CODE 25500

GOODYEAR

GOODYEAR AIRCRAFT CORPORATION

AKRON, OHIO

Final Engineering Report on

Modifications and Testing of

A One-Place Inflatoplane

GA-468

Contract NOnr 2368(00)

GER 10416 September 1961

TABLE OF CONTENTS

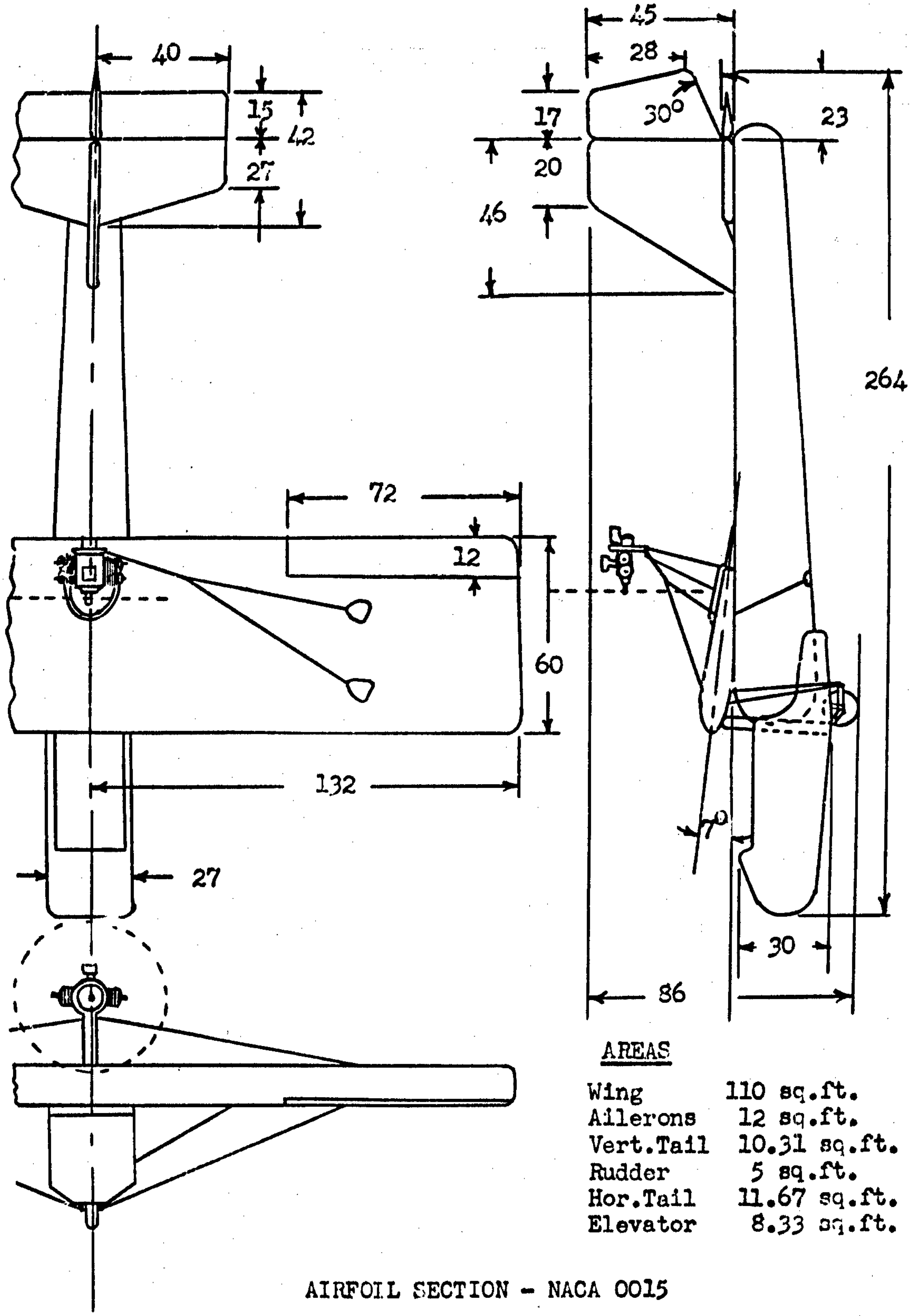
LIST OF FIGURES

SUMMARY

This report covers the development of the one-place Inflatoplane* since the completion of the prototype development program (ref. 1). Additional tests were conducted on the prototype and an improved, field evaluation model. Ten aircraft of the improved model were fabricated for evaluation. The modifications incorporated in the evaluation aircraft resulted in greater strength, improved performance, and increased life and utility. Development to date has indicated that the inflatable aircraft is well suited to applications where minimum storage space and weight, air droppability, rapid preparation for flight, excellent short field capability, good flight characteristics, and long range are required. Figure 1 shows the final aircraft configuration dimensions. Figures 2 and 3 show the GA 468 Inflatoplane in its inflated and packaged form respectively.

---

*TM Goodyear Aircraft Corporation, Akron 15, Ohio



AREAS

Wing	110 sq.ft.
Ailerons	12 sq.ft.
Vert.Tail	10.31 sq.ft.
Rudder	5 sq.ft.
Hor.Tail	11.67 sq.ft.
Elevator	8.33 sq.ft.

AIRFOIL SECTION - NACA 0015

FIGURE 1 - GA 468 INFLATOPLANE FINAL CONFIGURATION DIMENSIONS

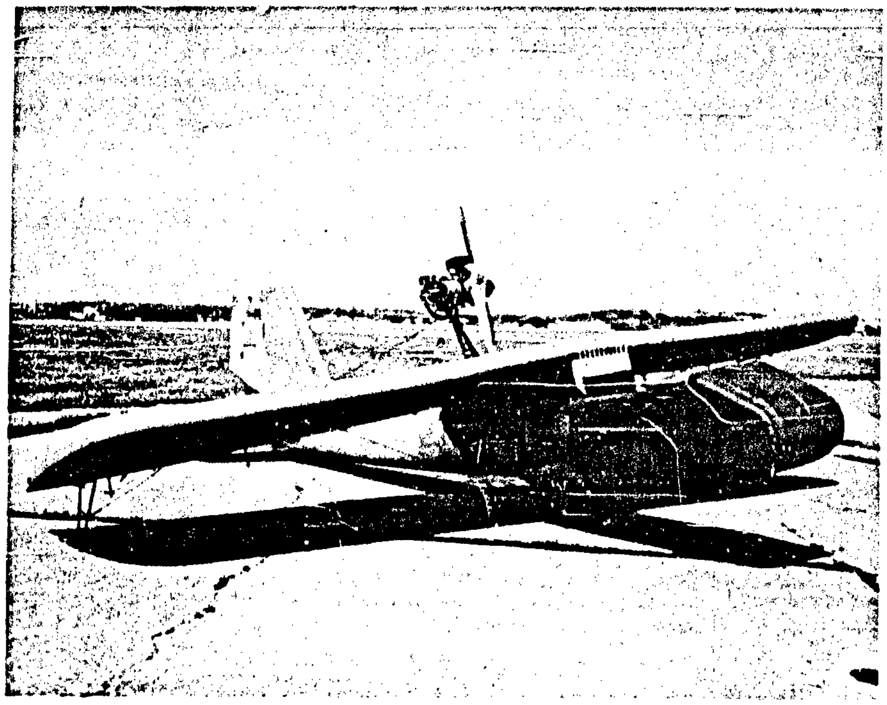


FIGURE 2 - GA-468 INFLATOPLANE

FIGURE 3 - GA-468 INFLATOPLANE PACKAGED

SECTION I - INTRODUCTION

Fiber materials have been used from immemorial to carry loads in the form of ropes and netting. The use of fiber materials grew with time into such things as belts to drive machinery, reinforcement for tires, etc. Later it was found that important properties could be added to the basic strength and flexibility of fibrous materials through the addition of coatings. These coatings could increase traction, weather resistance, and strength and could even provide a sealed surface. With these basic properties it was possible to build such things as balloons, pneumatic tires, airships, life rafts, and inflated radomes and buildings. These last three items were developed to provide a useful end item which was lightweight and easy to store when not in use. It was quite natural that the idea of an airplane made of inflatable fabric should eventually be conceived. Here would be an aircraft which could be stored like a rubber life raft and simply inflated for use.

Over the last 40 years a number of different concepts have evolved. The earliest one to actually be tried was a glider built by Mr. Taylor McDaniel in 1931. Although several flights were made the program died out. In 1955 interest was aroused again, separately, in Great Britain and the United States. The British version consisted of a large, thick, delta-shaped wing with a car suspended beneath. The cockpit, engine and landing gear were all rigidly connected. The wing, which was the only inflated section, was 24" thick and required an inflation pressure of only 1/2 psi. Profile of the wing (NACA 0024) was controlled by spanwise, porous webs connecting the upper and lower surfaces. Two models of this aircraft have been publicized to date.

The United States interests resulted from the development of a material called Airmat*. Since the end of World War II Goodyear Tire and Rubber Company has been developing and fabricating inflatable structures made of Airmat. Airmat material consists of two layers of fabric connected by continuous tie yarns dropped from one layer of fabric to the other during weaving. By varying the length of the tie yarns flat panels of various thickness could then be made. Up to this time inflated structures were limited to bodies of revolution or sections of bodies of revolution.

Realizing the possibilities of this material Goodyear Aircraft Corporation (GAC) made a sample airfoil Airmat section and tested it both statically and in a wind tunnel in 1952. Based on interest expressed by the Office of Naval Research (ONR) and the results of these tests, GAC fabricated a crude model of a one-place inflatable aircraft. The only rigid components on this aircraft, the GA-33, were the landing gear, engine and mount, wing struts, and controls (Figure 2, ref. 2). A great deal of design and test information was obtained from the GA-33 and incorporated into the ONR sponsored GA 447 (Figure 3).

The GA 447 was designed as a rescue vehicle and emphasis was placed on minimum weight and storage space. Weaving of the Airmat airfoil on standard looms was developed in this program, giving components with clean aerodynamic shapes not found in previous inflated aircraft (Figure 4). These new Airmat sections not only gave clean aerodynamic shapes but also very efficient structural properties. Together with close attention to weights of all components these properties gave an aircraft with exceptionally good performance,

---

*TM, Goodyear Tire and Rubber Company, Akron, Ohio

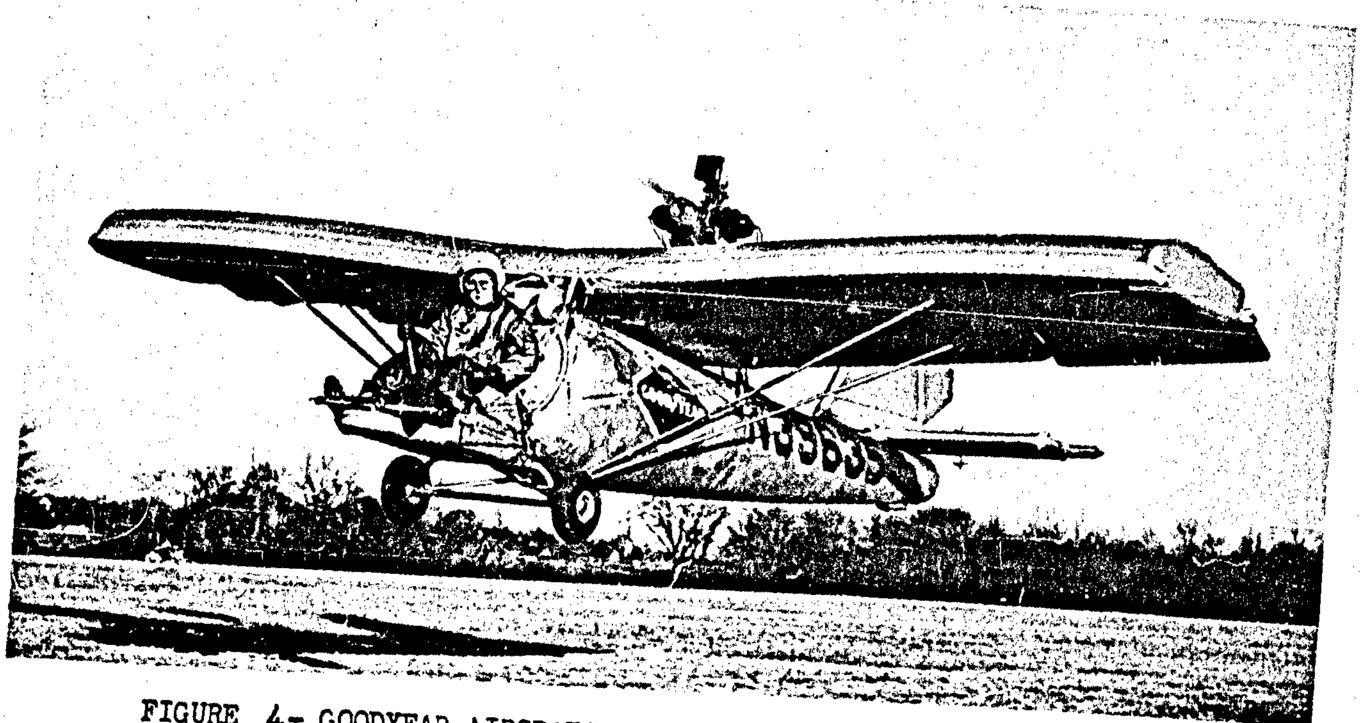


FIGURE 4- GOODYEAR AIRCRAFT CORPORATION'S INFLATOPLANE

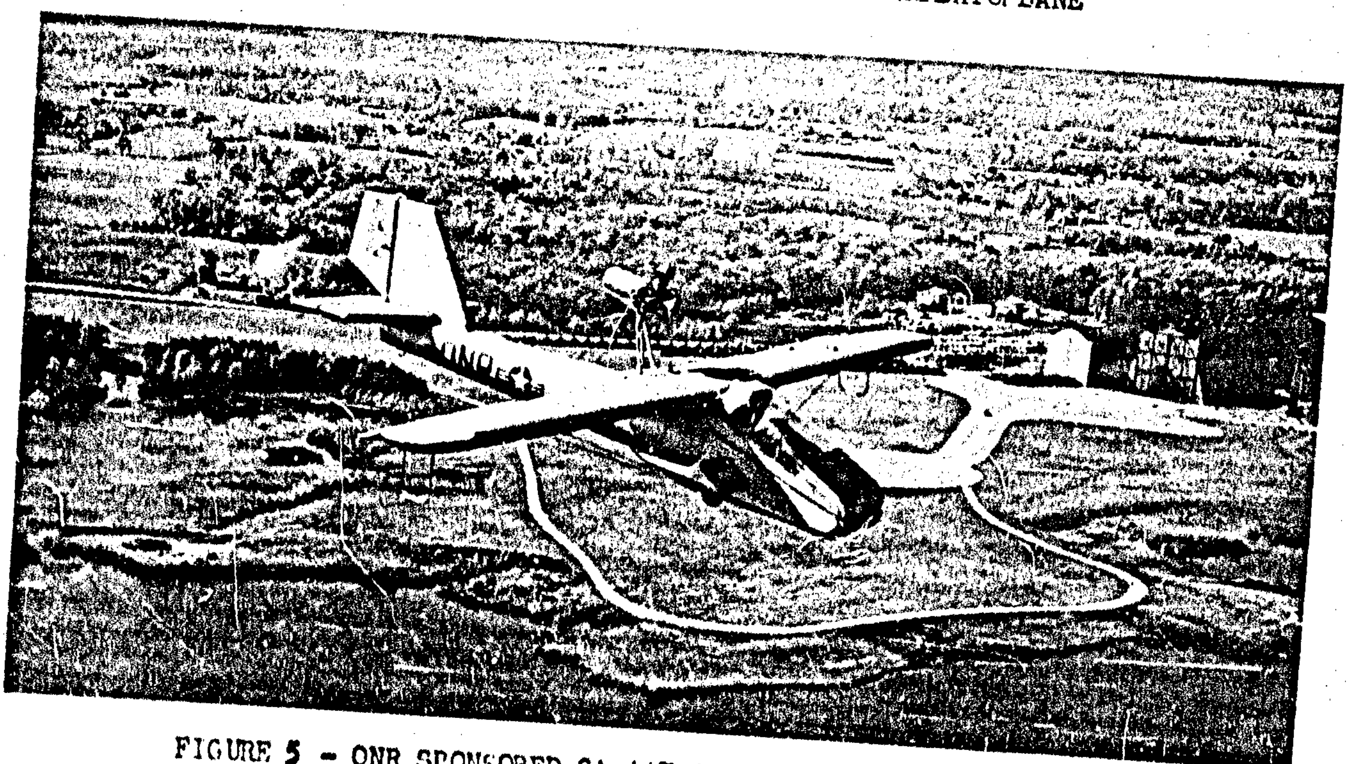


FIGURE 5 - ONR SPONSORED GA-447 ONE-PLACE INFLATOPLANE

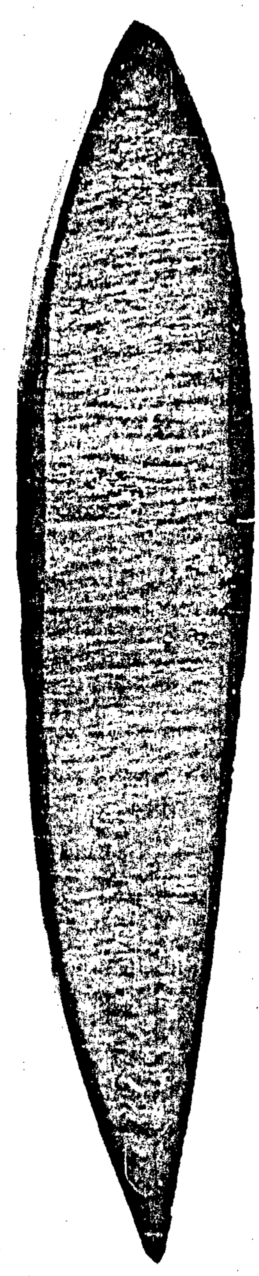


FIGURE 6 - "AIRMAT" AIRFOIL SECTION

proving that a truly efficient inflatable aircraft could be built.

With this experience the present program was initiated to fabricate and test ten improved models of this aircraft for field evaluation. The improvements were generally intended to simplify and improve operation, increase strength and life, and extend the utility. The original program called for only check flying of the aircraft prior to delivery. However, as the program progressed testing was extended to include full scale wind tunnel tests to study structural and aerodynamic properties, additional static tests and materials study, a 50 hour tie-down test to verify the compatability of the engine and aircraft, an engine PFRT, and flight testing to verify the flight safety of the aircraft and study the amphibious capabilities. Table I lists the aircraft's major characteristics.

Concurrent with this program was a separate program to develop a two-place inflatable aircraft with the same general characteristics as the one-place airplane. This objective was successfully achieved with only a 55 lb increase in empty weight over that of the one-place version (Figure 5, ref. 3). This showed that the weight and bulk of an inflatable aircraft need increase only a small percentage in order to double its payload.

Basic design information on the one-place aircraft is contained in the report on the initial development (ref. 1). This report describes the modifications made and tests performed on the aircraft.

TABLE 1

GA 468 - CHARACTERISTICS

Empty Weight	240 lbs
Gross Weight	550 lbs
Container Size	3 x 4 x 3.5 feet
Time to Prepare for Flight Using Engine Driven Compressor	5 minutes
Velocity (maximum)	62 knots
Velocity (cruise)	53.5 knots
Velocity (stall)	34 knots
Take-off Distance (on sod)	250 feet
Distance over 50' Obstacle (calculated)	575 feet
Rate of Climb at Sea Level	560 ft/min
Service Ceiling*	10,300 feet
Absolute Ceiling	13,000 feet
Range	375 nautical miles
Endurance	7 hours
Normal Inflation Pressure	7.0 psi
Minimum Inflation Pressure in Flight	4.8 psi
Minimum Emergency Inflation Pressure	4.0 psi

*Aircraft red lined to 4000 above terrain

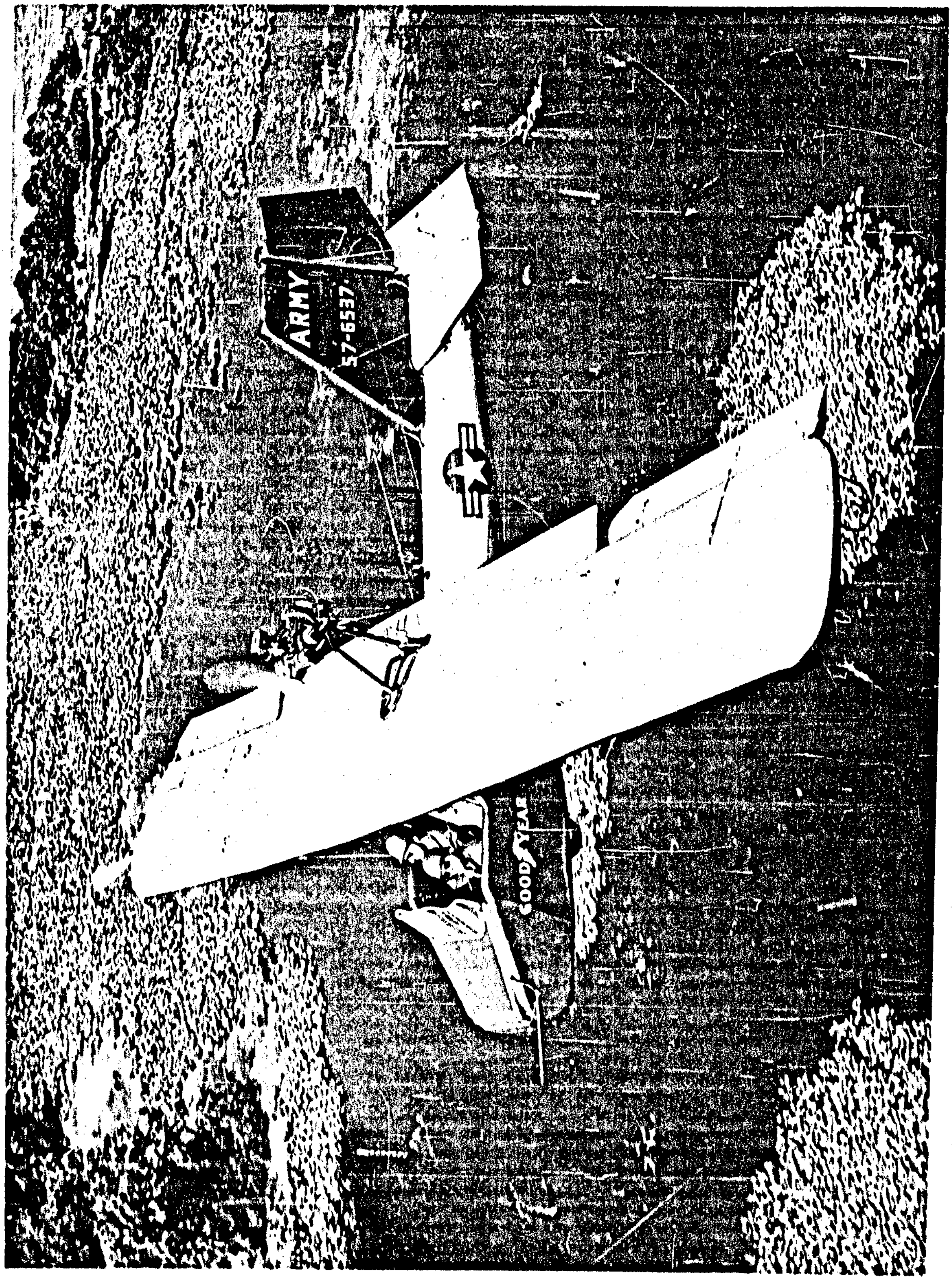


FIGURE 7 - ONR SPONSORED TWO-PLACE INFLATOPLANE

SECTION II - DISCUSSION

A. DESIGN IMPROVEMENTS

1. General

The objective of the original Inflatoplane (GA 447) development program was to test the selected configuration and its associated performance and operational features. This initial program verified design objectives, however, as in all experimental test programs of this type, areas of improvement were defined and consequently modifications were incorporated in the following model (GA 468). These modifications which improved the Inflatoplane's structure, performance, and usefulness are discussed below:

2. Magneto Ignition

The H-59A Nelson engine, used on the original GA 447, had a battery ignition system. Since the engine was not equipped with a generator, endurance was limited by battery life. Even with two 4½ lb batteries the engine would operate only 4 hours. In addition the battery storage life and the possibility of battery acid spillage on the fabric in packaging presented other problems. To overcome these problems the engine, was modified by Goodyear Aircraft Corporation (GAC) to incorporate a McCulloch magneto. The magneto was directly coupled to the rear end of the crankshaft. This coupling was also used to drive an air inflation pump through a timing belt (Appendix A).

The air pump presently used with the factory modified Nelson engine, H63A and the new model Inflatoplane, GA 468, is smaller and lighter than that used on the GA 447. The original pump weighed 10.5 lbs as compared with the new pump which weighs only 5.5 lbs.

3. Landing Gear

The unicycle landing gear on the GA 447 was designed for minimum weight and frontal area. With the minimum frontal area the ground clearance was 6 inches, which was felt to be marginal when considering rough field operations; therefore, the ground clearance was increased to 10.5 inches with a new design. The basic landing gear arrangement was retained. The wing tip and tail skids were redesigned to reduce weight and bulk in packaging, increase strength, and allow for easier maintenance.

4. Cockpit

The basic cockpit arrangement was retained. However, the Airmat wall thickness was increased from 2" to 3" for greater stiffness and strength, the landing gear opening was enlarged for easier access, and the canopy was removed to allow for easier entrance and exit. However, the angle of incidence of the front cockpit panel was increased to serve as a wind deflector.

5. Improved Fabrics

To provide for greater life, the strength of the fuselage fabric was increased. Processing of the wing and aileron material was improved, giving uniform cross sections and greater strengths. In addition, the improved procedures gave better structural strength, and smoother and straighter members. The results of these fabric improvements was an airframe with a greatly improved life limited primarily by the abuse it may receive from careless handling.

6. Wing Bracing

As a result of the wind tunnel and static tests on the GA 447 and GA 468 models, the wing bracing was modified by the addition of a brace wire on each side of the lower wing surface midway between the fuselage and forward outboard brace cable.

Also, as a result of these tests, the attachment points for the lower wing bracing system was changed to increase the load capability of the wing to approximately 5.0 g's. The attachment point on the landing gear for the two forward brace cables was moved twelve (12) inches aft of their former location. This move required that the landing gear be modified for the new attachment points and also that a plate be added beneath the landing gear ring to distribute the concentrated load. The rear outboard cable attachment point was moved to a point forty-eight (48) inches aft of the wing leading edge and located on the bottom of the fuselage section.

All the improvements of the extra cable and the cable attachment points relocation, improved the stability of the GA 468 aircraft under the limit load and high flight speeds, as well as increasing the strength of the wing.

7. Air System

The air selector - check valve and control lever were redesigned to provide greater efficiency and a simpler, more positive operation on the GA 468. The spring loaded relief valve was relocated to the jumper tube between the wing and fuselage to the left of and slightly behind the pilot's head. A manual override was provided in the valve as a safety feature. It was found that in its new location on the GA 468 the pilot can hear air being released whenever the valve is open.

In addition, the pressure instrument pick-up point was relocated from the cockpit panel to the relief valve described above. This change enabled the pressure instrument to sense any pressure loss in any component with a minimum time lag. Also incorporated in the pressure system was a low pressure warning light. The system operates by means of a pressure switch which energizes a red light located next to the pressure gage as the pressure decreases to 6.8 psi from the normal operating pressure of 7.0 psi. The light de-energizes at 6.85 psi as the pressure is increased. This installation allows for instant warning to pilot of decreasing air pressure in the aircraft giving the pilot time to take corrective action before the condition reaches emergency proportions.

8. Instrumentation

All GA 468 aircraft are equipped with a tachometer, accelerometer, airspeed indicator, air pressure gage with low pressure warning system, compass, and a dry-cell battery-operated cockpit utility light for night lighting the instrument faces. The aircraft for Army delivery have an altimeter and cylinder head temperature indicator in addition to the above.

9. Hydroski

Two possibilities for water take-off were considered on the GA 447. First of all, the possibility of the aircraft taking-off using the existing fuselage as a hull was investigated. It was found that although the shape of the body appeared to be approximately correct for water take-off, there were some sources of very high hydrodynamic drag, such as the wheel well. Also, the body was inadequate structurally for the high hydrodynamic loads. Consideration was given to re-designing the hull for use as a seaplane. This was found to be impractical at the time and was dropped. Secondly then, the use of a hydroski was considered. Several distinct advantages were immediately apparent. The natural flotation of the airplane could be used and a single ski could be designed which would be readily interchangeable with the single wheel. Also, with the hydroski the aircraft's capability could be extended to ice and snow.

The correct dimensions for the hydroski were determined by studying the hydrodynamic and aerodynamic drag on the airplane, lift on the wing and hydroski at different speeds, and available thrust. The dimensions of the hydroski were established as 72" in overall length and 18" in width. Bungee chords were placed at the front of the hydroski to give 2° of trim at take-off to reduce the wetted area, and consequently drag and suction to be broken when lifting off, and hold the ski in the proper attitude in landing. With this type of support for fixing the attitude of the ski, it was not necessary to taper the trailing edge of the ski as it would assume a natural planing attitude instantly at touch-down. The hydroski was designed with built-up "hat" sections and bulkheads and attached to the airplane through the unicycle gear axle. The leading edge bungee chords were snapped in place to D-rings on the cockpit. The entire weight of the hydroski was 16.0 lbs. No wing tip floats were required since the wing tipes themselves were ideally suited for this job. The wing tip skids used in land operations were snapped in the "up" position to reduce drag at the tips, although this was not found to be essential.

Flight tests on the GA 447 showed the ski design to be correct in all respects.

10. Universal Gear

After the successful demonstration of the hydroski, it was decided to design a combination wheel - hydroski landing gear for use from both land and water. The same ski geometry was retained for the new gear and a small opening provided through which the wheel protruded. A rubberized fabric seal was provided around the wheel to keep spray through the hole to a minimum. As in the case of the hydroski, trim was provided by bungee chords between the nose of the ski and the cockpit. For packaging the gear was divided into four 18" x 18" sections hooked together and held in place with quick release pins.

11. Mass Balance of Control Surfaces

During flight test phases of the Inflatoplane program the tendency for the rudder control to flutter at high speed was observed. This condition was also witnessed during the wind tunnel test program. As a result of various vibrations, static, and flight tests, mass balances were installed on the rudder to eliminate the tendency of fluttering at high speed.

12. Fuel Gage

Early in the modification program, several attempts were made to develop a fuel gage. All attempts were unsuccessful. However, late in the effort for amendment eight, a new development attempt resulted in the design of a low fuel-level indicator consisting of a one gallon reserve tank and a warning indicator. When the main fuel supply has been expended, the pilot is notified by the warning indicator that a reserve of one gallon of fuel remains. This system was mocked up, functionally tested, and found to be satisfactory, although it is not installed on the GA 468 Inflatoplane. A written description and drawings of the system have been submitted to ONR for review (ref. 4).

13. Fuel System Modifications

It was necessary to install a fuel filter and relocate the shutoff - fueling valve to improve the dependability of the fuel system. The filter installation was necessary to separate sediment of any kind which might interfere with carburetion. The shutoff - fueling valve was originally mounted in the rear of the cockpit and was attached to the walls of the fuel cell and fuselage. Relocation of this valve to the engine mount provided more convenient fueling and improved packagability of the aircraft.

14. Trim Control

As one of the objectives of Amendment Eight, a trim control system, was developed and installed on the Inflatoplanes. The system consists of bungee cords attached to the elevator control cables with the tension of the bungee cords controlled by a sliding control handle in the cockpit. This system allows for trim changes from stall to maximum level flight speed.

15. Miscellaneous

Besides the specific items noted above, improvements were made in many smaller items. Additional crotch tapes were added in the hinges and strap connections and cover patches were placed over the plastic control horn bases to prevent peeling under repeated packagings. The throttle control was changed to provide a continuous cable return system to the carburetor control arm, giving more positive, immediate response. The aileron bungee return system was redesigned by adding a horn, similar to the aileron, rudder, and elevator horns, near the hinge line which increased the moment applied by the bungee and thereby increased their effectiveness. The engine mount was reinforced by adding a plate between the two pylon members and gussets in the base. The fuselage saddle bracket was eliminated and replaced by two fabric patches to facilitate packaging.

All pulleys were redesigned to prevent the cables from leaving the pulley groove during operation or packaging of the aircraft. Also, where compound changes in direction of control cables were required swivel pulleys were designed and installed for safety of operation.

The horns used on all control surfaces were redesigned to give better resistance to wear to prevent damage during packing or handling. The wooden propeller was modified by laminating the outer five (5) inches of each blade with two plies of fiberglas cloth impregnated with epoxy resin. This was accomplished to give better resistance to shattering.

A ground air compressor and refueling unit was designed to be used for initial inflation and refueling where quietness of operation and great speed of inflation were not required. The portable air and fuel pump ground support unit is driven by a 4 HP gasoline engine through a timing belt which can be connected to either of the two pumps. The air pump can also be used for deflation for packaging by connecting the air hose to the pump inlet side.

B. SUMMARY OF TEST PROGRAMS

1. General

Tests were conducted to determine structural, flight and power plant characteristics and operational features. Under Contract Nonr 2368(00) these tests included the following:

a. Full scale wind tunnel tests on the GA 447 and GA 468

b. Static tests

c. Preliminary propulsion system tests

d. 50 hour tie-down test and 60 hour PFRT

e. Flight envelope tests

f. Hydroski and universal ski gear evaluation

g. Sound studies

h. Materials investigation

i. Flight demonstration of the design limits

j. Pallet and parachute delivery system

2. Full Scale Wind Tunnel Tests

At the conclusion of the development of the GA 447 it was felt that it would be highly desirable to conduct a full scale wind tunnel test on the aircraft. The purpose of this test was to determine the aerodynamic and structural deflection characteristics of the aircraft. These tests were conducted at the NACA Langley Field full scale wind tunnel and are reported in ref. 5 . The summary from this report is quoted below.

"An investigation has been conducted in the Langley full-scale tunnel to determine the aerodynamic and structural deflection characteristics of the Goodyear Inflatoplane over a range of test velocities from minimum stall speed up to speeds giving load factors for wing buckling. Tests were conducted over a range of speeds from approximately 41 to 70 mph with wing-guy-cable loads, wing-distortion photographs, and aerodynamic-force data recorded at each speed for a full range of angle of attack.

The airplane was longitudinally stable and had adequate pitch and roll control and normal stall characteristics at the lower speeds giving maximum load factors between 1 and 1.5. However, as speed was increased, aeroelastic effects associated with wing twist produced an increase in lift-curve slope and loss of stability near the stall. For speeds up to 65 mph, which produced a load factor of approximately 2, the maximum wing load was limited by stall with moderate wing deflections. However, at a speed just over 70 mph and at an attitude producing a load factor just over 2, a column-type buckling occurred on the inboard wing panel with the inboard wing section folding up and contacting the engine mounted above the wing. Additional tests were made with modifications to the wing-guy-cable system which reduced the aeroelastic effects on the aerodynamic characteristics and allowed load factors up to approximately 2.5 before a tendency for wing buckling occurred."

Based on the results of these tests, changes were made in the wing section and bracing arrangement as noted in the modifications section of this report.

In addition to the modifications suggested from the first wind tunnel tests, new modifications were indicated and accomplished as a result of the flight tests conducted on the GA 468 Inflatoplane and reported in Part I. After these additional modifications were accomplished, which resulted in an increase of the load carrying capability of the aircraft, ONR indicated that the increased load carrying capability should be verified by an additional wind tunnel test. The wind tunnel tests were performed in August 1960 but as of this date NASA has not released the test report; however, GAC has published a preliminary report (ref. 6) in which the pertinent data is presented. The summary of this report is quoted below.

"An investigation was conducted in the NASA Langley full-scale wind tunnel to determine the effect a change in the wing-guy-cable configuration would have on the load factors for wing buckling and to obtain aerodynamic characteristics of the Goodyear Inflatoplane. Tests were conducted over a range of speeds from approximately 45 to 80 knots with wing-guy-cable loads, wing-distortion photographs, and aerodynamic-force data recorded at each speed for a full range of angle of attack.

Several wing-guy-cable arrangements were tried before it was found necessary to add an aluminum plate between the landing gear and the fuselage to limit the fuselage deflection caused by the method of supporting the Inflatoplane, which is different than in flight. This lowering of the deflection reduced the aeroelastic effect on the aerodynamic characteristics and allowed tunnel load factors up to 4.76, flight load factor of 5.13, before wing buckling occurred.

During run 21h both the left and right wings buckled and the right wing cable, 2B, failed precipitating a separation of wing from the bulkhead straps and a rip in the wing. This failure, which was caused by a frayed cable, ended the tests."

3. Static Tests

Static tests were conducted on new patch designs, control assemblies, and the assembled aircraft to assure proper strength in all components. Also, static tests were conducted on the wing bracing configuration in an effort to increase the wing ultimate load.

Standard airship patches of known strength were used where possible. However, in several cases either the magnitude or method of application of the load necessitated the design of a new patch. These patches included a D-ring patch, an intermediate wing patch, and an engine mount - fuselage patch. Samples of each patch were cemented to a test wing section. The test consisted of loading each patch to 120% of its design limit load for 10 minutes and then increase the load until failure occurred. This test procedure is standard for all patches. Table 2 presents the test results.

TABLE - 2

PATCH TEST RESULTS

Patch Type	Loading Angle, Degrees	Limit Load, Lbs.	120% Limit Load, Lbs.	Breaking Load, Lbs.
D-ring	0	65	78	235
D-ring	0	65	78	270
D-ring	30	65	78	230
D-ring	30	65	78	255
D-ring	45	65	78	165
D-ring	45	65	78	180
Wing fan	45	375	444	1000
Wing fan	45	375	444	1000
Wing fan	45	375	444	1225
Wing fan	45	375	444	1325
Mount-Fuselage fan	45	122	147	350

These results show that all of these new patches are more than adequate for their design loads.

The assembled aircraft was statically loaded before flight check-out to the design limits to check the strength of the individual components and assembly connections. Tests included the following listed items:

1. + 3 and - 1.0 g normal wing load
2. + 2.5 and - 1.0 g vertical cockpit loads
3. 125 lb down tail load
4. 125 lb up tail load
5. 175 lb right and left vertical tail load
6. 230 lb engine thrust
7. Landing gear drop test, 5 ft/sec descent velocity 5 times
8. Controls
   a. 35 ft-lb aileron hinge moment
   b. 40 ft-lb rudder hinge moment
   c. 45 ft-lb elevator hinge moment

As was requested in Amendment Eight of the subject contract, considerable effort was placed on improving the ultimate load factor of the aircraft. The load factor which was to be achieved was 4.38 g's (load factor = 2.5 (limit load) x 1.75 (safety factor) = 4.38 g's) where the safety factor over limit load would be 1.75. Several solutions to the problem were considered: (1) increasing the operating pressure, (2) adding wing tip ballast, (3) decreasing gross weight of aircraft, and (3) adding a rigid spar. At the onset the latter seemed the most reasonable solution as the results of static tests indicated the ultimate load could be increased to approximately 4.5 g's which was above the 4.38 g goal. Although this solution was adequate, GAC engineering continued the investigation for a simpler and better improvement without compromising packaging and increasing the weight. As a result, the present modification was engineered and proved through static testing to meet the 4.38 g goal.

The modification consisted of moving the attachment point on the landing gear of the two forward brace cables 12 inches aft on the aircraft. A suitable bracket was designed and attached to the landing gear for the new attachment point. The rear brace cables were attached to the bottom of the fuselage at a station under the trailing edge of the wing. The aircraft,when static loaded in this configuration, supported 5.1 g's without failure (Figure 6). The static test fixture would not allow load in excess of 5.1 g's,however, this load carrying ability was verified in the wind tunnel tests.

4. Preliminary Propulsion System Tests

To verify engine operation with magneto ignition as proposed for the Model GA 468 evaluation aircraft, an H59-A engine previously used for the Model GA 447 development program was utilized in a series of static test runs. A magneto manufactured by the McCulloch Corporation, Los Angeles, California, for their Model 4318 engine was selected and an accessory drive housing fabricated to adapt the magneto installation to the Nelson H59-A engine. The design and operating characteristics of the two engine models were similar and permitted use of the magneto on the H59-A engine. A pylon engine mount was also fabricated for static test with the engine. In addition to testing the magneto, engine, and engine mount compatibility, the feasibility of engine starting by hand-propping was also included in the tests.

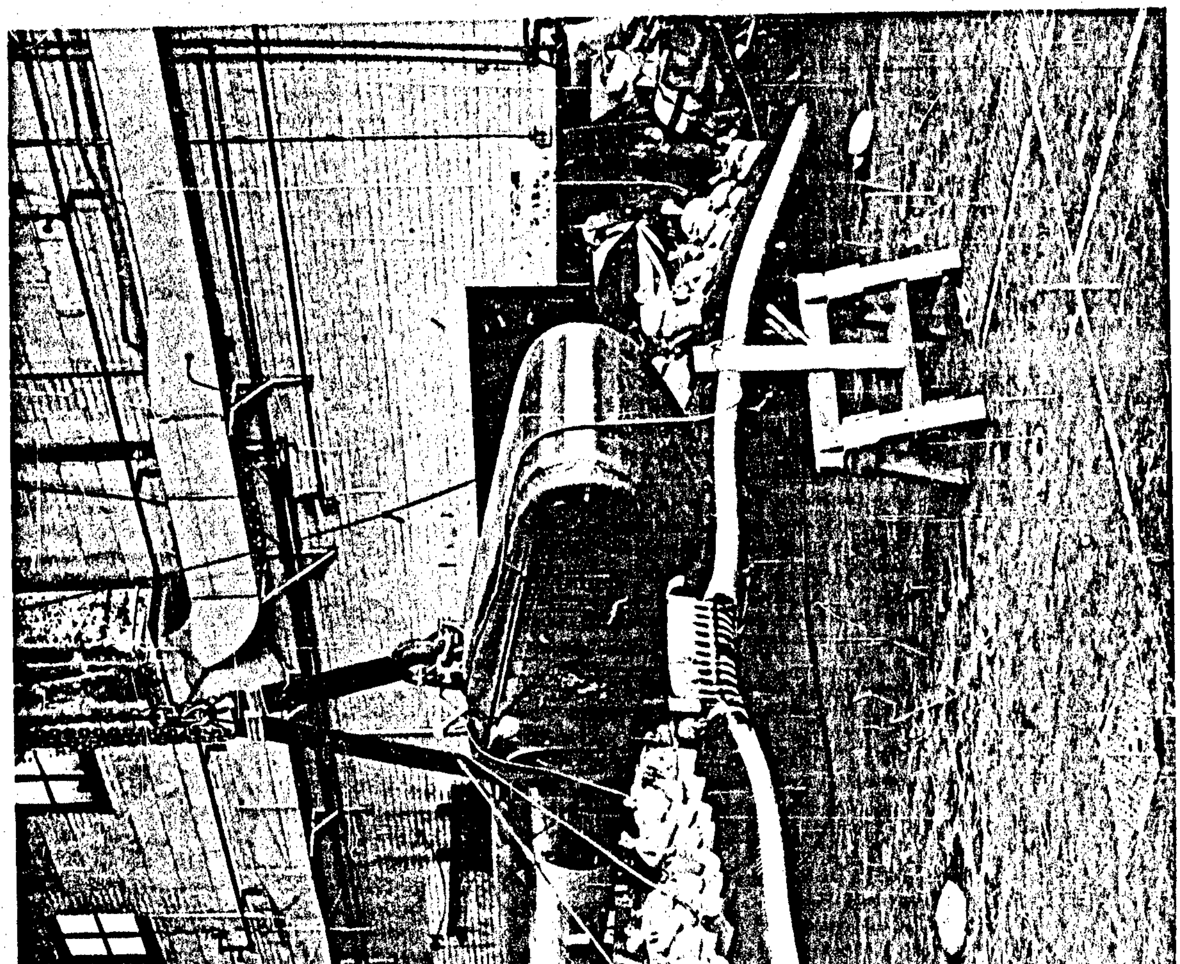


FIGURE 8 - GA 468 WING UNDER +5.0 g LOAD

The engine and pylon mount configuration was rigidly attached to the concrete floor of the test area with brace cables installed to simulate the actual installation on the airframe. It was decided that such a mounting configuration would subject the pylon mount to more severe operating conditions. At the conclusion of the testing the mount was inspected and found to be sound and suitable for installation on the evaluation aircraft. The operating schedule followed for the tests covered the complete range of engine operation from idle to maximum power. Also included were a series of 50 consecutive starts by hand-propping, and operation of the engine at various ignition timing settings ranging from 25° B.T.C. to 29° B.T.C. All cylinders were instrumented for temperature indication during those tests to provide warning of impending malfunction and for general engine condition. A total engine operating time of 25 hours was used in this preliminary testing and no major problems were encountered. The magneto installation was found to be suitable for operation on the Nelson Model H59-A engine when timed to the engine manufacturer's specification of 29 degrees before top-center. Some difficulty was experienced with the impulse coupling assembly of the magneto resulting in a binding condition and preventing proper operation of the coupling during engine start. This condition was attributed to improper register of the magneto drive to the engine crankshaft, and was corrected for proper register by trimming the engagement slots in the rubber coupling installed between the magneto drive and the engine.

It was also determined that the engine could be started by means of hand-propping. Engine starting was also found to be dependent on the procedure used for engine shutdown. Engine shutdown without fuel shutoff caused fouling of the spark plugs and an accumulation of unburned fuel in the crankcase. These conditions prevent subsequent satisfactory engine starting. It was determined that the fuel shutoff method recommended by the engine manufacturer provides the best means of engine shutdown within the design limitations of the engine. An electrical starting system would provide easier starting of the engine.

In general, engine operation during the testing was smooth and without incident. Cylinder head temperatures remained below the maximum specified value of 230°C. (450°F) at all times during the tests.

On the basis of the preliminary tests it was concluded that the Model H59-A engine could operate satisfactorily with a magneto ignition system and that the engine pylon mount was suitable for the proposed installation. It was also concluded that while starting the engine by hand-propping was dependent on priming technique, satisfactory engine starts could be made in this manner.

Subsequent procurement of the Model H63-A engine did not nullify the results of this testing as the two engine models (H59-A and H63-A) were basically similar and the magneto modification was adaptable to either engine model.

5. 50 Hour Tie Down and 60 Hour PFRT Tests

A requirement under Amendment Three of the subject contract was to perform a 50 hour tie-down test. This test was to enable the contractor to place a 50 hour flight rating on the H63-A engine and the inflatable airframe combination. The test was performed in accordance with specifications by the contractor. The test was completed after several problem areas in the engine were corrected. This test is reported in Appendix A. The tear down inspection following the completed test revealed several discrepancies in the engine and, as a result, BuWeps powerplants office requested the test be repeated plus a 10 hour penalty run (60 hour PFRT).

The 60 hour PFRT was performed at the engine manufacturer's plant. This test was completed successfully (ref. 14 and 15) with the only discrepancy being several small cracks appearing around the mounting bosses of the rear housing. The H63-A engine was given a 50 hour PFR (ref. 16) with a limitation that the rear housing be given a dye penetrant inspection after every 10 hours of operation. The 60 PFRT is also discussed in Appendix A along with discussion concerning additional engine modifications deemed necessary as a result of operation experience during flight demonstration program.

The hot fuel test required along with the 50 hour tie-down test to Contract Nonr 2368(00) was not performed for the following reasons:

a. Fuel Specification, MIL-F-5572B, gives the minimum and maximum Reid vapor pressure limits at 100°F as 5.5 psi and 7.0 psi, respectively, for Grade 80/87 octane aviation gasoline. Since the fuel system is pressurized by the air inflation system of the aircraft to a value of 7.0 psi, it can be reasonably assumed that appreciable vapor formation is practically non-existent.

b. The altitude limitation of 4000 feet imposed on aircraft operation and the low volume of fuel (2.68 cubic feet) carried will result in little or no fuel vapor formation.

c. The physical construction of the fuel system (refer to Figure 1-7, "Fuel System Schematic", ref. 7) with the fuel tank outlet located in the bottom of the bladder type tank and with no locations in the external fuel line between the tank outlet and carburetor inlet that could result in vapor lock, prevents fuel system malfunction from any vapor if present in the fuel. It should also be noted that no fuel pump is employed in the system so that pump cavitation problems are not applicable to this aircraft.

d. The float chamber of the carburetor is vented to atmosphere so that any vapor existing in the lines will be vented at this point in the system. The low fuel flow rates (2.0 to 6.2 gallons per hour) associated with the engine installation also assist in minimizing any vapor lock problem.

e. The aircraft have been operated over a wide range of ambient temperatures through their various flight test phases and flight demonstrations, and no fuel system malfunction attributable to hot or vapor producing fuel has ever been encountered.

Therefore, it is the contractor's opinion that the hot fuel test was not necessary for the present powerplant and fuel system installation and non-performance of the test was justified on the basis of the above listed items.

6. Flight Envelope Tests

Under Amendment Three it was requested that flight tests be conducted to verify or extend the flight envelope predicted by the data obtained from the wind tunnel tests of the GA 447 Inflatoplane, and to investigate any maneuvers which could result in unsafe operation of the aircraft. These tests were completed at the contractor's plant and reported in (ref. 8).

The results of these tests indicated that the flight limit loads could be safely withstood up to flight speeds of at least 67 knots. Maximum level flight speed was 62 knots. Cable tensions were recorded during all tests and all agreed closely with predicted values. No unsafe flight conditions were encountered; however, from the results of these tests it was recommended that no intentional spins or acrobatics be performed and that "g" limitations of plus 2.5 g's and negative 1.0 g's be imposed on the aircraft. It was concluded as a result of the tests that the aircraft was safe for flight.

7. Hydroski and Universal Ski Tests

The testing conducted on the hydroski and the universal ski gear consisted of operational tests. The tests were conducted at Goodyear Aircraft's Wingfoot Lake facility.

The hydroski tests were conducted on the GA 447 and the GA 468 Inflatoplane to provide a comparison of operation since there was some construction differences in the areas of the cockpit and landing gear. The operational tests consisted of ski and aircraft compatability, water handling of aircraft, planing technique, taxiing while planing, takeoffs and landings. The operational tests gave no indication of any major differences between the aircraft and with the takeoff characteristics of both quite similar to those on land. The gross weight of the aircraft for these tests ranged from 460 to 475 pounds.

The universal ski gear, designed for the GA 468 Inflatoplane, was tested only on this aircraft. Again, the tests consisted of operational tests which were the same as those mentioned for the hydroski with the addition of taxi, takeoff, and landing tests on land with the universal gear installed. The gross weight for these tests were from 480 to 490 pounds. The universal ski gear performed very satisfactorily on both land and water with the only difficulty being when the operational terrain was soft or rough terrain where the wheel submerged until the full surface of the ski comes in contact with the ground. This condition restrains the aircraft from movement. In addition to the above tests, the universal ski gear was tested in snow conditions of approximately 6 to 8 inches deep. Taxiing, takeoffs, and landings were performed with satisfactory results.

As a result of these tests, it was concluded that the universal ski gear enhances the value of the Inflatoplane by extending its utility without requiring any greater pilot skill and training.

8. Sound Studies

An investigation of the methods of muffler design was conducted on a very limited scale. A narrow band and octave band analysis of the exhaust spectrum of the One-Place Inflatoplane was taken at free field conditions.

The narrow band data, which was taken on the Mine Safety Appliance Soundscope, indicated that maximum noise amplitude occurs at the second harmonic rather than at the expected fundamental firing frequency. However, the first, third and fourth harmonic are of equal amplitudes and only several db's lower than the maximum level, showing that the exhaust output of the four cylinder, two cycle engine is a random noise. This condition is rather unique to the two cycle aircraft engine tested in that aircraft engines with four cycle operation tend to have a discrete frequency pattern.

An octave band analysis taken on a 50 foot radius and azimuth angles of 0°, 30°, 60°, 90°, 120°, and 150° (0° angle points to the front of the plane) indicated the directional spectrum is quite uniform. The overall noise level at this radius read 96 db's (re.0002 dyne/cm^2). Since the principle objective in muffling the noise level of the One-Place Inflatoplane was to reduce the detection distance, the conversation level at three feet, which is approximately 66 db, was taken as a design criteria for suitable observation at a given distance. Any level below this value can be considered difficult to hear under average conditions. By taking the measured value of noise level at 50 feet and applying the inverse square law, a noise level can be realized of 66 db at 1600 feet.

With this objective in mind, two types of mufflers were investigated to date: (1) single chamber resonator and (2) a combination of two resonators. The calculated decrease in the overall noise level expected from the single chamber resonator is 5 db. A 5 db reduction in overall sound pressure means that the distance of detection is reduced by a factor of two. A 10 db loss, a level which may be realized by the double resonator, would mean reducing the detection distance by a factor of approximately four.

The single chamber resonator would consist of a three inch perforated cylinder 18 inches in length and covered by a $6\frac{1}{2}$ inch jacket with equivalent length. A muffler of this type would weigh about seven pounds.

It appeared that the requirement for a very broad attenuation region could best be satisfied by a combination of resonators which are tuned to different frequencies. The calculated results of this type of muffler show a noise reduction of 10 db over a frequency band of width equal to about six times the lowest frequency of the band. However, the physical dimensions of this muffler would be 12 inches in diameter, 12 inches length and 15 pounds (approx.) in weight.

It is felt that a suitable muffler for the One-Place Inflatoplane can be developed by additional research and experimental work to obtain an ultimate design which would satisfy all of the following conditions: (1) weight (2) size (installation problem) and (3) maximum noise reduction.

A future study program to determine whether it is feasible to install a suitable muffler on the Inflatoplane would include investigations on:

1. Double-chamber resonant muffler (further considerations).
2. Calkins muffler.
3. Expansion-chamber type muffler.

4. Noise suppressors - this phase would include the experimental considerations to some of the jet noise suppressors that were tested at GAC on a Cold Flow Facility to determine their feasibility as mufflers on two-cycle reciprocating engines.

5. Back pressure effects on engine operation.

9. Material Investigation

In Amendment Eight of the subject contract additional information was requested regarding Airmat fabrics. This information was obtained by conducting the following physical tests:

1. Panel burst tests
2. Packaging effects
3. Fabric life under limit load
4. Airmat fabric tests per MIL-C-21189(AER)
    a. Rotoflex
    b. Creasing
    c. Tear strength
    d. Seam strength
    e. Cylinder elongation
    f. Cyclic loading

These tests have been performed on the three types of Airmat utilized in the Inflatoplane construction: (1) wing, code A350; (2) cockpit, A-351; and (3) empennage, flap and aileron, A-349. The results and discussion of these tests are reported in (ref. 9).

The physical tests substantiated the ability of the material to withstand mechanical abuse; dead load and panel burst tests indicated material strength degradation with age and use.

The Inflatoplane service life, as determined by the limit load test, was conservatively calculated as being a minimum of 12,000 hours, surpassing the 7500 hour minimum required of a vehicle of this category. Mechanical abuse resulted in only minor materials degradation and does not significantly reduce the vehicle's service life. Substantiating this was (1) the two to three percent increase in leak rate resulting from 75 packaging operations, (2) the minor increase in permeability of hydrogen after rotoflex and cyclic loading and (3) material strength after rotoflex and creasing. Permeability to hydrogen is not increased by rotoflexing; however, it does increase after application of a cyclic load of 10,000 cycles by a factor of 3 to 5 for the cockpit and empennage and a factor of 10 for the wing material, but does not increase notable thereafter up to 100,000 cycles. After rotoflexing and creasing, material strength is reduced by approximately 2 to 5 percent for the cockpit and empennage and 7 percent for the wing.

Except for the cockpit material of the physical tests and the new material used in the dead load and panel burst tests, all specimens were fabricated of Airmat materials from vehicles in excess of four years old which had been subjected to loads encountered during demonstration and/or test programs conducted during this period. Hence, the data presented substantiates the ability of these fabrics to perform as a structural material after significant aging and time under load.

10. Flight Demonstration of Design Limits

The flight demonstration was conducted in concurrence with Amendments Five and Eight of subject contract. The flight demonstration required that buildup tests be conducted at the contractor's facility and the demonstration performed at the Naval Air Test Center, Patuxent River, Maryland.

During the flight demonstration under Amendment Five at NATC, the contractor's test pilot inadvertantly exceeded the structural limitations of the aircraft (3.6 g's) which resulted in the aircraft's crash. A new aircraft completed the flight demonstration but due to test discrepancies and the crash of a second aircraft during a training flight all aircraft were grounded.

Amendment Eight requested the completion of the flight demonstration with a structurally stronger aircraft. As a result of extensive testing (Section II, Item B-3) and wind tunnel tests (Section II, Item B-2) the ultimate load of wing was increased in excess of 5.0 g's. Only minor modifications (described in Section II, Item B-3) of the aircraft was necessary to accomplish this increase in load capability.

Following the completion of the buildup tests at the contractor plant in preparation for the demonstration at NATC with the modified aircraft, the demonstration program was cancelled by ONR. Amendment Ten requested a report to be prepared and submitted on the flight data obtained during the buildup phase of demonstration program. All the data collected during the demonstration program under Amendments Five and Eight are reported in (ref. 10).

As a result of the flight demonstration program it was concluded that the aircraft successfully demonstrated all design limits and the limits of the V-n diagram.

11. Pallet and Parachute Delivery System

A program was conducted to design, fabricate and test a pallet and parachute delivery system to be utilized in conjunction with the one-place Inflatoplane. This system was designed to be transported in the bomb-bay of a P2V-7 aircraft. The results and discussion of this test is reported in (ref. 11).

As a result of this program, it was found possible to package the Inflatoplane and supporting equipment on a 4 x 6 x 2 foot pallet and parachute drop it successfully. One man was able to move the package a reasonable distance, remove the airplane from the pallet, and fuel and inflate the airplane in a short period of time. Future development of airborne delivery systems should include a thorough evaluation of the present system and the development of an externally carried container.

SECTION III - CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The development, design, fabrication and testing of the evaluation models of the One-Place Inflatoplane has led to the fabrication of an improved low performance aircraft over the previous Inflatoplane model. The design objectives of increased airframe strength improved airframe, increased load carrying capability, and improved operational features were achieved or exceeded. The numerous tests, as summarized in this report, supply data to support the achievement of the design objectives and the improved performance capabilities. The test programs also indicate the amount of mechanical and structural abuse that can be sustained without appreciably affecting the aircraft life.

The feasibility of inflated aircraft concept has been proven beyond any shadow of a doubt and will be substantiated even further during field evaluation. However, since the improvements were accomplished on essentially a carbon copy of the GA 447, the aircraft should be further refined by design before going into production.

B. RECOMMENDATIONS

In order to further refine and develop the Inflatoplane concept, Goodyear Aircraft recommends the following steps should be taken.

1. Develop and fabricate two-place Inflatoplane evaluation models.
2. Investigate the use of a gas turbine engine for use with the Inflatoplane.

3. Investigate the launching and landing techniques (shipboard and water) necessary for the operation of the aircraft from non-aircraft carrying ships.

4. Design, fabricate, and test air drop containers carried as an external store.

To assure safe operation of the Inflatoplane, its accessories and ground support equipment, it is recommended that operating personnel become thoroughly familiar with the operation characteristics. Reference 7 gives adequate coverage for this purpose.

REFERENCES

1. Goodyear Enginerring Report, GER 8146, Summary Engineering Report on the Development of a One-Place Inflatoplane, Akron, Ohio, dated 15 April 1957.

2. Goodyear Engineering Report, GER 7469, Summary Report on Goodyear Aircraft Inflatoplane, Akron, Ohio, dated 30 March 1956.

3. Goodyear Engineering Report, GER 8597, Summary Report on the Development of a Two-Place Inflatoplane, Akron, Ohio, dated 31 July 1958.

4. Goodyear Aircraft Letter to ONR, Code 461, X52-846, dated 2 February 1961.

5. NACA Research Memorandum, RM SL58E09, Wind Tunnel Investigation of the Aerodynamic and Structural Deflection Characteristics of the Goodyear Inflatoplane, Bennie W. Cocke, Jr., dated 14 May 1958, Langley Aeronautical Laboratory, Langley Field, Va.

6. Goodyear Engineering Report, GER 10012, Preliminary Results of the Wind Tunnel Investigation of the Aerodynamic and Structural Deflection Characteristics of Model GA 468 Inflatoplane, dated 14 October 1960.

7. Goodyear Engineering Report, GER 10118, Utility Handbook - Flight Operation, Maintenance and Inspection, Inflatoplane Goodyear Model GA 468, dated 6 March 1961.

8. Goodyear Engineering Report, GER 9017, Summary Engineering Report on Flight Testing of the VAO-3(6) Aircraft, dated 1 October 1958.

9. Goodyear Engineering Report, GER 10270, Airmat Materials Investigation of One-Place Inflatoplane GA 468, dated 30 June 1961.

10. Goodyear Engineering Report, GER 9066, Demonstration Progress and Instrumentation Report on the GA 468 Inflatoplane, dated 1 November 1958.

11. Goodyear Engineering Report, GER 9472, Preliminary Development of a Parachute-Pallet Delivery System for the One-Place Inflatoplane, dated 11 December 1959.

12. Military Specification, MIL-E-25113(ASG), Engines, Aircraft, Reciprocating, Preliminary Flight Rating Tests For, dated 7 February 1955.

13. Goodyear Aircraft Corporation, Preliminary Test Specification, Nelson H63-A Engine, Preliminary Flight Rating Test, dated November 4, 1958.

14. Goodyear Aircraft Corporation, Letter, X52-T888, to Office of Naval Research, Preliminary Flight Rating Test of the Nelson H63-A Engine, dated 30 December 1958.

15. Naval Air Material Center Letter, XE-1WVT: cts, to Chief, Bureau of Aeronautics (PP-23), Inspection of Nelson Model H63-A Engine Following Preliminary Flight Rating Test, dated 19 December 1958

16. Chief, Bureau of Aeronautics Letter, Aer-PP-232/2, to Office of Naval Research, Nelson H63-A Engine for the Goodyear Inflatoplane; Clearance for Flight Testing of.

17. Pesco Products Division, Engineering Report No. 4027, Report on 200 Hour Endurance Test of a 3P-207-JE Pump Equipped with Grade AAA Nat. Spauldite Blades, dated March 16, 1959.

18. Nelson Specialty Corporation, Test Report, Investigation to Determine Cause of Piston Failure in Engine No. 310, dated March 21, 1960.

19. Nelson Specialty Corporation, Test Report, Nelson Model H63-A Engine, Serial No. 314, dated 3 June 1960.

20. Goodyear Aircraft Corporation, Engineering Report GER 9382, Engineering Investigation, Accident to INFLATOPLANE Model GA-468, No. 4108, June 5, 1959, dated June 24, 1951.

A P P E N D I X   A

H63-A ENGINE TEST AND OPERATION

TABLE OF CONTENTS

SUMMARY

This appendix presents the results of the contractor's tests and operation of the Nelson H63-A engine as installed on the Model GA-468 Inflatoplane. The engine test consisted primarily of two endurance runs, a 50-hour tie-down and a 60-hour PFRT. Operation of the engine was observed during all aircraft flight testing and flight demonstrations. As a result of test and operation, it was found that while undesireable combustion conditions exist in the engine the test objectives were met and subsequent operation of the engine, which showed the need for additional engine modifications, indicated that the engine could be satisfactorily operated on the aircraft. In regard to storage and handling, it was found that the engine could remain in satisfactory condition when standard engine preservation procedures are applied. As an overall assessment of this engine installation, it is the contractor's opinion that the powerplant is suitable for the intended purpose but that if future procurement is made more attention be given to standard aircraft engine design and construction practice. Recommendations are made regarding adherence to operation, maintenance, and inspection requirements given in the revised handbook, extension of the 50 hour time limit on the engine, and deletion of the 10-hour housing inspection requirement.

SECTION I - INTRODUCTION

Item I of Amendment Number 3 to Contract Nonr 2368(00) stipulated that a 50-hour tie-down test be conducted by the contractor to determine the compatibility of the engine-airframe combination and to test the endurance of the Nelson H63-A modified engine to operate over a 50-hour period without breakdown. Considerable difficulty was experienced with the engine during this test; however, once resolved, the 50-hour period was completed without operational breakdown. Subsequent tear-down inspection of the test engine revealed certain discrepancies which were not acceptable to the BuWeps Power Plants Office. In conference with the BuWeps, ONR, ATC representatives, and the engine manufacturer, it was decided that a 60-hour preliminary flight rating test (PFRT) was to be conducted by the engine manufacturer with technical assistance from the contractor. The PFRT was completed without forced stoppage or breakdown. Final tear down inspection revealed cracks developing in the front section of the accessory drive housing. However, the engine was accepted on a 50-hour PFRT basis with the limitation that a dye penetrant inspection be made on this housing after every ten hours of engine operation. Detailed accounts of the two tests (50-hour tiedown and 60-hour PFRT) are presented in subsequent discussion.

Following engine testing the flight test phase was initiated and a training school conducted. As a result of the investigations of an inflight engine failure and an aircraft accident, certain modifications in regard to the propulsion system and its operation were made during this period. These modifications are also presented in detail in subsequent discussion.

Resumption of work on the contract during 1960 disclosed additional engine discrepancies which primarily concerned the quality of engine construction. Additional modifications were also incorporated in the propulsion system as their need was indicated by flight test operation of the aircraft.

The portions of the revised handbook relating to the engine, its operation, maintenance, and inspection, have been prepared with the inclusion of the contractor's experience with the engine throughout the contract as the governing factor in presenting such information.

SECTION II - DESCRIPTION

The Nelson Model H63-A engine as procured from its manufacturer, Nelson Specialty Corporation,San Leandro, California, is a four-cylinder, horizontally-opposed, air-cooled reciprocating engine operating on the two-cycle principle. The engine as furnished was equipped with a battery ignition system and a cable-rewind type starting system. For installation on the Model GA-468 Inflatoplane the battery ignition system was discarded in favor of magneto ignition. A magneto developed by the McCulloch Corporation for use on their Model 4318 engine was adapted by the contractor for installation on the H63-A engine. In addition, an air pump drive and mounting was designed to provide inflation air supply capability for the aircraft. These drives and mounting pads were combined in an accessory drive housing which was mated to the front section of the starter housing on the H63-A engine. This design modification also necessitated removal of the cable-rewind starting system. Since the magneto featured an impulse coupling, "hand-propping" of the propeller was selected as a starting method for the engine. A fuel pressure regulator was also added to the engine to reduce fuel pressure from the airframe fuel supply system to the value specified at the carburetor fuel inlet connection for proper engine operation.

SECTION III - 50-HOUR TIE-DOWN TEST

Since no requirement other than an operating time period of 50 hours was specified for this test, a test plan was prepared based on an endurance run in general accordance with Military Specification, MIL-E-25113 (ASG), (ref. 12) In addition, the test plan included a tear-down inspection to be conducted after the endurance run. The test plan also specified gasoline, oil and fuel mixture requirements which were based on the then current engine manufacturer's specifications given in the operating instructions furnished with the engines. The results of the 50-hour tie-down test were as follows:

1) After an initial five hours of test operation fuel mixture leakage was observed on a cylinder. Cylinder removal and inspection disclosed a crack in the integral intake manifold of the cylinder and subsequent investigation by the engine manufacturer concluded that the crack was a manufacturing defect.

2) The above cylinder removal also disclosed severe combustion area carbon build-up, and piston ring sticking. The remaining cylinders were removed with the same results and, in addition, a tight piston-connecting rod assembly was found. To resolve these discrepancies the engine manufacturer recommended that the oil specification be changed from Grade 1065 to a special oil recommended for two-cycle engines to reduce carbon build-up and ring sticking. Such an oil was obtained from the Standard Oil Company of Ohio (SOHIO) and a new piston and rod assembly were installed to continue the test.

3) A ten hour test period was then conducted to determine the effect of the oil specification change. At the conclusion of this test period the cylinders were removed for inspection of the combustion area. Some improvement was noted but considerable carbon build-up was still found along with piston ring sticking and another tight piston and rod assembly was found. The engine manufacturer then recommended that the carburetor be modified so that the engine could be operated on a 16 to 1 gasoline-oil mixture instead of the original 8 to 1 mixture ratio. This recommendation was based on disclosure that concurrent development of a new engine model indicated that previous engine models (H63-A and prior models) operated with very high piston dome temperatures which caused oil "coking" and resulting carbon build-up on the intake side of the pistons. The later engine models (H63-B and subsequent) are designed with an integrally cooled piston whose parts are not interchangeable with previous engine models. It was also determined that the high piston temperatures were also responsible for the tight piston and rod assemblies appearing during the engine tests. This condition, high temperature and resulting thermal expansion of the aluminum piston, allowed the wrist pin bearing assemblies to float and contact the connecting rods. It was recommended that an additional snap ring be installed at the inner end of shorter wrist pin bearing assemblies (snap rings were originally installed only at the outer end to prevent contact with cylinder walls) to prevent axial bearing movement. Since installation of the new type piston was not possible in the H63-A engine model, it was recommended by the engine manufacturer that in addition to the carburetor modification, snap rings be installed to prevent bearing movement so that the already procured engine model could be used.

4) The tie-down testing was resumed with the modified carburetor, pistons, and new fuel specifications and no further problems were experienced in operation of the engine. However, during the test it was found that the air pump, Pesco Model, 3P-207-JA, contrary to manufacturing claims, could not operate on residual lubrication, so that a temporary lubrication system was substituted to enable completion of the tie-down test in its other phases until the pump manufacturer could recommend suitable modification. A total engine operating time of approximately 96 hours was used to obtain 50 hours of operation without breakdown.

5) The tear down inspection conducted after the engine endurance run revealed several discrepancies that resulted in non-acceptance of the test results by the contracting agency. Of major concern were carbon build-up on the pistons, piston ring sticking, and heat discoloration of the piston wrist pins and wrist pin bearings.

At a conference between the contracting agencies, the contractor, and the engine manufacturer, the results of the 50-hour tie-down test and the tear down inspection were discussed. It was the opinion of the contracting agencies that lack of imminent failure in regard to the major discrepancies had not been sufficiently proved and that test rerun would be required before the engine installation could be considered acceptable. It was the contractor's opinion that carbon build-up, ring sticking, and wrist pin and bearing discoloration were inherent engine characteristics and the engine's ability to operate with these conditions existing was evidenced by the completion of the 50-hour endurance test without breakdown. It was also noted that the conditions in question did not exist on later model versions of the engine so that the problem could be resolved by engine model replacement. However, it was considered a more economical approach to utilize the present engine model and require a Preliminary Flight Rating Test (PFRT) plus a ten hour penalty run to verify engine integrity with the inherent characteristics of carbon build-up, ring sticking, and wrist pin and bearing discoloration, providing there were no indications of imminent failure following the test run. It was also agreed that a test specification would be prepared by the contractor, pre-test and post-test tear-down inspections would be made, and that these tear-downs and the endurance test would be conducted at the engine manufacturer's facility with technical assistance from the contractor.

SECTION IV - 60-HOUR PFRT TEST

For the preliminary flight rating test a test specification in general accordance with reference 12 was prepared by the contractor and approved by the contracting agency and the engine manufacturer. In general, the test specification (ref. 13) required pre-test and post-test tear-down inspections and applicable endurance test operation to fulfil the 60-hour time limit established for the engine. The results of the 60-hour PFRT were as follows:

1) A pre-test tear-down inspection was made on engine, Serial No. 312, at the engine manufacturer's facility, Nelson Specialty Corporation, San Leandro, California. Applicable measurements were recorded and magnaglo and zyglo inspections, as required, were conducted by Oakland Aircraft Engine Service, Inc., Oakland, California, an FAA approved engine repair station. The engine was found acceptable and reassembled for endurance test operation.

2) The engine was installed on a test stand equipped to measure propeller torque load and a power calibration run was made. Following the calibration run, the endurance schedule outlined in the test specification was followed and completed without incident or unscheduled shutdown. After completion of the endurance run, a power calibration run was made to compare with the results of the initial calibration run. A corrected power loss of 3.6 percent was noted in comparing the calibration runs which is within the allowable value of 5.0 percent specified in reference 12.

3) The engine was then given post-test tear-down inspection. Measurements recorded during the pre-test tear-down were checked and no appreciable wear could be found. Carbon build-up was found on the pistons and two piston rings were found stuck, however, no evidence of blow-by or overheating was found. Discoloration was found on the piston wrist pins but was primarily of a varnish-produced nature due to high temperatures developed in this area of the engine. No bluing of any rotating parts was found. The magna-glo inspection of applicable parts showed no defects present. However, zyglo inspection revealed cracks in the head fins of a cylinder, in the center bearing support stator, and in the front section of the accessory drive housing. The cracks in the cylinder and stator were superficial and minor with no imminent failure indicated. The cracks in the mounting bases of the accessory housing were further inspected at the contractor's facility by X-ray and etching. Four of six bosses were cracked but none of the cracks exceeded a 50 percent penetration in depth.

Based on the results of the 60-hour PFRT as outlined in (ref. 14) and (15), the engine was given PFRT approval by BuWeps, in reference 16, for 50 hours of flight testing with the requirement that the front section of the accessory drive housing be given dye penetrant inspection after every 10 hours of engine operating time.

SECTION V - ENGINE MODIFICATIONS

The Model H63-A engine as originally procured from the manufacturer has been extensively modified due to the installation design on the airframe, the results of the 50-hour tie-down and 60-hour PFRT tests, and from operational discrepancies occurring during the various flight test phases of the aircraft. Major modifications accomplished on the engine were as follows.

1) For installation on the Model GA-468 INFLATOPLANE, the engine was modified to incorporate magneto ignition and an air pump drive pad. These two items were combined in an assembly mounted on the rear of the engine which provided a direct drive from the engine crankshaft for the magneto and a belt drive from the magneto drive for the air pump. The magneto, in turn, was modified internally to permit operation inverted from its normal installation mounting so that the new accessory drive package could be reduced in size. The vibration isolators originally furnished with the engine were also modified to shift engine position longitudinally in relation to the pylon mount structure to permit a more compact engine-pylon mount installation. A fuel pressure regulator was installed at the fuel inlet fitting on the carburetor to reduce airframe fuel system pressure to acceptable engine operating limits.

2) Based on the results of the 50-hour tie-down and 60-hour PFRT tests the carburetors originally furnished with the engines were modified to permit engine operation on a fuel mixture consisting of 16 parts of gasoline to one part of oil by volume. The gasoline and oil specifications for engine operation were also changed to limit use of gasoline to aviation gasoline,

Specification MIL-F-5572A, Grade 80/87 octane and oil to SOHIO (Standard Oil Company of Ohio) two-cycle engine lubricating oil, SAE 30 Grade. The wrist pin bearing installation in the engine was changed to incorporate a second snap ring to prevent axial movement of the bearing assembly in relation to the piston and wrist pin. Installation of these snap rings also necessitated a change to shorter bearing assemblies due to piston boss limitations. The air pumps were modified by their manufacturer to replace the steel vanes with phenolic vanes to permit pump operation on a residual oil supply. With an initial lubricating oil supply of one-half ounce added to the inlet air port of the pump, a 10 hour time limit is specified for the pump when operating on the residual oil supply. Reference 17 is the pump manufacturer's test report of a 200-hour qualification run for the pump vane modification.

3) Investigation of an in-flight engine failure and an aircraft accident that occurred during the conduct of a training program for U.S. Army personnel revealed the need for an improved ignition timing procedure for the engine, possible need for improved shatter protection of the propeller, and revision of the handbook. The engine that failed in flight was returned to the manufacturer for inspection, test, and reconditioning and to determine the cause of failure. The engine manufacturer's investigation, (ref. 18), indicated that magneto timing was a major factor contributing to the engine failure thereby resulting in detonation and piston burning. The timing procedure was then reviewed and more adequate timing reference marks were established on the engine along with more detailed magneto-to-engine timing procedures

for inclusion in the revised handbook. The engine involved in the accident (ref. 20), was salvaged and also returned to the engine manufacturer for inspection, test, and reconditioning to determine if engine operation could have been a contributing factor in the accident. The engine manufacturer's investigation on this engine (ref. 19) did not disclose any condition that would have caused the accident. However, the accident did suggest the possibility that propeller damage occurred so that a recommendation was made that a metal propeller be installed in place of the wood propellers in use. This change was investigated and it was found that marginal conditions in regard to vibrating stress levels could be encountered in the operating range of the engine and that if such conditions existed complete endurance testing of the engine would be required. Therefore, it was recommended that the present wood propellers be modified by incorporating a five-inch covering of two-ply laminated fiberglas on each tip to increase shatter resistance.

SECTION VI - ADDITIONAL ENGINE MODIFICATIONS

Following a period of approximately one year, during which the aircraft were grounded, indication was noted of what could be expected in regard to engine preservation and storage. Engines returned to the contractor were found to have internal dissimilar metals corrosion due to lack of preservation and damage due to improper handling. Also, in connection with a resumption of flight testing and the assignment of government inspection for flight test clearance, certain conditions regarding the quality of engine construction became evident. In addition, a crankcase thru-bolt failure, fuel system stoppage, and a fuel pressure regulator mounting failure warranted additional modifications as continued operation of the flight test aircraft was made. The modifications made to the engine in regard to these discrepancies were as follows:

1) In the specific case of the engine, serial number 311, which was returned to the contractor from the contracting agency in a severely corroded condition and with no evidence of having received preservation treatment, repair was made to return this engine to serviceable condition. The primary area of corrosion was at a crankcase drain plug, with superficial corrosion occurring from dissimilar metal contact of various engine parts assembled to the crankcase and carburetor. It was found that aluminum drain plugs were used in the magnesium crankcase and these were replaced by cadmium-plated steel plugs in all engines. The affected drain area of engine No. 311 was ground, smoothed and the crankcase pickled in a 10 percent chromic acid solution and given MIL-M-3171, Type III, dichromate treatment. The various dissimilar metal parts were cleaned and given cadmium plate treatment. In addition, all assembly of these engine parts was made using wet chromate primer.

2) During the resumption of the final flight test phases it was noted that short stud installations were evident on the engines. The studs in question are used to attach the cylinders to the crankcase and the accessory housing to the crankcase. The studs used for accessory housing attachment were replaced with studs of suitable length, however, this could not be done with the cylinder attach studs. The engine manufacturer advised that stud length must be controlled so that adequate clearance is obtained to install the cylinders and that the top surface of the stud will be either flush or extend slightly above the top surface of the nut. It was also stated that throughout the engine development there was never a cylinder failure attributable to this method of stud installation.

3) Investigation of a crankcase thru-bolt failure revealed that torque specifications were excessive and resulted in thread deformation of the bolts with a weakening of the bolt in shear. Approval by the engine manufacturer was obtained to reduce the torque specification of the bolts to proper values to prevent recurrence of this failure. Investigation was also made of two fuel system malfunctions and resulted in modification to the external fuel supply system to the engine. The fuel pressure regulator was relocated in a less vulnerable area of the engine after a mounting failure occurred in ground handling of the engine, and a fuel filter was installed in the system when residue from a main fuel bladder tank repair clogged the fuel shut-off valve.

4) During the course of the flight testing conducted by the contractor following the 60-hour PFRT and its disclosure of cracks in the accessory housing, dye penetrant inspection has been conducted in accordance with reference 16. After a total of eleven such inspections on several engines

no cracks of any kind have been found in the subject housing. The only modification made in connection with this housing was the installation of longer mounting studs (2, above) which would not contribute to the strength of mounting bosses of the housing.

SECTION VII - HANDBOOK REVISION

In accordance with the handbook revision required by contract amendment, those portions of the handbook that require information regarding the engine have been expanded to include all aspects of engine operation that can reasonably be expected to be encountered. Since the handbook (ref. 7) now consists of three parts, a flight operating handbook, a maintenance handbook, and an inspection, requirements handbook, engine information relating to these phases of aircraft operation have been included. The flight operating handbook contains engine information relating to operating procedures for normal and emergency operation, engine operating limitations, and performance charts for range and endurance predictions. The maintenance handbook contains ground handling, preservation and storage, servicing, and maintenance procedures applicable to the engine. The extent of engine maintenance procedures given in this handbook are intended primarily for the line maintenance organizational level; however, procedures for conducting top overhaul of the engine are also included. The inspection requirements handbook includes applicable engine information for the preflight and post flight inspections and necessary special inspections. Reference 16 recommended that copies of the tear-down inspections following the engine tests be made available for flight and maintenance personnel. Information relative to the conditions disclosed by these tests and inspections have been incorporated in the handbooks.

SECTION VIII - CONCLUSIONS

On the basis of the two major engine tests conducted under this contract and the operational experience gained from the flight test phases and flight demonstrations, the following conclusions have been made by the contractor in regard to the propulsion system installation on the GA-468 Inflatoplane.

1) From the results of the 50-hour tie down test it was concluded that excessive carbon buildup, piston ring sticking, and wrist pin bearing movement and discoloration were the result of a characteristically high piston operating temperature. It was also concluded that contributing factors to these conditions were an oil rich gasoline-oil mixture and the use of additive type oils.

2) To allow continued use of the engine, it was concluded that the conditions disclosed by the 50-hour tie down test could be minimized by wrist pin bearing and carburetor modifications, change in gasoline and oil specifications, reducing the amount of oil in the fuel mixture, and by adherence to engine operating limitations in regard to engine shut-down and idle operating time.

3) The results of the 60-hour PFRT indicated that the engine was capable of operating without failure or breakdown with some amount of carbon buildup and wrist pin discoloration and that the above modifications and changes had significantly reduced the extent of these discrepancies. Also, the installation of shorter wrist pin bearings and an additional snap ring per bearing assembly had solved the problem of bearing movement.

4) Both engine tests indicated conclusively that the type and amount of lubricating oil used in the fuel mixture is an important factor in the operation of this particular engine model, and that adherence to fuel mixture specifications must be observed to obtain satisfactory engine operation.

5) Flight operation of the engine revealed the need for improved magneto-to-engine timing procedures and the incorporation of suitable timing reference marks between stationary and rotating parts of the engine.

6) The rear housing inspection after every 10 hour operational period is concluded to be excessive since after considerable operation of the engine, 11 inspections have not revealed any discrepanices.

7) The installation of fiberglas tips on the wood propeller has increased the propeller shatter resistance and increased the flight safety of the aircraft.

8) The engine assembly has exhibited marginal corrosion protection qualities. However, it is concluded that as long as proper preservation procedures are used in connection with operation and storage of the aircraft and engine, satisfactory engine condition will be obtained after prolonged storage.

9) The cylinder mounting stud length as installed by the engine manufacturer is adequate for the intended purpose and for operation of the engine within the 50-hour flight limitation. The engine manufacturer has sufficient operational experience with all models of the engine to indicate that no problem exists in this respect.

10) It was concluded that the original torque specification for the AN 3-31A and AN 3-16A crankcase thru-bolts was excessive and a reduced torque limit was placed in effect with satisfactory results.

11) The relocation of the fuel pressure regulator provides a more suitable mounting for this unit.

12) The addition of a fuel filter to the external fuel supply system will prevent fuel system and carburetor malfunction from contaminated fuel.

13) The incorporation of phenolic vanes in the air pump substantially increased the flight endurance time for operating the pump on a residual lubricating oil supply.

14) It was concluded that the revised handbook should contain engine information relating to all aspects of the testing and operational features of the installation.

SECTION IX - RECOMMENDATIONS

Based on the conclusions reached concerning the test results and operation of the H63-A engine, the following recommendations are made by the contractor in regard to its installation on the GA-468 Inflatoplane.

1) The Nelson Model H63-A engine as modified by the contractor is recommended for operational use in accordance with the specifications and instructions given in the revised handbook series (ref. 7) for a total operating period of 50 hours.

2) On the basis of operational experience with the engine it is recommended that operational use of the engine can be extended for an additional 50 hour period provided that a tear down inspection between these periods does not reveal unsatisfactory conditions. It is further recommended that this inspection be conducted by the engine manufacturer since overhaul instructions are not given in the present handbook series.

3) Based on the fact that no accessory housing cracks have been reported following a total of eleven 10-hour inspections, the contractor recommends deletion of the 10-hour dye penetrant inspection requirement stipulated for these housings in reference 16.

4) Prior to operation by the contracting agencies it is recommended that flight and ground personnel become thoroughly familiar with the operation and marginal characteristics of the engine in regard to gasoline and oil specification, magneto timing, and engine preservation procedures. The

revised handbook series covers these conditions adequately and can be used for this indoctrination.

5) If any future procurement of this engine type is made, it is recommended that specifications be prepared with emphasis on dissimilar metals, corrosion prevention and adherence to standard engine practice in regard to the use of fasteners and fittings.

FINAL REPORT

DISTRIBUTION LIST

Contract NOnr 2368 (00)
One-Place Inflatoplane

U. S. Army	No. of Copies
Commanding Officer Transportation Research Command Ft. Eustis, Va. TCREC-AD	2
President U. S. Army Aviation Board Ft. Rucker, Ala.	1
Commanding General U.S. Army Transportation Material Command 12th and Spruce Streets St. Louis, Mo. TCMAC-EP	1
Office, Chief of Transportation Department of the Army Washington 25, D. C. (TAFO-R)	1
Commanding General U. S. Continental Army Command Ft. Monroe, Va. (Material Devel.)	1
Chief of Research & Development Department of the Army Washington 25, D. C. (Aviation Div.)	1
Office, Deputy Chief of Staff for Operations Department of the Army Washington 25, D. C. (Aviation Div.)	1

U. S. Navy	No. of Copies
Chief of Naval Research Code 461 Washington 25, D. C. ALO/ONR	3
Chief of Naval Research Code 105 Washington 25, D. C. (Mr. B. Main)	
Bureau of Naval Weapons Code RA-6 Washington 25, D. C. (Mr. C. W. Shubart)	2
Commanding Officer Naval Air Test Center Patuxent River, Md. (Flight Test Div.)	1
Bureau of Naval Weapons Code RAAD-232 Washington 25, D. C.	1

U. S. Marine Corps

Marine Corps Development Center Marine Corps School Quantico, Va. (Air Section)	1

Commander Armed Services Technical Information Agency Document Service Center Arlington Hall Station Arlington 12, Virginia	5-10