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AIRCRAFT CONFIGURATION SURVEY FOR WEAPONS SYSTEM 118P

NORTH AMERICAN AVIATION INC LOS ANGELES CA

01 JUN 1956

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File No. ______ Report No. NA-56-521

NORTH AMERICAN AVIATION, INC.

INTERNATIONAL AIRPORT

LOS ANGELES 45, CALIFORNIA

ENGINEERING DEPARTMENT

AIRCRAFT CONFIGURATION SURVEY

FOR

WEAPONS SYSTEM 118P

CONTRACT AF33(600)-31243

(E. O. NO. 55-8-118L)

PREPARED BY

DESIGN ANALYSIS GROUP

APPROVED BY

H. A. Evans

H. A. EVANS, MANAGER

WEAPON SYSTEM ADVANCED DESIGN

No. of Pages 44 Date 1 June 1956

REVISIONS

DATE	REV BY	PAGES AFFECTED	REMARKS
			U.S.M.O. MAY 23 1958
			56RDZ-6556-15
			58AA 5386

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NORTH AMERICAN AVIATION, INC.
INTERNATIONAL AIRPORT
LOS ANGELES 45, CALIFORNIA

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INDEX TO FIGURES

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56RDZ-6556

1.0 INTRODUCTION

The Contractor has completed a study on a piloted special reconnaissance weapon system for use in tactical and strategic reconnaissance operations. The basic intent of this report is to summarize the performance requirements affecting the airplane design, the design assumptions used, and the design features of the selected airplane. Further, the envelope of maximum cruise altitude vs. airplane weight achievable by conventional and special means is presented. Finally, this summary gives a discussion of the design features including propulsion systems, aircraft configurations, equipment configurations, and structural design features. For a summarized result of the complete study refer to Report No. NA-56-520.

2.0 APPROACH

2.1 Problem. - The problem is to find the best design that meets the given requirements and falls within the given assumptions. The best design is defined as being the lightest weight design.

2.2 Solution. - The approach used in solving the problem is outlined by the following:

2.2.1 Study is initiated within each of the equipment groupings (engines, fuels, control surfaces etc.) to eliminate the alternates which either:

a) do not meet any one of the requirements, or

b) have inferior weight and performance characteristics on all counts when compared to any other alternative.

2.2.2 The remaining alternatives are systematically studied by

a) incorporating them into airplane designs, and

b) optimizing each of these designs to obtain the smallest gross weight that will satisfy the performance requirements.

2.2.3 The design whose combination of design features results in the lightest gross weight of all is the best design to meet the requirements.

3.0 <u>AF REQUIREMENTS</u>

3.1 Phase II 1/2. - The general requirements for this design are as follows:

a) Minimum cruise altitude - 75,000 feet

b) Range - 3000 nautical miles with
2400 at the cruise altitude

c) Operational - daylight photography, high order ferret
and radar reconnaissance

d) Operational date - 1958

3.2 Phase III. - The general requirements for this design are as follows:

a) Minimum cruise altitude - 100,000 feet

b) Range - same as Phase II 1/2

c) Operational - same as Phase II 1/2

d) Operational date - 1960

4.0 <u>ASSUMPTIONS</u>

4.1 To achieve lowest the possible gross weight without sacrificing mission capabilities the following criteria is used for each design:

a) Communication and guidance electronics are reduced to the minimum.

b) Reconnaissance equipment is packaged for different type missions, with only one type mission being accomplished in each flight. This is not done by sacrificing reconnaissance coverage or resolution, but is done by increasing the number of flights or airplanes needed for complete coverage by all types of reconnaissance.

c) Highly skilled maintenance and flight personnel and best available shop techniques are to be utilized.

d) Low gust conditions for high altitude cruise conditions allow the limit maneuver load factor to be reduced to 1.6.

e) Maintenance access doors are of the structural type and the number reduced to a minimum.

f) Operation of engines is at point of highest efficiency. This may result in higher temperatures and RPM at the expense of engine life.

g) The airplane is to be operated only along its design mission, and the structure is not compromised for off-design capability..

5.0 <u>CONFIGURATION</u>

5.1 Phase II 1/2. - The mission profile chart, general arrangement and inboard profile drawings for Phase II 1/2 design appear on pages 25, 26 and 27.

[redacted]

[redacted]

5.1.1 Power Plant. - Four (4) General Electric J79-X278 turbojet engines equipped with afterburners using LBSS (Land Based Supersonic) fuel are located in the aft fuselage.

5.1.2 Inlet Design. - A two dimensional fixed ramp type, side duct inlet and a variable geometry duct is used for each pair of engines. For maximum efficiency, a by-pass system and boundary layer bleed are employed.

5.1.3 Geometry. -

a) Wing area - - - - - - - - - - - - - - 2757 ft.^{2}

b) Aspect ratio - - - - - - - - - - - - 1.54

c) Thickness ratio - - - - - - - - - - .03

d) Angle of sweep - - - - - - - - - - - 52.41°

e) Wing span - - - - - - - - - - - - - - 64.9 Ft.

f) Overall length - - - - - - - - - - - 121.3 ft.

5.1.4 Stability and Control. -

5.1.4.1 Directional Stability and Control. - Directional stability is achieved through the use of two upper mounted vertical stabilizers. A rudder on each stabilizer is used for directional control.

5.1.4.2 Longitudinal Stability and Control. - The horizontal stabilizer (canard) is mounted forward of the wing on the forward part of the fuselage. The surface is all movable and auto-stabilized to obtain longitudinal control.

5.1.4.3 Lateral Stability and Control. - The excessive lateral stability inherent in a highly swept wing is offset by wing cathedral so as to reduce the dutch roll tendencies

[redacted]

[redacted]

of the design to an acceptable level. Lateral control is achieved by the use of ailerons.

5.1.5 Equipment. -

5.1.5.1 The equipment is divided into two primary groups:

5.1.5.1.1 Basic Electronics. - This equipment is defined as that which is always present in the airplane for normal communications, flight control, identification, etc. This group will consist of the following items totaling approximately 1002 lbs. in weight and occupying 20.1 cubic feet of space:

ARC-52 Command Radio

APX-19 with SIF Ground-to-Air IFF Transponder

APX-27 Air-to-Air IFF Transponder

ARA-37 UHF Direction Finder

N5C Auto-navigator

Standby Platform

ART-27 Crash Beacon

Automatic Flight Control System

Flight Programmer and Time Position Correlator

5.1.5.1.2 Reconnaissance Equipment. - This equipment is defined as that required to carry out the mission. The mission requirements have been divided into 5 types. The equipment equired for each mission is listed below.

5.1.5.1.2.1 Search Photo. -

a) 18 inch split vertical camera - 2 req.

[redacted]

b) 30 inch oblique camera - 2 req.

c) Stabilized mount

d) System control

5.1.5.1.2.2 Detail Photo. -

a) 48 inch camera - 4 req.

b) Stabilized mount

c) System control

5.1.5.1.2.3 Radar Mapping. -

APQ-56 High Resolution Radar System

5.1.5.1.2.4 Ferret System. -

a) DLD-1 D/F equipment (1 - 40 MC)

b) DLD-2 D/F equipment (30 - 1000 MC)

5.1.5.1.2.5 Radar Mapping System. -

a) Azimuth radar, indicator and camera.

5.2 Phase III. - The mission profile chart, general arrangement and inboard profile drawings for the Phase III design appear on pages 28, 29 and 30.

5.2.1 Power Plant. - Four (4) Aerojet air-turbo-rocket engines (ATR 2010) 103.1% size, using hydrogen fuel are located in the aft end of the fuselage.

5.2.2 Inlet Design. - A two dimensional fixed ramp type, bottom duct inlet and a variable geometry duct is used. For maximum efficiency a bypass system and boundary layer control system are employed. A cowl is installed over the lower section of the inlet during take-off and low speed flight to reduce duct

[redacted]

airflow for maximum duct efficiency at these speeds. This cowl is jettisoned at approximately Mach 1.8, and subsequently destroyed by a series of small explosive charges installed in the cowl.

5.2.3 Geometry. -

a) Wing area - - - - - - - - - - - - - - 6600 $ft.^2$

b) Aspect ratio - - - - - - - - - - - - 1.0

c) Thickness ratio - - - - - - - - - - - .03

d) Angle of sweep - - - - - - - - - - - 71.61°

e) Wing span - - - - - - - - - - - - - - 79.898 ft.

f) Overall length - - - - - - - - - - - 181 ft.

5.2.4 Stability and Control. -

5.2.4.1 Directional Stability and Control. -

Two upper mounted vertical stabilizers are located at the aft end of the fuselage, and in addition the wing tips fold down after take-off to increase directional stability at high speeds. Control is obtained through the use of rudders mounted on the vertical stabilizers.

5.2.4.2 Longitudinal Stability and Control. -

The horizontal stabilizer (canard) is mounted forward of the wing on the forward section of the fuselage. The surface is all movable, and auto-stabilized for longitudinal control.

5.2.4.3 Lateral Stability and Control. -

The excessive lateral stability inherent in highly swept wings is offset by wing cathedral to reduce dutch roll tendencies to an acceptable level. Spoilers are employed for lateral control. Lateral trim is achieved from a tab installed on the left hand wing panel.

5.2.5 Equipment. -

5.2.5.. The equipment for the Phase III design is divided into the same categories as on Phase II 1/2. The basic electronics are the same, and although the reconnaissance equipment specifications for the Phase III design are more exacting, it is believed that for the time period considered the two systems will compare closely in size and weight. For the Phase III Radar Mapping System, however, a side-looking Coherent Doppler system is used in lieu of the APQ-56 system.

5.3 Operational Date. -

5.3.1 Phase II 1/2. - To meet the Air Force operational date requirement of 1958 would require that the Contractor have a design in the prototype stage of development at the present time. Since there is no such airplane that could be modified to meet the Phase II 1/2 requirements, the earliest operational date is determined mainly by the Contractor's, ability to design and manufacture the airplane from the beginning. 1961 is the earliest possible operational date under these circumstances. This estimate is based upon approximately 2 months delay in order to have the engines and equipment available to support this program when required.

5.3.2 Phase III. - The Phase III program is primarily dependent upon engine development to achieve the required performance. Since the engines for this program can not be made available until 1963, this is the earliest operational date for the Phase III program.

6.0 Performance Envelope - The submittal requirement as outlined in section 1.3 of the Statement of Work asks for the maximum altitude capability vs. flight Mach number. This is altered so as to plot the maximum altitude capability vs. airplane gross weight such that for each gross weight the flight Mach number used is that which gives the highest cruise altitude. This envelope is shown as Figure 7 on page 31 of this report. The lower boundary is defined by designs similar to the Phase II 1/2 submittal airplane which is of conventional design. The upper boundary consists of three designs. Below 83600 feet the maximum altitude capabilities are achieved by designs using scaled versions of the X278 engine burning Zip fuel in the afterburner. Between 83600 and 85400 feet designs using scaled versions of the X278 burning hydrogen fuel achieve the highest cruise altitude. Above 85400 feet designs similar to the Phase III submittal design have the highest cruise altitude capability.

7.0 Discussion

7.1 Propulsion

7.1.1 General - In determining the engine-fuel combination to be used for the submittal designs the first step is to check all the possible engine-fuel combinations for the following requirements:

a) A 50 hour test engine-fuel combination must be available approximately 20 months before the operational date.

b) The engine-fuel combination must have an altitude limit above the required minimum cruise altitude.

c) Performance data sufficient to evaluate a design which uses the engine-fuel combination must be available at this time.

Figure 8 on page 32 of this report lists all the engine-fuel combinations considered in this study and notes whether each satisfies the above requirements. Those which do not meet any one requirement can be eliminated.

The next step in this elimination process is to compare the remaining engine-fuel combinations on the basis weight and performance. The performance parameters of greatest importance in this comparison are:

a) Specific fuel consumption (S.F.C.) at limit Mach number and minimum cruise altitude.

b) Engine thrust to engine weight ratio (T/W) at limit Mach number and minimum cruise altitude.

c) Limit Mach number (M_{limit})

The affect of these performance parameters on the airplane design is the following: lower S.F.C. means greater endurance, higher T/W means less engine weight, and higher limit Mach number means greater range.

Study indicates that maximum range and altitude are achieved when cruise is performed at the highest possible speed. This is due to the increase in engine thrust-per-pound-of-weight and miles-per-pound-of-fuel (speed divided by fuel flow) which accompany an increase in speed. The above effects more than off-set the added structural penalty for increased skin temperatures.

Therefore, the above performance parameters are given at limit Mach number and minimum cruise altitude in order to present a fair comparison between engine-fuel combinations. Figure 9 on page 34 of this report lists the engine-fuel combinations that survived the first elimination and compares the above parameters for each of them. Those that show all three parameters to be inferior to some other combination may be dropped from further studies.

Engine-fuel combinations which cannot be eliminated from consideration by the above comparison must then be incorporated into an airplane design for final elimination. A comparison of these designs is presented in Figures 10, 11, 12 and 13.

All designs listed are compared on the basis of range for equal gross weight with all design features being comparable. This final chart indicates the reason for the engine choice on both Phase II 1/2 and Phase III submittal designs.

7.1.2 Engine Types

7.1.2.1 Ramjet - The relatively high thrust-weight ratio and average specific fuel consumption make this type of engine an item of consideration. However, since a ramjet requires a booster stage to obtain altitude and cruise speeds and an APU unit to operate the equipment, the increased weight associated with this design eliminates it from consideration for the final design.

7.1.2.2 Turbofan - In general, turbofan engine altitude capabilities and supersonic cruise specific fuel consumption are not favorable for either Phase II 1/2 or Phase III requirements. The performance characteristics coupled with questionable availability are sufficient to eliminate it from consideration.

7.1.2.3 Turbojet

7.1.2.3.1 General - Turbojet engines using LBSS fuel are considered superior for Phase II 1/2 designs, since these engines accomplish the mission at less gross weight than the other available types of engines.

7.1.2.3.2 Subsonic - The General Electric J-85 was investigated for possible use in a subsonic reconnaissance vehicle for Phase II 1/2 requirements. Fuel was limited to liquid hydrogen since conventional fuels limited the cruise altitude to below 65000 feet. However, since this design does not meet the required range and lacks the passive defense capabilities of supersonic flight, it was not considered for final presentation.

7.1.2.3.3 Supersonic - The General Electric J79-X278 is chosen for installation in the final design. Figure 7 presents a plot of take-off gross weight versus altitude for this engine, using various types of fuels. Zip and liquid hydrogen are superior to JP-5 fuel from a gross weight consideration, however, availability of Zip fuel and operational problems of hydrogen fuel do not warrant their consideration for the time period of the Phase II 1/2 design. Altitude limitations of the J79-X278 engine do not permit its use in Phase III designs.

7.1.2.4 Air-Turbo-Rocket - The altitude requirements of the Phase III design require the use of unconventional fuels and an advanced engine design of high supersonic capabilities. The air-turbo-rocket engine has these characteristics and is selected for installation in this design. The Aerojet ATR-2010 using hydrogen fuel is considered to be the best engine-fuel combination. The use of hydrogen fuels will require considerable development, however, this engine will be available by 1963.

7.1.2.5 Rocket Engine - The high specific-fuel-consumption even with the more exotic fuel-oxidizer combinations more than offsets their high engine thrust-weight ratio for long range vehicles.

7.1.2.6 Rax Engine - The latest information that the Contractor has received is contained in Garret Report RD-4R dated 15 February 1956. This report does not include sufficient data to complete a design study based on this engine. It is felt that the ATR-2010 engine cycle reflects somewhat the potentialities of the Rex III cycle and that further study is warranted. However, no quantitative comparison is available at this time.

7.1.3 Engine Installation - The primary factors determining location of engine installations are as follows:

a) Low drag

b) Low duct losses

c) Minimum exhaust impingement on other parts of the airplane

d) Minimum structural weight

The engine installation for both Phase II 1/2 and Phase III is located in the aft fuselage for minimum frontal area and therefore less drag. Duct losses are higher for this installation than for wing-mounted engine pod, but friction drag, wave drag and interference drag will be considerably less. It is believed that this installation also contributes more to the reliability of the airplane due to the vibration and exhaust impingement problems of a wing mounted engine pod.

7.1.4 Inlet Duct Placement

7.1.4.1 Phase II 1/2 - In this design the cross-sectional area of the forward fuselage is primarily determined by the equipment installation. The most efficient and practical configuration is rectangular in nature. With this design, side ducts are utilized since they can be faired directly into the sides of the envelope containing the engines and thus present the most efficient configuration with the minimum frontal area and therefore drag.

7.1.4.2 Phase III - In this design the cross-sectional area of the fuselage is primarily determined by the large volume of low density hydrogen fuel. The most efficient and practical design is determined to be elliptical in nature with a horizontal major axis. Engines can be installed in this configuration without unnecessarily widening the basic fuselage. A bottom inlet results in smaller duct losses and lower drag for this design by using a more direct route for air flow. Top ducts were not used since for good pressure recovery at high angles of attack, the inlet must be placed near the nose of the fuselage. This results in greater duct losses and higher drag from the added duct length required.

7.1.4.3 Inlet Design - The duct inlets for both systems are designed to operate as efficiently as possible through the range of air speeds. This presents a considerable problem in controlling the amount of air entering the engine, and also in maintaining smooth air flow through the numerous shock configurations present in the duct. Studies show the best solution to these problems is a double angle fixed ramp in front of the inlet lip, with a movable section aft of the lip to control the shock waves. Since the inlets on both airplanes are designed to supply the amount of air needed for top speed operation there is a bypass system to remove the air not needed by the engines at lower operating speeds. In order to remove the turbulent boundary layer air from the ramps and duct, three separate bleed systems are used. This separation of the bleed system as to low, medium or high pressure area being bled prevents a high pressure bleed from reversing the flow and dumping into a low pressure area. On the Phase III design, a separate cowl is designed to limit the amount of air entering the duct in low supersonic region. This cowl is installed due to the low net thrust of this engine installation in the region of Mach 1.0 to 1.5. This characteristic is due to the poor off-design performance of an inlet designed for high Mach numbers (Mach 4.0). Two effects are responsible for this low performance:

a) Large Ramp Drag - For efficient high speed operation, the initial ramps have high turning angles, high ramp pressures and high ramp drags at transonic speeds.

b) Large bypass and/or spillage drag - When the inlet capture area is sized for efficient high speed operation, the resultant capture area at transonic speeds provides far more air than the engine can use. This excess air must be either bypassed or spilled. Either of these creates high drags.

These drag items are subtracted from gross thrust to obtain net thrust and reach a maximum in the region of Mach 1.0 to 1.5. Four methods were studied to achieve more efficient operation in this region on the Phase III design:

[redacted]

a) Jettisonable rocket units to augment the thrust in the region of Mach 1.0 to 1.5

b) Additional air-turbo-rocket engines

c) Programming of flight to dive the airplane through this region

d) Addition of jettisonable cowl to restrict airflow at low speeds

A weight penalty was calculated for each of the above alternatives. The jettisonable cowl received the smallest penalty and was chosen as the best solution. This cowl is jettisoned at approximately Mach 1.8 and subsequently destroyed by a series of small explosive charges placed in the cowl.

7.2 Wing Configuration

7.2.1 General - The IBM 701 Configuration Analysis Program systematically varies the wing design parameters to obtain an airplane of lightest gross weight for each parameter considered. The wing configurations of both Phase II 1/2 and Phase III designs are obtained in this manner.

7.2.2 Aspect Ratio - Aspect ratio is necessarily small for high speed airplanes. High aspect ratio for these configurations would result in higher drag with an attendent increase in structural weight plus an added structural penalty for vibration and flutter.

7.2.3 Angle of Sweep - Drag can be effectively reduced for supersonic flight by increasing angle of sweep. However, since stall stability is also decreased for low speed applications, sweep angle can only be increased within certain bounds. The sweep angle for Phase III can be larger than for Phase II 1/2 since the decrease in wing loading allows take-off and landing operations to take place at lower lift coefficients. Obtaining this large sweep angle and low aspect ratio results in the delta wing design.

7.2.4 Thickness Ratio - Thin wings are desirable from a standpoint of reducing drag even though wing structure is heavier. However, the minimum value is restricted by detail design, available materials and manufacturing techniques to obtain the required strength. For the time period considered, it is believed that a wing with a 3% ratio between thickness and chord is that limit for these designs.

7.3 Stability

7.3.1 Longitudinal - For balance reasons, the wing is placed at the aft end of the fuselage. This limits the location of the horizontal stabilizer to two possibilites.

a) On booms extended aft of the engines

b) On the fuselage forward of the wing

Locating the horizontal aft of the wing requires additional structure plus the problems of buffeting and overheating due to the passage of exhaust gases. The horizontal stabilizer is, therefore, located on the forward fuselage.

To achieve the required degree of static and dynamic stability throughout the airplanes speed range, the canard must be either aerodynamically or artifically free-floating. Studies made on other of the Contractor's projects show that the artificial method results in the lightest weight. This is due mainly to the excessive flutter tendencies even at moderate indicated air speeds of the aerodynamic free-floating system.

7.3.2 Directional Stability. - Study indicates that for the same total area one or two vertical stabilizers are equally effective, however, the dual configuratio chosen because it weighs less. The stabilizers are moun... on the upper aft section of the fuselage. The Phase III design has folding wing tips for added stability at high Mach numbers and high angles of attack.

7.4 Control. -

7.4.1 Lateral. - A study of the effectiveness of spoilers and ailerons was conducted to determine the best design for each airplane. Both systems give the same response and rate of roll. Ailerons are selected for the Phase II 1/2 design since they require less structural and installation weight. Spoilers are selected for the Phase III design since for this wing configuration ground clearance is a problem with the long chord aileron required.

7.4.2 Directional. - Rudders are selected for directional control in lieu of all-movable tails for weight reasons.

7.4.3 Longitudinal. - Investigation reveals that the all-movable, auto-stabilized canard is lighter and more effective over the entire speed range than elevators. This is selected for both designs.

7.5 Equipment. -

7.5.1 General. - Although the 118P Weapons System airplanes are designed for minimum weight with a single reconnaissance capability per mission, alternate equipment configurations for more complete coverage were investigated as noted below. The effect on gross weight of increasing equipment for additional coverage at the same altitude, range and velocity is shown in figure 14 on page 39 of this report. This study was conducted for Phase II 1/2 designs only. The results shown can be applied, qualitatively at least, to Phase III designs.

7.5.2 Alternate I. - This configuration differs from the design configuration by the addition of certain electronics equipment to be added to the basic fixed electronics equipment. This consists of long range communications, guidance radar and other items to make a complete fixed electronic installation. The increase in equipment weight totals 869 pounds over the design load. This configuration requires no additional crew.

7.5.3 Alternate II. - This configuration consists of the fixed electronics of Alternate I plus either of the following reconnaissance installations:

a) Radar reconnaissance, search photo and complete pulse ferret.

b) Radar reconnaissance, detail photo and complete C.W. ferret.

Either of the above reconnaissance installations gives the airplane medium reconnaissance capability per mission with an added equipment weight of 4209 pounds, over the design load. This installation requires a crew of two.

7.5.4 Alternate III. - This configuration consists of the complete fixed electronics equipment plus equipment for complete reconnaissance capability per mission. This installation adds approximately 6650 pounds of equipment over the design load and requires a crew of two.

7.6 Structural Design Criteria. -

7.6.1 General. - Early in the study it was determined that by establishing the new design criteria set forth below, a considerable weight saving could be effected without sacrificing the basic reconnaissance mission. The effect of these criteria on gross weight of designs which meet the Phase II 1/2 requirements is shown in figures 15, 16 and 17 on pages 40, 41 and 42 of this report.

7.6.2 Load Factor. - The limit load factor is reduced to 1.6 since the mission is performed at high altitudes where gust loads are at a minimum. Ultimate load factor is established at 2.0 or 1.25 times the limit load factor.

7.6.3 Design Dynamic Pressure. - Design dynamic pressure is established at 1500 psf supersonically and 500 psf subsonically.

7.6.4 Accessibility. - With the assumption that maintenance personnel would be highly skilled and bases of operation well equipped for maintenance, access doors are reduced to a minimum. The remaining doors are of the structural type for maximum structural efficiency. It is not anticipated that this will greatly curtail maintenance time since the results of a recent survey by the contractor indicate that approximately only 4 1/2% of maintenance time is consumed in opening and closing access doors.

7.6.5 Design Flight Hours. - Figure 18 presents a plot of Design Flight Hours versus take-off gross weight. The term Design Flight Hours is defined as the flight time in which the airplane will have a 50-50 possibility of exceeding limit load factor due to gusts.

7.7 Performance Envelope. - The curves presented on figure 7 were generated by the Configuration Analysis Program which uses the IBM 701 digital computer. Using designs which employed various engine-fuel combinations as base-point-airplanes, the program determines the engine size, fuel load and airframe geometry that results in the minimum weight design for each of a range of minimum cruise altitudes while holding total range constant.

The series of designs which are chosen to represent the conventional means are those similar to the Phase II 1/2 submittal design. It is noted that the Phase II 1/2 submittal design can only use full size versions of the X278 for engine availability reasons, while the optimum engine size from a weight standpoint is somewhat smaller. This fact is responsible for the above difference since the curve plots only optimum designs.

The curve representing the maximum altitude attainable by special means is composed of three series of designs as shown. This illustrates the fact that the type of design which will result in minimum weight depends upon the design altitude. The portion of this curve which uses designs similar to the Phase III submittal design does include the submittal design. It is assumed in this case that a scaled version of the ATR-2010 can be made available in the required time.

8.0 MODIFICATION OF SM-64A MISSILE

8.1 As a part of this study, the contractor was requested to calculate weight and performance characteristics of a SM-64A (NAVAHO) missile modified to contain a pilot. A summary of these calculations is shown in figure 19, page 44.

This modification is made in the following manner:

a) The SM-64A mold lines remain intact except for the addition of a pilot's canopy.

b) The SM-64A power plant and air induction system remain the same.

c) Space is allotted within the fuselage for the pilots compartment, eléctronic and reconnaissance equipment bays and landing gear wells. The remaining space is filled with fuel.

d) Additional engines for powered landings are not added as was the case in all other ramjet designs considered.

e) The same structural and design criteria as all other designs presented herein are used, (i.e. load factor, design dynamic pressure, Design Flight Hours, etc.) so that the structure is not the same as the SM-64A but does reflect the Contractor's practice for a piloted aircraft of this type.

The existing 1st stage booster is used to reach the maximum initial cruise altitude (53350 ft.) and velocity (Mach 3.25). The second stage vehicle then cruises for approximately 3830 nautical miles in 1.74 hours.

All the fuel, including the normal allowance for reserve, is consumed during this cruise period since auxiliary engines for subsonic cruise and landing are not added. Landing is necessarily with power off for this configuration.

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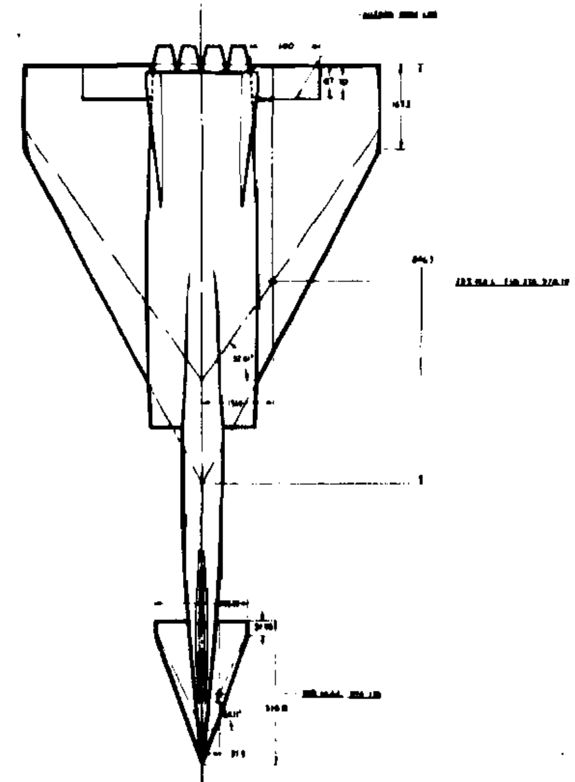
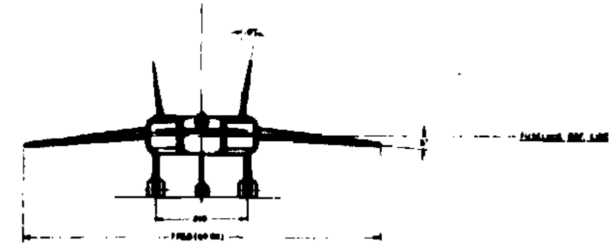




DIMENSIONAL DATA

WING	
AREA	2757 SQ. FT.
ASPECT RATIO	1.528
TAPER RATIO	0.2
SWEEPBACK (25% ELEMENT)	[illegible]°
AIRFOIL SECTION	NACA [illegible] (NAA MOD)
MAC LENGTH	[illegible] IN
AILERON AREA [illegible] SQ. FT. EACH	DEFLECTION [illegible]

CANARD SURFACE (EXPOSED)	
AREA	[illegible] SQ. FT.
ASPECT RATIO	1.147
TAPER RATIO	0.119
SWEEPBACK (25% ELEMENT)	65.0°?
AIRFOIL SECTION	NACA [illegible] (NAA MOD)
MAC LENGTH	211.8 IN

VERTICAL TAIL	
AREA	160 SQ. FT. EACH
ASPECT RATIO	[illegible]
TAPER RATIO	0.1
SWEEPBACK (25% ELEMENT)	[illegible]°
AIRFOIL SECTION	NACA [illegible] (NAA MOD)
MAC LENGTH	[illegible] IN
RUDDER AREA	[illegible] SQ. FT. EACH

GENERAL DATA

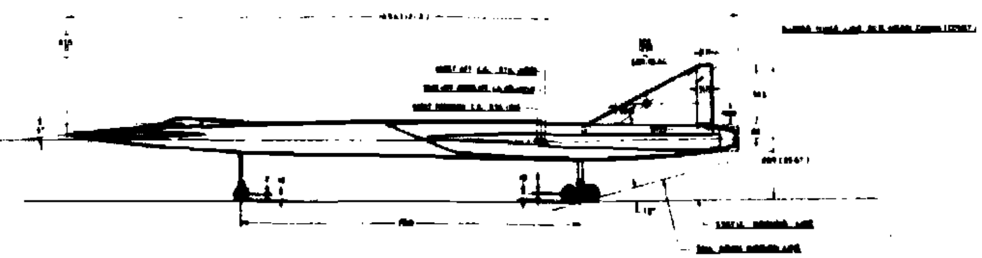
MAIN ALIGHTING GEAR
36 x 11 TYPE VII FOUR WHEEL BOGIE

AUXILIARY ALIGHTING GEAR
26 x 6.6 TYPE VII DUAL

ENGINE DESIGNATION
FOUR GE X275

TAKE-OFF GROSS WEIGHT — [illegible]
USEFUL LOAD (BASIC MISSION) — [illegible]

[redacted]



GENERAL ARRANGEMENT SYSTEM 110A PHASE 2

D266-1

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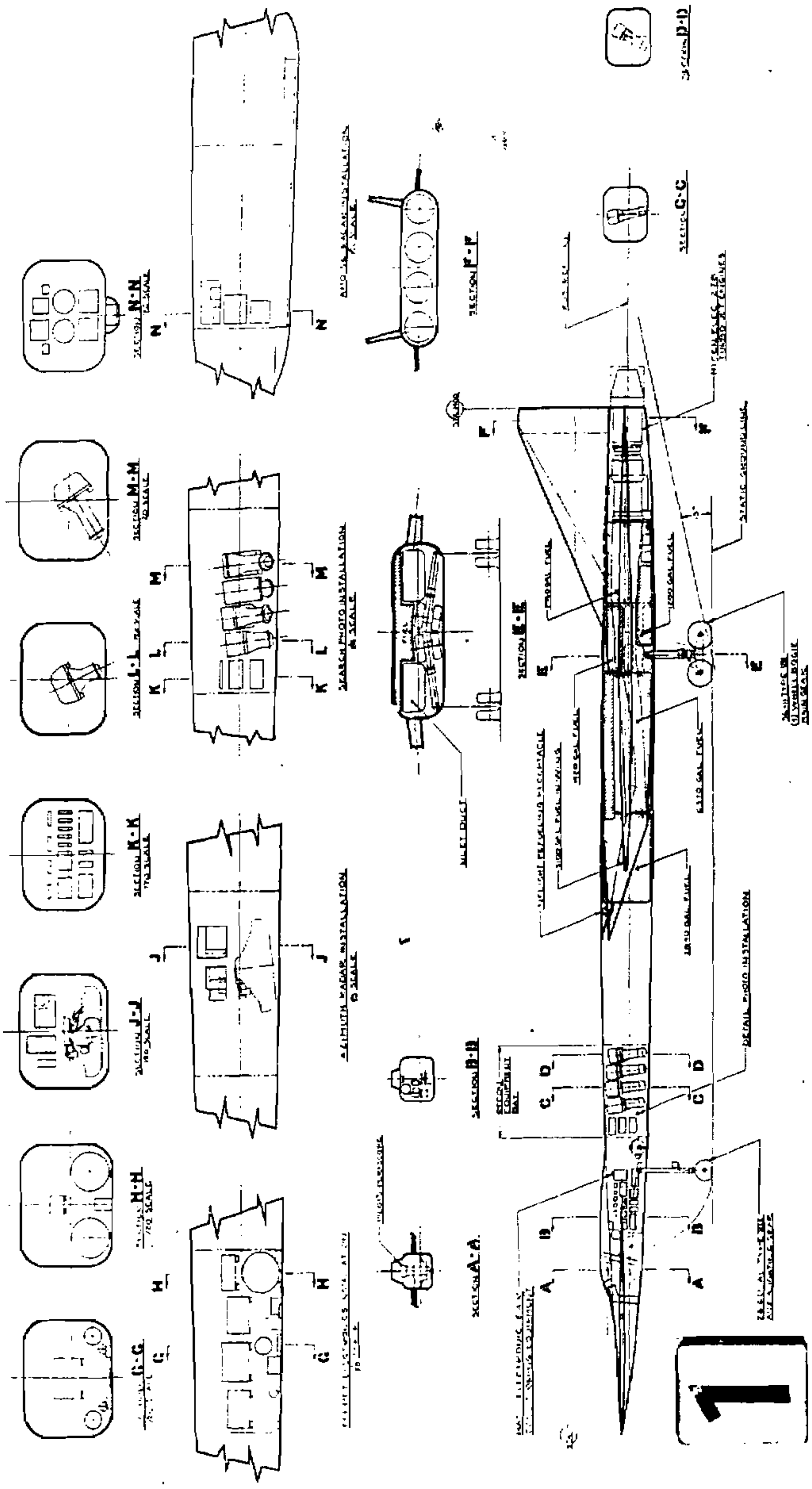

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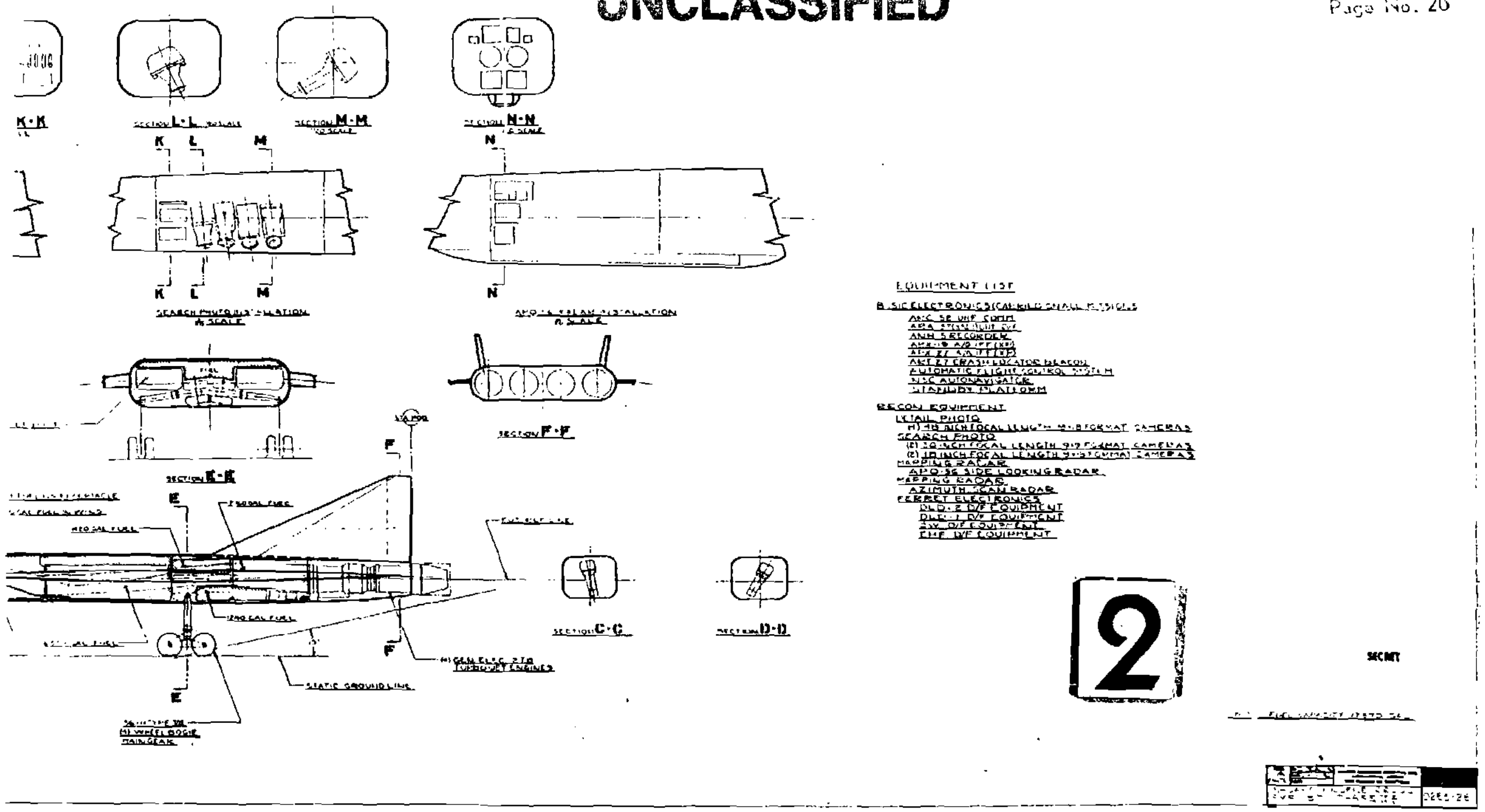

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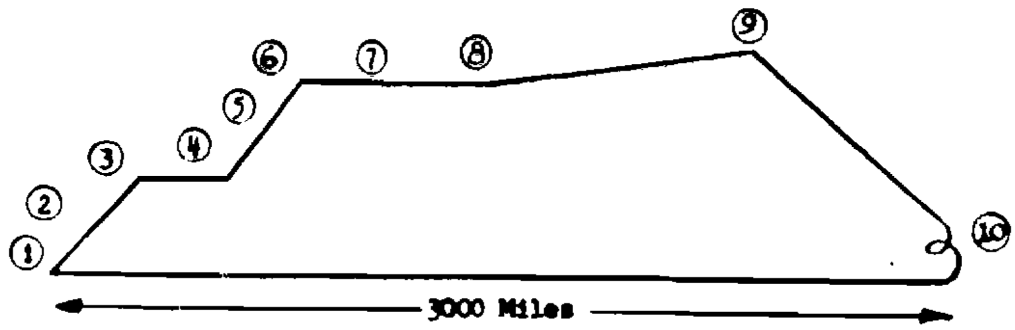
[redacted]

MISSION PROFILE



1. Fuel allowance to start engines, taxi, and take-off is five minutes of normal power.

2. Climb out to 27,000 feet using military power at 385 knots EAS ($q = 500$ psf) limit speed.

3. At 27,000 feet hold climb speed to 560 knots TAS and continue climb on military power to 36,089 feet.

4. Level off at 36,089 feet and accelerate to Mach 1.5 with maximum power.

5. Climb with maximum power from 36,089 feet and Mach 1.5 to 61,500 feet and Mach 3.2 without exceeding 665 knots EAS ($q = 1500$ psf) limit speed at any time.

6. At 61,500 feet limit speed to constant Mach 3.2 and continue climb to 75,000 feet.

7. Level off and cruise at 75,000 feet at Mach 3.2.

8. At point where best cruise altitude equals 75,000 feet, initiate cruise-climb at constant Mach 3.2 and continue cruise along best cruise altitude profile.

9. At descent point, retard throttle to idle and initiate optimum distance glide with gradual deceleration as allowed by altitude.

10. Fuel allowance at sea level landing point for reserve and landing is 10 percent of original fuel.

[redacted]

FIGURE 3

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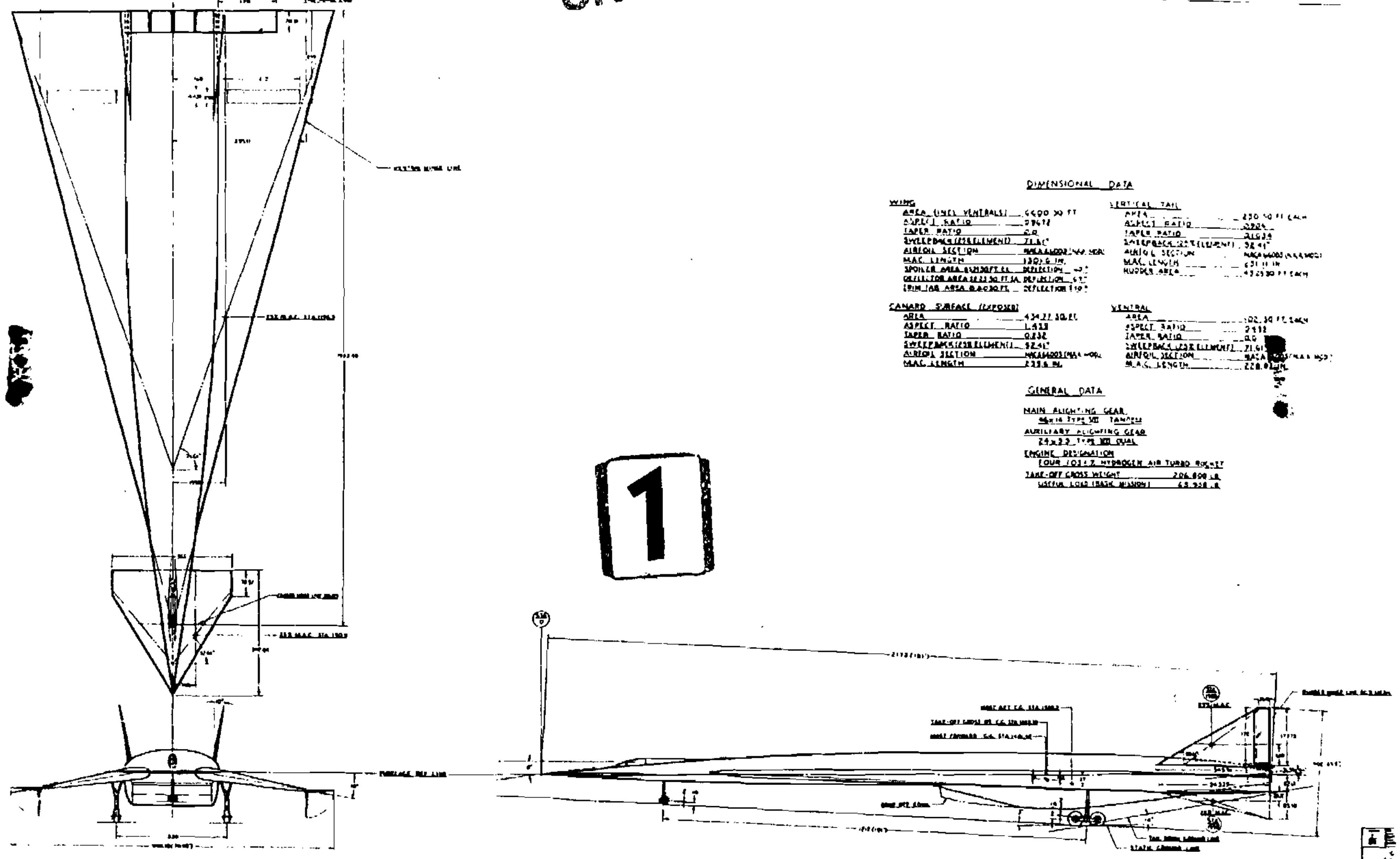

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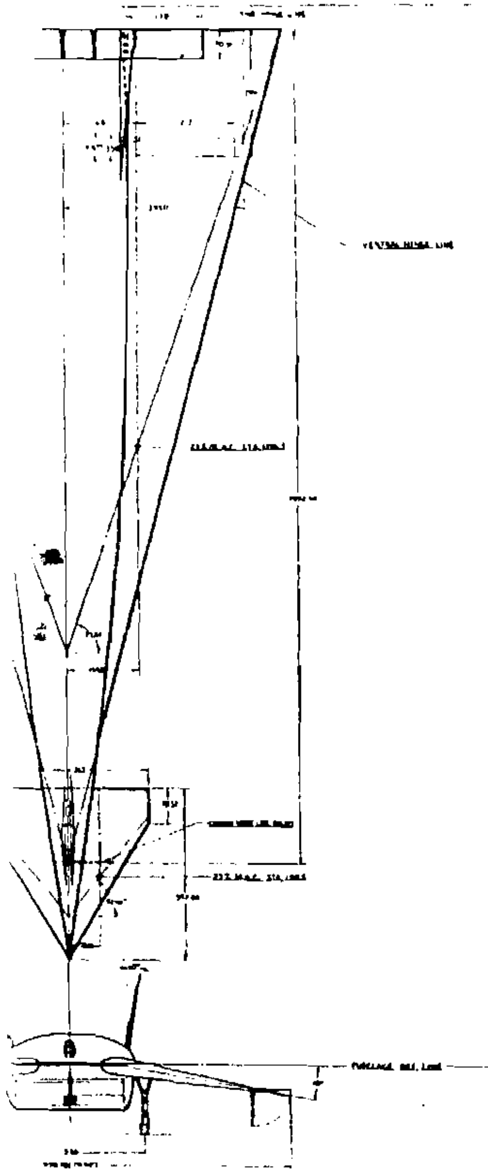
NA 56-5?? Fig. No. 4 Page No. 28



DIMENSIONAL DATA

WING
- AREA (INCL. VENTRALS) ____ 6600 SQ FT
- ASPECT RATIO ____ 0.9617
- TAPER RATIO ____ 0.0
- SWEEPBACK (25% ELEMENT) ____ 72.61°
- AIRFOIL SECTION ____ NACA 65003 (NAA MOD)
- MAC LENGTH ____ 1301.6 IN.
- SPOILER AREA [illegible] SQ FT EA. ____ DEFLECTION 10°
- DEFLECTOR AREA [illegible] SQ FT EA. ____ DEFLECTION 40°
- TRIM TAB AREA [illegible] SQ FT ____ DEFLECTION [illegible]

VERTICAL TAIL
- AREA ____ 170 SQ FT EACH
- ASPECT RATIO ____ 0.904
- TAPER RATIO ____ 0.1034
- SWEEPBACK (25% ELEMENT) ____ 76.41°
- AIRFOIL SECTION ____ NACA 66003 (NAA MOD)
- MAC LENGTH ____ 231.11 IN.
- RUDDER AREA ____ 43.39 SQ FT EACH

CANARD SURFACE (EXPOSED)
- AREA ____ 424.77 SQ FT
- ASPECT RATIO ____ 1.932
- TAPER RATIO ____ 0.232
- SWEEPBACK (25% ELEMENT) ____ 52.41°
- AIRFOIL SECTION ____ NACA 65003 (NAA MOD)
- MAC LENGTH ____ 235.6 IN.

VENTRAL
- AREA ____ 102 SQ FT EACH
- ASPECT RATIO ____ 0.992
- TAPER RATIO ____ 0.0
- SWEEPBACK (25% ELEMENT) ____ 71.61°
- AIRFOIL SECTION ____ NACA 65003 (NAA MOD)
- M.A.C. LENGTH ____ 228.81 IN.

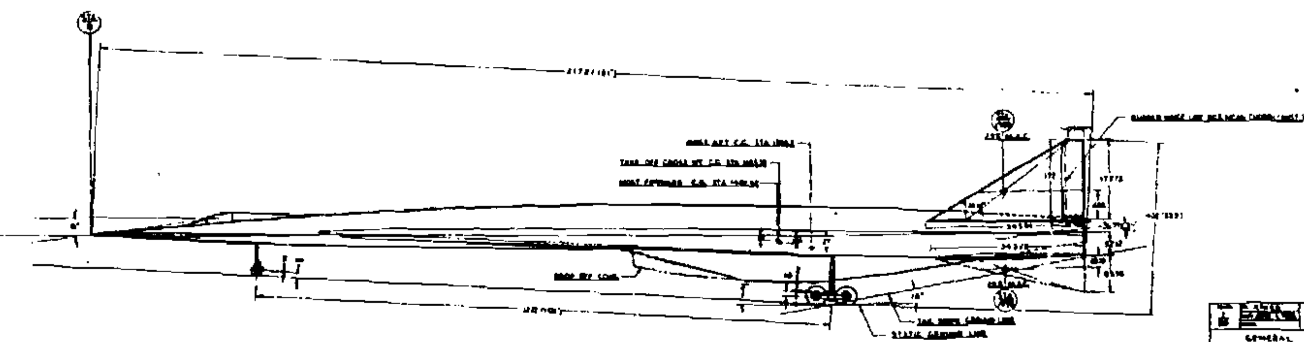
GENERAL DATA

MAIN ALIGHTING GEAR
44x16 TYPE VII TANDEM

AUXILIARY ALIGHTING GEAR
24x5.5 TYPE VII DUAL

ENGINE DESIGNATION
FOUR 10317 HYDROGEN AIR TURBO ROCKET

TAKE OFF GROSS WEIGHT ____ 206,800 LB
USEFUL LOAD (BASIC MISSION) ____ 65,950 LB



2

SECRET

GENERAL ARRANGEMENT SYSTEM 110P PHASE III

D265-2

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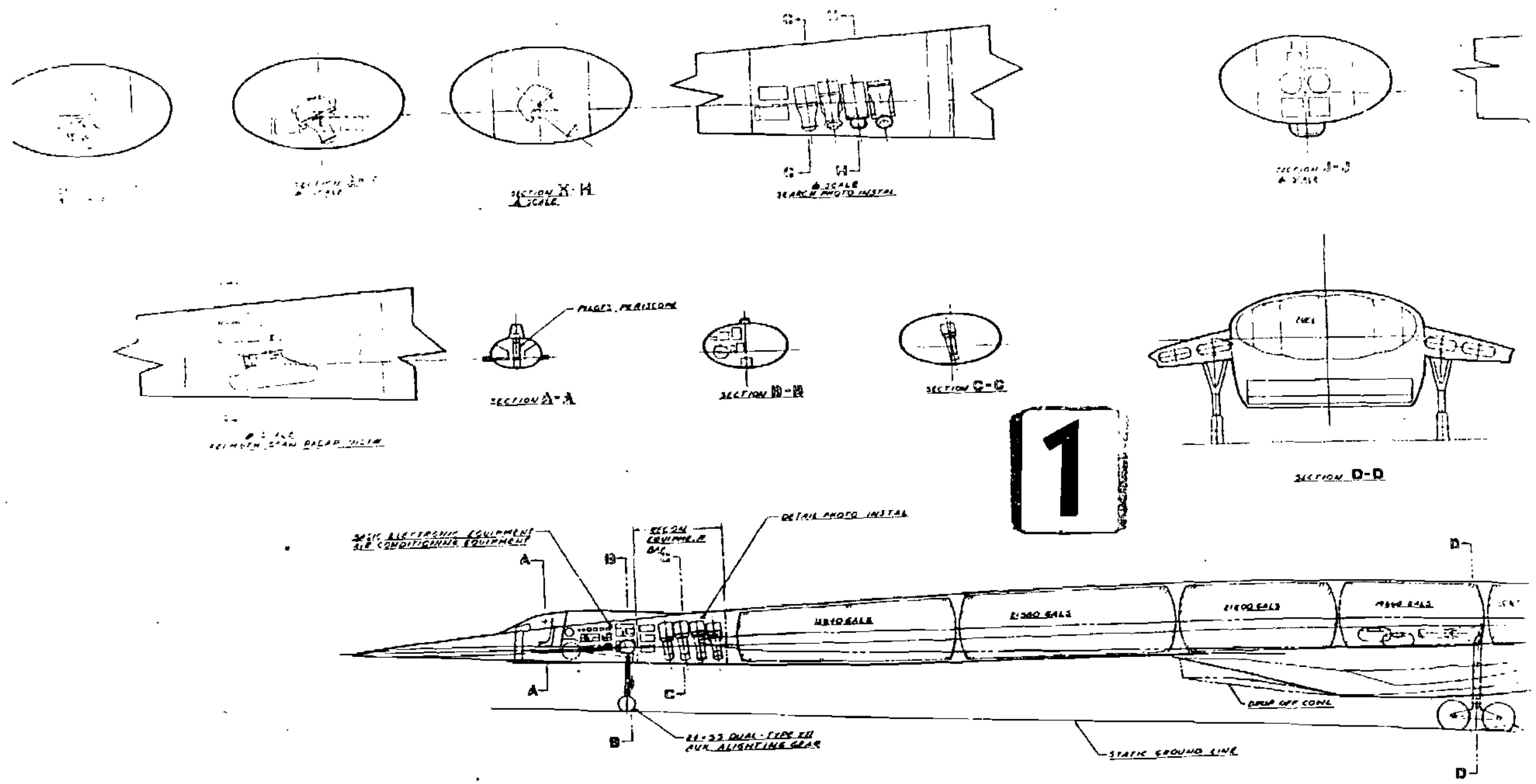

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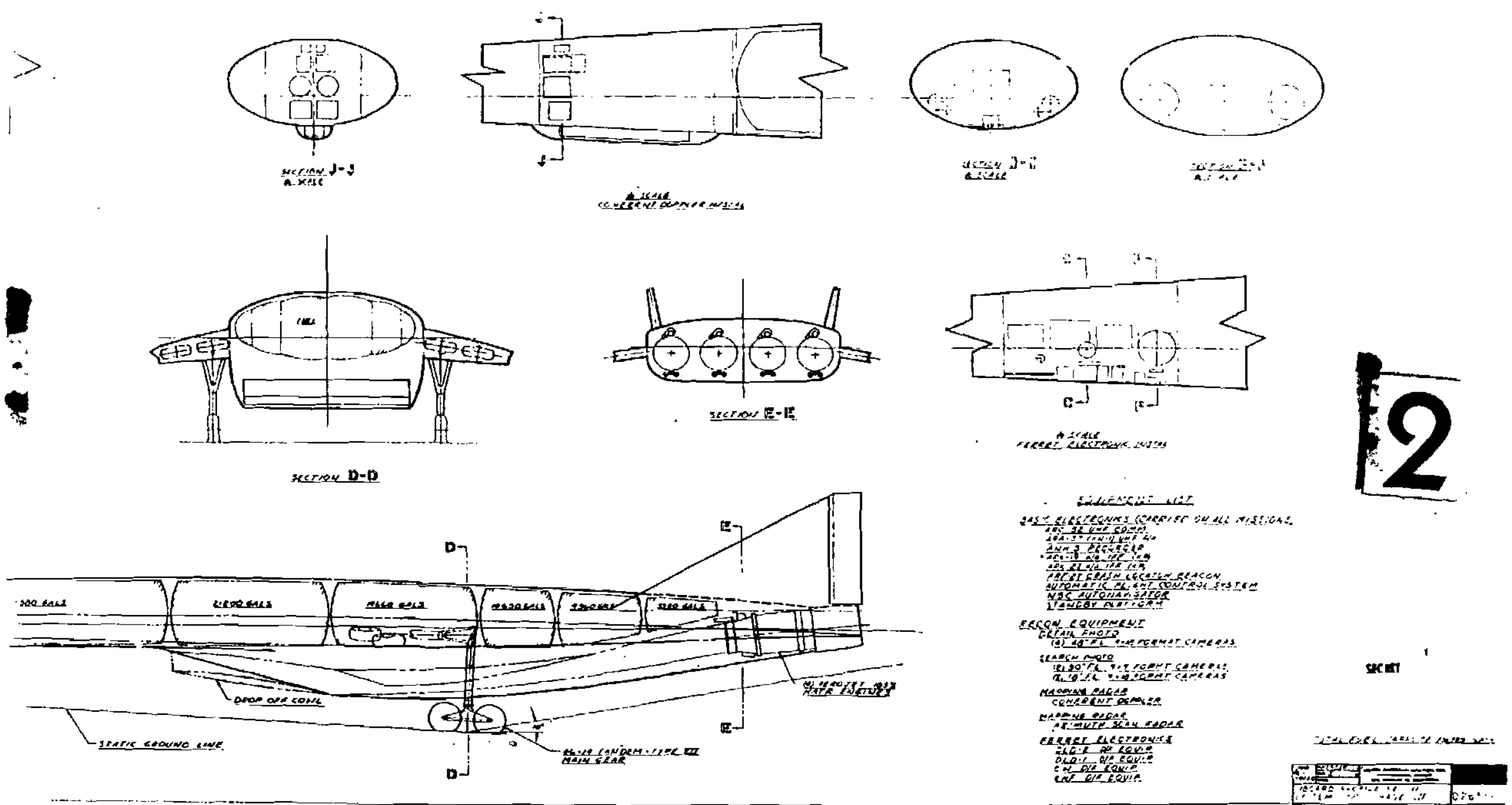
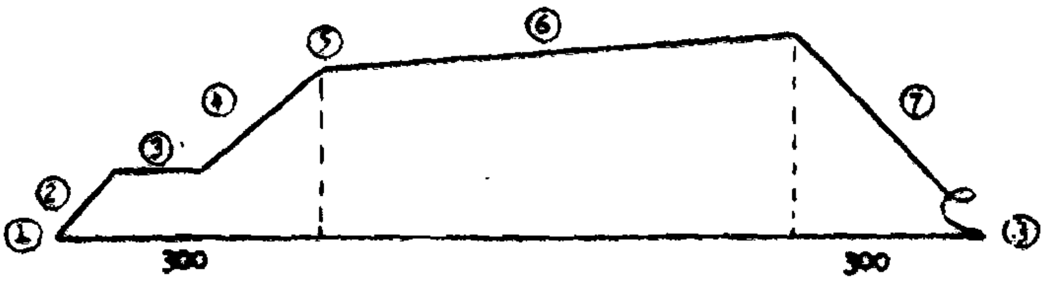

SECTION J-J
SECTION D-D
SECTION E-E
FERRET ELECTRONIC SYSTEM
EQUIPMENT LIST
RECON EQUIPMENT
DETAIL PHOTO
SEARCH PHOTO
MAPPING RADAR
COHERENT DOPPLER
AZIMUTH SCAN RADAR
FERRET ELECTRONICS
AUTOMATIC FLIGHT CONTROL SYSTEM
DROP OFF COWL
STATIC GROUND LINE
MAIN GEAR
SECRET

2

[redacted]

MISSION PROFILE



1. Fuel allowance to start engines, take-off, and accelerate to best subsonic climb speed is five minutes of normal static sea level thrust.

2. Climb on course at best subsonic climb speed to 36,089 feet.

3. Accelerate on course to Mach 2.1 at 36,089 feet with maximum power.

4. Climb and accelerate on course to Mach 4.0 and 88,500 feet with maximum power.

5. Climb on course with maximum thrust to 100,000 feet at Mach 4.0 within 300 nautical miles of take-off point.

6. Cruise on course with up to maximum thrust at Mach 4.0 at altitudes for best cruise, not less than 100,000 feet, to a point 2700 nautical miles from the take-off point.

7. Begin speed and altitude decrease at 2700-mile point, throttle engines back to idle setting, and continue on course to 3000-mile landing point.

8. Fuel allowance for reserve and landing is 10 percent of initial fuel.

Note: All fuel flows are increased 5 percent as a service tolerance.

[redacted]

FIGURE 6

PREPARED BY: H.R.B.	NORTH AMERICAN AVIATION, INC.	PAGE NO. 31
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DATE		MODEL NO. WS 118P

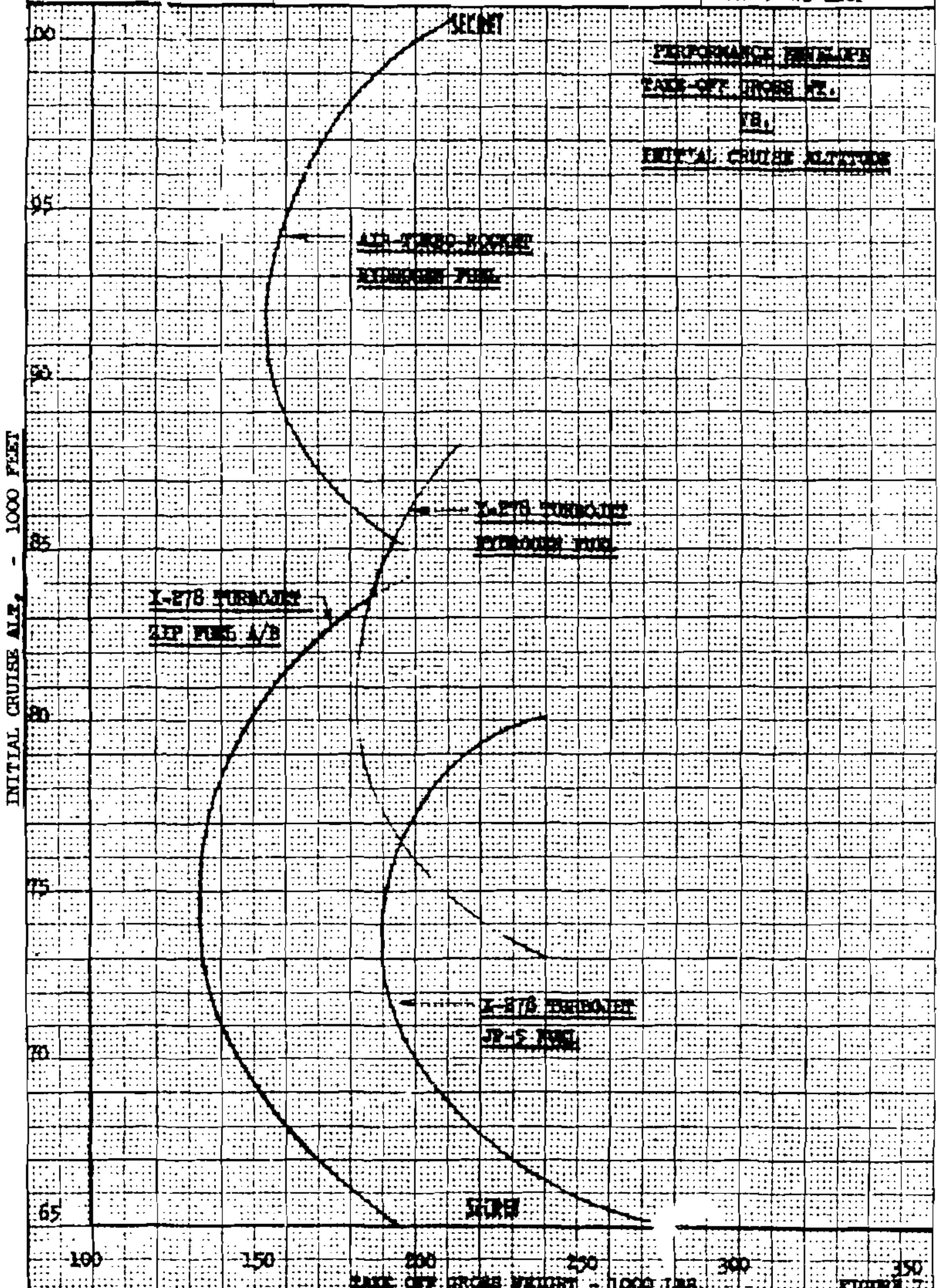

FIGURE 7

[redacted]

ENGINE FUEL COMPARISON

ENGINE & FUEL		ENGINE AVAILABILITY PHASE II 1/2	ENGINE AVAILABILITY PHASE III	DATA AVAILABILITY	ENGINE ALTITUDE LIMIT ABOVE MIN. CRUISE ALTITUDE PHASE II 1/2	ENGINE ALTITUDE LIMIT ABOVE MIN. CRUISE ALTITUDE PHASE III
JT9A-20	JP	Yes	Yes	Yes	Yes	No
J89 (700-B3)	JP	Yes	Yes	Yes	Yes	No
J79-X278	JP	Yes	Yes	Yes	Yes	No
J79-X278	ZIP (A/B only)	No	Yes	Yes	Yes	No
J79-X278	H_2	Yes	Yes	Yes	Yes	No
TJ32C5	JP	Yes	Yes	Yes	Yes	No
TJ32C17	JP	Yes	Yes	Yes	Yes	No
J-85	JP	Yes	Yes	Yes	No	No
J-85	H_2	Yes	Yes	Yes	Yes	No
PDA2-2	JP	Yes	Yes	Yes	No	No
X84-C	JP	No	No	Yes	No	No
SJ110-B3	JP	Yes	Yes	Yes	Yes	No
WTF7	JP	No	Yes	Yes	No	No
WTF8	JP	No	Yes	Yes	Yes	No
1965 Mach 3.2	JP	No	Yes	Yes	Yes	No
J54-WE	JP	Yes	Yes	Yes	Yes	No
ATR 1010	JP + NO	No	Yes	Yes	Yes	Yes
ATR 2040	H_2	No	Yes	Yes	Yes	Yes
ATR 3010	Acetylenic	No	Yes	Yes	Yes	Yes
Rex III	H_2	No	Yes	No	- -	- -
RJ43	JP	Yes	Yes	Yes	No	No
XRJ59-MA-1	JP	Yes	Yes	Yes	Yes	No
XRJ47-W-7	JP	Yes	Yes	Yes	Yes	No
1960 Study Ramjet	JP	Yes	Yes	Yes	Yes	No
1960 Study Ramjet	ZIP	No	Yes	Yes	Yes	No
1960 Study Ramjet	H_2	Yes	Yes	Yes	Yes	No
1965 Study Ramjet	H_2	No	Yes	Yes	No	Yes
1965 Study Ramjet	ZIP	No	Yes	Yes	No	Yes
1965 Study Ramjet	JP	No	Yes	Yes	No	Yes
1965 Advanced Study Ramjet	JP	No	Yes	Yes	No	Yes
1965 Advanced Study Ramjet	ZIP	No	Yes	Yes	No	Yes

FIGURE 8

NORTH AMERICAN AVIATION, INC.
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[redacted]

ENGINE-FUEL COMPARISON

ENGINE & FUEL		ENGINE AVAILABILITY PHASE II 1/2	ENGINE AVAILABILITY PHASE III	DATA AVAILABILITY	ENGINE ALTITUDE LIMIT ABOVE MIN. CRUISE ALTITUDE PHASE II 1/2	ENGINE ALTITUDE LIMIT ABOVE MIN. CRUISE ALTITUDE PHASE III
1965 Advanced Study Ramjet	H_2	No	Yes	Yes	No	Yes
PR20-108-66	JP	Yes	Yes	Yes	No	No
XLR-73-AJ-1	WFNA + JP	Yes	Yes	Yes	Yes	Yes
Study Rocket	LOX + JP	No	Yes	Yes	Yes	Yes
Study Rocket	LOX + Hyd.	No	Yes	Yes	Yes	Yes
Study Rocket	$F_2 + NH_3$	No	Yes	Yes	Yes	Yes

[redacted]

ENGINE-FUEL COMPARISON

ENGINE & FUEL		S.F.C. AT M_{LIMIT}	T/W	M_{LIMIT}
J79A-20	JP	2.69	1.269	3.0
J89 (700-B3)	JP	2.87	1.418	3.0
J79-X278	JP	2.52	1.465	3.2
J79-X278	H_2*	.905	1.68	3.2
TJ32C5	JP	4.15	1.03	3.0
TJ32C17	JP	3.02	1.890	3.7
J-85	H_2*			2.0
SJ110-B3	JP	2.82	1.20	2.0
J54-WE	JP	2,8	1.09	3.0
AMR-1010	JP + BO	5.29	4.08	4.0
[redacted] 2040	H_2*	1.066	2.147	4.0
[redacted] 3010	Acetvlenic	3.38	2.14	4.0
[redacted]59-MA-1	JP	3.5	2.15	3.5
XRJ47-W-7	JP	*2.38	3.81	3.25
1960 Study Ramjet	JP	2.675	6.7	3.2
1960 Study Ramjet	ZIP	2.14	8.9	3.2
1960 Study Ramjet	H_2*	0.95	8.9	3.2
1965 Study Ramjet	H_2*	0.97	1.635	4.0
1965 Study Ramjet	ZIP	2.60	1.832	4.0
1965 Study Ramjet	JP	2.635	1.635	4.0
1965 Advanced Study Ramjet	JP	2.42	1.667	4.0
1965 Advanced Study Ramjet	ZIP	1.553	3.33	4.0
1965 Advanced Study Ramjet	H_2*	.868	1.667	4.0
XLR-73-AJ-1	WFNA + JP	14.05	37.6	No Limit
Study Rocket	LOX + JP	12.59	68.5	No Limit
** Study Rocket	LOX + Hyd.	11.40	74.7	No Limit
** Study Rocket	F_2 + NH_3	11.38	78.2	No Limit

NOTE: * On the basis of the information presented here, hydrogen fuels would appear to be the best in all cases. However, due to its large specific volume there are drag and weight penalties involved in the use of a hydrogen fueled engine. Therefore, no conclusion can be reached as to the relative merits of hydrogen fuel without incorporating this type of engine into a complete airplane design.

** The characteristics of these two study rocket motors are so similar that only one, the LOX plus Hydrazine fueled one, need be further compared with other Phase III engine types.

FIGURE 2

ENGINE-FUEL COMPARISON
PHASE II 1/2 SINGLE STAGE

Engine Designation		X278		J89	TJ32C17	X278	J85
Fuel Type		LBS8		LBS8	LBS8	H_2	H_2
Take-off Gross Weight	Lbs.	207800	[illegible]	207800	207800	207800	207800
Cruise Condition: Initial Altitude	Ft.	75000	75000	75000	75000	75000	75000
Mach Number		3.2	3.0	3.0	3.7	3.2	.8
Lift - Drag Ratio		6.45	6.55	6.55	5.50	4.53	18.0
Specific Fuel Consumption	Per Hr.	2.52	2.69	2.87	3.02	.905	.468
Total Range	N.Mi.	3020	2536	2452	2600	2849	2940
Weight Summary: Structure	Lbs.	38006	39481	39481	37000	64300	99890
Power Plant	Lbs.	[illegible]3288	37655	33705	35685	50925	37400
Fixed Equipment	Lbs.	1[illegible]178	12029	12029	12428	12178	12200
Fuel System	Lbs.	3929	3750	3870	3880	15667	12700
Fuel	Lbs.	120399	114886	118716	118807	64730	45610
Fuel Used: 5 Min. SLS Normal Power	Lbs.	5840	5090	4010	2820	3120	7440
Achieve Cruise Speed and Altitude	Lbs.	28580	29050	31870	31450	10250	3610
Cruise	Lbs.	72847	68116	69744	71275	44495	26279
Glide at Idle Power	Lbs.	1092	1140	1220	1381	392	3720
Reserve	Lbs.	12040	11489	11872	11881	6473	4561
Distance Gained: Achieve Cruise Speed & Altitude	N.Mi.	254	248	248	300	254	158
Cruise	N.Mi.	2566	2092	2008	2055	2395	2530
Glide at Idle Power	N. Mi.	200	196	196	245	200	258

FIGURE 10

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FORM 10-6-1 REV. 8-47

ENGINE - FUEL COMPARISON
PHASE II 1/2 TWO-STAGE

Engine Designation			RJ47 ◄	—1960 Study Ramjets	— ►	XLR-73
Fuel Type			LBSS	LBSS	H_2	LOX Plus
Take-off Gross Weight		Lbs.	207,800	207,800	207,800	207,800
Second Stage Gross Weight		Lbs.	116,000	116,000	116,000	116,000
Booster Gross Weight		Lbs.	91,800	91,800	91,800	91,800
Cruise Condition:	Initial Altitude	Ft.	75,000	75,000	75,000	75,000
	Mach Number		3.25	3.2	3.2	3.2 - 8.6
	Lift - Drag Ratio		5.96	5.96	4.18	6.0
	Specific Fuel Consumption	Per Hr.	2.38	2.42	.970	14.05
Total Range		N.Mi.	2,785	2,485	2,745	880
Weight Summary: (Second Stage Only)	Structure	Lbs.	21,170	21,320	28,500	21,320
	Power Plant	Lbs.	14,850	17,620	20,530	8,330
	Fixed Equipment	Lbs.	10,678	10,678	10,678	10,678
	Fuel System	Lbs.	1,428	1,335	6,240	1,630
	Fuel	Lbs.	43,674	40,847	25,852	49,842
Fuel Used: (Second Stage Only)	5 min. S.L. Normal Power Achieve	Lbs.	- -	- -	- -	- -
	Cruise Speed and Altitude	Lbs.	- -	- -	- -	- -
	Cruise	Lbs.	39,307	36,762	23,267	44,858
	Glide at Idle Power	Lbs.	- -	- -	- -	- -
	Reserve	Lbs.	4,367	4,085	2,585	4,984
Distance Gained:	Achieve Cruise Speed & Altitude	N. Mi.	30	30	30	
	Cruise	N. Mi.	2625	2325	2585	30
	Glide at Idle Power	N. Mi.	130	130	130	820

FIGURE 11

NORTH AMERICAN AVIATION, INC.
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[redacted]

ENGINE-FUEL COMPARISON PHASE III SINGLE STAGE

Engine Designation			ATR1010	ATR2010	ATR3010
Fuel Type		Lbs.	LRBS	H_2	-Acetylamie
Take-Off Gross Weight		Lbs.	206,800	206,800	206,800
Cruise Condition:	Initial Altitude	Ft.	100,000	100,000	100,000
	Mach Number		4.0	4.0	4.0
	Lift - Drag Ratio		6.20	5.95	6.10
	Specific Fuel Consumption	Per Hr.	3.54	.852	2.655
Total Range		N. Mi.	468	3001	480
Weight Summary:	Structure	Lbs.	59980	70866	59980
	Power Plant	Lbs.	31860	45385	39730
	Fixed Equipment	Lbs.	19115	19115	19115
	Fuel System	Lbs.	3030	12755	2780
	Fuel	Lbs.	98815	59879	85195
Fu[redacted] Used:	5 Min. S.L.S. Normal Power	Lbs.	17820	4700	13090
	Achieve Cruise Speed & Altitude	Lbs.	69300	20700	55500
	Cruise	Lbs.	0	26400	3245
	Glide at Idle Power	Lbs.	6095	1551	4840
	Reserve	Lbs.	0	5928	8520
Distance Gained:	Achieve Cruise Speed & Altitude	N. Mi.	168	168	168
	Cruise	N. Mi.	0	2533	12
	Glide at Idle Power	N. Mi.	300	300	300

[redacted]

FIGURE 12

FORM 10-G-1 REV. 5-47

ENGINE FUEL COMPARISON PHASE III TWO STAGE

Engine Designation			Study RJ	Study RJ	Study RJ	Study Rocket
Fuel Type			LBSS	ZIP	H_2	Lox & Hydrazine
Take-off Gross Weight		Lbs.	206800	206800	206800	206800
Second Stage Gross Weight		Lbs.	127600	127600	127600	127600
Booster Gross Weight		Lbs.	79200	79200	79200	79200
Cruise Condition:	Initial Altitude	Ft.	100000	100000	100000	100000
	Mach Number		4.0	4.0	4.0	4.0 - 9.1
	Lift - Drag Ratio		6.10	6.10	5.95	6.10
	Specific Fuel Consumption	Per Hr.	3.150	2.32	1.130	11.40
Total Range		N. Mi.	1225	1565	2455	1110
Weight Summary: (Second Stage Only)	Structure	Lbs.	23020	23020	26950	23020
	Power Plant	Lbs.	22705	22795	21835	5230
	Fixed Equipment	Lbs.	15685	15685	15685	15685
	Fuel System	Lbs.	572	560	2610	1115
	Fuel	Lbs.	17228	17140	12120	34150
Fuel Used: (Second Stage Only)	5 Min. S.L.S. Normal Power		- -	- -	- -	- -
	Achieve Cruise Speed & Altitude	Lbs.	- -	- -	- -	- -
	Cruise	Lbs.	15505	15426	10908	30735
	Glide at Idle Power	Lbs.	- -	- -	- -	- -
	Reserve	Lbs.	1723	1714	1212	3415
Distance Gained:	Achieve Cruise Speed & Altitude	N. Mi.	45	45	45	45
	Cruise	N. Mi.	970	1310	1800	45
	Glide at Idle Power	N. Mi.	210	210	210	1020

FIGURE 13

[redacted] WEIGHT TRADE

GROSS WEIGHT INCREASE VS. ALTERNATE EQUIPMENT CONFIGURATIONS

FOR PHASE II 1/2 SUBMITTAL AIRPLANE

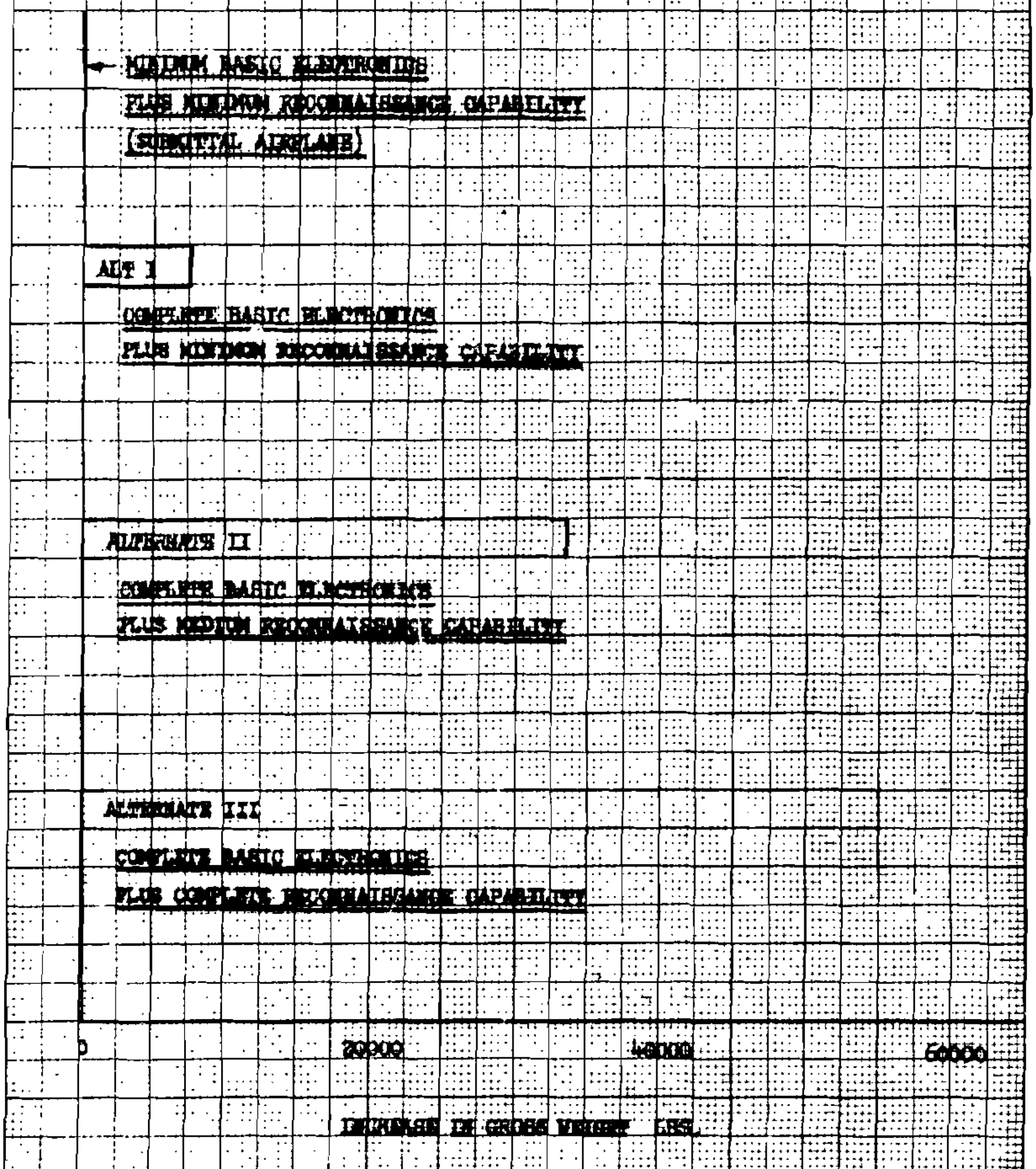


FIGURE 14

[redacted]

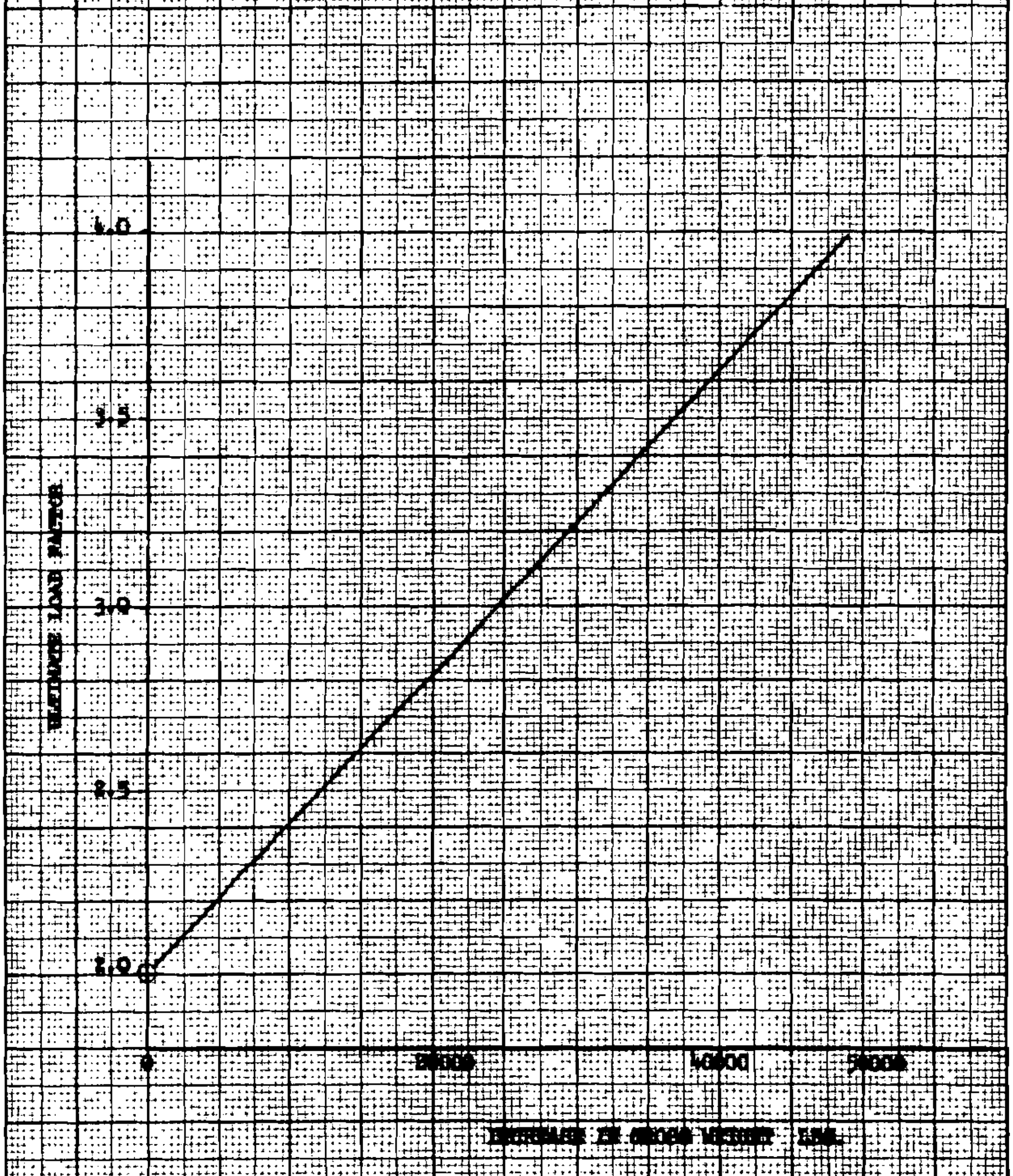
[redacted]

[redacted]

GROSS WEIGHT TRADE

GROSS WEIGHT INCREASE VS. ULT. LOAD FACTOR

FOR PHASE II 1/2 [illegible] AIRPLANE



[redacted]

FIGURE 33

FORM EJ 147

PREPARED BY H.R.B.	NORTH AMERICAN AVIATION, INC.	PAGE NO. 41 OF
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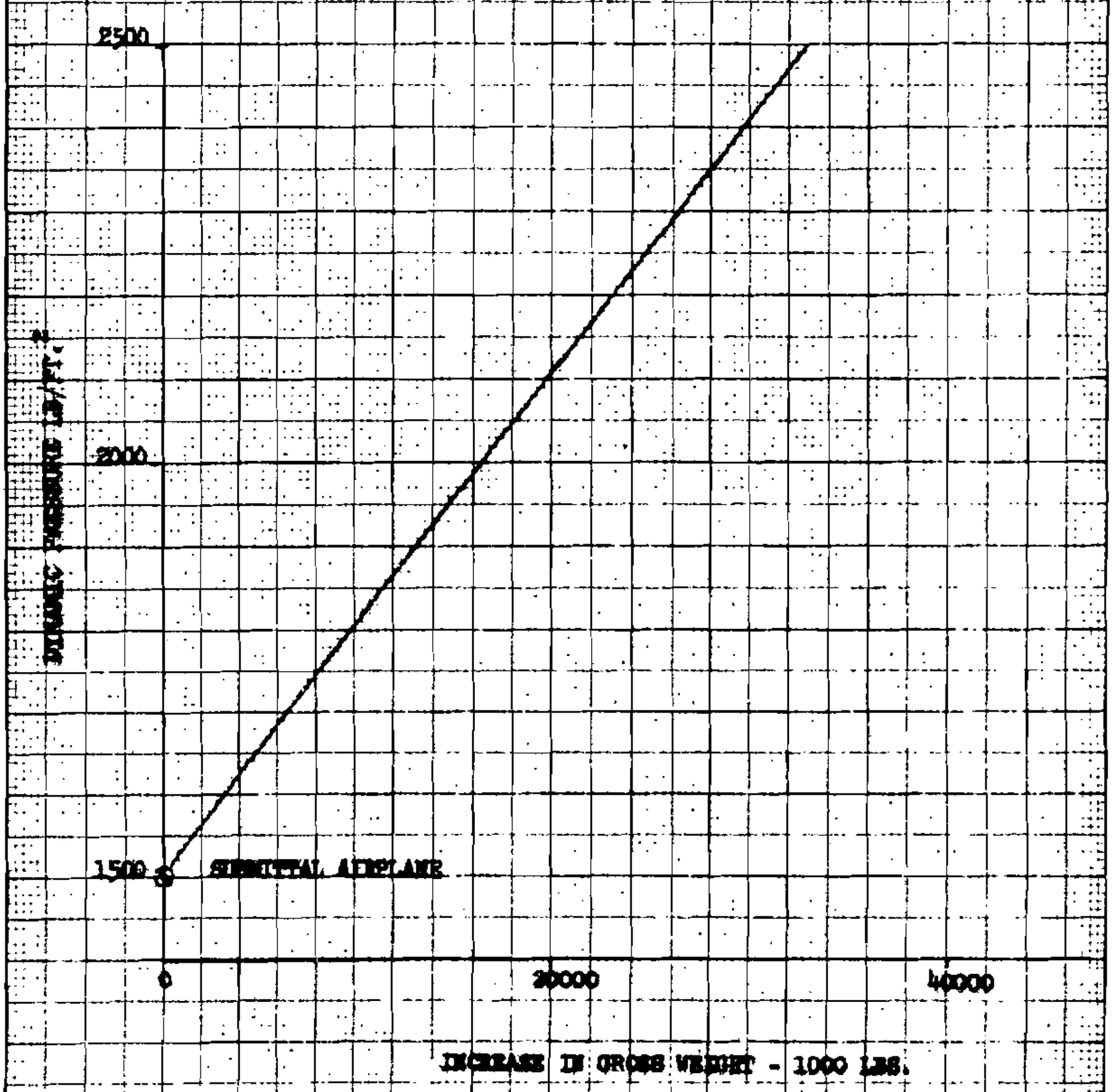
[redacted]

GROSS [redacted]HT TRADE

GROSS WEIGHT INCREASE VS. DYNAMIC PRESSURE

FOR PHASE II 1/B SUBMITTAL AIRPLANE



[redacted]

FIGURE 16

PREPARED BY H.R.B.	NORTH AMERICAN AVIATION, INC.	PAGE 42
CHECKED BY		REPORT NO. NA56-521
DATE		MODEL NO. WS 118P

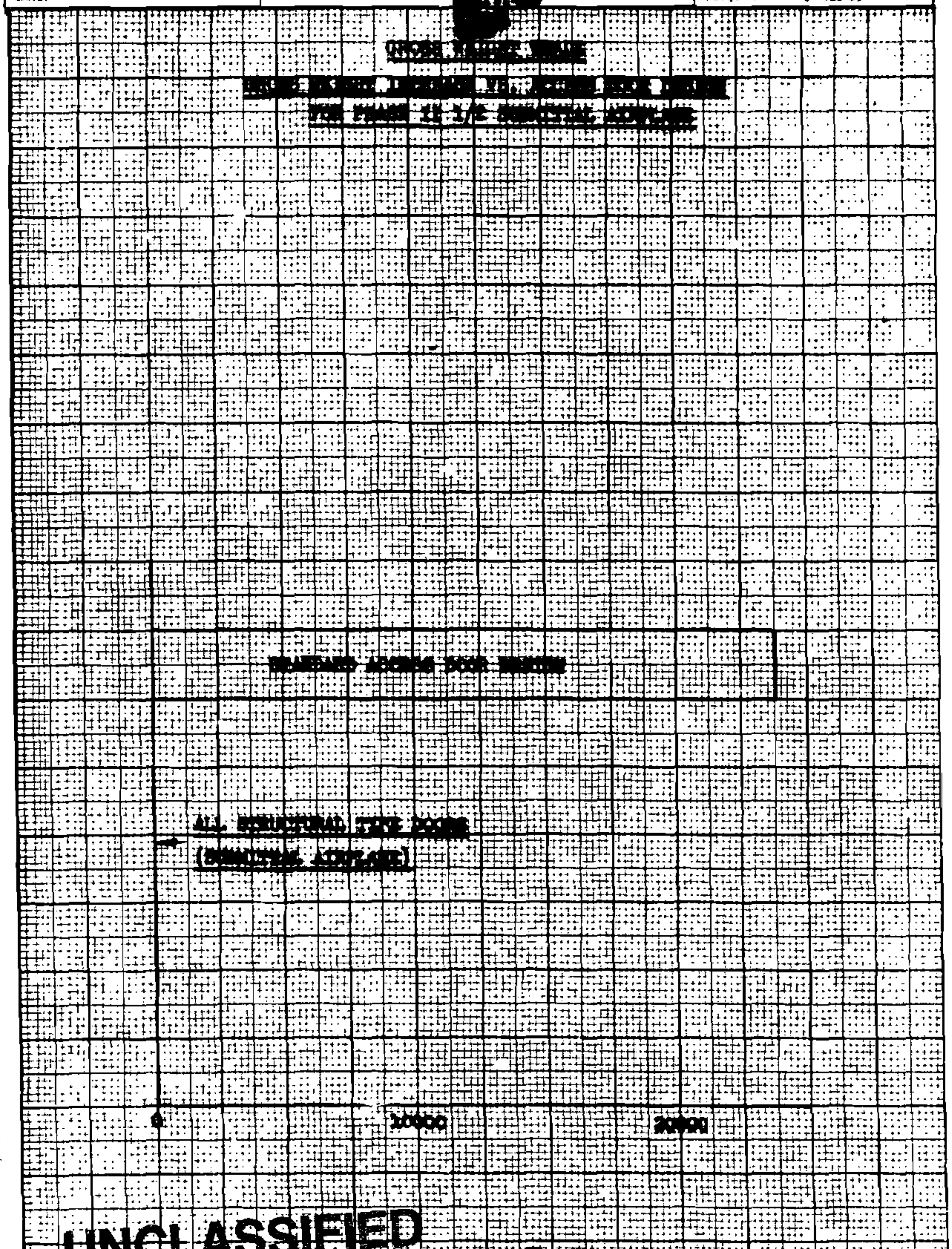


FIGURE IV

GROSS WEIGHT TRADE CURVE-GROSS WEIGHT INCREASE VS. DESIGN FLIGHT HOURS FOR PHASE II 1/2 SUBMITTAL AIRPLANE

NOTE: Design life based on 50-50 probabilit. of gust loads exceeding limit load factor

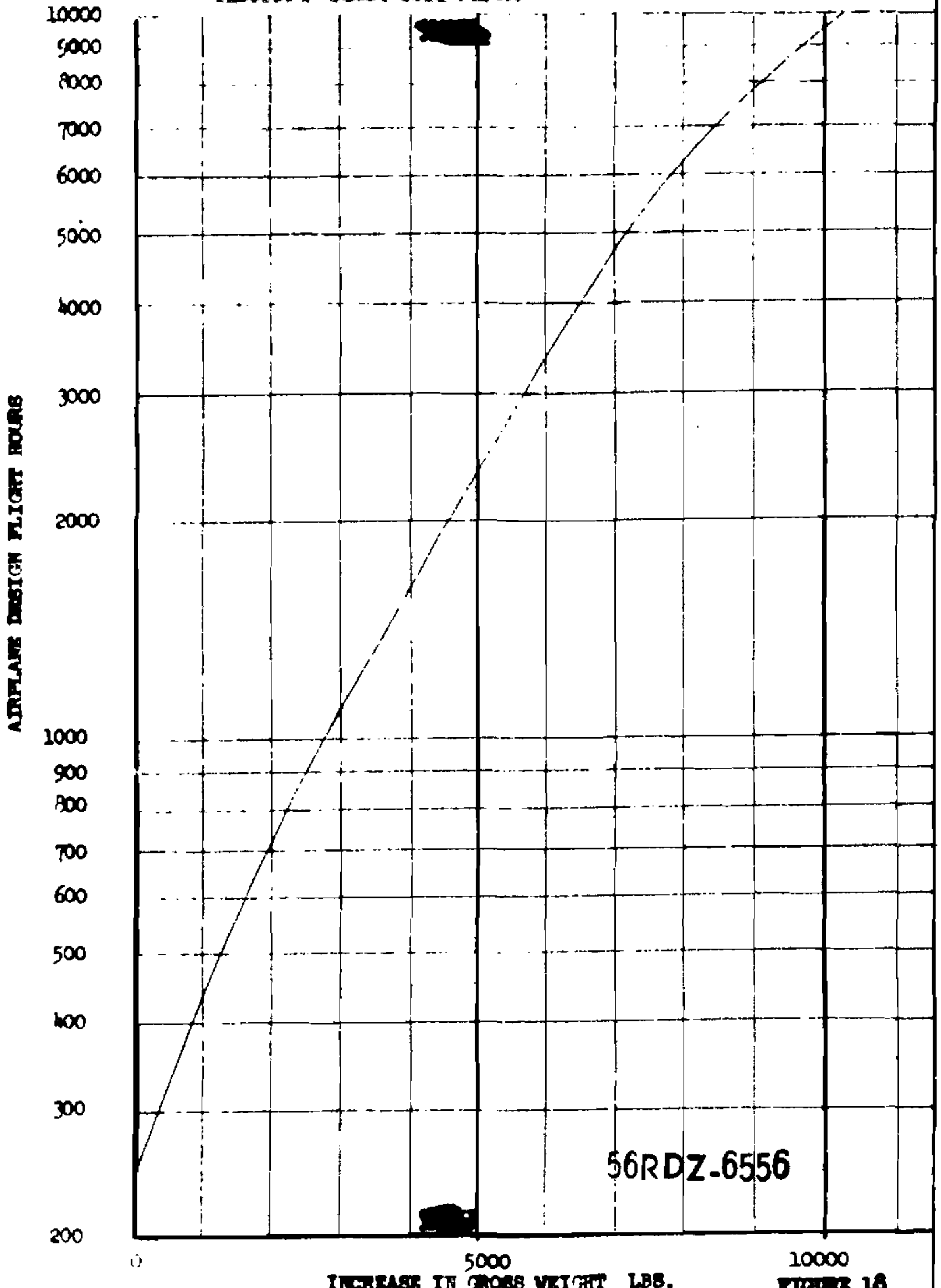


FIGURE 18

[redacted]

DESIGN BRIEF

MODIFIED USM-64A

Take-off Gross Weight - Lbs.	300,152
Booster Stage Weight - Lbs.	169,200
Second Stage Weight - Lbs.	130,452
Booster Stage Fuel Weight - Lbs. (LOX + JP5)	156,700
Second Stage Fuel Weight - Lbs. (JP5)	84,370
Initial Cruise Altitude - Ft.	53,350
Cruise Velocity - Mach No.	3.25
* Range - Nautical Miles	3,950
Final Cruise Altitude - Ft.	71,800
Second Stage Propulsion	(2) XRJ47-W-7 Ramjet Engines
Wing Area - Sq.Ft.	761
Wing Span - Ft.	42.75
Fuselage Length - Ft.	87.3

* Includes:
(1) 30 N. Mi. for initial launch.
(2) 90 N. Mi. glide after cruise.
(3) Range at 100% fuel used

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[redacted]

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