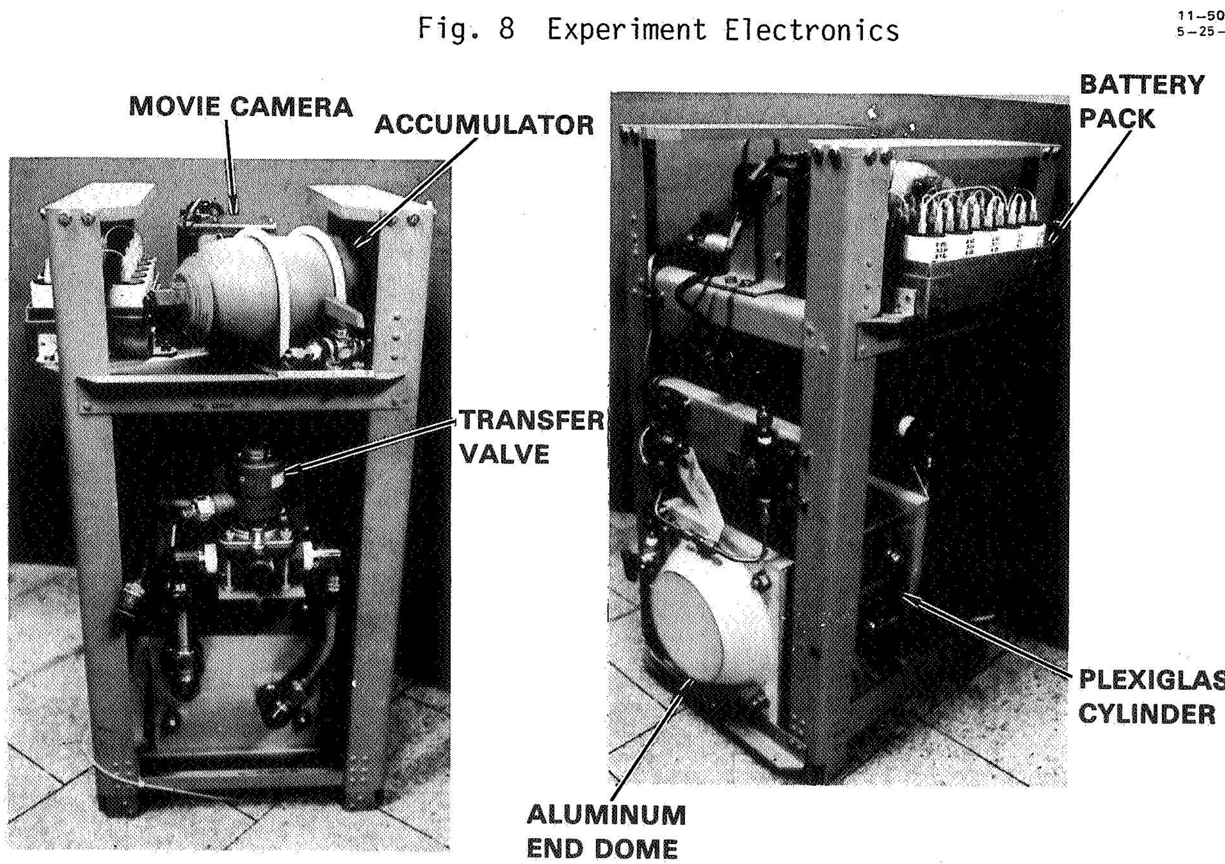

Fig. 9 G-0074 Experiment

The high temperature test was performed by installing the fully serviced payload inside an insulated thermal enclosure. Conditioned air at 150°F was circulated through the enclosure for a five hour period to bring the payload to an equilibrium temperature of 140°F. The payload was activated, and an entire mission sequence was run while maintaining the equilibrium temperature. There was no evidence of structural damage, and all light, camera, valve and switch functions occurred normally.

The vibration tests were performed with the fully serviced payload installed in a NASA shipping cylinder to simulate the flight canister. The imposed vibration spectrum (6 g_{RMS} - overall) was in accordance with the NASA flight specification for GAS payloads. Tests were performed in each of three axes (2 lateral and 1 vertical) for 40 seconds per axis. There was no evidence of structural damage as a result of the vibration tests.

An acoustic test was performed to verify the operational integrity of the payload following vibration testing. An acoustic environment was imposed which duplicated the sound pressure level and frequency spectrum measured inside the GAS canister on the STS-3 mission at liftoff. The payload was activated successfully with its acoustic switches at a threshold sound pressure level of 110 dB, and an entire mission sequence was run. All light, camera, valve and switch functions occurred normally.

The low temperature test was performed by installing the fully serviced payload inside the same thermal enclosure used for the high temperature test. Conditioned nitrogen at -20°F was circulated through the enclosure for an 18 hour period to bring the payload to an equilibrium temperature of -10°F. The payload was activated, and an entire mission sequence was run while maintaining the equilibrium temperature. There was no evidence of structural damage, but one valve (the accumulator solenoid valve) failed to operate. All other light, camera, valve, and switch functions occurred normally. The failure was traced to a faulty capacitor in the control circuit. The capacitor was replaced and a low temperature test was repeated successfully.

On the basis of these tests, the experiment was certified for flight.

IV. Summary

The Get-Away-Special experiment described in this paper will demonstrate technology for designing more versatile, lower cost surface tension propellant acquisition systems. It will demonstrate a full-tank gallery concept for future altitude control systems that can be off-loaded to provide enhanced mission flexibility. In addition, it will demonstrate a low-cost method for propellant acquisition in future orbit maneuver propulsion systems requiring large diameter propellant tanks.

The experiment has been fabricated and tested successfully to simulated flight environments. It will be delivered to NASA-KSC on 9 June 1983 and is scheduled to be flown on the STS-41-F mission on 23 August 1984.