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



TRECOM TECHNICAL REPORT 63-66

## THE MARVEL PROJECT

### REPORT OF PRELIMINARY FLIGHT TESTING OF MARVELETTE XAZ-1

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

November 1963

prepared by:

MISSISSIPPI STATE UNIVERSITY
The Aerophysics Department
State College, Mississippi



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FORT EUSTIS, VIRGINIA

In support of the Marvel project at Mississippi State University, an interim test-bed aircraft, the Marvelette, has been built to evaluate functionally the compatibility of the various features of the Marvel design (boundary-layer control, cambered wing, ducted propeller, fiber-glass structure). Also, the Marvelette, designated XAZ-1, will provide information for the refinement of the Marvel design and will be a readily available laboratory for exploration of low-speed aerodynamics in flight.

This report presents pilot evaluation and flight data on the Marvelette for the first ten aircraft checkout flights.

GARY N. SMITH
Project Engineer

PAUL J. CARPENTER
Group Leader
Applied Aeronautical Engr Group

APPROVED.

FOR THE COMMANDER:

LARRY M. HEWIN
Technical Director

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# THE MARVEL PROJECT

## PART B

## REPORT OF PRELIMINARY FLIGHT TESTING OF MARVELETTE XAZ-1

Aerophysics Research Report No. 46

Prepared by
The Aerophysics Department
Mississippi State University
State College, Mississippi

for

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

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# INTRODUCTION

Before an aircraft is delivered for flight testing, its various components, structural, mechanical, and electrical, must have passed a rigorous ground-testing program in which static and dynamic loads are applied to the structures and in which considerable tethered engine tests are performed to check engine operation, hydraulic systems, electrical systems, and engine cooling and vibration. After satisfactory completion of the ground tests the aircraft must be flown to demonstrate its flying characteristics, performance, and structural integrity.

The initial phase of a flight-test program on an experimental aircraft is ground handling and taxi tests to check ground maneuverability and braking. The high-speed taxi tests, at speeds close to flying speed, provide an opportunity to check control response; this check would indicate any obvious control irregularities which could be corrected before the first flight, while giving the pilot an idea of the feel of the aircraft.

The second phase of a flight-test program consists of the shake down phase of pilot familiarization, a functional check of all phases of operation, and a decision as to the airworthiness of the aircraft from the standpoint of safety. An attempt is also made to iron out the "bugs" and to prepare the aircraft for flight testing. During the shake down phase, engine cooling and vibration are closely monitored, and possible alterations to the system are made to insure that the engine-manufacturer's limits are adhered to and that the vibration is acceptable. Stability check flights are made to establish the acceptability of the airplane or to investigate any modifications necessary to make the airplane acceptable from the standpoint of safety, controllability, and maneuverability, as dictated by the final use of the airplane. Performance testing can also be carried out if the test vehicle is representative of the final configuration.

This report deals with the ground testing and initial flight-test phases of the MARVELETTE XAZ-1 airplane with a variable camber, a high-lift, boundary-layer controlled wing, and a shrouded propeller. Mainly because inadequate engine cooling has been a major problem, the flights have necessarily been of short duration. Nevertheless, during the first ten flights, which had a total flying time of 110 minutes, considerable flight data have been obtained, and decisions as to the safety, maneuverability, and controllability of the aircraft have been reached. Also, a number of problems associated with the above criteria as well as those involving inadequate propeller twisting, brake heating, and undercarriage problems have been solved.

## SUMMARY OF PRE-FLIGHT TESTING

Development and testing of the MARVELETTE and its components began over a year before its first flight away from the runway in November of 1962. The details of the component development will be presented in another report. A brief summary of this testing and development is given here.

Taxi tests were begun with the fuselage about six months before the delivery of the wings. These tests showed reasonable tail effectiveness with both power on and power off but with some improvement for the power-on case. They also showed that controllable pitch was essential for the propeller. The propeller was then modified with an electric actuator for pitch control. Other tests in this period concerned engine cooling and shaft vibration. The vibration tests led to installation of a center bearing on the shaft to suppress a first-bending-mode critical frequency in the operating range. Development was also required to improve blower performance. Wheel pants were added to act as fenders to prevent stones from being thrown into the propeller. About three months, extending into early 1962, were required for completion of the wing installation. In this same period, an extended nose was installed as a mounting for flight instrumentation and to provide a long-moment arm for required nose ballast. Additional jury sturts were also installed on the shroud to control propeller tip clearance.

Shake down taxi runs at high speed on the runway were made following the wing installation. Some lift-offs from the runway were made in March of 1962. During one of these, a failure in the left main landing-gear strut occurred. As an expedient, the landing gear from the Anderson-Greenwood AG-14 had been used. It was overloaded, however, and failed from the ground impact. New main landing-gear legs were then made by the use of a fiberglass cantilever spring principle. Some damage also had occurred as a result of the gear failure which was repaired with addition of reinforcement where indicated. The nose-wheel-steering system taken from the AG-14 was also considered unsatisfactory. It was therefore changed at this time to steer from the rudder pedals rather than from the aileron control. The brakes were likewise changed to individual toe controls rather than a single heel brake. An addition of 2½ inches was made to the chord of the elevator and rudder segments at this time to improve controllability.

Taxi runs were again initiated with the new landing gear in August of 1962. Low-pitch stops were added to the propeller along with counterweights for moving to high pitch. After blower-belt troubles had been corrected, observations of the flow pattern on the wings were made with tufts. Brake heating from these severe taxi runs required a redesign of the lower end of the fiberglass spring to protect the plastic parts from heat. Changes in the axles, added cooling area, better ventilation, and a heat shield corrected the problem.

Development of flight instrumentation proceeded at this time, and final adjustments were made to prepare the airplane for flight. High-speed taxi tests were resumed in November of 1962. These were followed by lift-offs with varying amounts of camber. A movie-camera installation on the tail was used to record the action of tufts on the wings. The first flight away from the runway was made November 16, 1962, in the course of one of these tests and is described in the flight test summary.

Further developments followed this flight. A nose-wheel fairing was installed to reduce drag. Taxi tests with it resulted in a violent nose-wheel shimmy, which was eliminated by removing the springs from the steering system. Fins were also added between the elevator and rudder sections of the tail. These are described in the flight test summary. A mechanical inspection and overhaul of parts which had accumulated several hours of testing time was also made at this time in preparation for the first series of test flights. In addition, outlet ducts were added to reduce pressure drop on the engine cooling air and to reduce the temperature in the engine compartment. Between later flights it was found necessary to add an engine-oil cooler.

## SUMMARY OF INITIAL FLIGHT TESTS AND PILOT EVALUATION

The MARVELETTE XAZ-1 airplane is a test bed for the MARVEL configuration (Reference 1). The results of these tests are to be applied to the design of the second-generation airplane, the MARVEL. The test-bed nature of the MARVELETTE warranted the acceptance of many design and construction compromises that would not be appropriate to a more refined vehicle. First in these compromises was a weight increase, particularly in the tail, along with necessary ballast in the nose; this resulted in an aircraft with a high power loading. The 95 horsepower available for the engine are reduced by about seven horsepower by the boundary-layer control blowers. The remaining 88 shaft horsepower give a power loading of nearly 23 pounds per horsepower at a gross weight approaching 2000 pounds. Combined with a wing loading of nearly 19 pounds per square foot, the result is an underpowered airplane. Our flight and testing techniques had to be oriented around this consideration.

The relatively shallow climb angle results in a considerable period in which the airplane could not be returned to a runway in the event of a mechanical failure. Thus, in order to take advantage of favorable terrain for a possible forced landing in this area, all our takeoffs were toward the south from the Starkville airport. Most of the flights were made early in the morning to utilize the calm conditions, to obtain accurate in-flight measurements, and to avoid winds unfavorable for takeoff in the preferred direction. The cooler temperatures prevailing at this time also improved performance.

Previous high-speed, taxi, runway-skimming flights, beginning in March of 1962, had demonstrated that the airplane was manageable and reasonably safe for flight. It was in the course of the concluding phase of this program that engineering test pilot Sean Roberts made the first flight on November 16, 1962. Because of gusty wind conditions and uncertainty of stopping in the runway length, he elected to fly around the traffic pattern. The airplane had been prepared for this eventuality, and no difficulty was encountered. Closely controlled programming was required, however, to clean up from the full camber condition, to increase airspeed, and to climb out from the field.

Following a period of maintenance, clean up, and instrumentation developments, a series of shake down flights were begun. Early in these flights it became clear that the large moment of inertia about the lateral and vertical axes contributed a tendency toward an oscillation, particularly in pitch. The aircraft was completely manageable, but increased damping in pitch appeared desirable. Consequently, small fins were added to the four spaces between the rudders and elevators. These fins were expected to increase the tail volume, make the outside of the duct more effective, and end-plate the movable surfaces to improve their effectiveness.

The added fins apparently succeeded in improving both steadiness and controllability, although some pitching oscillation is still present. It is probable that most of the oscillation results from lost motion in the elevator control linkage. This definitely undesirable feature is another of the manufacturing compromises accepted in the test bed. The pitch oscillation and generally slight tendency to wallow is most pronounced with the reduced power settings used for landing approach. This reduced steadiness is probably the result of reduced flow through the duct at low power settings. Stability is generally good, however, and there is no difficulty in making coordinated turns. So much directional stability is present that little use of the rudder is required.

There is a definite tendency for the airplane to continue rolling into a turn, and opposite aileron must be applied and usually held in the turn. Aileron control is adequate, however. This rolling tendancy is greater at larger camber settings and reduced airspeed. Since the boundary-layer control system is not fully developed, some separation of flow exists at larger camber settings. It is possible that a differential separation exists in rolling that contributes to this effect. This effect will be examined in the next series of flights.

At present, sufficient elevator trim is not available to trim out control forces for all flight conditions. In most cases a backward pull is required on the controls to hold the nose up. This is partly because the airplane is rigged in the same way as the MARVEL, which is intended to cruise over 200 m.p.h. At the low speeds of the MARVELETTE tests, a considerable amount of up-elevator is required to trim out. This condition is relieved to a great extent, however, by the operational flexibility provided by the camber-changing wing.

The camber-changing wing serves two main functions. First, it serves with the boundary-layer control system as a high-lift device. Second, it serves as a variable incidence device. When camber is increased, the effective incidence of the wing relative to the tail is increased. This results in a nose-up moment which is greater than the pitching moment resulting from the increased camber. Increasing camber can therefore be used for trimming the airplane at lower speeds as well as for providing increased lift. This trimming effect is most pronounced for the first 10 to 15 degrees of camber. The camber-changing wing is also used to take off and land in a more level attitude, which is required by the small tail clearance. It is usual, however, to drag the tail skid in landing.

There has been no noticeable bounce on any of the landings. The tail skid usually strikes the ground first, and the airplane rotates to the main landing gear and then to the nose wheel. The aircraft then rolls straight ahead, and moderate braking brings it to a stop in less than 1000 feet. No attempt has been made yet to use short-field techniques.

Most landing approaches have been made at 85 to 90 m.p.h., with the propeller set at nearly low pitch. Enough throttle was used to adjust the approach path and maintain 1700 to 2500 r.p.m. on the engine. This provided relatively little thrust with low pitch settings but kept the blowers near full output to insure adequate boundary-layer control for landing. Below 1700 r.p.m., moderately severe vibration was noted under these conditions. Since this does not occur in ground runup, it was thought that a portion of the propeller blade was stalled in a windmilling condition. Since operation in this range was not needed, it was avoided in flight.

The propeller pitch mechanism is electrically operated from a cockpit switch. Since a governor is not provided, the r.p.m. must be monitored frequently by the pilot and corrections made as changes in airspeed require them. In flight, the pilot is quickly warned of any changes in r.p.m. by a change in engine noise pitch. The need for pitch control appears to be considerably greater with a ducted propeller than with an open one. On the takeoff run, the propeller switch must be pulsed every few seconds to avoid overspeeding the engine. Once constant climb-out airspeed is established, the propeller requires no further attention. This manual system is generally undesirable because it occupies some of the pilot's attention, but it provides a better opportunity to study the propeller action for various flight conditions.

Studies of early climb data indicated that the propulsive efficiency was not as high as would be expected during climb and cruise. Ground tests and in-flight measurements of inflow velocity distribution ahead of the propeller indicated a need for revised propeller-twist distribution. Following the addition of three degrees of twist in the propeller blades, there was a noticeable improvement in climb and cruise performance. As presently set, the high pitch position of the blades will only permit 113 m.p.h. without exceeding 2500 r.p.m.

In these first ten flights, shake down and preliminary measurements have been made over a considerable range of variables. Flying speed was varied from 65 to 120 m.p.h., and camber settings were varied from 0 to 30 degrees. Flights have been kept to short duration, the longest being 16 minutes, while the greatest height above takeoff was 1400 feet. No stalls or violent maneuvers were attempted. A good feel for most ordinary flight attitudes and variables was obtained.

From these flights we already have found several changes to incorporate in the MARVEL design. One item for improvement is in the camber-change mechanism. Experience in flight indicates that a more powerful actuator and lower friction bearings are required. Studies are also under way to eliminate the objectionable qualities in the control system. The lost motion and stiffness will have to be corrected in the next vehicle. Some redesign will also be in order to eliminate the tendency to trim nosedown with power on and noseup with power off. This effect is not pronounced enough to present difficulty in flying, but it does not represent good practice. These and other indicated improvements will be further evaluated in the next series of flight tests.

## CONCLUDING REMARKS

The most important conclusion which can be drawn from the results of the initial flight-testing program is that although the MARVELETTE is unconventional in that it has a variable-camber wing and a ducted propeller with the moveable control surfaces incorporated in the duct, the general handling characteristics are very similar to those of a conventional airplane. The variable-camber wing behaves in a manner similar to that of a flapped wing, except that the lift-drag ratio of the variable-camber configuration is much higher than that of the flapped airfoil, especially at large flap angles.

The ducted propeller performs satisfactorily, in that sufficient thrust is available to accelerate the airplane from 0 to 70 m.p.h. in 17 seconds even though the blade-twist angles are not yet optimised for maximum thrust at low forward velocities. The low climb-out angle of the airplane is the only major feature that is detrimental to the safety of the aircraft under normal operating conditions, but this feature is taken for granted in high-performance airplanes where an engine failure shortly after takeoff would make it impossible for the airplane to return to the airfield.

The major effect of the shroud is thrust augmentation, although the directional-stability contribution is sufficient to overshadow the rudder effect in normal flying. The flight results have shown that the assumptions used in designing the shroud and control surfaces are reasonably correct for adequate control of the airplane. A problem has been stiffness in the control linkages in the elevator circuit, but this can be cured by alterations in the linkage design.

The response of the controls is adequate to control and to maneuver the airplane in the normal flight category in all phases of flight.

The MARVELETTE is sufficiently safe, controllable, and maneuverable to perform the research task for which it was designed and built, namely the development of the shrouded propeller and the variable camber wing with the solutions of the accompanying internal and external aerodynamic problems.

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# XAZ-1 MARVELETTE
## SPECIFICATIONS

Dimensions:

| | |
|---|---|
| Wing Span | 26 ft., 2.4 in. |
| Length | 27 ft., 11 in. |
| Height | 7 ft., 11 in. |
| Wing-Mean Geometric Chord | 48.5 in. |
| Taper Ratio | 6.7 |
| Aspect Ratio | 6.5 |
| Sweep at 35 Per Cent Chord | 0° |
| Washout | 2° |
| Incidence at Root | +1° |
| Camber-Changing Span (including fuselage) | 18 ft. |
| Aileron Span (each) | 3 ft., 6 in. |
| Diameter of Propeller | 5 ft., 6 in. |
| Outside Diameter of Propeller Duct | 6 ft., 3.5 in. |
| Chord of Propeller Duct | 32.3 in. |

Areas:

| | |
|---|---|
| Wing (including ailerons and camber-change portion) | 106 sq. ft. |
| Ailerons | 11 sq. ft. |
| Propeller Duct (projected horizontal) | 22 sq. ft. |
| Propeller Duct (projected vertical) | 18 sq. ft. |
| Elevators (2) (projected) | 12.0 sq. ft. |
| Rudders (2) (projected) | 7.2 sq. ft. |
| Propeller Disc Area | 24 sq. ft. |

Propulsion:

| | |
|---|---|
| Engine (Continental C-90) | |
| Maximum T. O. Horsepower | 95 |
| Maximum Rated Horsepower | 90 |

Weights:

| | |
|---|---|
| Empty with Standard Instrumentation | 1723 lb. |
| Useful | 263 lb. |
| Gross | 1986 lb. |

TABLE 1

PILOT'S FLIGHT REPORT INFORMATION
FOR FIRST FIVE FLIGHTS OF XAZ-1 MARVELETTE

| Item / Flight No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Date | November 16, 1962 | January 9, 1963 | May 2, 1963 | May 7, 1963 | May 16, 1963 |
| Condition of Airplane | Set up for ground skim | Cleaned up | Added fins on shroud - extra cooling | Oil cooler added | Set up for propeller study, new oil-temperature gauge |
| *Air Temperature | 50° | 40° | 45° | 60° | 70° |
| *Wind - Surface | 15, S | 10, S | Light, N | Light, N | Light, S |
| *Wind - Above 100 Feet | 20, S | 15, S | 15, N | 15, N | Moderate, SW |
| *Turbulence | Moderate | Moderate | Nil | Nil | Light |
| *Humidity | Moderate | Low | Moderate | Moderate | Moderate |
| Fuel - Gallons | 6 | 12 | 13 | 11 | 11 |
| XAZ-1 Pilot | Roberts | Bryant | Bryant | Bryant | Bryant |
| Chase Pilot | --- | --- | Roberts - Navion | Roberts - Navion | Roberts - Navion |
| Photographer | --- | Benci - Ground | Benci - Navion | Benci - Navion | Benci - Navion |
| Monitor in Tower | Maxey | Maxey, Roberts | Maxey | Maxey | --- |
| Monitor in Jeep | Welch, Bryant | Welch | Welch | Welch | Welch |
| Test Objective | High-speed taxi to photograph tuft pattern on wing | Shake down, familiarization, and color photos | Shake down and check of handling with added fins | Check oil cooling and measure across wing skin | Measure inflow velocity distribution ahead of propeller |
| Instrumentation[1] | Standard and tufts on wings and camera on tail | Standard and ground photos | Standard and movie photos from chase plane | Standard and connection across skin at first row of holes and still photos from chase plane | Standard and static rake ahead of propeller and photo-manometer and movie shots from chase plane |
| Takeoff Time | 9:00 A.M. | 9:15 A.M. | 5:55 A.M. | 5:50 A.M. | 5:20 A.M. |
| Takeoff Speed | 65 m.p.h. | 70-75 m.p.h. | 75-80 m.p.h. | 75-80 m.p.h. | 75-80 m.p.h. |
| Takeoff Camber | 30° | 10° | 8° | 9° | 11° |
| Climb Speed | 95 m.p.h. | 90 m.p.h. | 90-95 m.p.h. | 85 m.p.h. | 80-85 m.p.h. |
| Average Rate of Climb | 300 ft./min. | 400 ft./min. | 346 ft./min. | 333 ft./min. | 300 ft./min. |
| Maximum Height | 300 ft. | 1000 ft. | 1100 ft. | 1200 ft. | 800 ft. |
| Measurements[2] | Standard and movies of wing tufts | Standard and ground camera photos (movie) | Standard and movie photos from chase plane | Standard and across wing skin and still photos from chase plane | Standard and propeller inflow distribution and movies from chase plane |
| Operation | Satisfactory except cracked exhaust | Satisfactory except camber change would not go below 12.5° and oil temperature over red line | Satisfactory except oil temperature was high | Satisfactory except camber change stuck at takeoff setting, oil temperature high | Satisfactory except pressures exceeded manometer limits |
| Approach Speed | 80 m.p.h. | 90 m.p.h. | 80-90 m.p.h. | 95 m.p.h. | 80-85 m.p.h. |
| Landing Time | 9:05 A.M. | 9:28 A.M. | 6:10 A.M. | 6:00 A.M. | 5:30 A.M. |
| Time in Air | 5 minutes | 13 minutes | 15 minutes | 10 minutes | 10 minutes |
| Landing Camber | 12° | 12.5° | 20° | 7° | 5° |
| Remarks | Camber change reduced from 30° to 10° on climb-out | Large moment of inertia noted -- increased damping in pitch indicated fins added to shroud to improve pitching oscillation - improved cooling of engine compartment needed | Fins improved pitching oscillation but did not completely eliminate it. Mostly noticed at reduced power settings | Indications of poor propulsion efficiency on climb lead to ground and taxi tests of thrust, flow on propeller and shroud and inflow velocity to propeller. | Repeat flight required to get inflow data. Takeoff and climb noticeably slower in higher air temperatures |

* Estimated Values

[1] Standard instrumentation consists of usual flight and engine instruments plus internal wing pressures and flow rates for each wing and pitch and side slip indicators. All are recorded at approximately one second intervals by an automatic camera. Two-way radio communication is also standard.

[2] Standard measurements consist of the film record of the standard instruments plus relevant data radioed to tower for recording.

TABLE 2

PILOT'S FLIGHT REPORT INFORMATION
FOR FLIGHTS SIX THROUGH TEN OF XAZ-1 MARVELETTE

| Item \ Flight No. | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|
| Date | May 18, 1963 | June 6, 1963 | June 7, 1963 | June 7, 1963 | June 10, 1963 |
| Condition of Airplane | Same | $3^{o}$ twist added to propeller | Same - new blower belt | Same | Same |
| *Air Temperature | $60^{o}$ | $65^{o}$ | $72^{o}$ | $77^{o}$ | $78^{o}$ |
| *Wind - Surface | Light, N | Very Light, S | Calm | Calm | Very Light |
| *Wind - Above 100 Feet | Moderate, N | Light, S | Light | Light | Moderate, W |
| *Turbulence | Nil | Nil | Nil | Nil | Light |
| *Humidity | Moderate | Very High, Dew | High, Hazy | Moderately High | High |
| Fuel - Gallons | 11 | 10.5 | 11 | 12 | 10 |
| XAZ-1 Pilot | Bryant | Bryant | Bryant | Bryant | Bryant |
| Chase Pilot | Roberts - Cub | Roberts - Cub | Roberts - Cub | Roberts - Cub | Roberts - Cub |
| Photographer | --- | Harris - Cub | --- | --- | Benci - Cub |
| Monitor in Tower | Maxey | Maxey | Maxey | Maxey | Maxey |
| Monitor in Jeep | Welch | Welch | Welch | Welch | Welch |
| Test Objective | Repeat of flight five with better hookup | Evaluate twist on propeller and recheck inflow distribution | Propeller inflow velocity distribution at 80 m.p.h. with varying camber and tufts | Repeat at 100 m.p.h. and wing-tuft observation | Repeat at 100 m.p.h. and tuft observations, also $25^{o}$ and $30^{o}$ camber at 70 m.p.h. |
| Instrumentation[1] | Standard and inflow with cabin static and total head to cabin instrument | Standard and inflow and still photos from chase plane | Standard and inflow and wing tufts | Standard and inflow and wing tufts | Standard and inflow and wing tufts and still and movie camera in chase plane |
| Takeoff Time | 5:20 A.M. | 5:08 A.M. | 4:49 A.M. | 6:08 A.M. | 5:04 A.M. |
| Takeoff Speed | 75-80 m.p.h. | 75 m.p.h. | 75-80 m.p.h. | 80 m.p.h. | 75-80 m.p.h. |
| Takeoff Camber | $7^{o}$ | $7^{o}$ | $7^{o}$ | $9^{o}$ | $8^{o}$ |
| Climb Speed | 85 m.p.h. | 90-93 m.p.h. | 85 m.p.h. | 85 m.p.h. | 85 m.p.h. |
| Average Rate of Climb | 300 ft./min. | 330 ft./min. | 320 ft./min. | 280 ft./min. | 260 ft./min. |
| Maximum Height | 700 ft. | 1200 ft. | 1200 ft. | 1400 ft. | 1000 ft. |
| Measurements[2] | Standard and repeat of propeller inflow with better hookup at 60, 70, 80, 90, 100, 110 m.p.h. | Standard and repeat of propeller inflow with twist at 75, 80, 90, 100, 110 m.p.h. and still photos from chase plane | Standard and repeat of propeller inflow at 80 m.p.h. and 2500 r.p.m. for $0^{o}$, $5^{o}$, $10^{o}$, $15^{o}$, $20^{o}$, $25^{o}$, $30^{o}$, camber and tuft observations from chase plane | Standard and repeat of propeller inflow at 100 m.p.h. and 2500 r.p.m. for $0^{o}$, $4^{o}$, $10^{o}$, $15^{o}$ camber and tuft observation from chase plane | Standard and propeller inflow at 100 m.p.h. and 2500 r.p.m. for $0^{o}$, $5^{o}$, $10^{o}$, $15^{o}$, $20^{o}$ camber, also 70 m.p.h. for $25^{o}$ and $30^{o}$ camber and tuft and movie shots from chase plane. |
| Operation | Satisfactory | Satisfactory - blower belts changed after flight | Satisfactory | Camber change would only go to $15^{o}$ | Satisfactory |
| Approach Speed | 85 m.p.h. | 90 m.p.h. | 90 m.p.h. | 90 m.p.h. | 90 m.p.h. |
| Landing Time | 5:20 A.M. | 5:22 A.M. | 5:09 A.M. | 6:17 A.M. | 5:20 A.M. |
| Time in Air | 10 minutes | 14 minutes | 10 minutes | 9 minutes | 16 minutes |
| Landing Camber | $20^{o}$ | $15^{o}$ | $15^{o}$ | $16^{o}$ | $18^{o}$ |
| Remarks | Inflow data indicated improper twist on propeller for climb and cruise - $3^{o}$ twist put into propeller | Previous flight attempt on 6/4/63 was aborted because of trouble with propeller pitch control - trouble corrected - $3^{o}$ twist improved climb and cruise | Tuft observations showed separation proceeding from trailing edge as camber was increased beyond $15^{o}$ - further work on high-lift system indicated | Sticking of camber change required, repeating measurements for larger camber settings | High drag at $20^{o}$ camber, 100 m.p.h. Lost altitude at rated power. Considerable separated flow noted for above condition. |

* Estimated Values

1 Standard instrumentation consists of usual flight and engine instruments plus internal wing pressures and flow rates for each wing and pitch and side slip indicators. All are recorded at approximately one second intervals by an automatic camera. Two-way radio communication is also standard.

2 Standard measurements consist of the film record of the standard instruments plus relevant data radioed to tower for recording.

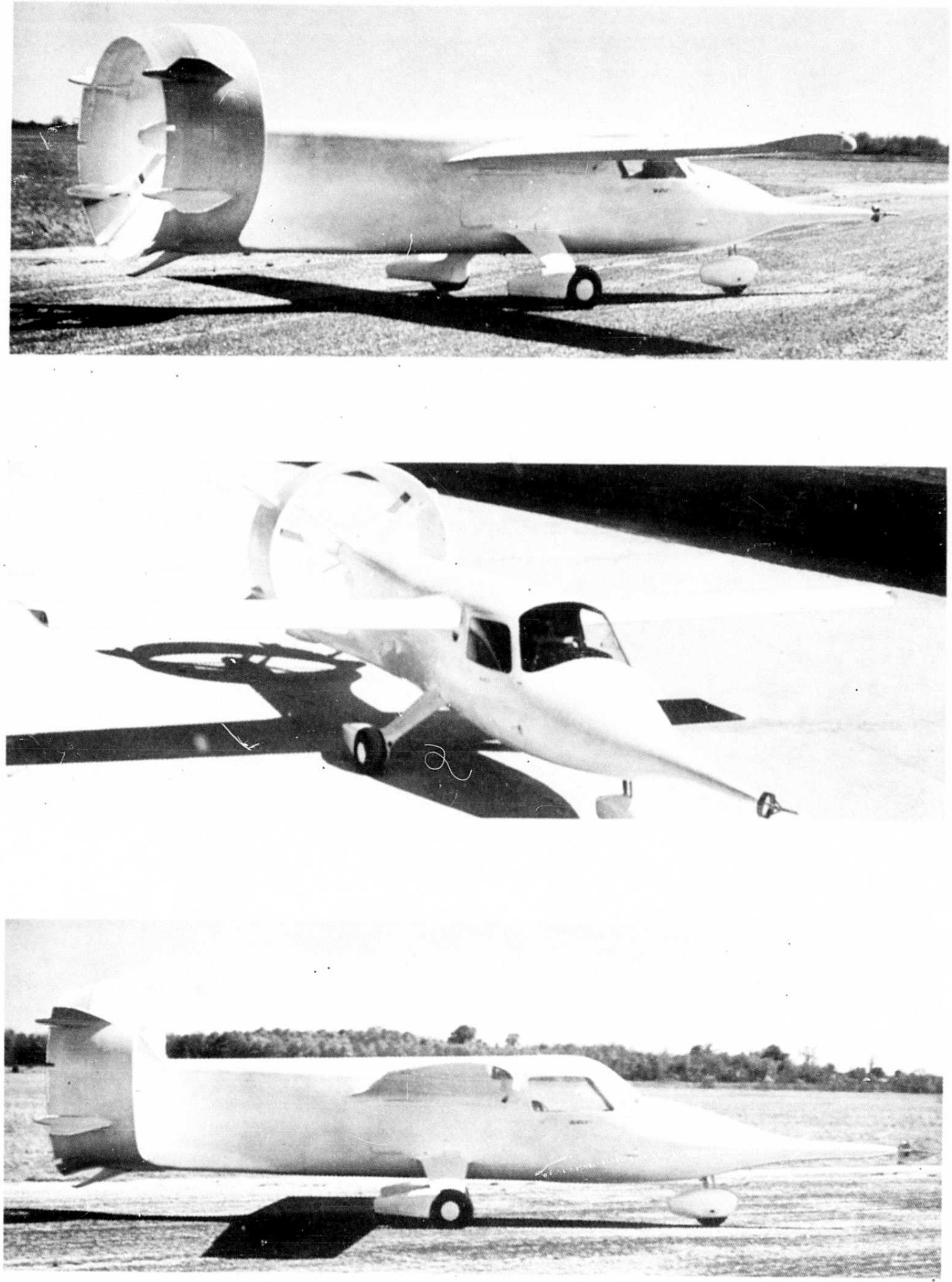


Figure 1. Three Views of MARVELETTE XAZ-1.

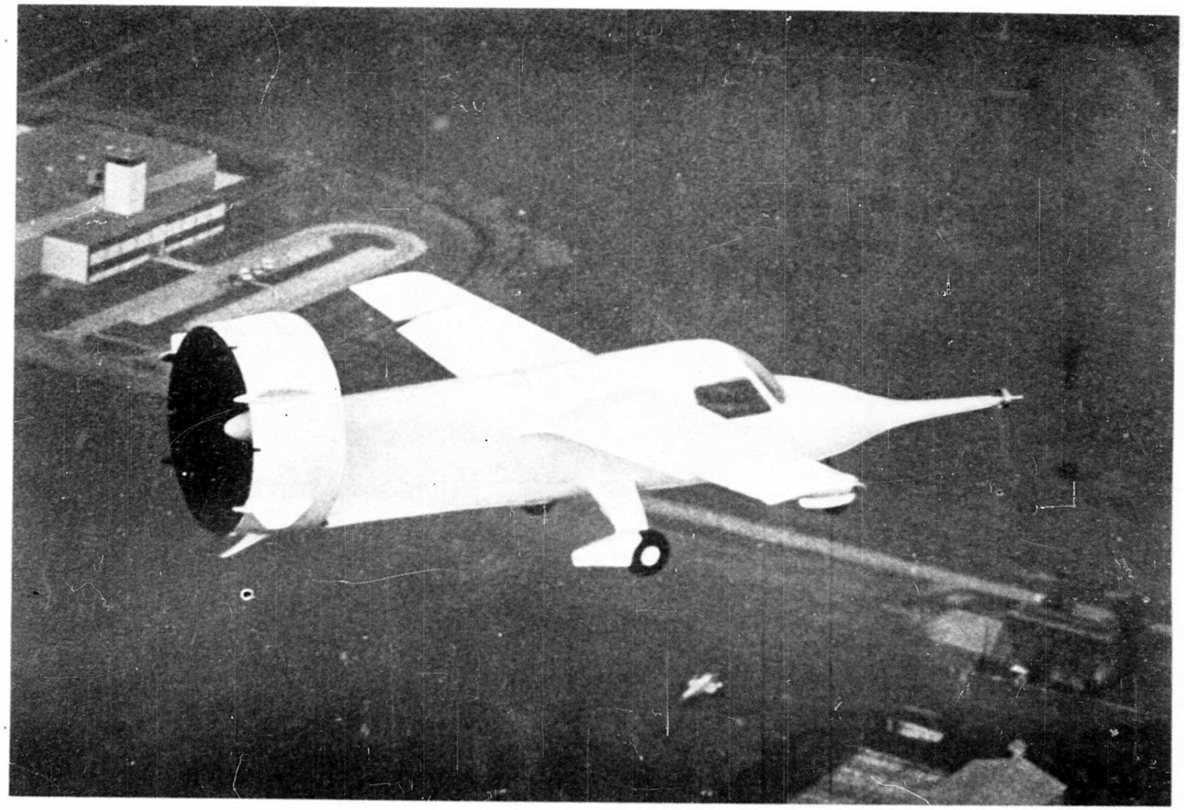


Figure 2. Flight View of MARVELETTE XAZ-1.

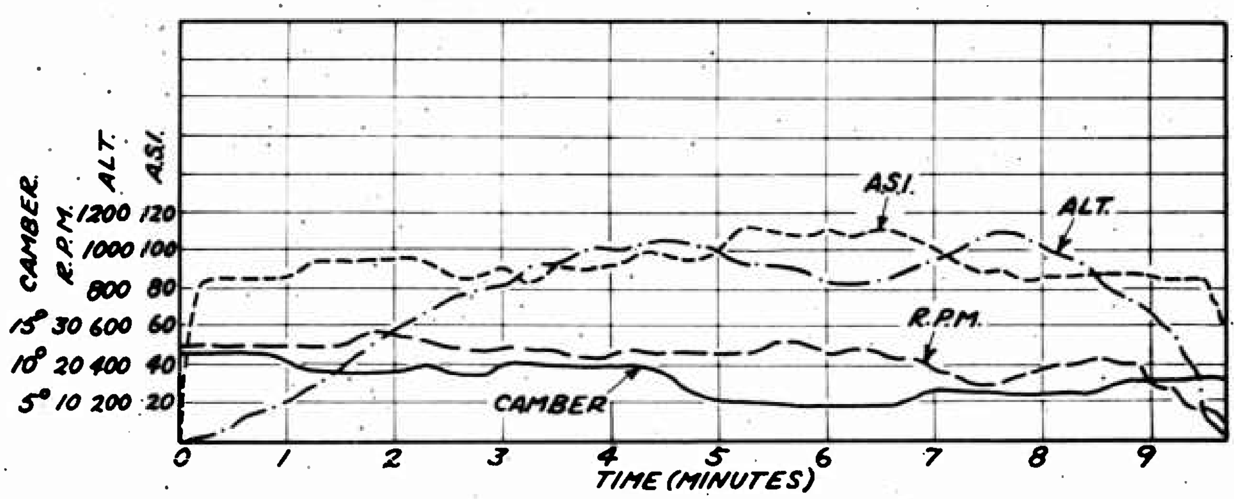
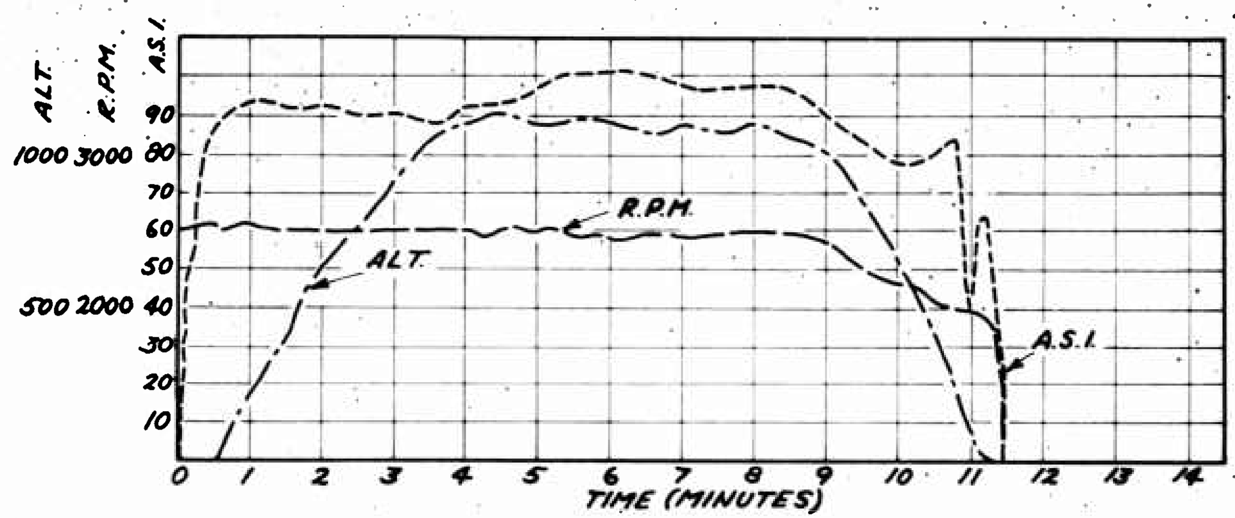



Figure 3. Flight 2.

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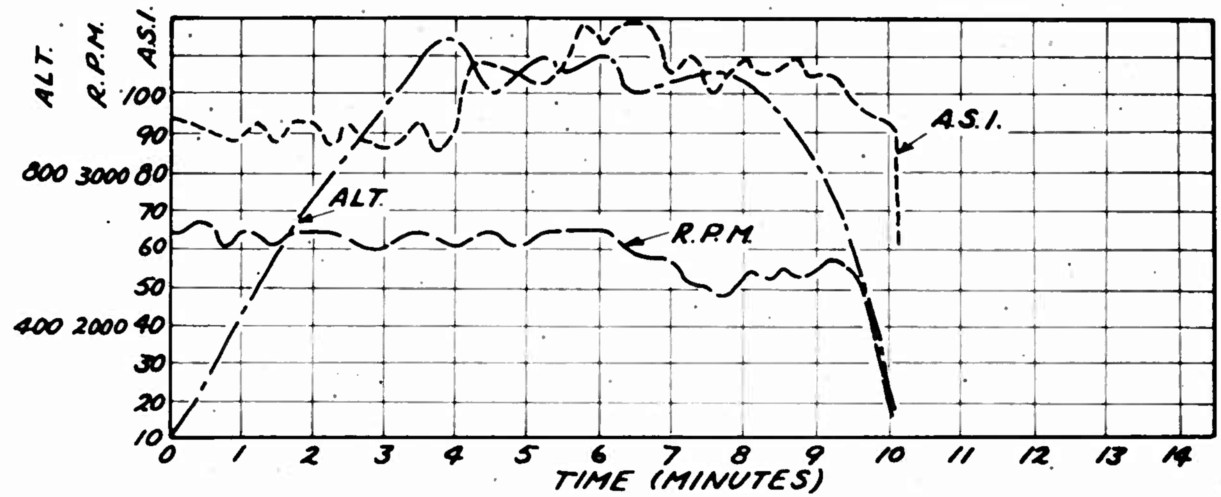


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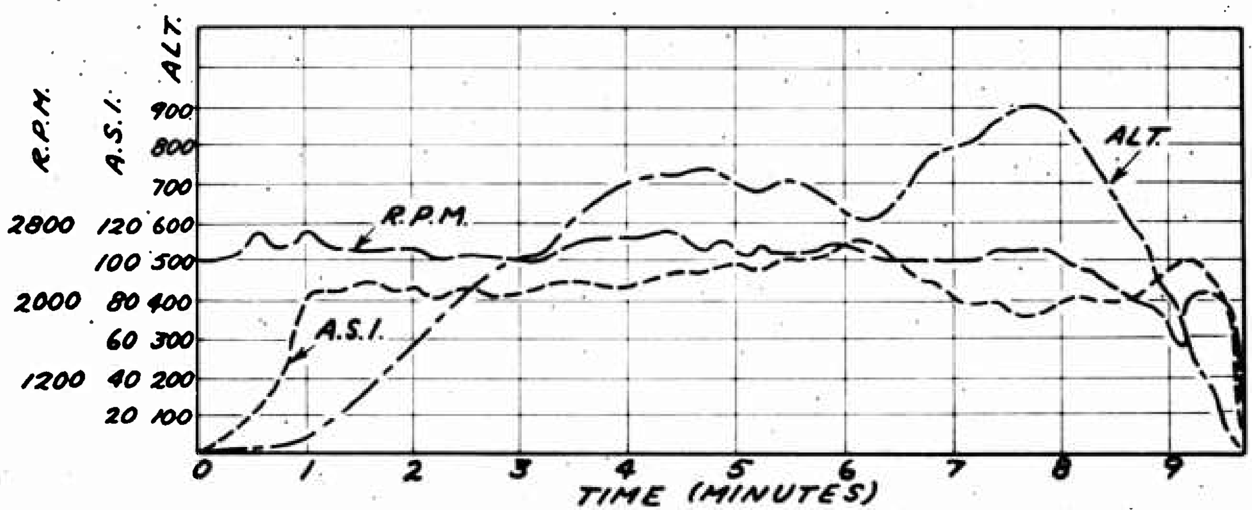


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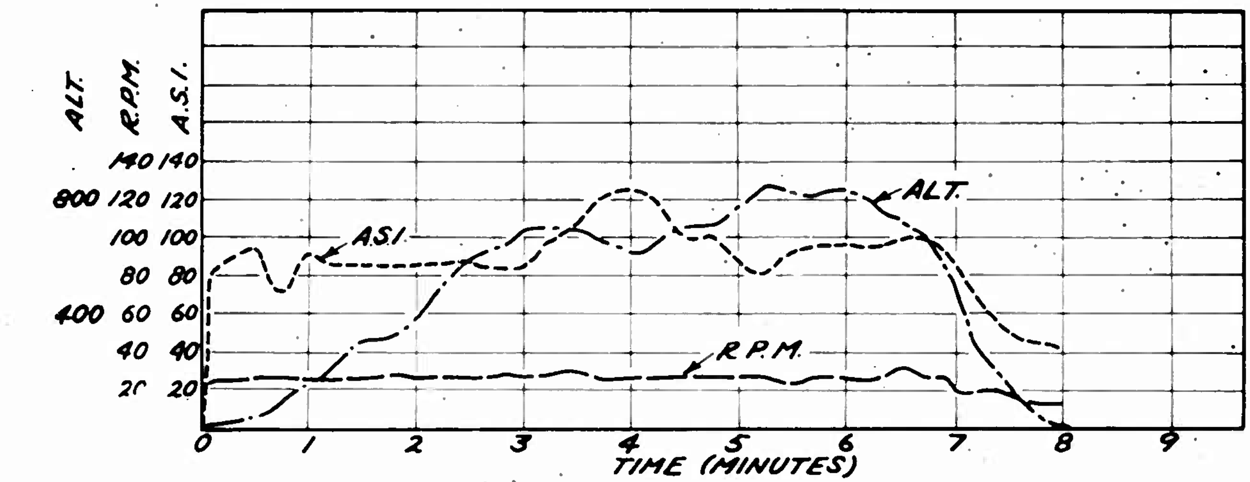


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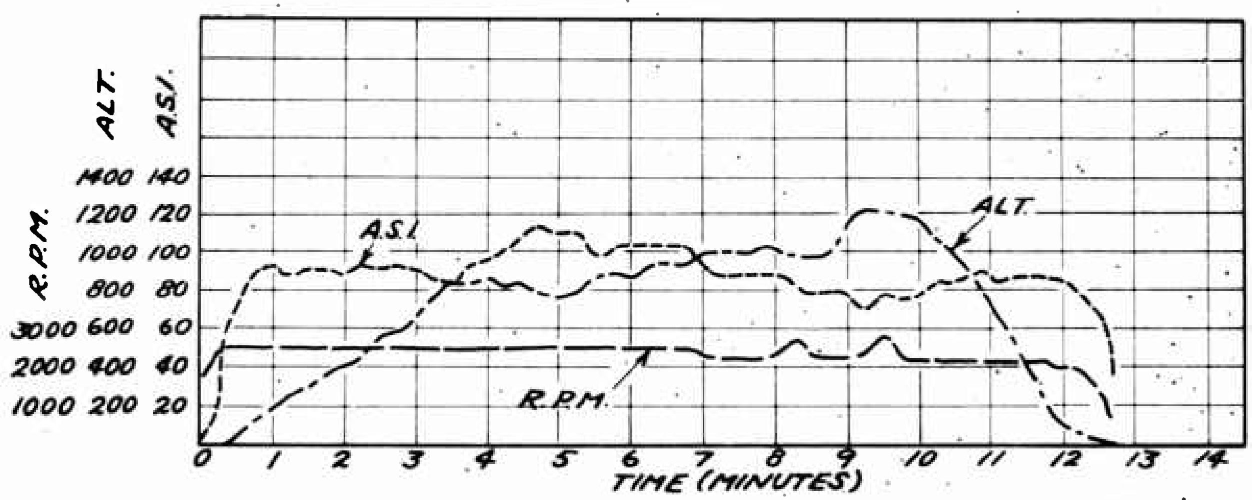


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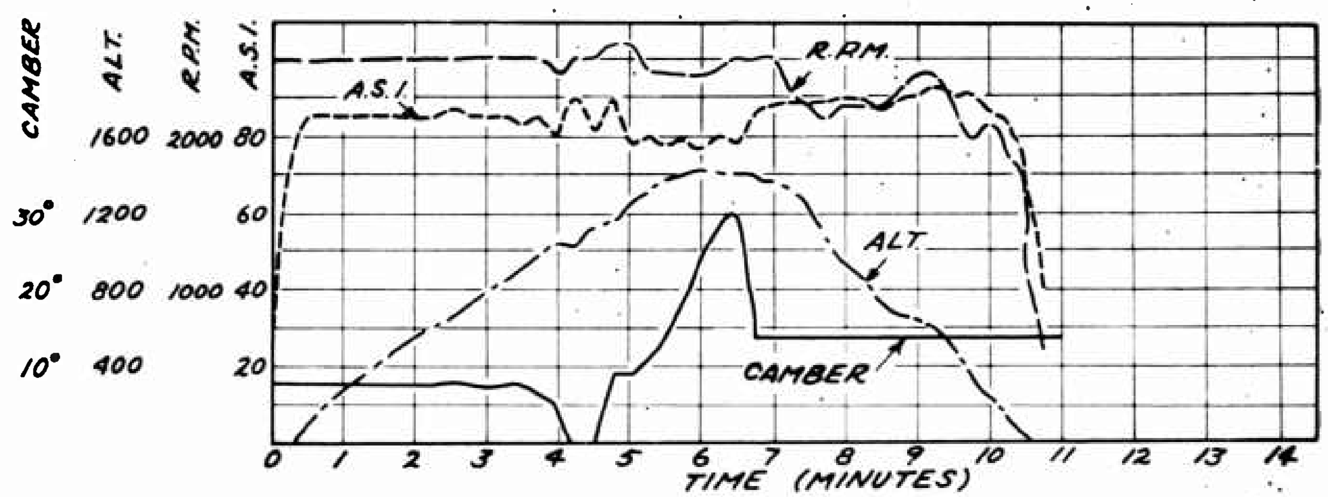


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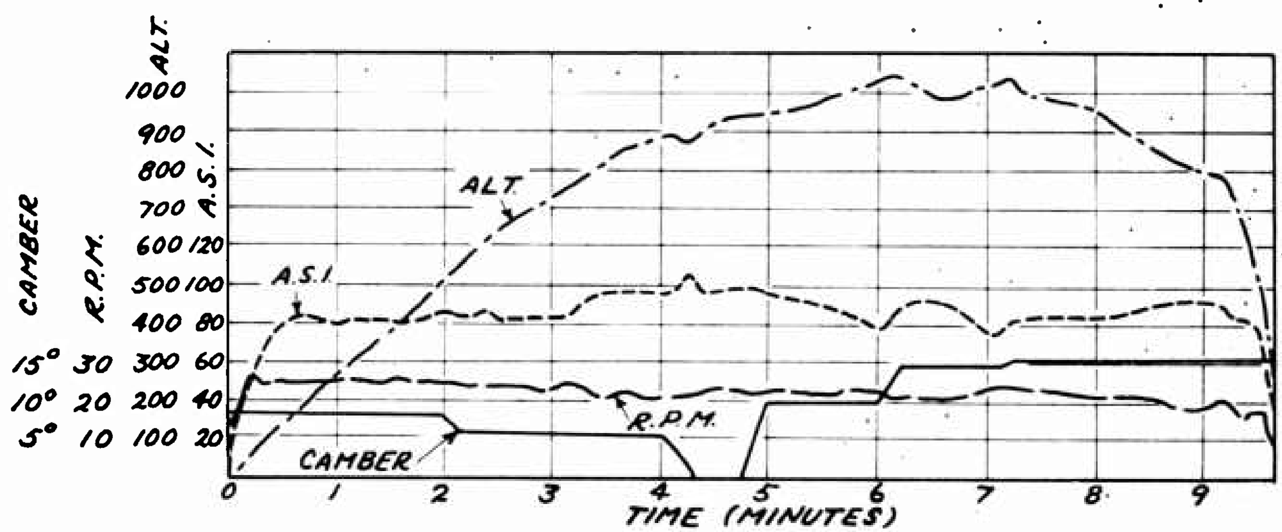


Figure 10. Flight 9.

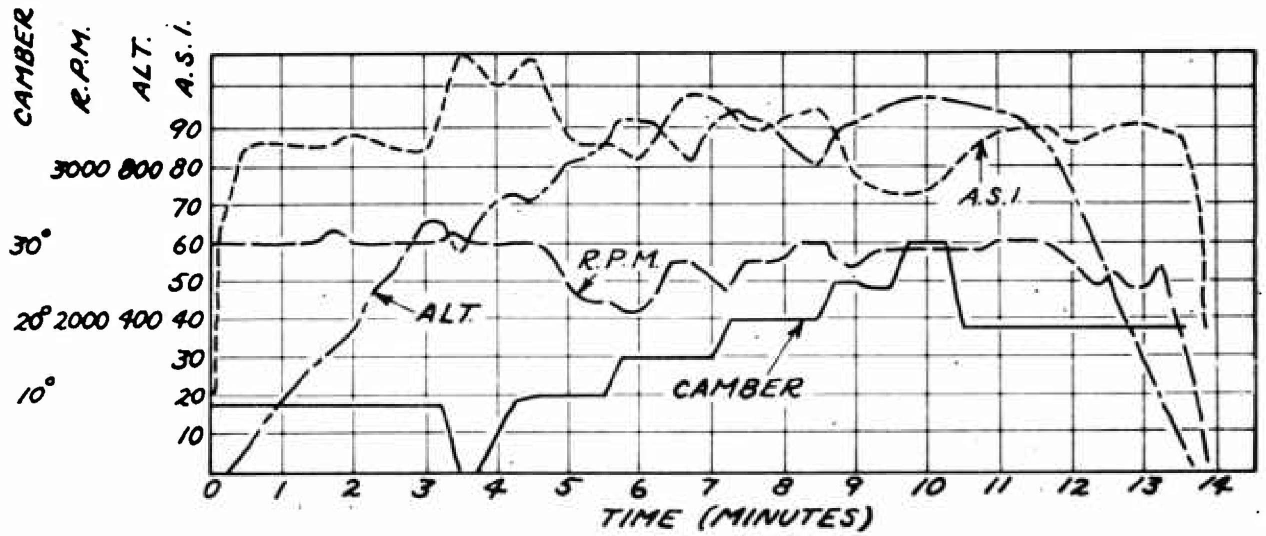


Figure 11. Flight 10.

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