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TRANSPORTATION RESEARCH COMMAND  
FORT EUSTIS, VIRGINIA

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CAS AD No.

TRECOM TECHNICAL REPORT 63-54

### THE MARVEL PROJECT

THE MARVELETTE AIRPLANE  
BACKGROUND AND DESCRIPTION

Task 1D121401A14203  
(Formerly Task 9R38-11-009-03)  
Contract DA 44-177-AMC-892(T)

November 1963

prepared by:

MISSISSIPPI STATE UNIVERSITY  
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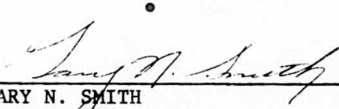
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HEADQUARTERS  
U S ARMY TRANSPORTATION RESEARCH COMMAND  
FORT BELT STIS, VIRGINIA 23604

This report is a presentation of a research project currently being undertaken at Mississippi State University, in which an aerodynamic research aircraft, the Marvel, is being designed to explore the problem areas inherent in STOL fixed-wing aircraft. After several years of experimentation with modified off-the-shelf aircraft, it became evident that full evaluation of new STOL design techniques was severely limited by basic configurations of available aircraft and that an aircraft incorporating the latest techniques in its basic configuration should be designed and tested.

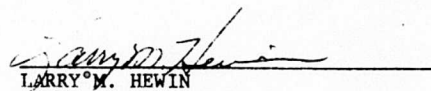
As an interim step toward refinement of the Marvel design, a test bed aircraft, the Marvelette (XAZ-1), has been designed, built and flown. This report presents the background history of the Marvel and the description of the Marvelette.

  
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Task 1D121401A14203  
(Formerly Task 9R38-11-009-03)  
Contract DA 44-177-AMC-892(T)  
TRECOM Technical Report 63-54

November 1963

## THE MARVEL PROJECT

### PART A

#### THE MARVELETTE AIRPLANE BACKGROUND AND DESCRIPTION

Aerophysics Research Report No. 45

Prepared by  
The Aerophysics Department  
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State College, Mississippi

for  
U. S. ARMY TRANSPORTATION RESEARCH COMMAND  
FORT EUSTIS, VIRGINIA

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## ORIGIN OF MARVEL PROJECT

The XAZ-1 MARVELETTE is part of the MARVEL Project undertaken by the Aerophysics Department of Mississippi State University. The project was originally sponsored by the Office of Naval Research, but is now supported entirely by the U. S. Army.

The term "MARVEL" stands for Mississippi Aerophysics Research Vehicle, Extended Latitude. Basically, this refers to an aerodynamic research aircraft specifically designed to explore the problem areas inherent in wide speed range, fixed-wing airplanes of interest in Army operations. These problem areas include high lift, low drag, high thrust, and the compatibility of the above with the requirements for good visibility, large usable volume, and rough field or pantobase operation.

The Aerophysics Department started research in these fields in 1950 under sponsorship of the Office of Naval Research. Experiments were conducted on stabilizing the laminar boundary layer by suction through distributed perforations in the wing skin of a TG-3 sailplane using battery-powered electric blowers. In the course of this work, it was found that the distributed suction technique was a powerful method of delaying turbulent separation at high-lift coefficients. Considerable success in using this method on another TG-3 sailplane (Figure 1) led to the modification of an L-21 for high-lift work (Figure 2).

The high-lift L-21 contributed much to understanding the aerodynamics involved in delay of separation. It was also a valuable tool for evaluating the mechanical and operational problems associated with this high-lift system. The blower system was belt driven from the engine and was available at only partial capacity when throttled back for landing. In spite of this, the airplane demonstrated a potential for excellent short-field capability. The steep climb-out angle achieved and the limited initial acceleration pointed out the need for very high thrust at low speeds. Modest thrust improvements were achieved by trying different propellers, but a really sizeable boost in thrust appeared to require a different basic approach. A study was therefore made of the ducted propeller as a means toward this end.

A duct or shroud was placed around the pusher propeller of an Anderson-Greenwood AG-14 (Figure 4). Large improvement was noted in static and low-speed thrust of this airplane. Research was conducted to explore the variables associated with a ducted propeller using both the airplane and static models. This airplane also provided much experience in vibration and mechanical problems arising from the ducted propeller.

About the same time, a second-generation high-lift modification was started using an L-19 (Figure 3). This airplane had a more refined boundary layer control system than the L-21. The blowers were hydraulically driven from the engine with an automatically variable ratio that permitted use of full blower capacity for landing. Because of difficulties inherent in the airplane, however, it was some time before the full potential of the system was realized. This required a long period of research and rather extensive modifications. Final results were impressive from the power-on lift coefficient of approximately 5.2 achieved and the short-field capability resulting from it. Several factors appeared to limit further progress with this configuration, however, and other designs were explored.

In research on the high-lift L-19, it was found that an annular region of low dynamic pressure surrounds the slip stream of an open propeller. The impingement of this lower velocity airflow on the wing causes early separation and limits the lift of the wing. The pusher configuration was expected to eliminate this difficulty. Also, if the thrust benefits of the ducted propeller are to be utilized, the duct must be placed toward the rear for visibility and stability considerations.

A study was made of ways to combine an optimum high-thrust system with an optimum high-lift system in one airplane. The ducted pusher fits this concept for improved low-speed thrust. However, the duct may contribute no thrust or even have drag at high speed. The duct would therefore have to be utilized to replace another component of the airplane to realize a net advantage. It was found that the lateral force characteristics of the duct closely approach those required for the tail surfaces. One configuration was evolved using the ducted propeller as the tail surface of the airplane along with a canard-type elevator in front (Figure 5). This plan was discarded, however, because of reduced visibility and interference with the airflow over the wing.

Further innovations were indicated in the wing to favor the high-lift system. To minimize negative pressure peaks at high-lift conditions, a camber-changing system was designed for use instead of flaps. Fiberglass structure was specified to minimize the surface irregularities that would lend to early separation. Cantilever construction and specially designed fillets and fuselage intersections were expected to reduce interference effects. These innovations were further required to be compatible with low drag for the high-speed case and to provide a suitable test vehicle for laminar boundary layer control if necessary.

In summary, an aircraft was designed under the designation of MARVEL (Figure 6) which was to serve as a research vehicle for high-thrust, high-lift, and low-drag requirements of Army aviation. The compatibility of the systems with each other for achieving these requirements on the same aircraft would be investigated along with their meeting the inherent needs for good visibility, large usable volume, and rough field or panobase operation. The aircraft was to be powered by a 250-horsepower turbine engine.

The Allison T63 gas turbine was the engine selected for this power plant, but this engine was not yet available at the time of the original proposal. A substitute proposal was therefore made for a limited or first-generation test vehicle to prove the feasibility of the configuration. This aircraft, designated MA-18 (Figure 7), was to be modified from an Anderson-Greenwood AG-14 airplane owned by the Navy and assigned to Mississippi State University, Aerophysics Department. The plan was to remove the tail and tail booms from the AG-14 and to build a tail and propeller duct onto the pod with an extension shaft to drive the propeller. The wings would be clipped and a camber-changing section provided behind the spar.

The design was discarded in favor of a modified one using the AG-14 pod, engine, landing gear and engine mounts, but the MARVEL wings (Figure 8). This would provide early evaluation of the MARVEL wing system in a powered aircraft of the ducted propeller-tail configuration. This aircraft was designated MA-18B MARVELETTE and later received the Army designation XAZ-1.

Pending the availability of the turbine engine, the possibility of building two glider versions of the MARVEL was considered. These gliders would be towed aloft and used in aerodynamic research. Negotiations for procurement of these gliders were conducted with a firm in West Germany. This plan was later abandoned in favor of a powered version of the MARVEL to be built in the United States. The construction would be held off until MARVELETTE flight data was available to finalize the design. The construction would reasonably coincide with the delivery of the Allison T63 turboshaft engine.

U. S. ARMY XAZ-1

MARVELETTE

The MARVELETTE airplane is a research aircraft intended mainly as a test bed for the MARVEL configuration. It uses some parts of the Anderson-Greenwood AG-14, some from the MARVEL, and some made especially for it.

The MARVELETTE uses a tapered high wing of cantilever construction. Conventional ailerons of short span and wide chord provide roll control. A camber-changing portion occupies the space behind the spar and inboard of the ailerons. This is the same wing as planned for the MARVEL. Fiberglass construction provides the necessary aerodynamic smoothness.

The fuselage is of conventional aluminum alloy construction except for an extended fiberglass nose that carries batteries, ballast, and instrumentation. The cabin area is taken from the AG-14 and utilizes an abreast, two-place seating layout immediately ahead of the wing. The engine compartment occupies the center of the fuselage behind the wing spar (Figure 9). An eight-foot fiberglass shaft drives the tail-mounted propeller (Figure 10). The fuselage sides are flattened back to a vertical trailing edge (Figure 11). At the top, a circular boss supports the propeller and flairs into the spinner. At the bottom, it flairs into the circular propeller duct which also serves as the empennage.

The fiberglass duct surrounds the 66-inch-diameter propeller. The trailing-edge portions of the airfoil profile are composed of articulated segments that serve as control surfaces (Figure 12). Two segments on either side act as rudders, and four segments, top and bottom, act as elevators. An intricate linkage connects them to a cable control system in the fuselage (Figure 13). Massive fiberglass struts maintain the required close alignment and carry thrust loads at the upper sides into the fuselage (Figure 14). Additional small steel jury struts were installed at the lower sides to maintain close propeller tip clearance. A fiberglass spring skid underneath protects the duct from ground contact (Figure 15).

A conventional fixed tricycle landing gear is used (Figure 16). The nose gear is taken from the AG-14. It is supported on a spring-oil strut and is steerable from the rudder pedals. The main gear was originally taken from the AG-14, but following a failure, it was replaced by a fiberglass spring cantilever strut type. Conventional toe-actuated hydraulic brakes with additional cooling capacity are used.

Streamline fairings for the sheels and struts reduce drag and protect the propeller from stones.

The propeller has three aluminum alloy blades of constant chord and zero twist outboard of the fiberglass cuffs (Figure 17). Pitch is controlled from a cockpit switch by an electric motor in the shaft. The motor turns pitch arms on the blades through reduction gears, a screw jack, and a spider (Figure 18). This mechanism is enclosed in a fiberglass spinner providing complete fairing with the fuselage and blade cuffs.

The propeller is driven by a Continental C-90 four-cylinder opposed engine rated 95 horsepower for take-off. This full power is not delivered to the shaft, however, because up to seven horsepower is used to drive the blowers providing boundary layer control and engine cooling.

The boundary layer control system utilizes a camber-changing wing (Figure 19) with distributed suction applied through thousands of small holes in the upper surface (Figure 20). The interior of the wing serves as a duct to convey the air from the perforated surface to the blowers which maintain the necessary low pressure to draw air into the wing. There are two blowers mounted in the fuselage immediately ahead and on either side of the engine (Figure 21). Each blower draws air from its wing through an elbow connecting to the flexible fillet that seals each wing to the fuselage. In addition, a crossover duct through the fuselage head of the wing spar serves to equalize the pressures in the two wings (Figure 22). Air from the blowers passes directly to the engine baffling system for cooling. It then discharges through an exhaust augmented jet pump into a tail pipe with a flapped outlet under and ahead of the propeller spinner (Figure 23).

The two seven-inch diameter boundary layer control blowers derive their power from the engine by independent systems of belts, governors, and flexible shafts. The object of the governors is to maintain the blowers close to their design operating speed of 10,000 r.p.m. over a considerable range of engine speeds. High blower output is desirable for landing when low engine output is required. The governors enable the pilot to have nearly full blower power with low propeller thrust by using low pitch on the propeller and 1800 r.p.m. on the engine.

Permanent instrumentation is provided to inform the pilot of flow through each blower and internal pressure in each wing. Other pressure measurement capability is represented by approximately 100 static pressure orifices in the wing surfaces connected to a terminal

board (Figure 24) in the fuselage. A swiveling pitot-static source is installed at the extreme forward end of the nose boom (Figure 25). This vane-directed probe also senses yaw and pitch attitude which is displayed on instruments in the cockpit (Figure 26). The readings of these and the usual flight and engine instruments are recorded photographically at approximately one-second intervals by an automatic camera in the cockpit (Figure 27). This instrumentation is intended to serve the most frequent needs of the testing and research program. Other special instruments, such as a multiple photo manometer, will be used as temporary installations for specific tests. Another temporary installation of this type is a control force measuring device.

The primary function of the MARVELETTE is to serve as a test bed for this unconventional configuration. Results of this experience will be applied to the MARVEL. Toward this end, initial flights have been of a shake-down nature. A flight test program is under way to make measurements of flight characteristics, pressure distributions, flow patterns, performance, and other pertinent data. After this, the aircraft will be available as an aerodynamic research tool.

APPENDIX



Figure 1. TG-3 Sailplane Modified for Research on High-Lift Boundary Layer Control.



Figure 2. L-21 Airplane Modified To Use High-Lift Boundary Layer Control.



Figure 3. L-19 Airplane Modified for a More Advanced High-Lift Boundary Layer Control System.

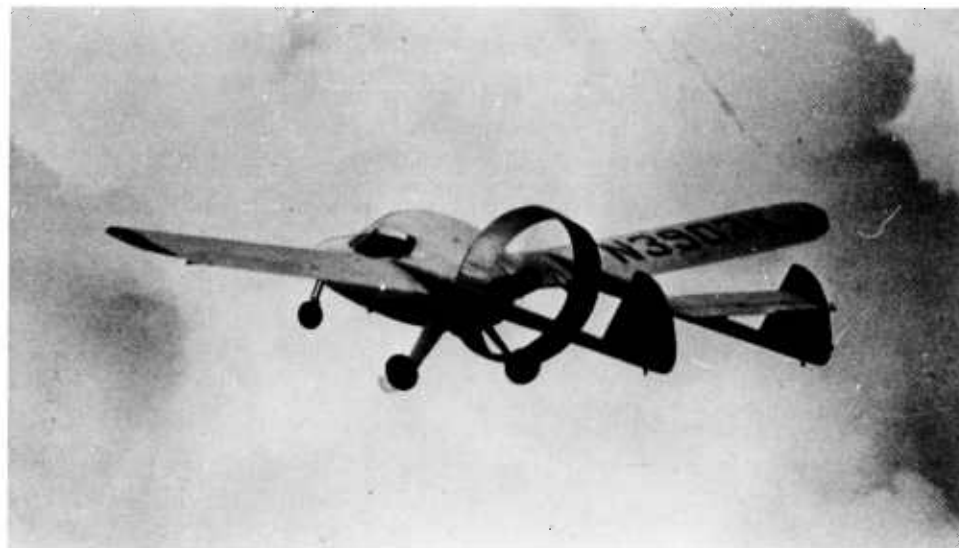


Figure 4. Modified AC-14 Airplane Using a Ducted Propeller for High-Thrust Research.



Figure 5. MA-16 Canard Configuration Considered for High-Lift and High-Thrust Combination.

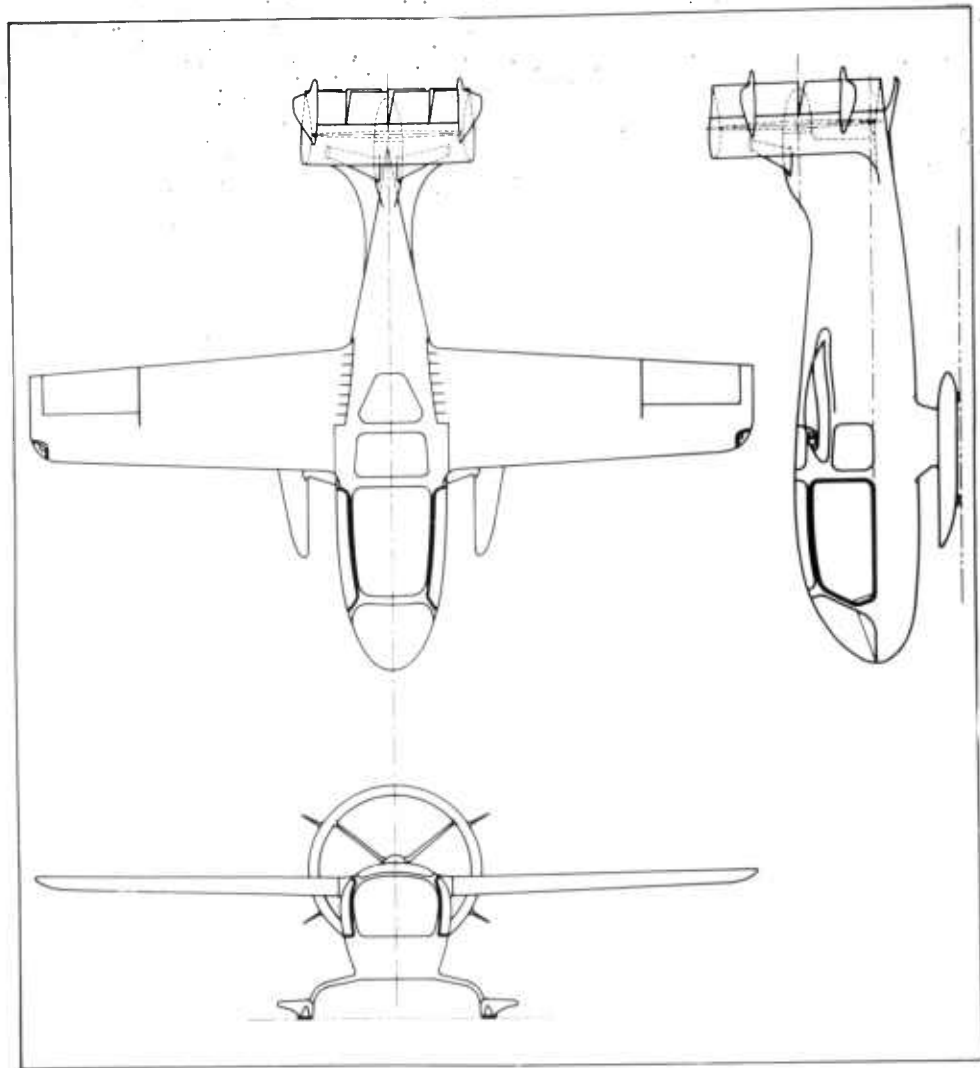


Figure 6. MA-17 MARVEL Final Configuration Adopted for STOL Research Vehicle on MARVEL Project.

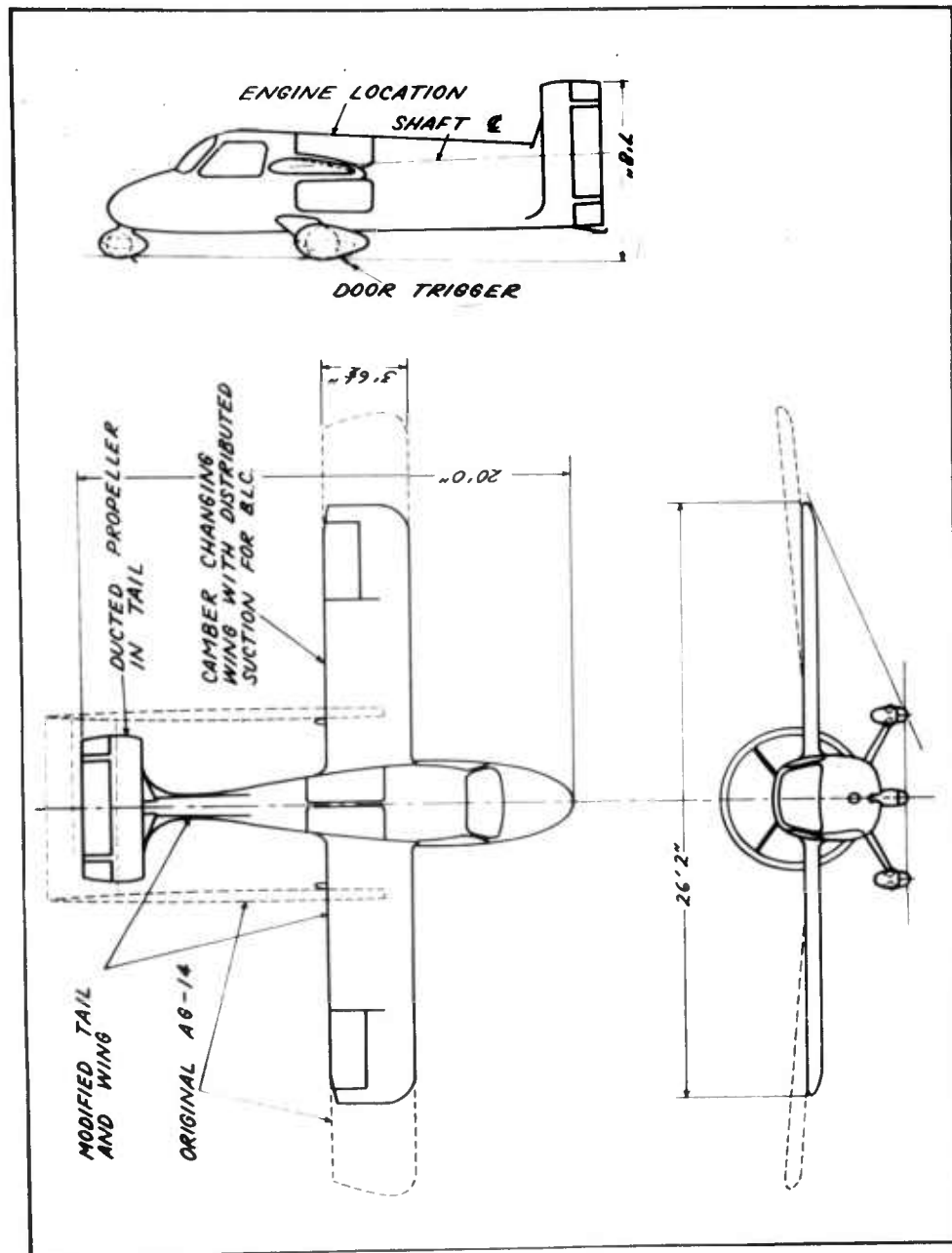


Figure 7. MA-18 Proposed Modification to AG-14 for Test Bed of MARVEL Configuration.

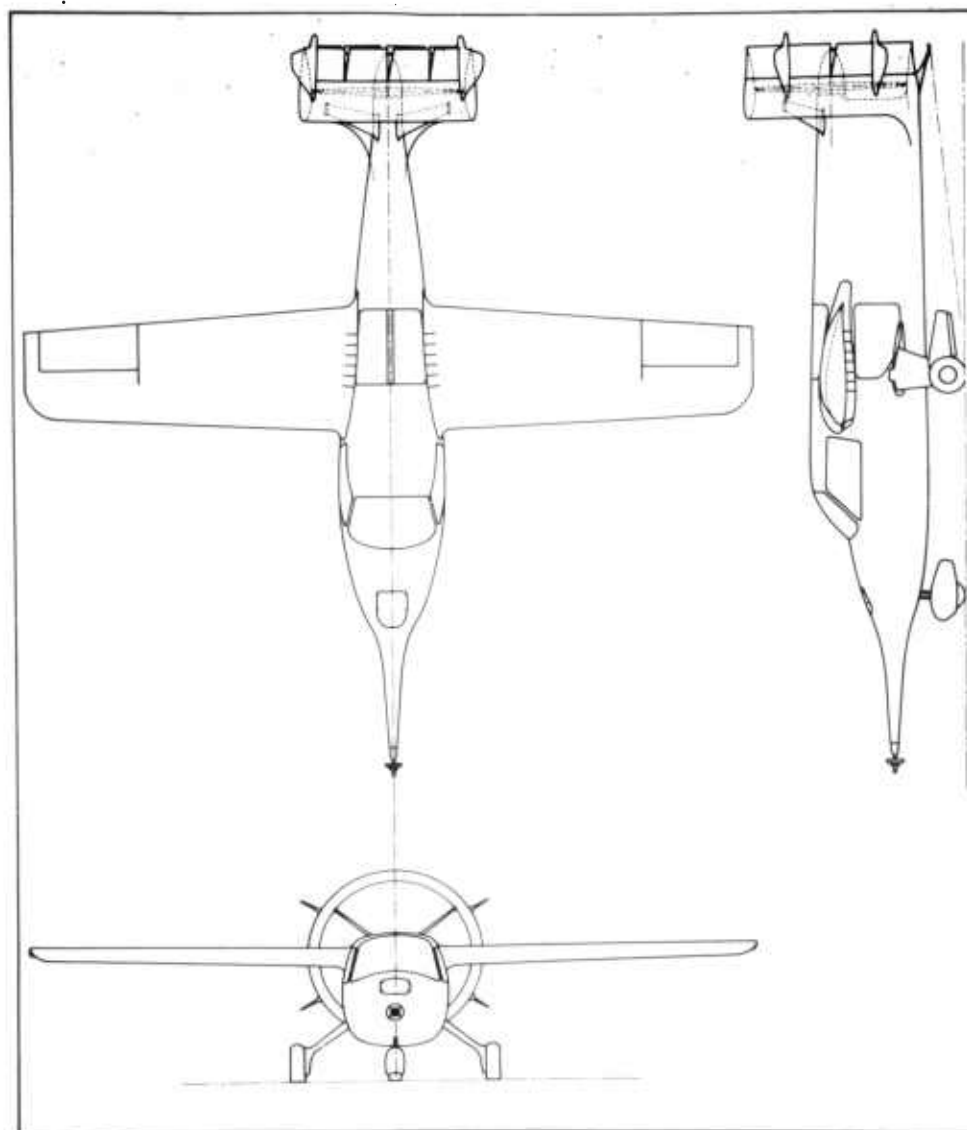


Figure 8a. MA-18B MARVELETTE Design Adopted for First-Generation Test Bed of MARVEL Configuration.



Figure 8b. General Views of MARVELETTE.

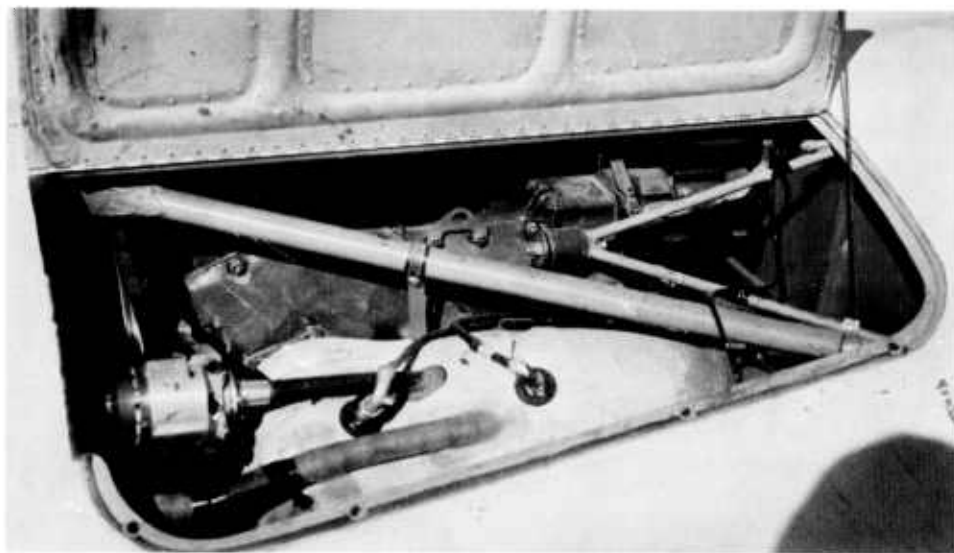
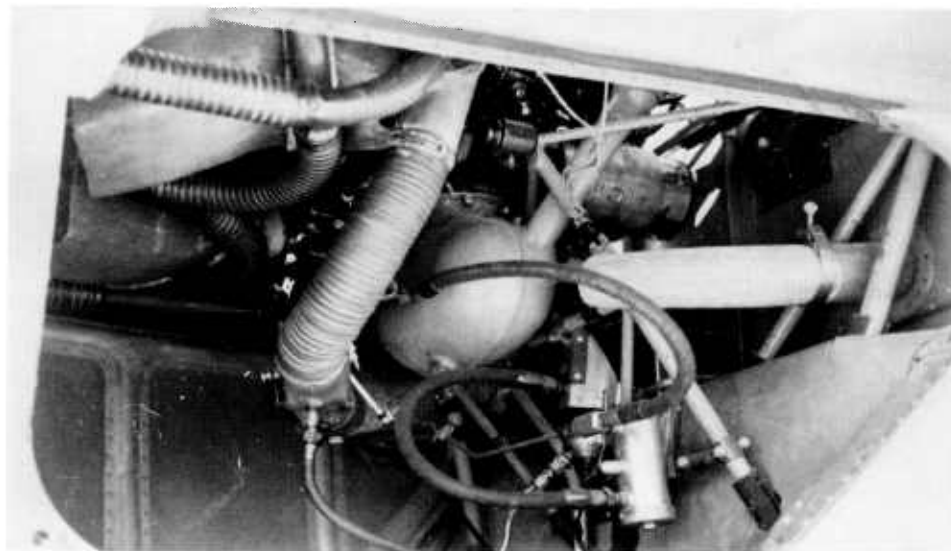


Figure 9. Top (lower photo) and Side (upper photo) Views of Marvelette Engine Compartment.



Figure 10. Extension Shaft and Propeller of MARVELETTE.

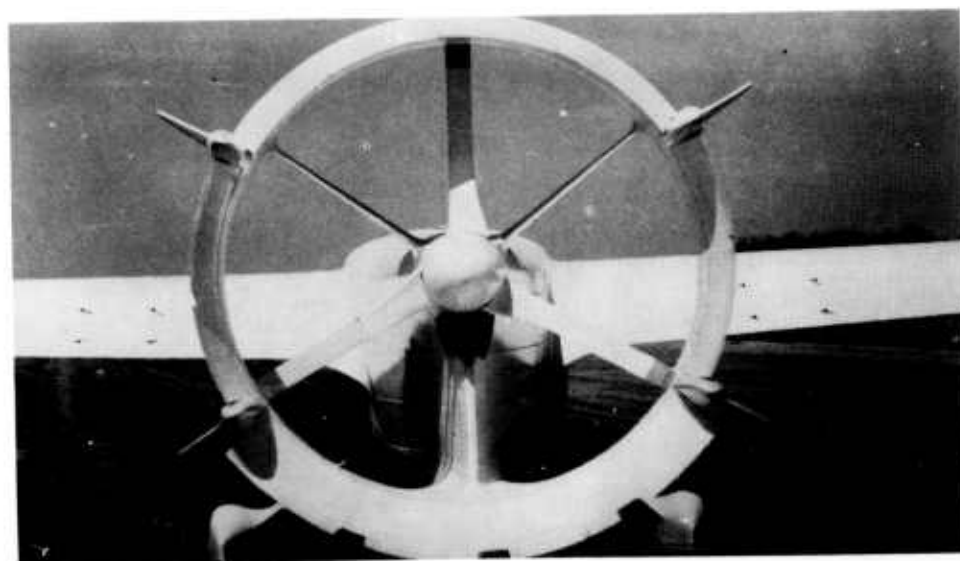


Figure 11. Detail of MARVELETTE Rear Fuselage Showing Blending Into Shroud and Propeller Spinner.

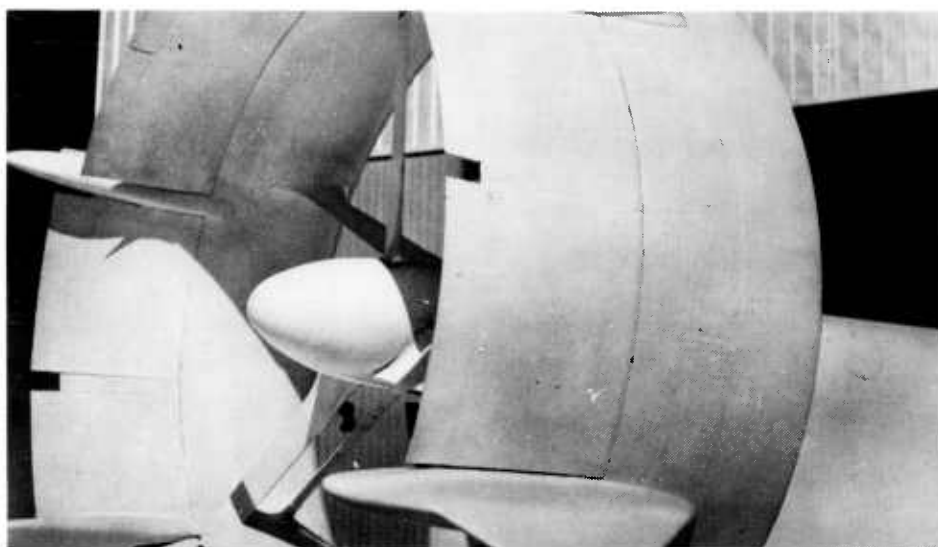
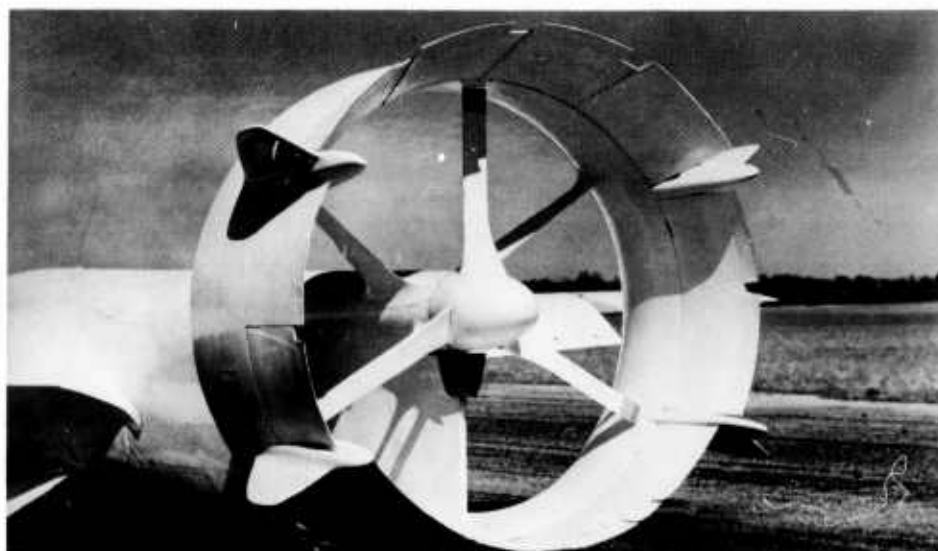


Figure 12. Details of MARVELETTE Elevator and Rudder Segments in the Trailing Edge of Propeller Duct.

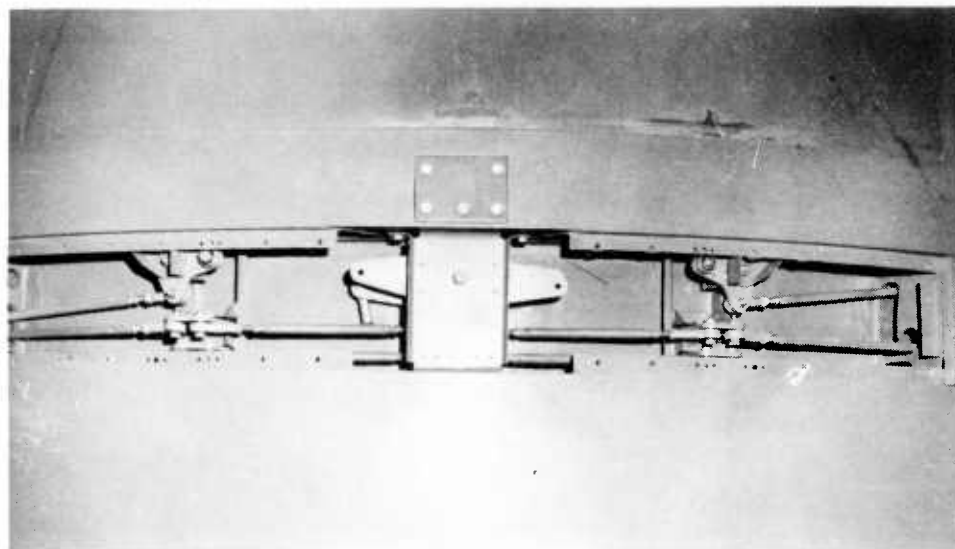


Figure 13. Detail of Linkage Used in MARVELETTE Propeller Duct for Rudder and Elevator Controls.

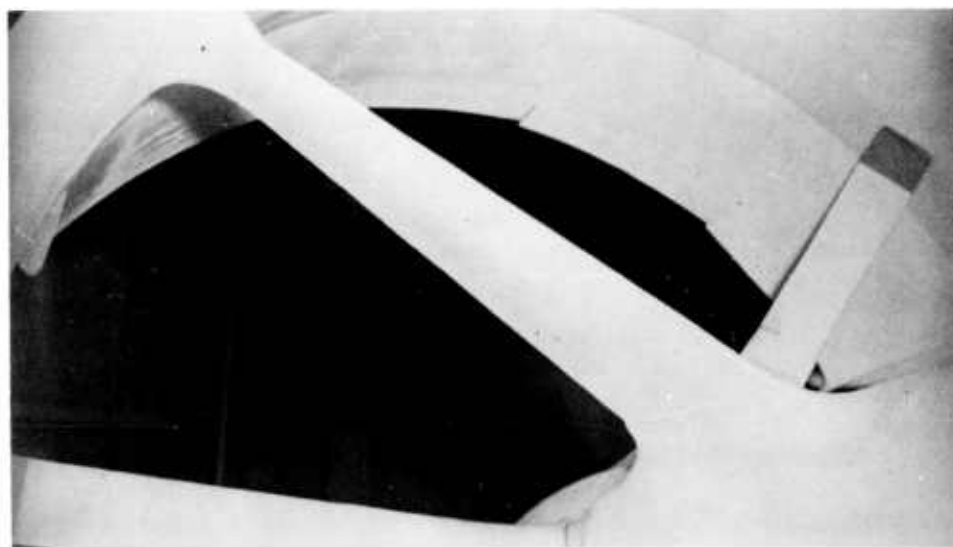


Figure 14. Detail of Upper Fiberglass Struts That Carry Thrust of MARVELETTE Propeller Duct.

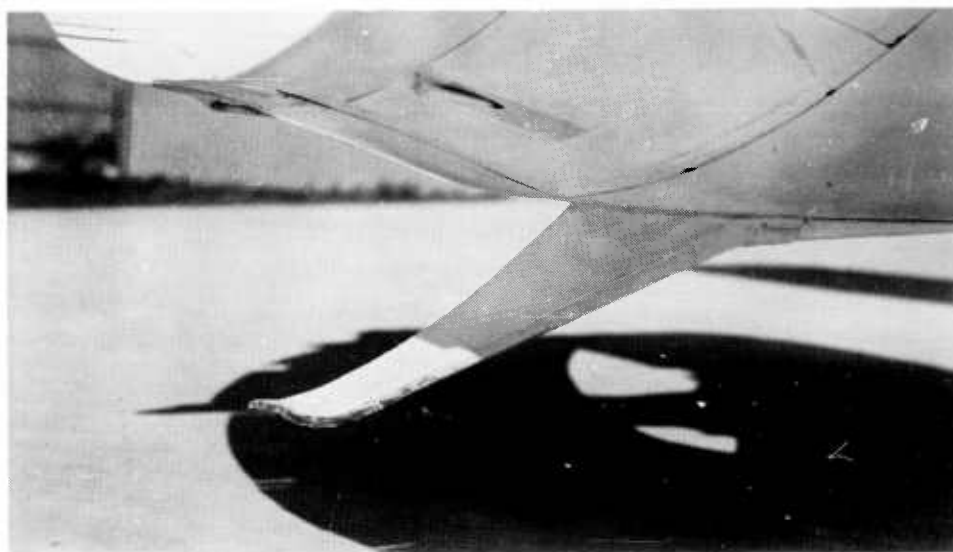


Figure 15. Detail of Fiberglass Spring Tail Skid Used to Protect MARVELETTE Tail From Ground Contact.

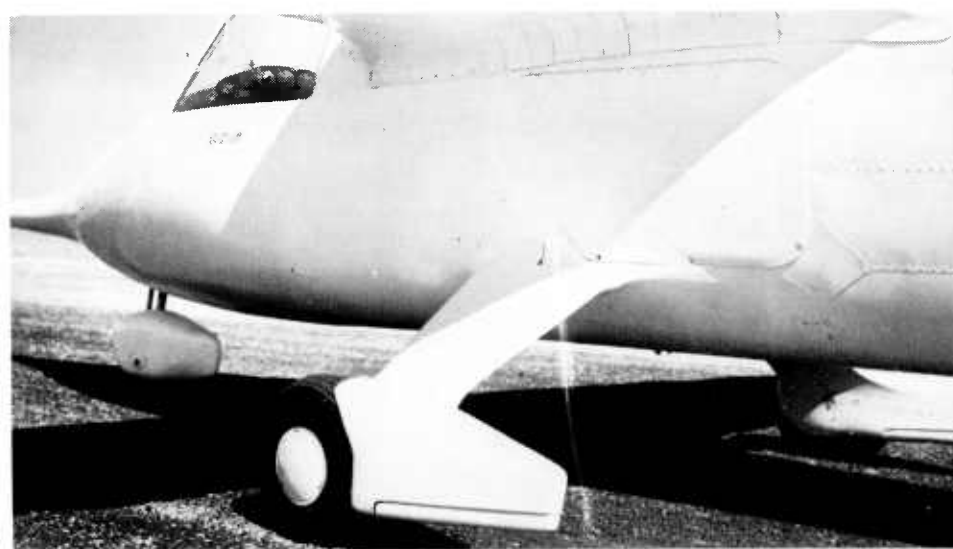


Figure 16. Detail of MARVELETTE Landing Gear Showing Fiberglass Spring Strut on Main Gear. Conventional Spring-Oil Nose Gear is from AG-14.



Figure 17. Detail of Fiberglass Cuffs Used on MARVELETTE Propeller to Fair Blades into Spinner.

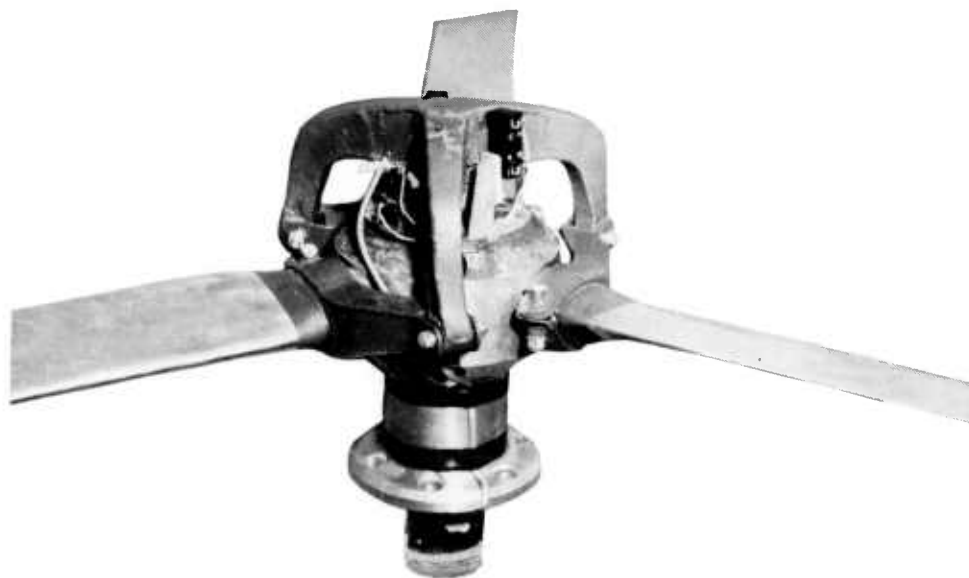


Figure 18. Detail of Mechanism Driven by Electric Motor (at bottom) Through Internal Gear and Screw System To Change Pitch of MARVELETTE Propeller Blades.



Figure 19a. Camber-Changing Wing System Used on MARVELETTE  
Shown in Up and Down Positions.

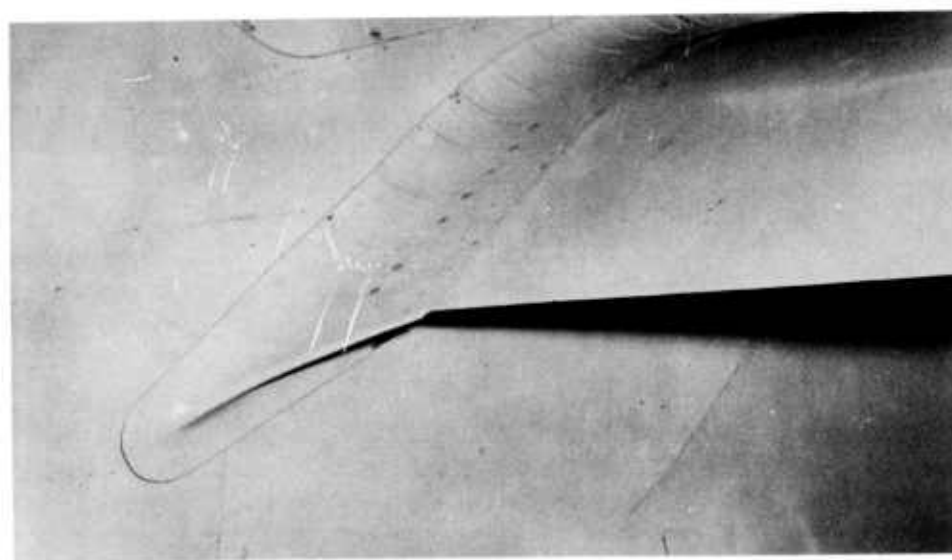
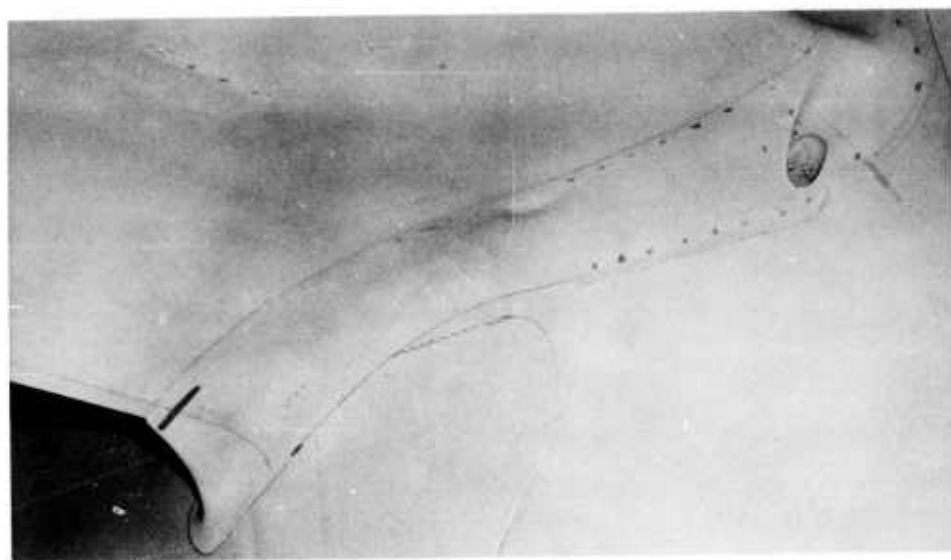


Figure 19b. Detail of Flexible Fillet Used To Accommodate to Camber-Changing Wing. Upper Photo Shows Under Side in Down Position, Lower Photo Shows Upper Fillet in Down Position.

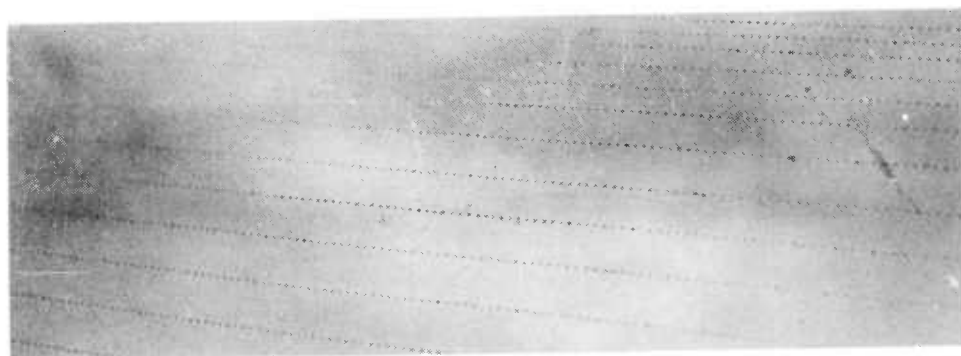


Figure 20. Detail of Perforations in Upper Wing Skin of MARVELETTE for Applying Suction to the Boundary Layer. Rows of Holes Run Spanwise.



Figure 21. Details of MARVELETTE Blowers Showing Components (left) and Installation as Viewed From Above (right). Belt and Pulley System (at bottom) Drives Blower (upper left corner) Through the Flexible Shaft (center).

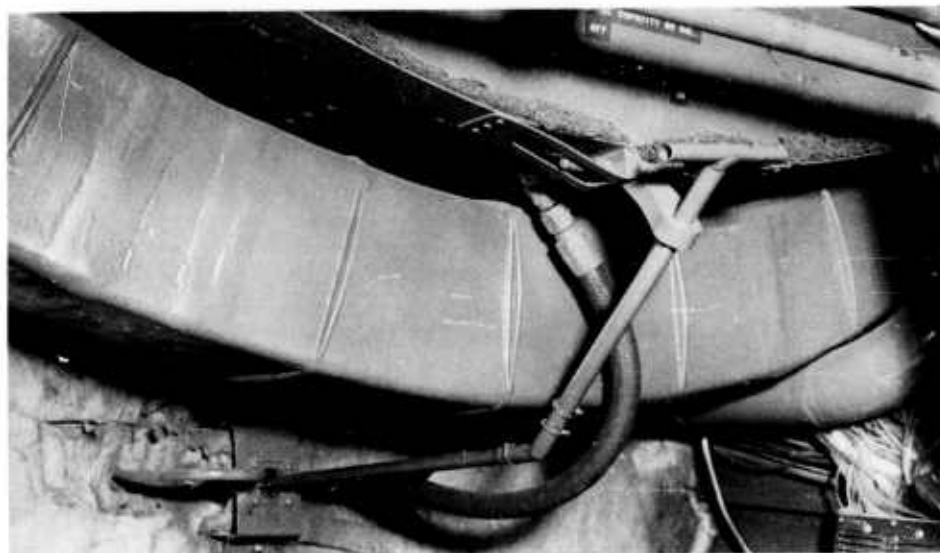


Figure 22. Detail of Fiberglass Crossover Duct Used in MARVELETTE To Equalize Internal Wing Pressures.

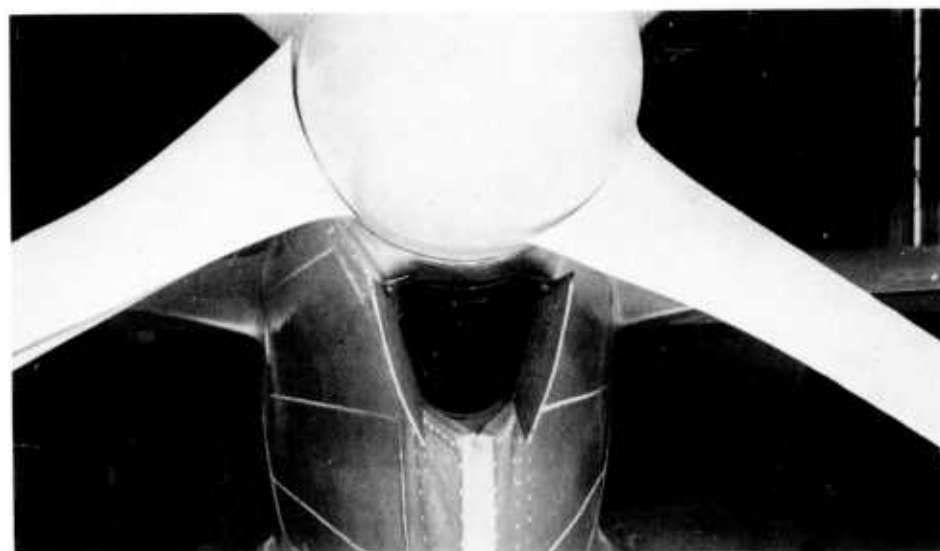


Figure 23. Detail of Adjustable Flap Used on Tailpipe of MARVELETTE Which Exhausts Boundary Layer Control, Cooling Air, and Engine Exhaust Gases.

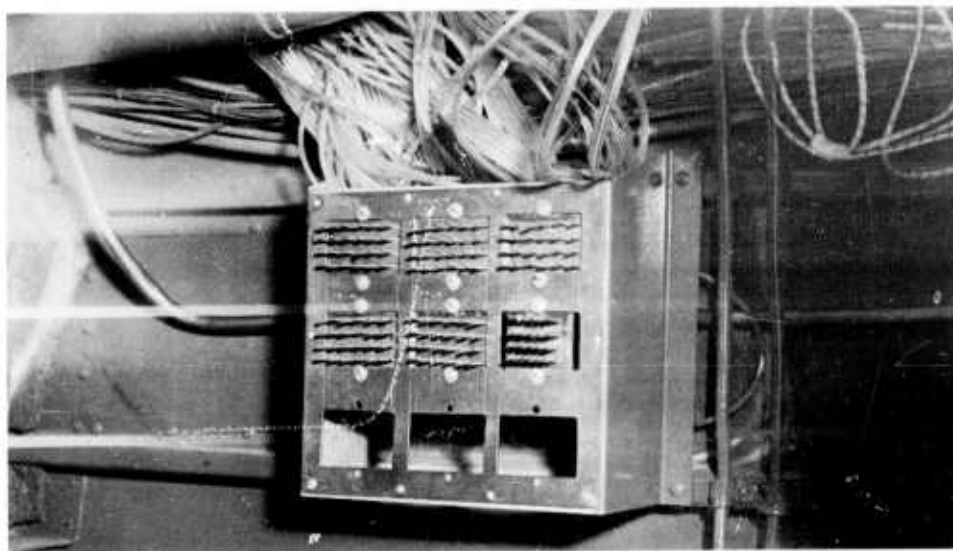


Figure 24. Detail of Terminal Board for Connections to Static Pressure Orifices in the Left Wing Skin of the MARVELETTE.

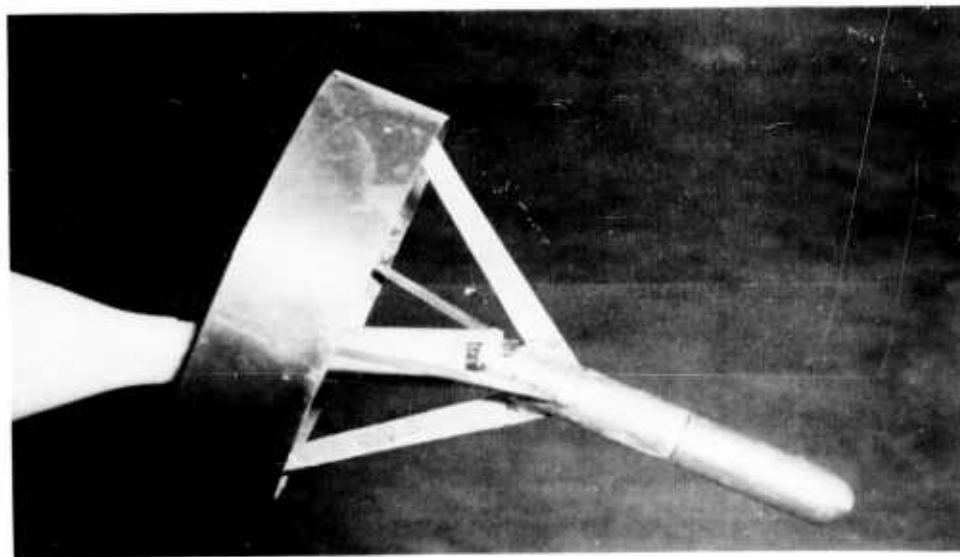


Figure 25. Detail of Swiveling Nose Probe Used To Measure Free Stream Static and Dynamic Pressure and Angles of Pitch and Side Slip.



Figure 26. Detail of Cockpit Showing Controls and Permanent Instrumentation in MARVELETTE.



Figure 27. Detail of Camera Used to Record Instrument Readings in the MARVELETTE.

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