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LIFT CRUISE FAN V/STOL AIRCRAFT
CONCEPTUAL DESIGN STUDY
T-39 MODIFICATION
VOLUME I TECHNICAL REPORT

By Donald W. Elliott, et al.

November 1976

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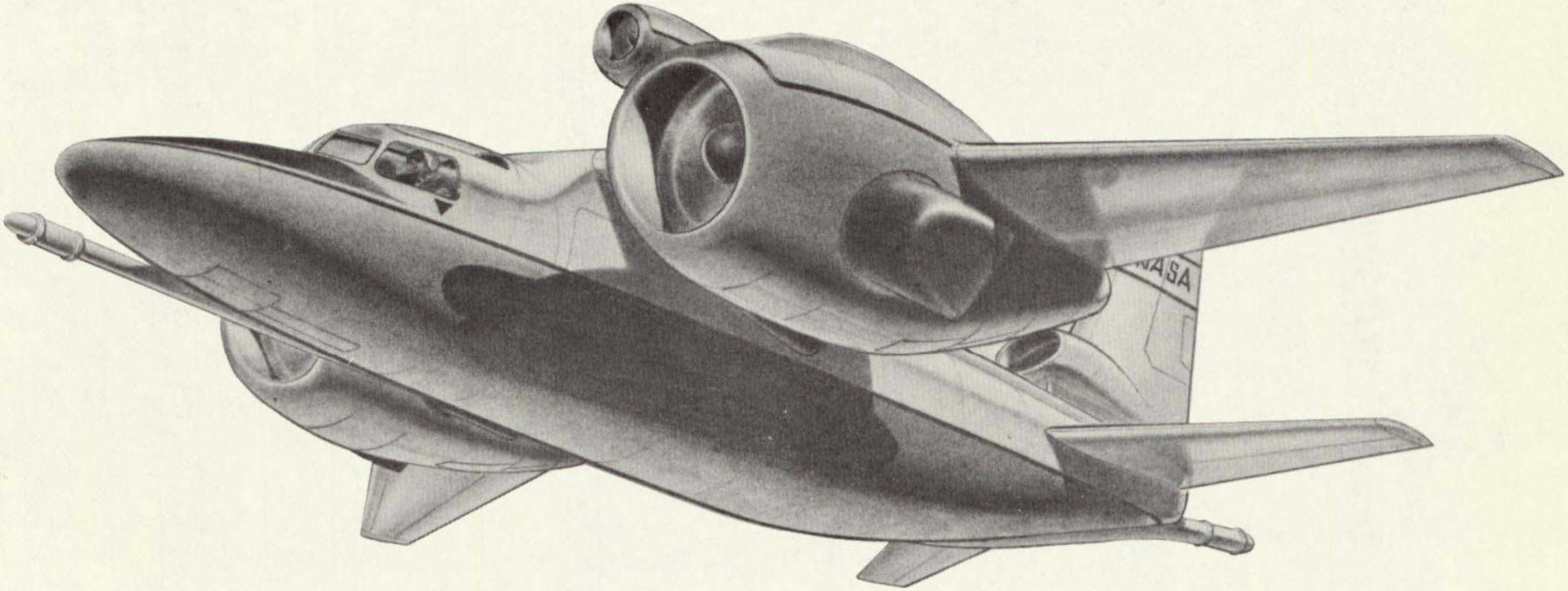
for

AMES RESEARCH CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



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Volume I

SUMMARY

This report contains the results of a study conducted by the Columbus Aircraft Division of Rockwell International which investigated the conversion of two T-39 aircraft into lift cruise fan research and technology vehicles. The concept is based upon modifying the T-39A (NA265-40) Sabreliner airframe into a V/STOL configuration by incorporating two LCF-459 lift cruise fans and three YJ-97 gas generators. The propulsion concept provides the thrust for horizontal flight or lift for vertical flight by deflection of bifurcated nozzles while maintaining engine out safety throughout the flight envelope. The configuration meets all the study requirements specified for the design with control powers in VTOL and conversion in excess of the requirement making it an excellent vehicle for research and development.

The aircraft retains the basic flying surfaces and fuselage of the T-39A, with the wing repositioned to the top of the fuselage. In cruise flight, control is obtained by use of the existing ailerons, elevator and rudder. Vertical flight, pitch control is obtained by using a reaction control pitch pipe driven by a third engine under normal conditions or by a portion of the remaining gas generators during engine-out. Directional control is obtained by differentially deflecting vanes in each nozzle; and roll control is obtained by increasing the speed of one fan and spoiling lift in the other fan. A hydraulically operated triply redundant fly-by-wire system is connected to the existing conventional flight control system for use in the vertical mode.

The propulsion transmission system consists of ducting, valves and expansion devices that connect the gas generators to the fans and interconnect the gas generators to provide engine out capability and roll control. Valves in the system provide roll control and engine isolation for starting and in the event of an engine failure. To minimize cost, the ducting was made as short as possible with a uniform size of 16.8 inches inside diameter covered with 0.25 inches of insulation. Forced cooling and purging are provided in the fuselage compartment and nacelles. All valves are identical with activating mechanisms tailored for each specific use.

This study relects a conceptual effort, both as to airplane characteristics and the program tasks/cost data presented. Accordingly, such information is subject to refinement and iteration in subsequent proposal and program phases, consistent with a proof of concept technology effort utilizing goals in lieu of operational requirements.

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LIST OF SYMBOLS

AC	Alternating Current
a	vertical acceleration (ie $^a/_g$)
AFCAS	Advanced Flight Control Actuation System
ATS	Air Turbine Starter
ADF	Airbourne Direction Finder
AMPR	Aircraft Manufacturers Planning Report
BCA	Best Cruise Altitude
$\overline{c}$	mean aerodynamic chord (also MAC)
C_D	Drag Coefficient ($^D/qS$)
C_{D_O}	Drag Coefficient at zero lift
CFE	Commercially Furnished Equipment
$C_{f_{eff}}$	Skin friction coefficient (total a/c + interference allowance)
c.g.	Center-of-gravity
C_L	Lift Coefficient ($^L/qS$)
℄	Centerline
C_{η_β}	Yawing Moment Coefficient due to sideslip ($^{\partial C_\eta}/_{\partial \beta}$)
C/SAS	Control and/or Stability Augmenter System
C_T	Thrust Coefficient ($^F/_{qS}$)
CTOL	Conventional Takeoff and Landing
D	Drag Force
DC	Direct Current
DCPR	Defense Contractors Planning Report (see Cost Information Reports (CIR) for Aircraft, Missiles, and Space Systems, dated 21 April 1966)
D.L.L.	Design Limit Load
e	Oswald Efficiency Factor
ECS	Environmental Control System
EGT	Exhaust Gas Temperature (°K)
ETC	Energy Transfer Control
F	Force (Newtons)
FBW	Fly-by-Wire
FDGW	Flight Design Gross Weight
g	Acceleration of gravity ($^m/sec^2$)
GG	Gas Generator
GFE	Government Furnished Equipment
h_t	height of horizontal (water line)
I_{xx}	Moment of inertia about specific axis xx, roll; yy, pitch; zz, yaw ($Kg\text{-}m^2$)
IFF	Identification, Friend or Foe
KEAS	Equivalent airspeed in knots
L	Lift (N) or Length (m)
L/C, LC	Lift Cruise
LDGW	Landing Design Gross Weight
ℓ_t	Tail Arm (distance from $\overline{c}_{wing}$ to $\overline{c}_{horiz}$)
M, Mn	Mach number
MAC	Mean aerodynamic chord (also $\overline{c}$)
MDD	Drag Divergence Mach number

LIST OF SYMBOLS (Continued)

MF	Multiplying Factor
N	Side Force
NWLO	Nose Wheel Lift Off
N_Z	Normal Force
OAT	Outside Air Temperature (TT_∞)
P_T	Total Pressure
q	Dynamic Pressure (KPa)
R_N	Reynolds Number
S	Area
STOL	Short Takeoff and Landing
S_{wet}	Wetted Area
TACAN	Tactical Air Navigation
TT_∞	Ambinet Total Temperature
UHF	Ultra High Frequency
V	Velocity (m/sec)
VFR	Visual Flight Rules
VHF	Very high frequency
v_j	jet velocity
v_o, v	Free stream velocity
VOR	VHF omni-range
V/STOL	Vertical and Short Takeoff and Landing
VTOL	Vertical Takeoff and Landing
W	Weight
α	Angle of Attack
β	Sideslip Angle
δ	Deflection Angle
$\theta, \dot{\theta}, \ddot{\theta}$	Pitch Angle, rate, acceleration
$\phi, \dot{\phi}, \ddot{\phi}$	Roll Angle, rate, acceleration
$\psi, \dot{\psi}, \ddot{\psi}$	Yaw Angle, rate, acceleration

SI CONVERSIONS

Length	feet x 0.3048 = meters (m)
Mass	pounds x 0.45359 = kilograms (kg)
Volume	gallons x 0.003785 = cubic meters (m^3)
Velocity	knots x 0.51444 = meters per sec
Force	pounds x 4.448 = Newtons (N)
Density	slug/ft^2 x 515.379 = kilograms per cubic meter (kg/m^3)
Pressure	psf x 47.88 = pascals (Pa) psi x 0.068965 = bars
Inertia	slug-ft^2 x 1.3557 = kilogram - square meter $(kg\text{-}m^2)$
Temperature	°R x 0.5555 = Degrees Kelvin (°K)

1.0 INTRODUCTION

This study was conducted under NASA Contract Number NAS 2-9307, dated 19 July 1976, for the purpose of planning a design, modification, and test program for two lift cruise fan research and technology aircraft. The aircraft, powered by gas driven tip turbine fans, was based on the rework of a T-39 Sabreliner airframe. This study was preceded by NASA funded programs investigating the viability of integrating lift cruise fan in various types of aircraft, References (a) through (e). The basic lift cruise swivel nozzles used in these configurations were substantiated by model and full scale tests found in References (f) through (h). The study was performed at the Columbus Aircraft Division of Rockwell International.

The study includes an aerodynamic and control concept and identification of structural rework. In addition, a preliminary estimation of performance is included with appropriate ground test programs leading to a contractor flight test prior to delivery to NASA. Volume I contains technical data on the conceptual design, power system integration and performance of the research and technology aircraft. Volume II contains parametric cost, scheduling and planning documentation.

2.0 STUDY OBJECTIVES AND GUIDELINES

To support the study objectives stated in Contract NAS 2-9307, the aircraft was investigated in four design areas; namely, (1) structural concept, (2) control concept, (3) aerodynamic configuration, and (4) integration of a propulsion system capable of vertical and cruise flight. Each design area was affected by the performance goals set forth in Reference (i).

A risk assessment was made to realistically temper the success oriented nature of the program and is discussed in Volume II (Reference (j)).

The study was prepared considering safety the prime goal; secondarily, effectivity and versatility in the vehicle was sought at the mininum cost.

The guidelines for the study fall into two categories. Those program oriented and those vehicle oriented. The following two lists summarize these guidelines. The guidelines allowed the Contractor to evolve a design that can be low cost and yet provide a successful research vehicle. The reduction of the T-39 load factor from +4, -1 to +2.5, -0.5 gave an incentive for use of existing structure since the design loads of the old structure could encompass those of the modified airframe. The crew requirements were logical considering the existing T-39 capability. A no compromise stance on safety obviously dictated ejection seats. Although the sink rate required is high, considering the use of an Air Force airframe, it appears to be necessary to provide a long life and compatibility with the desire to have shipboard trials. The payload volume requirements are

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quite modest considering the potential of five times (247 cu. ft.) the requirement available in the present airframe. The payload weight is a function of vehicle performance and as such can only be critical if it limits the usefulness of the vehicle.

In the discussion of program objectives and guidelines, the following contractual items dictated the configuration. These are:

2 Lift Cruise Fans - LCF 459
3 Gas Generators - YJ-97-GE-100
Longitudinal Control by Pitch Pipe
T-39 Sabreliner Airframe - NA-265-40
Basic Configuration Based on Reference (e)

Table I
Guideline Summary

Program

- Assume experimental type shop facilities
- Design for simplicity and low risk (minimize sophistication).
- Optimization of an aircraft or system is not a primary goal.
- Testing - minimum to provide safety but in keeping with program cost goals.

Aircraft

- Vehicle is to be a research and technology vehicle not a prototype or mission oriented operation aircraft.
- Configuration to be based on previously studied vehicles (Reference (e))
- Account for gas generator failure; assume no fan failure.
- Crew: 2 (flyable by either)
- Ejection seats desirable
- Pressurized Cockpit desirable
- Load Factor: +2.5 g, -0.5 g
- Maximum Sink Rate: 12 fps
- Min. Cruise Capability:
  300 KEAS at SL
  0.7 Mn at 25,000 ft.
  Endurance of two hours
- Payload: 2500 lbs; (50 cu. ft.)
- VTOL Missions: 5 circuits of 6.6 nmi
- STOL Missions: 11 circuits of 6.6 nmi
- Fuel Reserves: 4 min. of hover or VTOL operation and 10% for STOL mission.
- Control Power: Defined for single axis and combined control.

3.0 AIRCRAFT DESCRIPTION

The configuration documented here is a proof-of concept V/STOL research and technology aircraft. This concept incorporates a gas tip driven lift cruise fan propulsion system into an existing airframe to provide a vehicle capable of hovering from a vertical takeoff, transitioning and cruising at 0.75 Mach.

The general arrangement is shown in Figure 3.1 with pertinent dimensional data. The configuration has a T-39A Sabreliner airframe and a propulsion system consisting of two LCF 459 fans and three YJ-97-GE-100 gas generators. The lift-cruise system uses bifurcated swivel nozzles to deflect the fan flow in each fan nacelle. The aircraft is controlled laterally and directionally with these nozzles and longitudinally with a pitch pipe in vertical flight and with aerodynamic surfaces in convetional wing-borne flight. The vehicle has a payload of 2,500 lbs and a useful "V" load of 6,590 lbs. The purpose of this configuration is to describe a V/STOL concept that will meet a given criteria. The details of this description will be sufficient to provide a cost for the design, fabrication and testing of two aircraft.

The following details include the propulsion system, aerodynamic configuration, control concept, structural concept, and a systems modification.

3.1 Propulsion System

The research and technology aircraft is based on the propulsion concept of gas driven tip turbine fans used to provide lift during vertical, hover and transitional phases of the flight envelope; and thrust during the cruise or wing borne portion of flight. Lift cruise fans have the characteristics of providing propulsive lift for vertical flight while maintaining low specific fuel consumption for efficient cruise.

The propulsion elements of the lift cruise fan system are shown in Figure 3.2 with some representative parameters tabulated. The fan was matched to the gas generator at 100 percent engine rpm. This distinction is noted since it is possible to design fans for partial gas generator flow or multiple gas generators. The total flow of the gas general (69 lbs/sec) is ducted at 53 psia and 1375°F to the fan scroll which completely surrounds the fan and impinges on the 364 tip turbine blades (7 per fan blade). The resultant force turns the 59 inch fan to provide a weight flow of 612 lbs/sec at a 1.25 fan pressure ratio with an estimated mixed turbine-fan exhaust nozzle temperature of 250°F. This assumes mixing of the turbine exhaust (1000°F), around the periphery, with the fan flow at approximately ambient conditions.

Although the fans are matched one-for-one with the gas generators, it may be anticipated that during an emergency only a portion of the gas generator flow is desirable for powering the fan. In this case, a variable exhaust area scheme is used to provide the appropriate nozzle area. In Figure 3.2 a concentric, bifurcated inlet to the fan scroll is equipped with a valve; when the valve is closed a portion of the 360° plenum is cut off (noted by crosshatching)

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and only that remaining is fed by the gas generator. Obviously the flow remainder must have some appropriate area to exhaust into whether it be another fan, a pitch pipe, or an overboard dump. The portion blocked for this study is 18 degrees and is used to feed the longitudinal control pitch pipe during emergency conditions (i.e. one engine failed). The performance of swivel nozzles has been the subject of model and full scale tests, References (f) through (h). The performance level of the swivel nozzles used in this study is based upon the data of Reference (g) and is shown in Figure 3.3. The losses vary for nozzle deflection and have been included in the fan performance calculations as a function of the lift or cruise regime being addressed. The modulation of thrust will be discussed in the controls portion, Section 3.3.

3.2 Aerodynamic Configuration

Given the power components, two fans and three gas generators, and a T-39 Sabreliner airframe, the aerodynamic arrangement has some basic inherent limitations. These limitations are not evident in normal operation but come to light during a gas generator failure mode. The prime consideration is to minimize the trimming requirement so that during Level 2 the maximum amount of gas goes through the fans where it is augmented. If a large trimming moment exists (assuming the third engine is supplying the thrust) during Level 1, it must also be satisfied during Level 2. This requires thrust that cannot be augmented and results in a vehicle with much less lift in Level 2. The lack of lift could result in operating without "V" capability sometime during a mission. Elimination of an avoidance curve has been a design goal. This leads to the configuration where the fan thrust (lift) in vertical operation must go through the center-of-gravity in order to minize the trim requirements. The fan air deflection method (swivel nozzles) chosen for this study requires an unobstructed area beneath them for normal operation. Considering the use of an existing airframe with a low wing and an aerodynamic center close to the center-of-gravity, it becomes obvious that the wing would have to be moved to provide the following requirements: (1) unobstructed fan flow, (2) a center of lift and center of gravity very close to each other and (3) an aerodynamic center within trimming distance of the c.g. to provide a positive cruise stability margin of five per cent. This major aerodynamic change is represented in Figure 3.4. Structurally the rework involved is comparatively minor.

The nacelle design was driven by keeping the lift cruise nozzle on the center-of-gravity and locating the fan and gas generator as far aft as possible to minimize the forward travel of the center-of-gravity. The location of the gas generator was governed by two goals: (1) minimal ducting losses and (2) closeness to the center-of-gravity. The duct loss picture necessitated the shortest duct run possible which resulted in an installation in the nacelle. The low cost criteria is reflected as a minimum rework philosophy. Nacelle mounted gas generators keep the fabrication in an all new portion of structure. Although the total ducting length is not effected by fuselage vice nacelled gas generator location (i.e. due to the need for a crossover duct), the gas path during normal operation is shortened, and reduction of internal losses is significant.

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Although the roll inertia is larger, the control power in vertical flight is more than adequate to meet the roll requirements in an aerodynamic approach configuration.

Leading edge slats that run full span on the basic Sabreliner are aerodynamically operated and provide an incremental lift coefficient of 0.3. The slats, outboard of the nacelles, will be retained but positively actuated to eliminate the possibility of an asymmetric condition occurring during transition. The incremental lift at 15 degrees of slat and aileron deflection is estimated to be ~ 0.36 at a lift coefficient of 0.8 $C_{L_{max}}$. The flaps have been eliminated due to cross ship hot gas ducting. By retaining the slats and partially deflecting the ailerons, the maximum lift coefficient is estimated to be 1.5; providing a conventional power off stall speed in a landing configuration of approximately 112 knots.

All of the exhaust from the third gas generator provides longitudinal trim and control in Level 1 operation. In Level 2 operation, this gas generator provides power to the fan normally supplied by the disabled gas generator and also a portion of the flow required to maintain trim and produce the emergency pitch control. The location criteria for the third engine is the same as for the two prime gas generators, i.e. short ducts and center-of-gravity control. From a c.g. standpoint the engine must be located in the aft portion of the fuselage. Location of the engine in the cabin area is undesirable for several reasons; 1) lack of accessibility, 2) encroachment on internal volume, and 3) excessive rework. Therefore, the gas generator was placed above the upper longerons and in the aft portion of the fuselage and in the same plane as the crossover hot gas ducting. Early attempts to provide a forward facing engine and inlet (i.e. semi-flush above the wing center section proved unsatisfactory due to very high exhaust ducting losses.

Horizontal tail requirements must be met for several conditions, in Figure 3.5 these requirements are graphically represented. The Sabreliner 75 horizontal at 90 square feet was used to replace the Series 40 horizontal at 77 square feet. In the vertical or powered lift regime, a zero stability line at 60 knots is shown for a 90 square foot horizontal. The line moves to the right with increasing speed indicating increased stability. The limit line is in cruise configuration with no thrust; this line represents five per cent stability as requested in the guidelines. The center-of-gravity extremes are a function of the vehicle fuel and payload with the aft extreme being full fuel and the forward an operational empty weight (no payload). The nose wheel lift off requirement is most severe at the forward center-of-gravity but indicates a 56 square foot horizontal is adequate. All the requirements are well within the area of the T-39 Series 75 Sabreliner horizontal. The cost and rework are minimized by using the Series 75 horizontal and maintaining the existing control system. No problem is forseen in control or stability, however, some level of buffet may be experienced in the wake of the cruise nozzle. This can be corrected by slight deflection of the cruise nozzles if required. The available pitch pipe control is quite large and independent of lift as will be discussed later. Due to this high level of pitch control, it is the Contractor's

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opinion that the risk of a low horizontal is sufficiently small, and can be quantified early enough in the program, to justify the cost and weight savings resulting from using the Series 75 horizontal in the existing location. The vertical will be raised to keep the rudder above the inlet fairing.

The remaining feature of the aerodynamic configuration is the pitch pipe mounted externally and running the full length of the fuselage. The nozzles at either end provide trim capability and a pitching moment for both normal and emergency flight conditions. In normal operation (Level 1) the total flow from the third gas generator is ducted through the pitch pipe, roughly half to the forward nozzle and the other half to the aft nozzle. Any trim requirements or pitching moments are derived by differentially varying the area from one nozzle to the other while retaining the total area required by the gas generator. In Level 2 only enough flow is provided to the pitch pipe to accommodate the combination of maximum trim plus maximum single axis pitch control. The nozzle area is reduced accordingly. The third engine is used exclusively in Level 1 to provide pitch control and is isolated from the gas generators during normal operation. During Level 2, the remaining two engines provide both power for fan lift and pitch control. The thrust required for pitch is set aside by the internal fan scroll valves. The Level 2 thrust available in the pitch pipe is shuttled fore and aft to meet the trim and control requirements and is always contributing to the lift. The aerodynamic configuration is based on the philosophy of providing a safe research vehicle with the following characteristics: maximum lift; minimum trim requirements and no lift loss for trim; low duct losses; and minimum rework to the existing airframe. The pitch pipe is an example of cost and weight preempting a cleaner aerodynamic shape. The non-insulated external pipe saves approximately 100 pounds in insulation weight and eliminates the need to modify the frames of the fuselage. For safety it also keeps the hot gas duct out of the cockpit area.

3.3 Control Concept

The control of this aircraft is divided into the vertical and cruise flight regime. The existing mechanical systems are retained except for the replacement of the control wheels with sticks. The rudder pedal assemblies are retained since the ejection seat placement is compatible with the existing rudder pedal location. The cruise control surfaces; namely, ailerons, elevator and rudder provide satisfactory control moments throughout the cruise regime. The new stick design will provide the proper gearing for satisfactory control harmony.

The vertical propulsion control system is completely new. It is a triply redundant fly-by-wire dual actuator hydraulic system. The pitch pipe for longitudinal control is extended the full length of the aircraft to isolate the hot efflux from the benign fan exhaust. In this manner fan efflux will not be complicated by the markedly different pitch control exhaust velocities and temperatures that could influence ground effect studies. During Level 1 operation the pitch pipe is fed from the third engine and pitch is obtained by modulating the approximately 2500 pound thrust flowing out of each nozzle. This system is independent of the lift systems in Level 1 and provides more than adequate longitudinal control. During Level 2, when the third engine is powering a fan, the pitch pipe is powered by a fraction of the two operating gas generators. The fan output for Level 2 has been limited by an internal valve that physically prevents flow from impinging on the turbine blades for the full 360°. The fan configuration design provides for blocking out 18 degrees. The excess flow not needed for thefan output is ducted to the pitch pipe. This quantity of flow is always available to the pitch pipe and cannot be diverted to the fan during Level 2 operation. Essentially, this provides a source of pitch control independent of the lift system as in Level 1. The percent of flow restricted from the fan is predicated on the trim and pitch requirements of Level 2 operation. This has been determined to be equivalent to 600 pounds of thrust from both fans. Figure 3.6 summarizes the hover and transitional control concept and indicates the magnitude of control power available about each axis.

Laterally the system used is a combination of power transfer by means of valves in the ducts near each fan, which produces transient over-temperature on the system that provides an incremental thrust increase on one fan, coupled with a spoiler system on the opposite fan, to give an identical thrust decrement. This flow transfer provides approximately 1070 pounds additional thrust for maximum control during one minute VTO operating conditions. Spoiling is accomplished by vanes in the outboard lift cruise nozzle exits. The couple thus produced is a pure rolling moment with no vertical translation. The minimum rolling moment is produced at one minute VTO conditions since the allowable over temperature is a minimum. If the power setting is below the one minute VTO rating, the temperature increment from operating conditions to the allowable is greater; therefore, thrust for roll is greater. Figure 3.7 shows the aboslute thrust increment as a function of power setting for Level 1 and 2 operation. Note, at 90 percent of the one minute VTO rating, double the roll increment is available. To reiterate, the roll increment is a function of the temperature difference from operating condition to limit, and is a percentage of the thrust output. For Level 2 the lift output is reduced by the amount set aside by the scroll valve, however, the available increment during intermediate power for roll is larger due to the lower operating temperature.

Directional input is derived from asymmetric deflection of the vanes in the lift cruise nozzle exhausts. The maximum yaw requirement can be met with less than two degrees of deflection of the normal component to the lift, making the lift loss extremely low. The roll yaw performance is indicated for Level 1 and 2 in Figure 3.8 and 3.9. The excess control about all axes is highly desirable for a research vehicle and provides not only a superior level of safety but versatility in evaluating control responses and power.

Coupling occurs for both roll and yaw inputs when the nozzles are in any orientation other than directly down. The use of an electronic C/SAS computer provides an easy method to decouple these controls. A roll input causes a proverse yawing moment; a yaw input produced an adverse rolling moment. The magnitude of these coupled moments vary as a function of nozzle angle but are easily cancelled by appropriate circuitry in the computer. The control concept provides power about each axis that exceeds the NASA guidelines. It is also

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effectively independent of the lift system in that no control input effects the lift. Both attributes are desirable for VTOL types of aircraft. The lateral and directional control methods appear to be satisfactory for future operational vehicles. Proof of concept will be a result of these research vehicles.

3.3.1 Flight Control System

A fly-by-wire system that operates in parallel with the existing controls is used for hover and conversion flight. This system is illustrated for each control axis in Figures 3.10, 3.11 and 3.12. In the pitch axis a dual hydraulic actuator controls the fore and aft pitch pipe nozzle through appropriate linkages. Roll control is obtained by modulating the gas flow to the wing fans with a control valve plus modulating a nozzle spoiler, shown in Figure 3.13. Yaw control is obtained by vectoring the nozzle thrust with the same nozzle vanes that are used for the spoiler. A dual hydraulic actuator is used for moving the yaw vanes. A set of control vanes and actuators is provided in both the left and right wing. The proper mixing of yaw and roll is accomplished in the computer and the proper mix of roll and yaw command for a given nozzle angle will be supplied to the actuator. Pitch trim shifts that may occur with nozzle angle changes will be supplied from the computer. SAS functions of damping and stability augmentation will also be supplied from the computers.

The computer amplifier electronics will be a triple redundant system with both self checks and cross channel monitoring. The system is expected to use one computer system driving the actuator with the other two systems in active standby. In the event a failure is detected in one system it will be switched off. If the controlling unit shows a failure, the control will be immediately switched to one of the active standby units.

The actuation system will use an AFCAS design with direct drive torque motors controlled by the computer. Each half of the dual actuator will have redundant channels controlling the torque motors with sufficient feedback to have fail operate capability for each half of the dual actuator. Feedback sensors to control the actuator will be mounted at the actuator.

As the conventional system is in parallel with the fly-by-wire hover system the conventional surfaces will be moving at all times. Therefore, conventional control will be slowly phased in as the aircraft speed increases and the conventional surfaces become effective. As the conventional surfaces become effective, the stick forces will increase as aerodynamic forces increase. The existing stick centering bungees presently in the system will be used to provide positive centering in hover. An additional centering bungee will be added to the lateral channel to provide the feel and positive centering required for control in hover.

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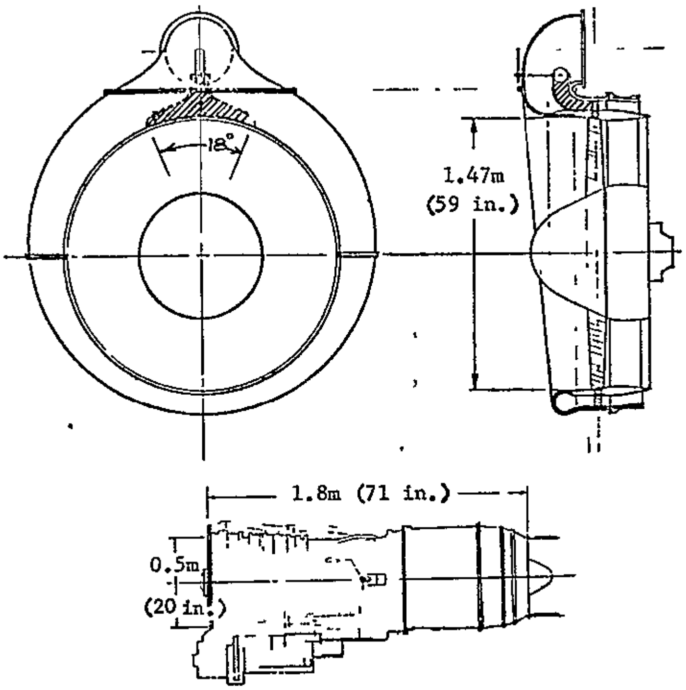

	YJ-97	LCF 459
Thrust N (Lbs)	1111 (4945)	2724 (12,120)
Gas Temp. °F	1375	250
Airflow Kg/Sec (Lbs/sec)	30.95 (69)	293 (612)
Fuel Flow Kg/Hr (Lbs/hr)	2096 (4620)	------
Weight Kg (Lbs)	335 (739)	385 (850)

Figure 3.2 Propulsion System

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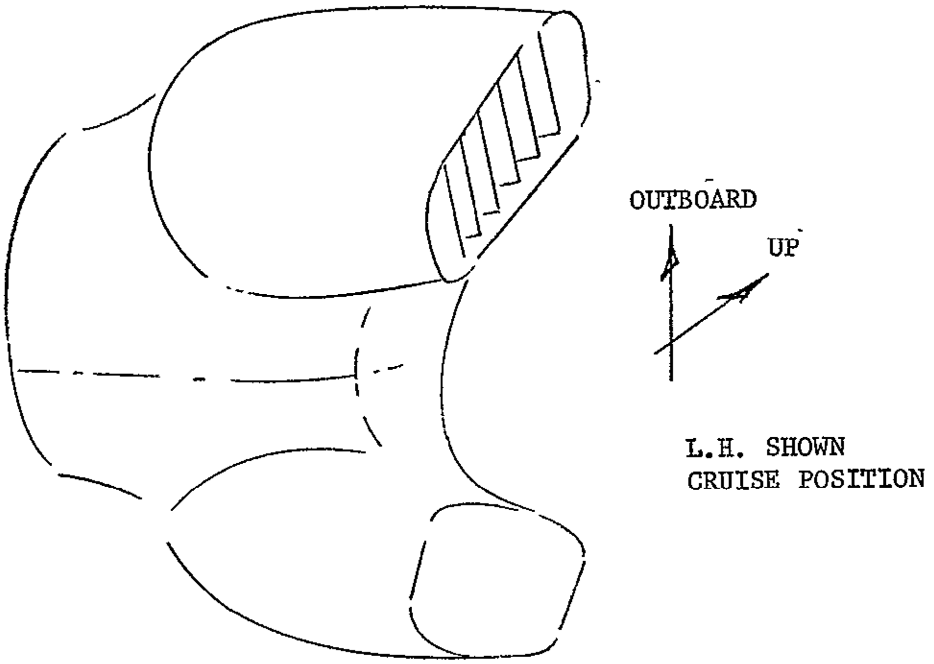


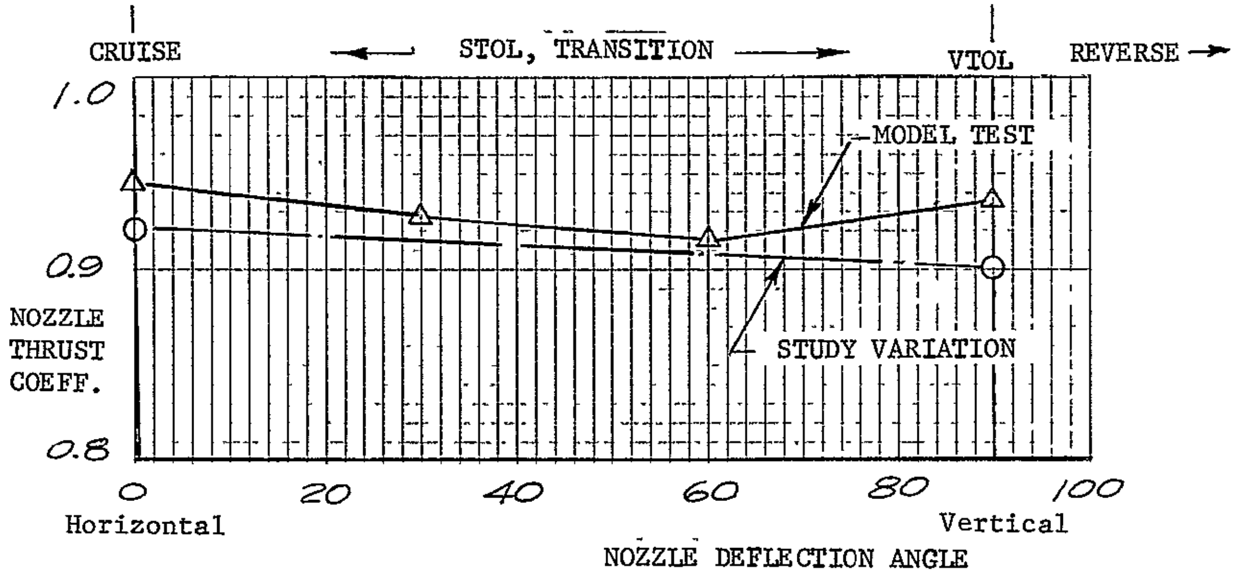
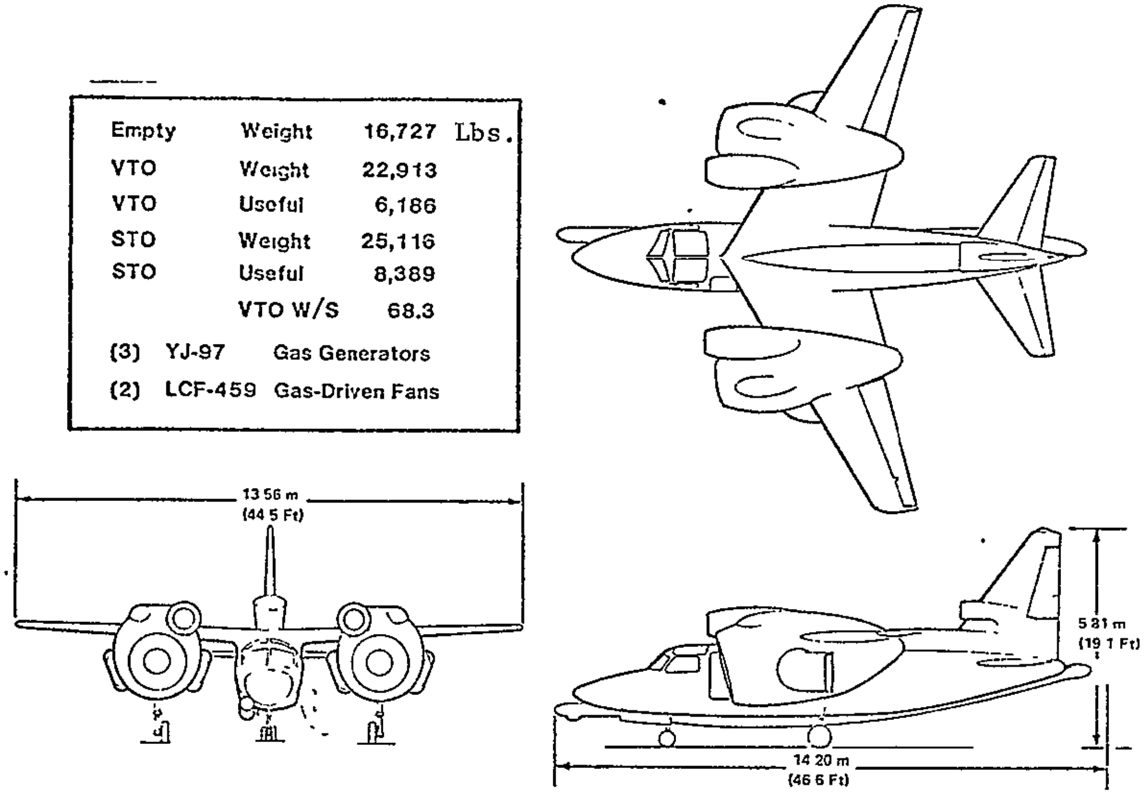


Figure 3.3 Swivel Nozzle Performance

Empty	Weight	16,727 Lbs.
VTO	Weight	22,913
VTO	Useful	6,186
STO	Weight	25,116
STO	Useful	8,389
	VTO W/S	68.3

(3) YJ-97 Gas Generators
(2) LCF-459 Gas-Driven Fans



	Wing	Horizontal	Vertical
Area m^2 ($Ft.^2$)	31.78 (342.0)	8.37 (90.1)	3.93 (42.3
Aspect Ratio	5.77	4.16	1.5
Span m (Ft.)	13.56 (44.5)	5.91 (19.4)	2.43 (8.0)
M.A.C. m (In.)	2.55 (100.6)	2.37 (60.1)	1.75 (69.0)
Taper Ratio	0.32	0.33	0.30
$Sweep_{L.E.}$	32° 15'	35°	36°
Section	$64A212_{Root}$ $64A012_{Tip}$	64A010	63A010

Figure 3.4 General Arrangement

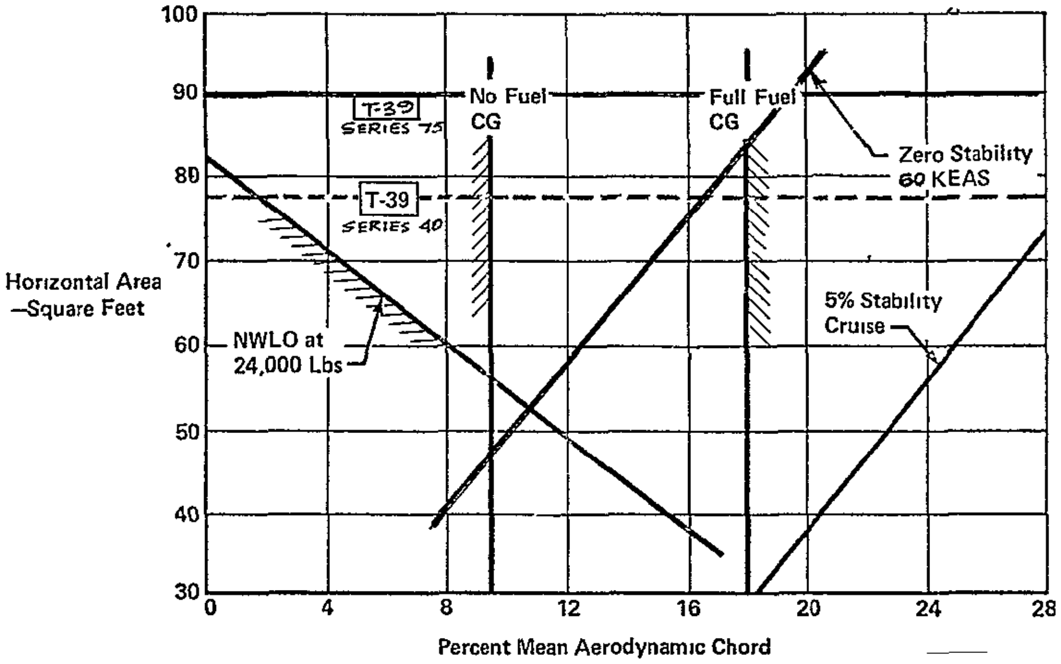
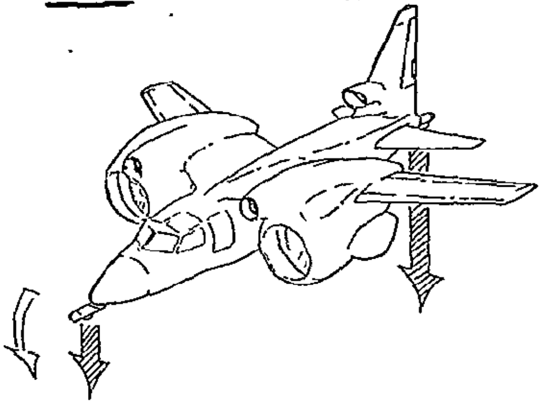


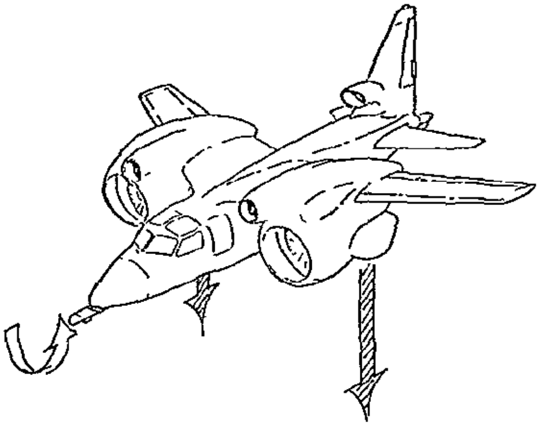
Figure 3.5 Horizontal Tail Requirements

PITCH (Modulated Lift from Variable Nozzle Area)



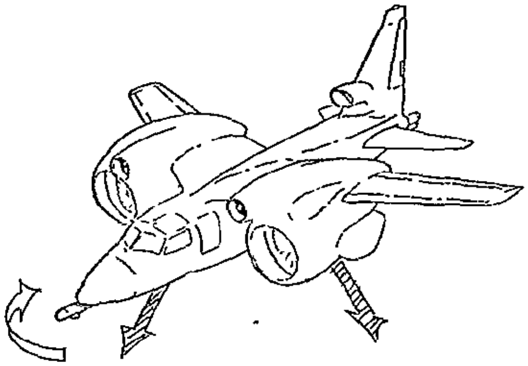
	Level 1	Level 2
$\ddot{\theta}_{reqd}$	0.5	0.3 (rdn/sec^2)
I_{yy}	35,000 slug ft^2	
M_{reqd}	17,600	10,560 ft lbs
$\ddot{\theta}_{ava}/\ddot{\theta}_{reqd}$	>5	2.5

ROLL (Differential Lift from Thrust Transfer and Spoiling)



$\ddot{\psi}$	0.3	0.2
I_{zz}	53,250	
M_{reqd}	18,974	12,660
$\ddot{\psi}_{ava}/\ddot{\psi}_{reqd}$	2.67	2.0

YAW (Deflected Lift from Exhaust Vanes)



$\ddot{\phi}$	0.9	0.4
I_{xx}	31,750	
M_{req}	28,576	7,696
$\ddot{\phi}_{ava}/\ddot{\phi}_{reqd}$	1.10	1.75

Figure 3.6 Hover Control Concept

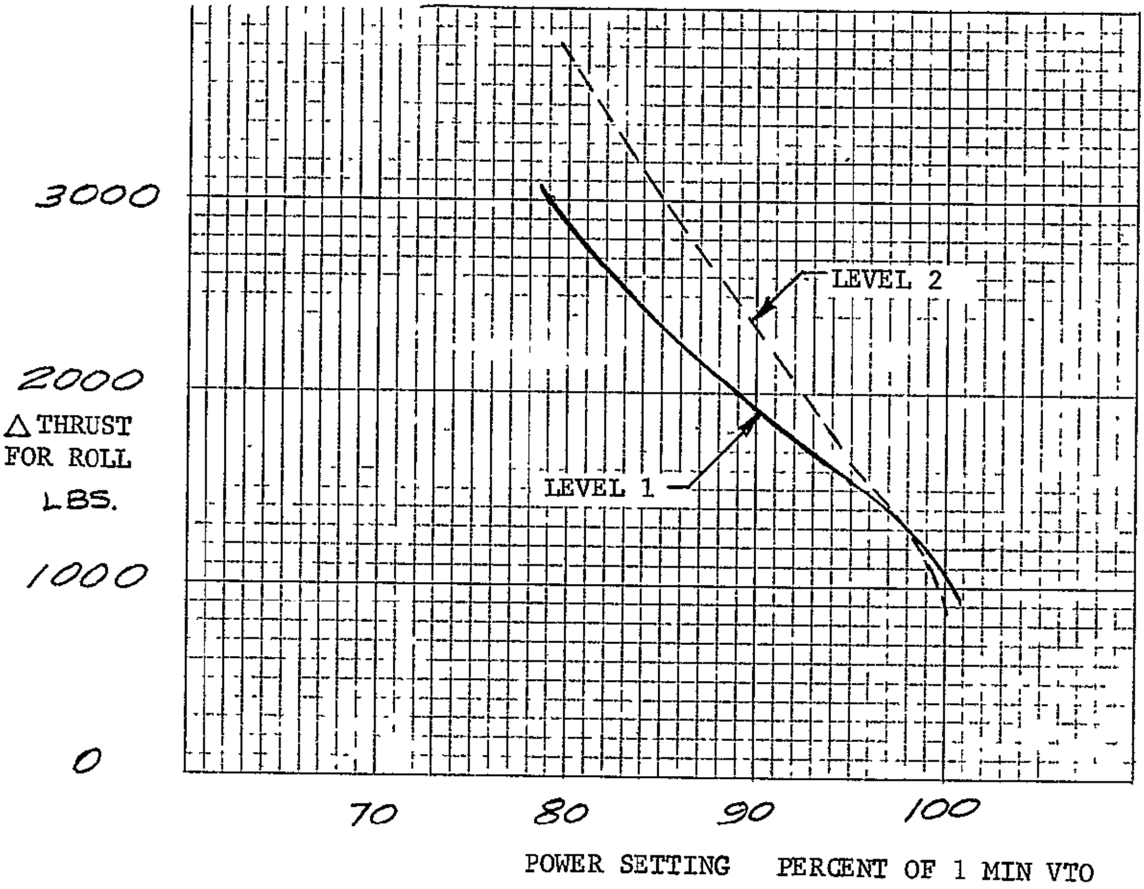


Figure 3.7 Roll Control Power

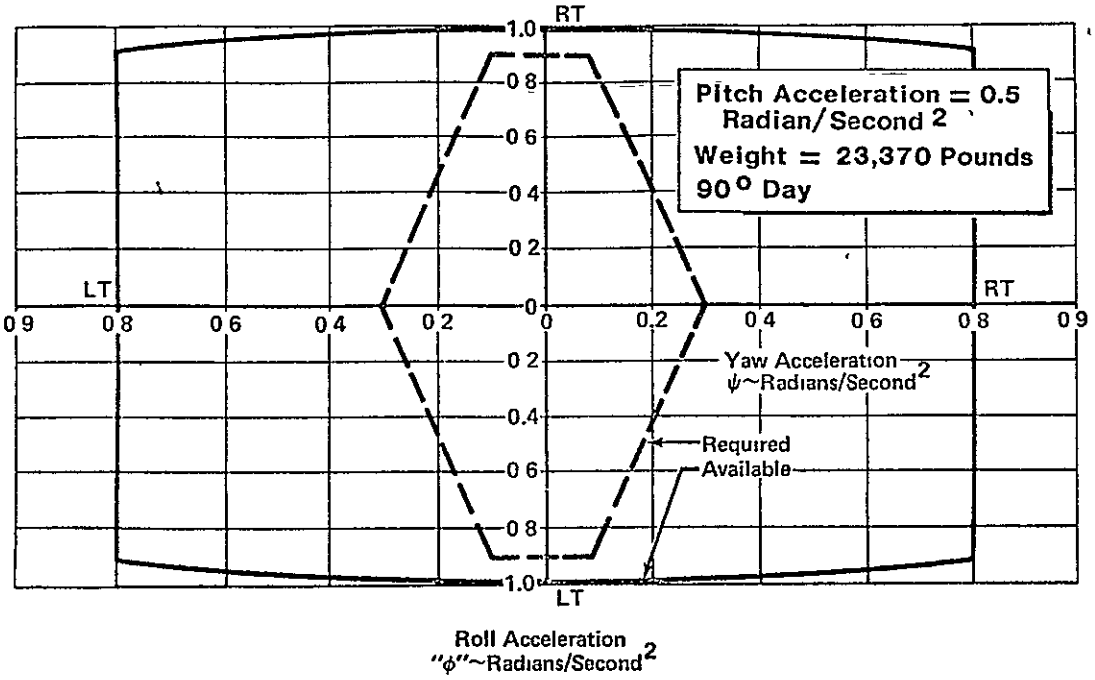


Figure 3.8 Roll-Yaw Control Level 1

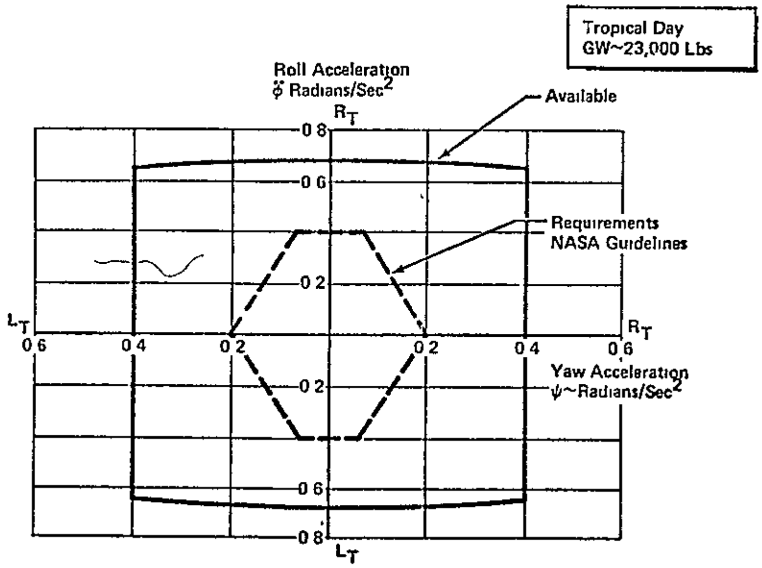


Figure 3.9 Roll-Yaw Control Level 2

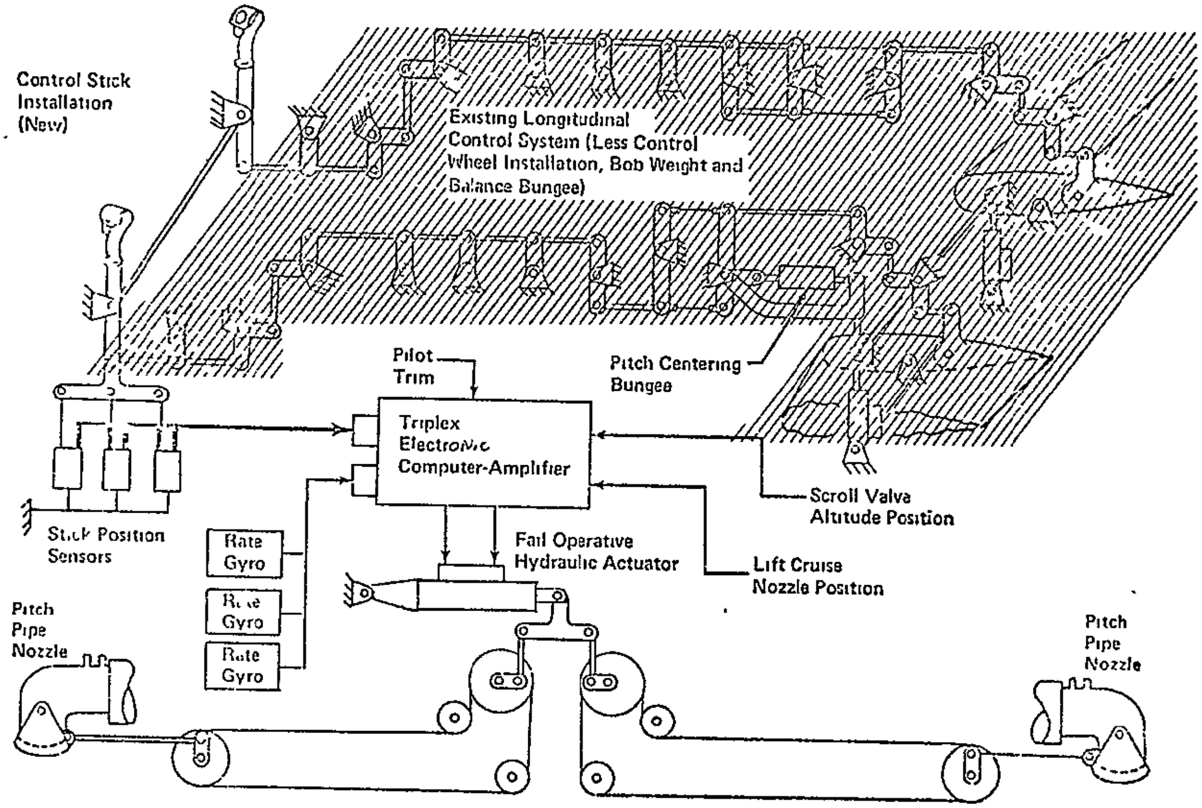


Figure 3.10 Longitudinal Control System

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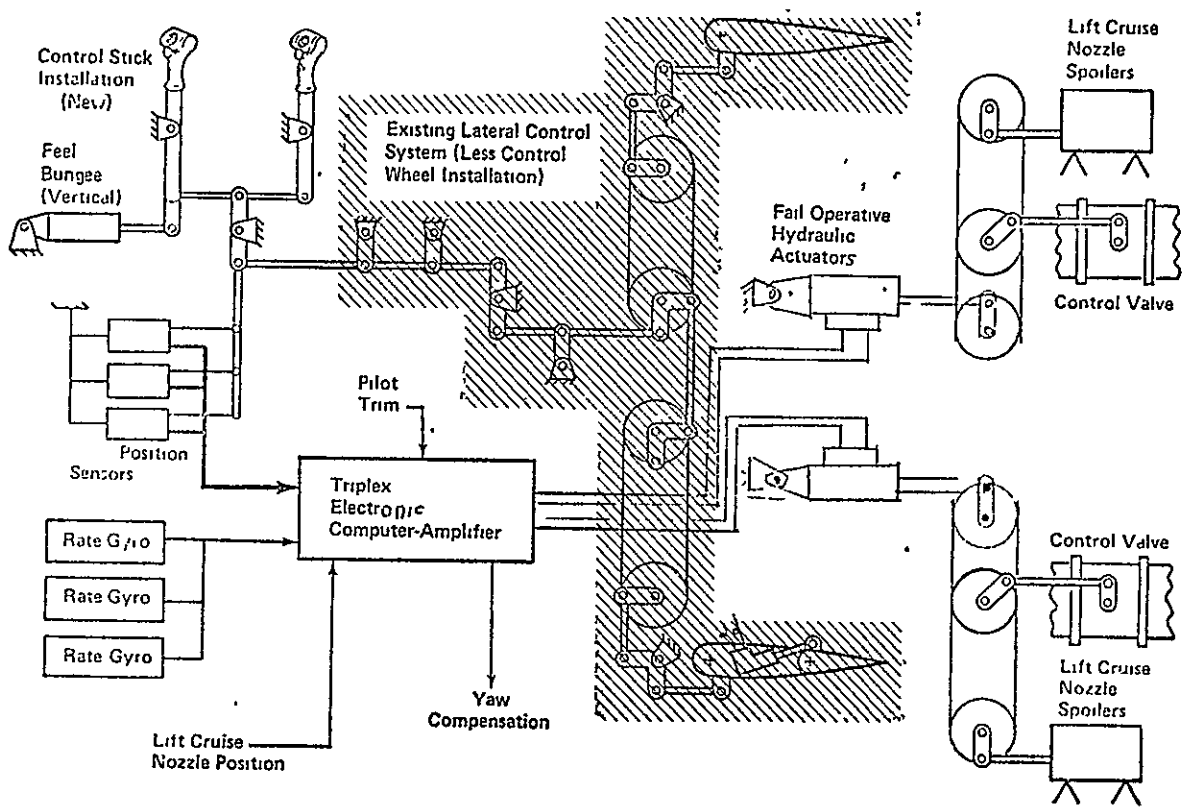

Figure 3.11 Lateral Control System

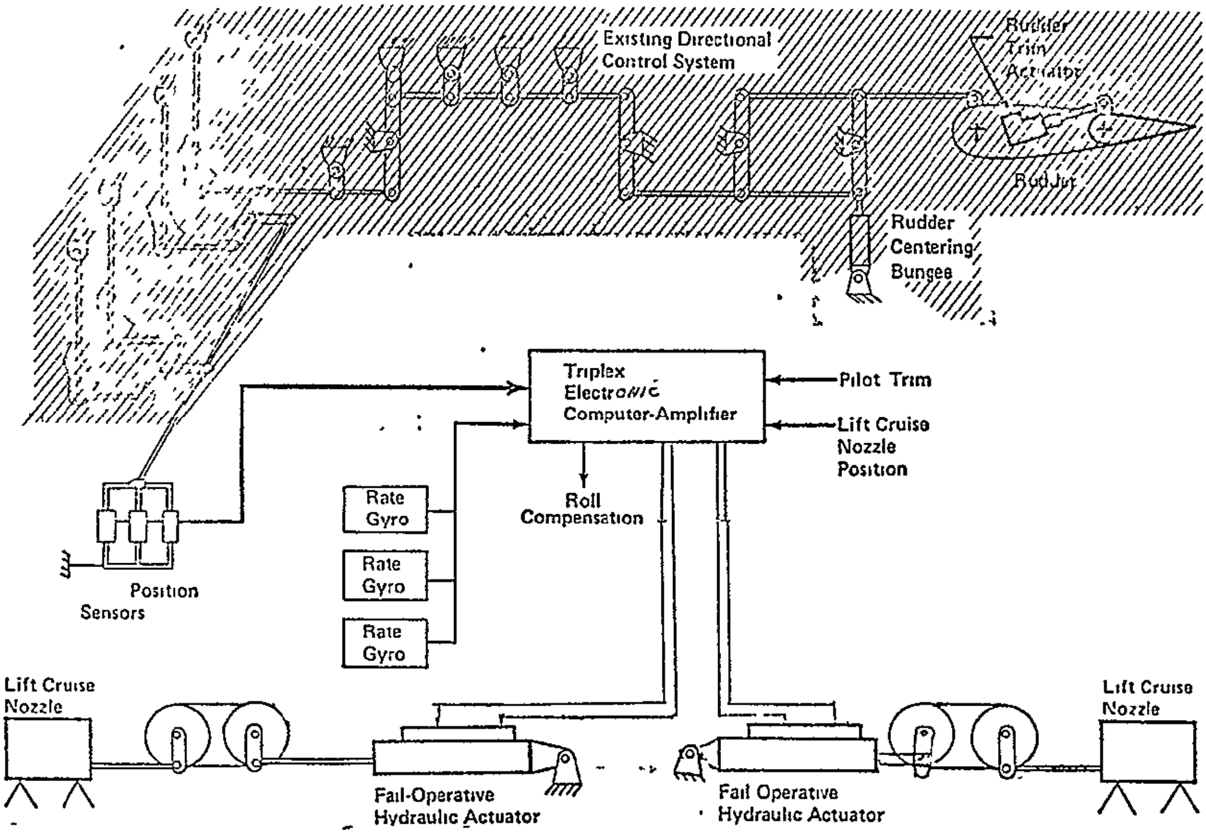

Figure 3.12 Directional Control System

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3.4 Structural Concept

The prime goal within the requirement of a safe aircraft is low cost. This is realized by a philosophy of minimizing the rework to the existing T-39 airframe. The description found in Section 3.0 implies the low rework philosophy. It can be seen that the major portion of the ducting lies in a plane that is above the upper longeron and aft of the rear spar. With the exception of the pitch pipe which has a connecting duct inside of the cabin, all ducting is external to the prime structure. This preservation of the prime structure not only minimizes the rework but also eliminates the need for elaborate tooling during the rework effort.

3.4.1 Background - The maximum use of existing airframe components has been emphasized in the evaluation of the structural modifications required for installation of a gas turbine lift fan system in a model T-39A airplane. From a structures standpoint, this modification is based upon the requirement to provide a sound airframe for two experimental prototype vehicles for flight test evaluation in specific VTOL and STOL operating modes. Airplane configuration changes involved in the installation of the lift cruise fan system as shown in Figure 3.1 include the following major modifications to the existing T-39A airframe:

1. Relocation of the wing from the bottom of the fuselage to the top of of the fuselage.
2. Removal of existing fuselage mounted engines and nacelle pods.
3. Installation of wing mounted nacelles containing provisions for mounting of gas generator, turbine fan, thrust nozzles, hot gas ducts, valves, controls and main landing gear.
5. Removal of the existing training edge flaps and modification of the airfoil shape inboard of the nacelles.
6. Installation of an aft fuselage mounted inlet duct, gas generator and hot gas distribution duct.
7. Relocation of the vertical stabilizer above the aft inlet duct.
8. Installation of an externally mounted "pitch pipe" extending from hose to tail along the side of the fuselage.
9. Installation of ejection seats and modification of the existing cockpit enclosure and wind screens.
10. Installation of a nose gear with longer stroke and high load capacity.

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The modifications listed above result in an increase in airplane maximum flight design gross weight ranging from 14,000 pounds for the model T-39A to approximately 22,980 pounds for the proposed lift cruise fan version. The basic symmetric flight design limit load factor, N_z, for the T-39A model is +4.0g and the proposed design limit load factor for the lift fan prototype is +2.5g. A gross comparison of FDGW x N_z for the two configurations (14,000 x 4.0 = 56,000 vs. 22,980 x 2.5 = 57,450) indicates that the combination of increased weight and reduced load factor of the lift fan modification results in a roughly equivalent N_z x W load factor for symmetrical pull up conditions. Figure 3.14 illustrates a proposed VN_z operational envelope which includes a symmetrical maneuver limitation between N_z = -0.5 to +2.5G and a 300 knot airspeed limitation at 20,000 feet altitude. The N_z load factor associated with 25 feet per second and 50 feet per second gust encounter are also shown in Figure 3.14 and it may be noted that the 50 fps gusts produce load factors slightly in excess of 2.5G, as shown below:

Critical Flight Loads

Configuration	Condition	Maneuver	N_z (Limit)	Wt. (Lbs.)	N_z x W
NA 265 Series (T-39A)	1501 F1	Symmetrical Flight	4.00	14,000	56,000
	4005 F1L	Abrupt Roll	2.67	14,000	37,380
	40019 JL	Abrupt Roll	2.33	15,000	34,950
	4025 JL	Abrupt Roll	2.33	16,316	38,016
Lift Fan	1	Symmetrical Flight	2.50	22,979	57,450
	2	Gust	2.80	22,979	64,341

Landing design gross weight of the T-39A was originally rated at 13,000 pounds at a maximum sink speed of ten feet per second. This was later increased to 17,500 pounds on ship 7 and subsequent. For the lift fan version the LDGW is approximately 21,910 pounds with a maximum design sink speed of 12 feet per second in VTOL or STOL landing modes. An A-4 main landing gear with a 16 inch stroke and a T-2 nose gear with a 14 inch stroke are proposed to replace the existing T-39A landing gear which has a 10 inch stroke. These increased strokes provide increased energy absorption capability such that landing gear loads for the heavier airplane and higher sink speed are not significantly greater than the T-39A at LDGW of 13,000 pounds as shown in Table II.

For symmetrical flight conditions the wing bending and torsional loads inboard of the nacelle are relieved by the weight of the nacelle which is located forward of the wing box. Landing gear spin up loads and nacelle inertia loads introduce significant nose down torsion moments in the wing box inboard of the nacelle which are approximately equal but in an opposite direction to the T-39A flight design torque loads. A summary of these flight and landing wing loads at the side of the fuselage are presented in Table III for comparison with the T-39A wing loads. This comparison shows that the shear load at the wing reference axis is smaller for the lift fan configuration due to the inertia relief of the nacelle, the wing up bending moment M_x is slightly less and the torsion moment M_y is roughly equal but in the opposite direction for landing spin up conditions. Wing to fuselage attachment loads for these flight and landing load cases are shown in Table IV. Forward attach fitting loads are increased significantly and aft loads are increased slightly due to the nose down torsion loads produced during landing gear spin up and the increased airloads resulting from the 2.80 N_z gust load factor at FDGW of 22,980 pounds.

A review of the T-39A structural analysis indicates that the wing box structure inboard of the nacelle will have sufficient strength for these modified wing loadings. A beef-up will be required in the forward wing to fuselage attachments. Outboard of the nacelle the wing box structure is critical for abrupt roll conditions. By limiting the rate of roll in the lift fan aircraft the shear, bending and torsion in the wing outer panel can be reduced to a level which does not exceed the existing design loads for the T-39A structure. The 2.80 N_z symmetrical gust loads will also fall within the existing strength capability of the wing outer panel and, therefore, very little modification of the wing structure outboard of the nacelle will be required.

The general conclusion which may be drawn from these preliminary load comparisons is that most of the existing T-39A airframe components will have adequate strength for use in a lift cruise fan conversion with a flight design gross weight of 22,980 pounds limited to a max. symmetrical flight maneuver load factor of +2.5g,+2.80 gust load factor and maximum landing sink speeds of 12 feet per second. Beef-up and modification will be required in local attachment areas and in portions of the structure which interface with major configuration changes. Figure 3.15 illustrates the existing T-39A structural arrangement. The following paragraphs describe the type and extent of the modifications anticipated in each of the major airframe structural components to achieve the proposed T-39A lift cruise fan conversion.

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Table II

T-39A Lift Cruise Fan Modification
Landing Gear Load Comparisons
(Ultimate Loads)

Config.	Cond. No.	Condition	Weight (Lb.)	Main Gear			Nose Gear		
				F_V (Lb.)	F_D (Lb.)	F_S (Lb.)	F_V (Lb.)	F_D (Lb.)	F_S (Lb.)
NA 265-* 30 & -40	7013	Take-Off Run Nz = 2.0	17760	24552	0	0	4174	0	0
	7016	Turning	17760	20862	0	10435	2088	0	1044
	7200	3 Point Level/Spin Up (10 ft/sec sink speed)	13000	20653	15571	0	8182	6170	0
	7202	3 Point Level/Max V (10 ft/sec sink speed)	13000	20967	5242	0	11589	2898	0
	7203	2 Point Level/Spin Up (10 ft/sec sink speed)	13000	21069	15885	0	0	0	0
	7205	2 Point Level/Max V (10 ft/sec sink speed)	13000	23400	5850	0	0	0	0
	7207	Tail Down/Spring Back (10 ft/sec sink speed)	13000	22494	-17397	0	0	0	0
	7218	N. Wheel Yawing	13000	8130	0	0	3240	0	2592
Lift Fan A-4 Main (16" Stroke) T-2 Nose (14" Stroke)	A**	2 Point V Landing (12 ft/sec sink speed)	21910	24500	0	0	0	0	0
	B**	2 Point STOL/Spin Up (12 ft/sec sink speed)	21910	24500	7500	0	0	0	0
	C**	3 Point STOL/Spin Up	21910				13500	4500	0

* Ref. NA59-1560 ** Operational Loads

Sign Convention as follows: $+F_V$, up $+F_D$, aft $+F_S$, right

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Table III

T-39A Lift Cruise Fan Modification
Design Load Comparisons
Wing Loads at Side of Fuselage
(Ultimate Loads)

Config.	Cond.	Type of Maneuver	Weight (Lb)	Nz (Limit Value)	Swept Reference Axis Loads @ W.S. 36.00		
					Sz (Lb)	Mx (In.Lb)	My (In.Lb)
NA 265-* 30 & -40	1515	Symm.	16,316	4.0	29512	4848337	965638
	1517	Symm.	14,000	4.0	30441	5169006	953185
	3057L	Steady Roll	14,000	2.67	16623	4195980	670201
	3057R	Steady Roll	14,000	2.67	20322	3752275	1109166
	6910	Gust	12,096	4.73	28930	4291140	597531
Lift Fan	A**	V Landing (12 ft/sec sink speed)	21,910	3.24	20717	1964615	-240487
	B**	STOL Landing (12 ft/sec sink speed)	21,910	3.24	20552	3212168	-1060945
	C	Symm.	22,979	2.5	17249	4450392	327758
	D	Gust	22,979	2.80	19318	4984439	367088

* Ref. NA 59-1560 ** Operational Loads

Sign Convention as follows: +Sz, up +Mx, compression in upper surface +My, nose up

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Table IV

T-39A Lift Cruise Fan Modification
Design Load Comparisons
Wing to Fuselage Attachments
(Ultimate Loads)

Config.	Cond.	Type of Maneuver	Weight (Lb.)	Nz (Limit Value)	Fwd. Attach Pz (Lb.)	Fwd. Attach Px (Lb.)	Aft Attach Pz (Lb.)	Aft Attach Py (Lb.)
NA 265-30* & -40	1501F1	Symm.	16,316	4.0	-9727	-1266	33595	0
NA-276	3017 J	Steady Roll	14,000	2.67	-14428	3097	27555	77
	3126	Steady Roll	16,316	0	-5064	14207	14317	1589
	6910	Gust	12,096	4.73	-6314	86	30069	0
	7211	Ldg.(10 ft./sec.)	13,000	-	-9908	3734	28047	572
Lift Fan	A **	V Ldg. (12 ft./sec.)	21,910	3.24	-6485	-	27088	-
	B **	STOL Ldg. (12 ft./sec.)	21,910	3.24	-26020	7500	38440	--
	C	Symm.	22,979	2.5	-16474	-95	35076	0
	D	Gust	22,979	2.80	-18450	-106	39285	0

*Ref NA59-1560 & NA62-775 ** Operational Loads

Sign Convention as follows: $+P_z$ up on fuselage, +Px aft on fuselage, +Py to right side of fuselage

3.4.2 Wing - The complete wing structure of the T-39A is illustrated in Figure 3.16. The main box sturcture is all aluminum construction and consists of a single cell, multi-rib, torque box with integral fuel tanks from centerline to tip. An additional integral fuel cell is located in the leading edge in the area adjacent to, and outboard of, the side of the fuselage. Leading edge structure and extendable slats are attached to the front spar outboard of the leading edge fuel cell, and aileron and flap are supported from rear spar hinge fittings. The main landing gear trunnion is an integral part of the rear spar and is located adjacent to the side of the fuselage. The wing is attached to the fuselage with fittings located on the front and rear spars at the side of the fuselage.

For the lift fan modification this complete wing structure will be relocated from the bottom of the fuselage to a position at the top of the fuselage as shown in Figure 3.1. It is intended to utilize 100% of the basic wing torque box structure, including the leading edge fuel tank as is with local beef-up as required for nacelle and fuselage attachment fittings. The aileron with its support fittings will also be retained with a 30 inch inboard extension added. Principal modifications to the remaining portions of the wing structure are shown in Figures 3.17 and 3.18 and consist of the following items:

1. Remove wing leading edge structure between front spar Sta. 77 & Sta. 172
2. Remove slats between slat Sta. 77 and Sta. 162
3. Remove trailing edge flap and flap supports
4. Remove wing inboard trailing edge structure
5. Add nacelle front and rear spar attachment fittings
6. Local beef-up of front and rear spar at nacelle attachments
7. Add revised trailing edge airfoil fairing and hot duct support provisions between nacelle and side of fuselage
8. Add new airfoil fairing to upper surface of wing from ℄ to side of fuselage.

3.4.3 Nacelle - The proposed lift fan nacelle structure is shown in Figure 3.19. This is a totally new structure designed to house all of the components of the primary lift cruise propulsion system plus the main landing gear. Construction of the nacelle structure is primarily aluminum alloy stiffened skin, longerons, and frames with high temperature alloys utilized in the areas of hot gas generator and turbine fan mounts, and in the plenum duct and nozzles. Insulation and compartment cooling

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are provided around the hot gas ducts and turbine scroll to maintain acceptable structural temperature levels in the adjacent aluminum nacelle and wing box structure.

Attachment of the nacelle to the wing box is provided at four locations where the sides of the nacelle interface with the wing front and rear spars. Sufficient beef-up will be provided in the wing attachment fittings and spar web reinforcements to allow distribution of nacelle shear and torsion loads into the total wing torque box through existing wing ribs adjacent to the nacelle.

Principal load bearing elements of the nacelle structure are as follows:

1. Canted wing attachment frames located parallel to the wing front and rear spars.
2. Main gear trunnion bulkhead.
3. Nozzle bearing mount plates and nozzle bearings.
4. Fan mount frames.
5. Upper longerons located below wing box surface.
6. Lower longerons located near bottom of nacelle.
7. Cantilevered gas generator mount structure.
8. External skins and wheel well webs.

Other non-primary structural elements of the nacelle are the gas generator inlet cowling, fan inlet cowling, gas generator access doors, over-wing fairing, plenum duct and main landing gear doors.

3.4.4 Fuselage - The existing T-39A fuselage structure, illustrated in Figure 3.20, is aluminum alloy construction consisting basically of longerons, frames and skins. The structural arrangement as modified for the lift cruise fan conversion is shown in Figure 3.21. A basic objective of this fuselage modification is to preserve all of the existing primary longerons, side frames, side skins and lower fuselage structure and limit the rework to that portion of the structure above the upper longerons. This objective has been achieved, with a few exceptions, by routing the pitch control ducting external to the bottom side of the fuselage and keeping this hot gas ducting above the fuselage upper longerons.

In the forward fuselage a major modification is required to the wind screens and cockpit enclosure structure to allow installation of ejection seats. All of the wind screens and wind screen framing in the cockpit area aft to fuselage station 143, shown in Figure 3.22, are to be removed and replaced with new glazing and framing as shown in Figure 3.21. The existing pilot and co-pilot seats are to be removed and replaced with Rockwell LW-3B lightweight ejection seats which will provide zero-zero ejection escape capability through the new transparent upper cockpit enclosure panel. A new canted bulkhead will be added for mounting of the LW-3B ejection seats and will be integrated with the existing bulkhead at Sta. 143 to form a pressure bulkhead. A cockpit door will be added at Sta. 143 for isolation of the pressurized cockpit from the cabin which is to be unpressurized in the lift fan configuration. Cockpit pressurization in the lift cruise fan configuration will be limited to 7.5 psi ultimate differential versus the existing 18.4 psi ultimate ground test pressurization capability of the existing T-39A cockpit and cabin.

Rework of the forward fuselage is required for removal of the existing nose landing gear and installation of a T-2 nose gear. New trunnion attachment fittings and down lock fittings are required in addition to rework of the cockpit pressure bulkhead at Sta. 76, revision of nose well frames, raising of the cockpit floor above the gear and beef-up of wheel well webs and caps. Consideration should be given to the possibility of restricting the landing attitudes for VTOL and STOL operation so as to keep the nose gear loads within the capability of the present T-39A nose gear, thereby reducing the extent of rework required and eliminating the need for a T-2 gear. Other local structural rework will be required in the cockpit floor and nose gear well area as a result of control system changes resulting from replacement of the existing wheel control column with a stick control.

All of the fuselage structure above the upper longerons aft of fuselage station 206 will be removed and replaced with new structure required for installation of the wing, ducting, gas generator and gas generator inlet. The wing is positioned in the upper fuselage such that the lower surface of the wing has one half inch clearance above the upper longerons after removal of the upper fuselage frames and skins. Fore and aft location of the wing remains the same as in the T-39A configuration with the inboard front spar plane located at fuselage station 208.125. The wing is positioned with 3° 45' positive angle of incidence relative to the fuselage reference axis vs 0° incidence in the T-39A configuration.

Wing to fuselage attachments will be identical to the T-39A with the exception that fittings now located on the fuselage lower frames at stations 206 and 264.25 will be inverted and moved to the top of these frames. Stronger fittings will be required at the front spar due to increased loads and new aft spar fittings will be required to permit bolting to a new upper frame at station 264.25 after positioning of the wing box on the fuselage. Upper fuselage frames and skin forward of station 206 will be retained and new frames and fairing skin will be added to the top of the fuselage between stations 150 and 206 as shown in Figure 3.23. The forward wing to fuselage drag and vertical load fittings are attached to this new structure at the side of the fuselage in the same manner as the existing T-39A with the exception that the fittings are inverted and switched L.H. to R.H. Beef-up of the fuselage side frames at stations 206 and 264.25 is also required to permit wing load introduction at the top of the fuselage.

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Upper fuselage frames and skin between stations 206 and 264.25 which are removed will be replaced with new frames and skin at the level of the upper longeron beneath the wing box. Flat skin and straight frame caps can be tolerated in this portion of the fuselage with the elimination of cabin pressurization requirements for the lift cruise fan configuration.

The open cavity in the bottom of the fuselage between stations 206 and 264.25, formerly occupied by the main wing box will be covered by a new fairing structure. The area between stations 264.25 and 298.5 formerly occupied by the main gear wheels, and covered by the main gear doors as shown in Figure 3.24, will also be covered with a new fairing structure. The main gear, gear doors, controls, and actuating mechanism will be removed and replaced with a frame stiffened fairing mounted from the existing floor beams and gear door beam as shown in Figure 3.25. The honeycomb sandwich floor panels located in this area will be used as is with the exception of the right hand panel between stations 264.25 and 298.5. A 12-inch diameter hole will be cut in this panel for routing of the duct which supplies gas to the externally mounted pitch control duct.

Installation of a General Electric YJ-97 gas generator in the aft fuselage requires a revision to the fuselage structure above the upper longerons aft of station 264.25. The gas generator is mounted tail forward above the upper longerons, as shown in Figure 3.21, with the inlet duct facing forward at the base of the vertical stabilizer. The vertical stabilizer is located upward to a position above the inlet and the fuselage moldlines are revised to enclose the curved inlet duct. All of the existing upper fuselage frames and skin are removed and replaced with new frames longerons, skins and doors which enclose the gas generator and ducting, and a new upper deck structure is added beneath the gas generator and duct to separate the engine compartment from the cabin. Existing T-39 structure is shown in Figures 3.26 and 3.27. Some modification of the upper portions of the aft fuselage fuel cell bulkheads at stations 333.625 and 357 is required to provide clearance for the engine and duct installation. All of the added structural components will be of aluminum alloy with sufficient insulation of the adjacent hot ducting and compartment cooling provided to maintain structural temperatures within acceptable limits.

No changes are to be made in the basic structural attachment of the horizontal stabilizer to the fuselage. An interchangeable Series 75 90 ft^2 horizontal is used in lieu of the 75 ft^2 T-39A horizontal. The vertical stabilizer and rudder will be relocated upward approximately 30 inches above the existing T-39A configuration. Structural attachment of the vertical stabilizer rear spar to the fuselage will be provided by extension of the existing fuselage canted bulkhead at station 457.06 and the front spar attachment fitting will be tied to a new engine inlet frame located at station 443.5. The new fuselage skins and framing located in the vicinity of the engine inlet duct will be sized to provide conservative strength and stiffness margins for the extended vertical stabilizer configuration.

ALTITUDE 20,000 FT
WEIGHT 22,979 LB.
WING AREA 342 FT.^{2}

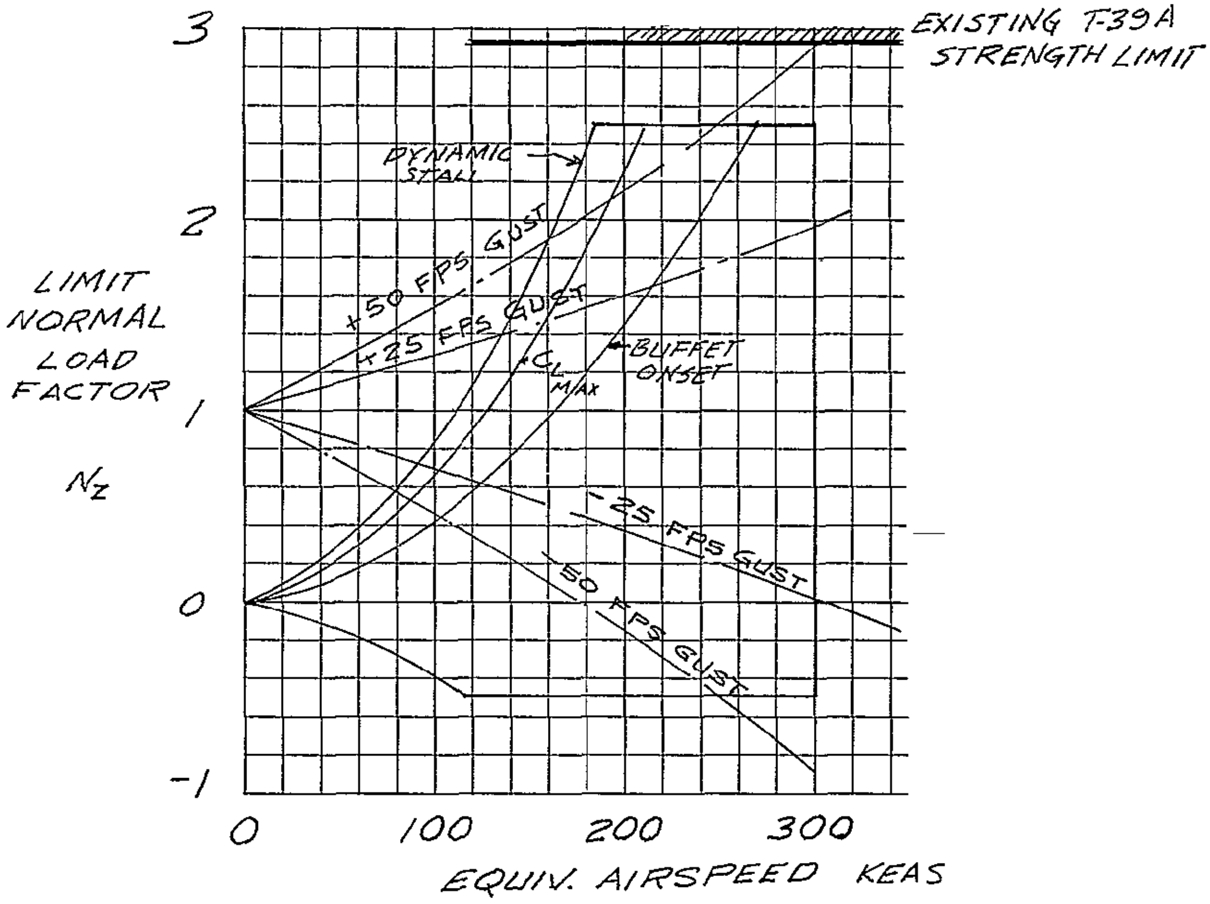

Figure 3.14 Speed-Load Factor Diagram

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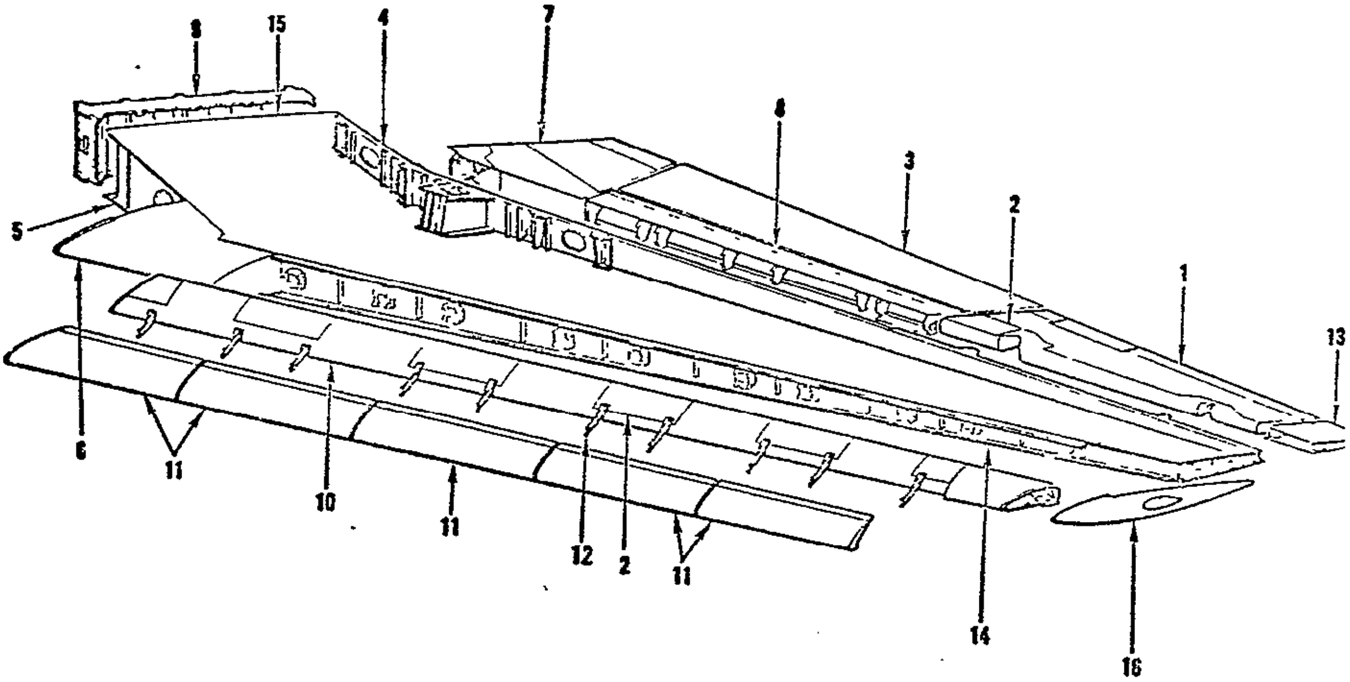

Nomenclature

Index No.	
1	AILERON (SEE FLIGHT CONTROL SYSTEM)
2	WING COVERS AND DOORS
3	WING FLAP (SEE FLIGHT CONTROL SYSTEM)
4	WING INBOARD AND OUTBOARD REAR SPAR
5	WING INBOARD FRONT SPAR
6	WING INBOARD LEADING EDGE SKIN ASSEMBLY
7	WING INBOARD TRAILING EDGE STRUCTURE ASSEMBLY
8	WING INTERMEDIATE TRAILING EDGE STRUCTURE ASSEMBLY
9	WING JOINT ASSEMBLY
10	WING LEADING EDGE INTERMEDIATE STRUCTURE ASSEMBLY
11	WING LEADING EDGE SLAT ASSEMBLIES
12	WING LEADING EDGE SLAT TRACKS
13	WING OUTBOARD TRAILING EDGE STRUCTURE ASSEMBLY
14	WING OUTBOARD FRONT SPAR
15	WING PANEL STRUCTURE
16	WING PANEL TIP ASSEMBLY

Figure 3.16 T-39A Wing Structure

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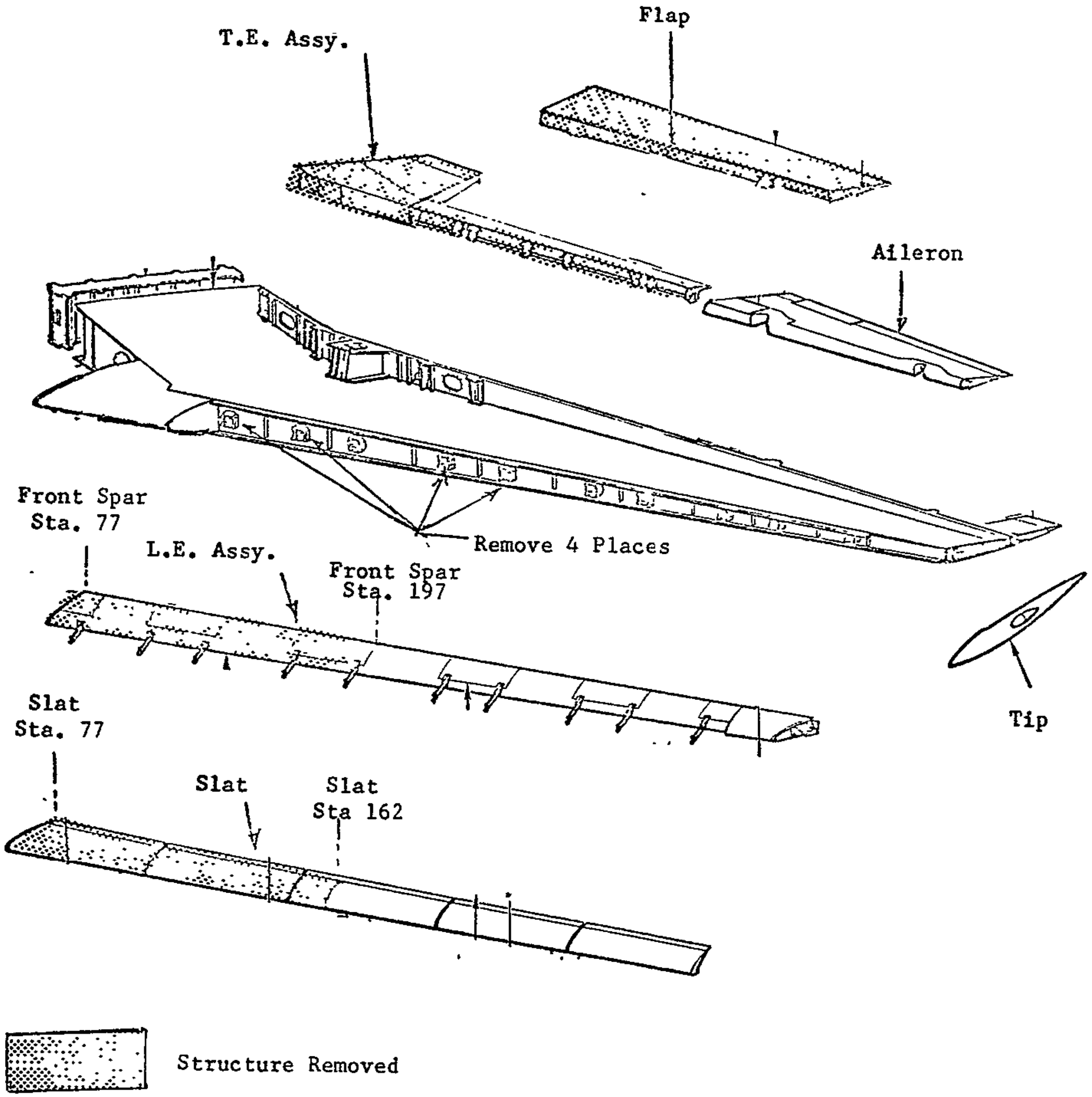

Figure 3.17 Wing Structure Deletions

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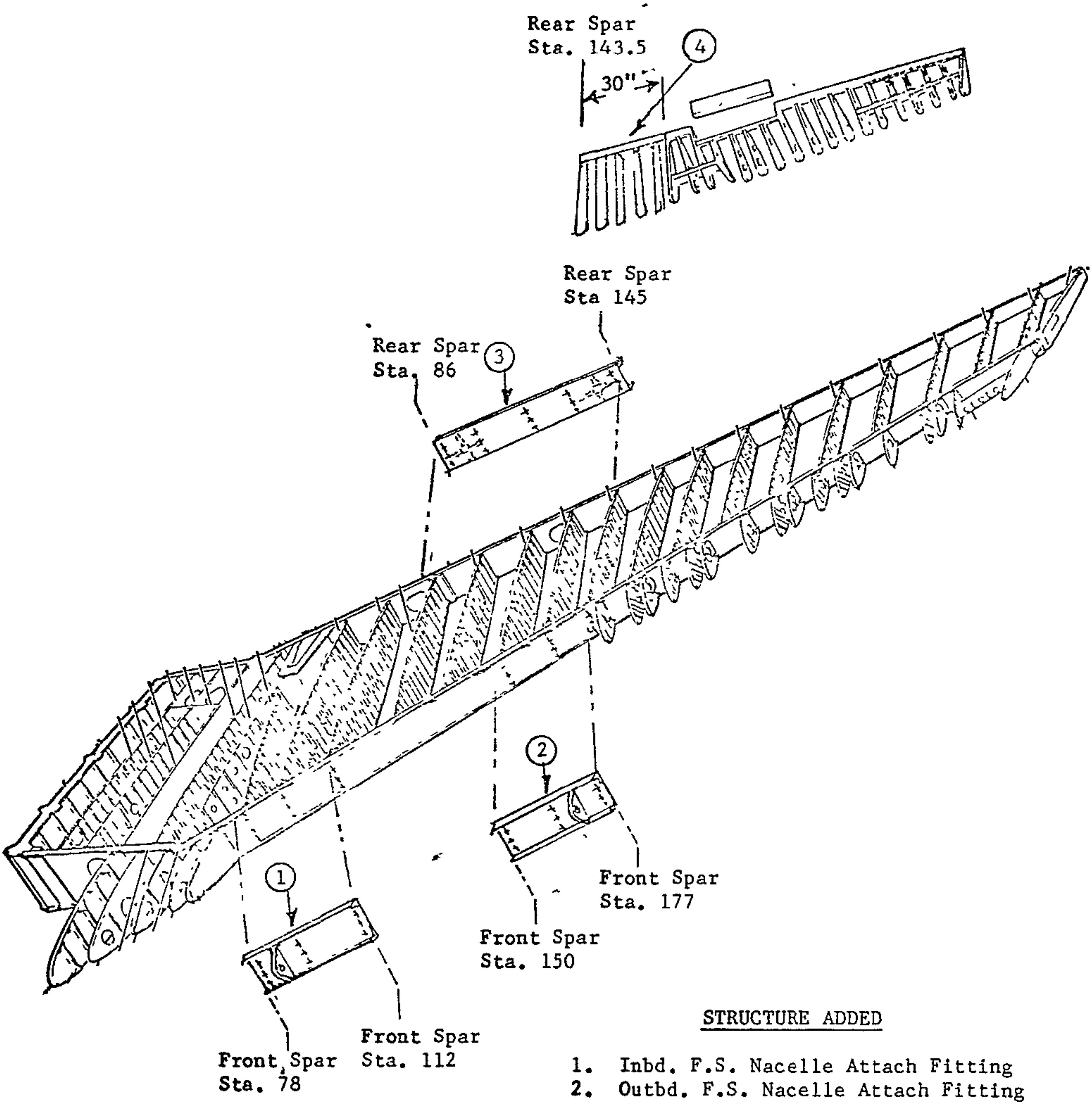

STRUCTURE ADDED

1. Inbd. F.S. Nacelle Attach Fitting
2. Outbd. F.S. Nacelle Attach Fitting
3. Rear Spar Nacelle Attach Fitting
4. Aileron Extension
5. Inbd. Trailing Edge Fairing

Figure 3.18 Wing Structure Additions

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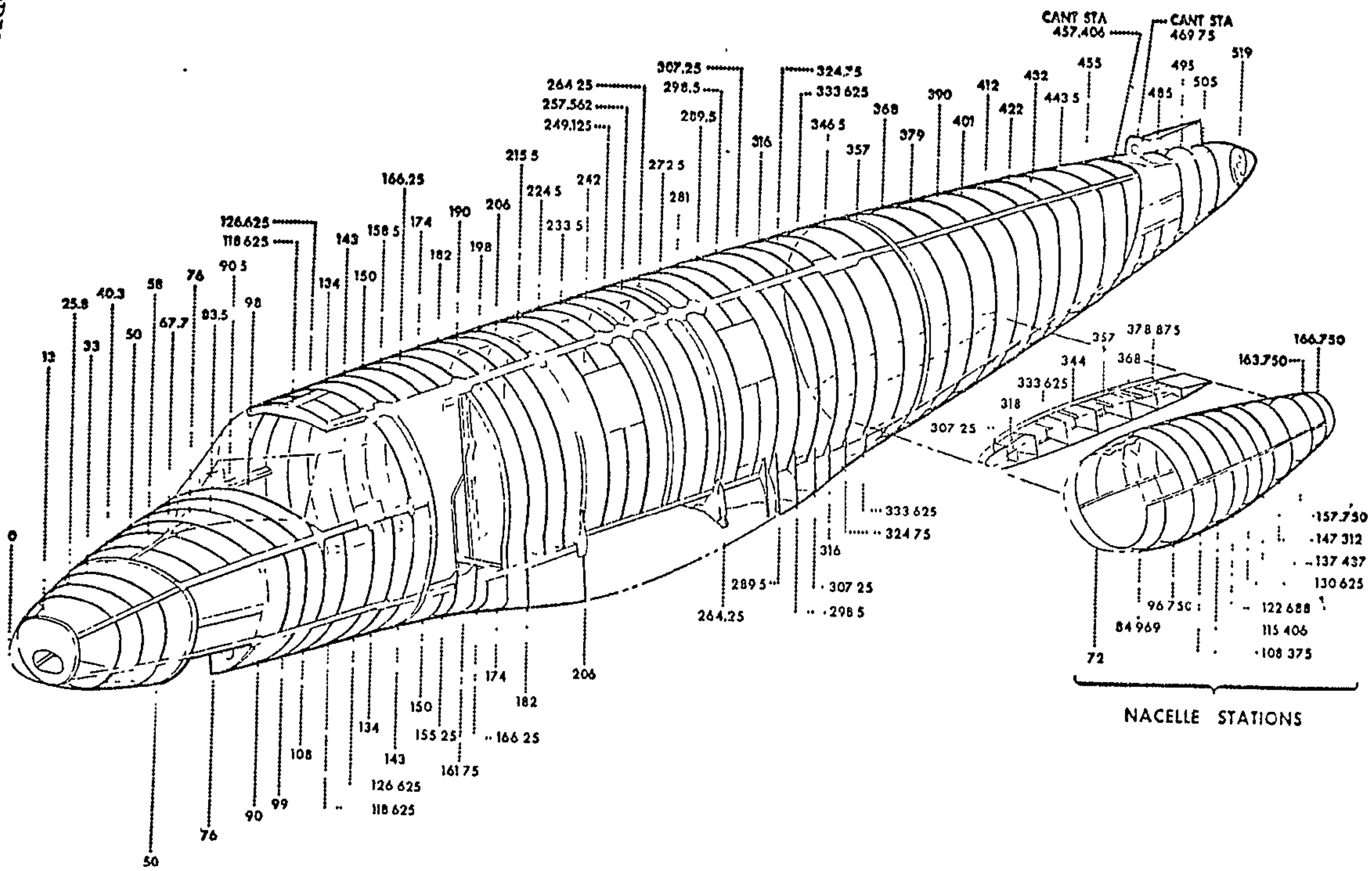

Figure 3.20 T-39A Fuselage Structure

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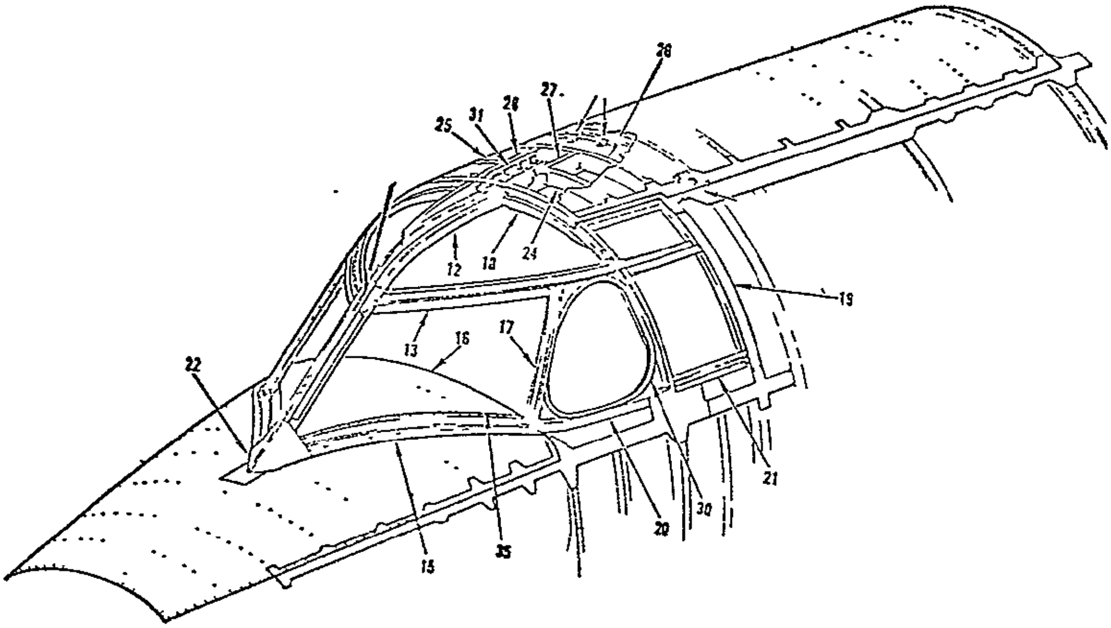

Figure 3.22 Cockpit Enclosure (T-39A)

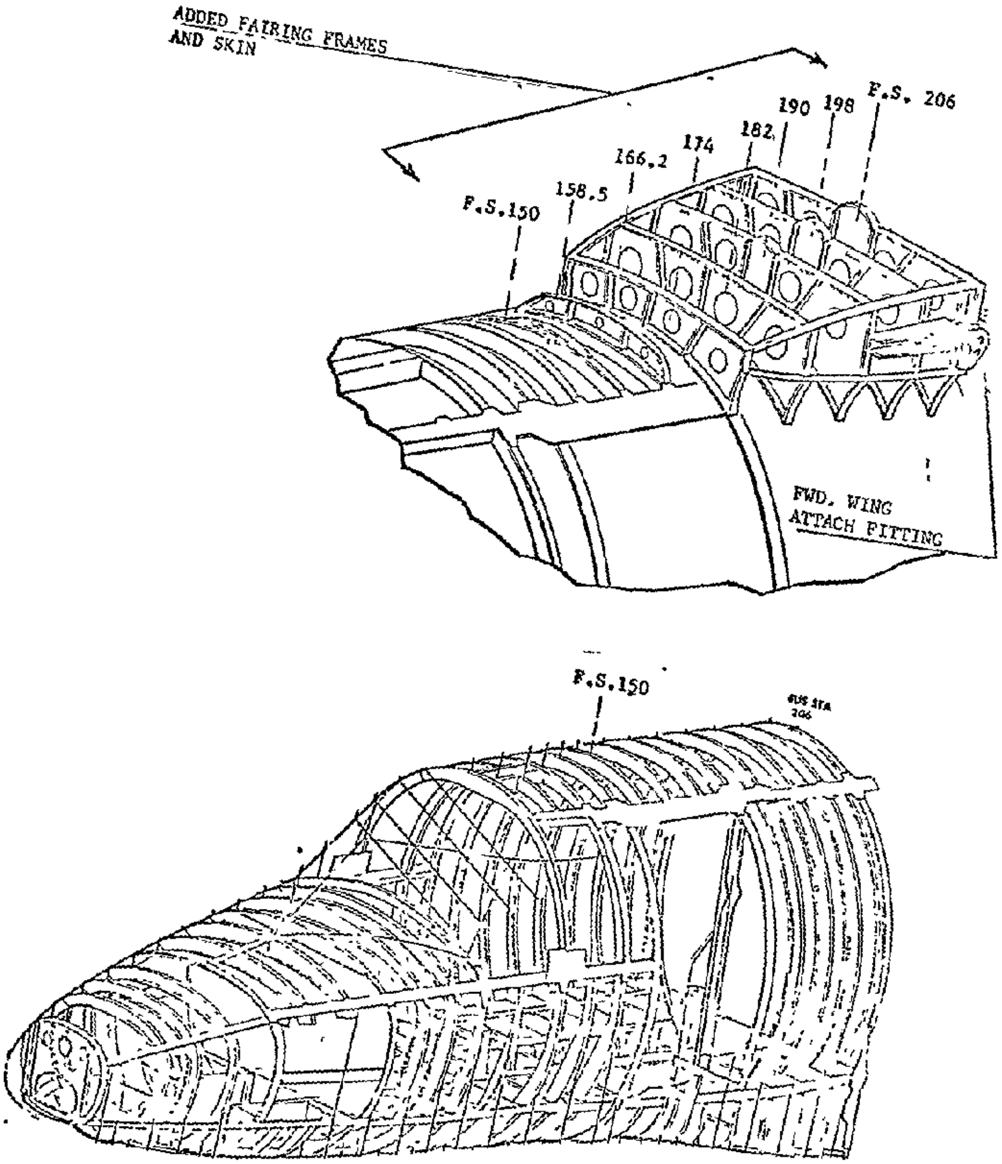

Figure 3.23 Fwd. Fuselage Wing Fairing Modification

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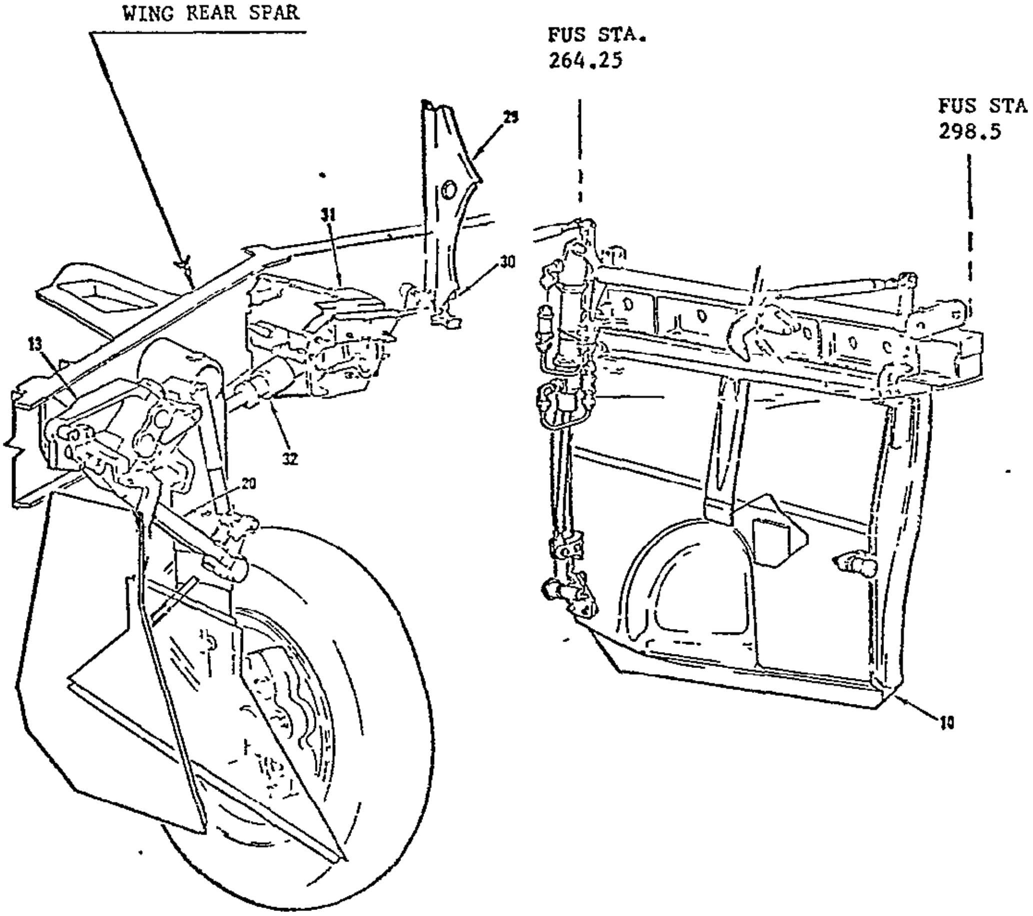

NOTE: For lift cruise fan modification; remove main gear, gear door, actuating mechanism and controls

Figure 3.24 T-39A Main Landing Gear Installation

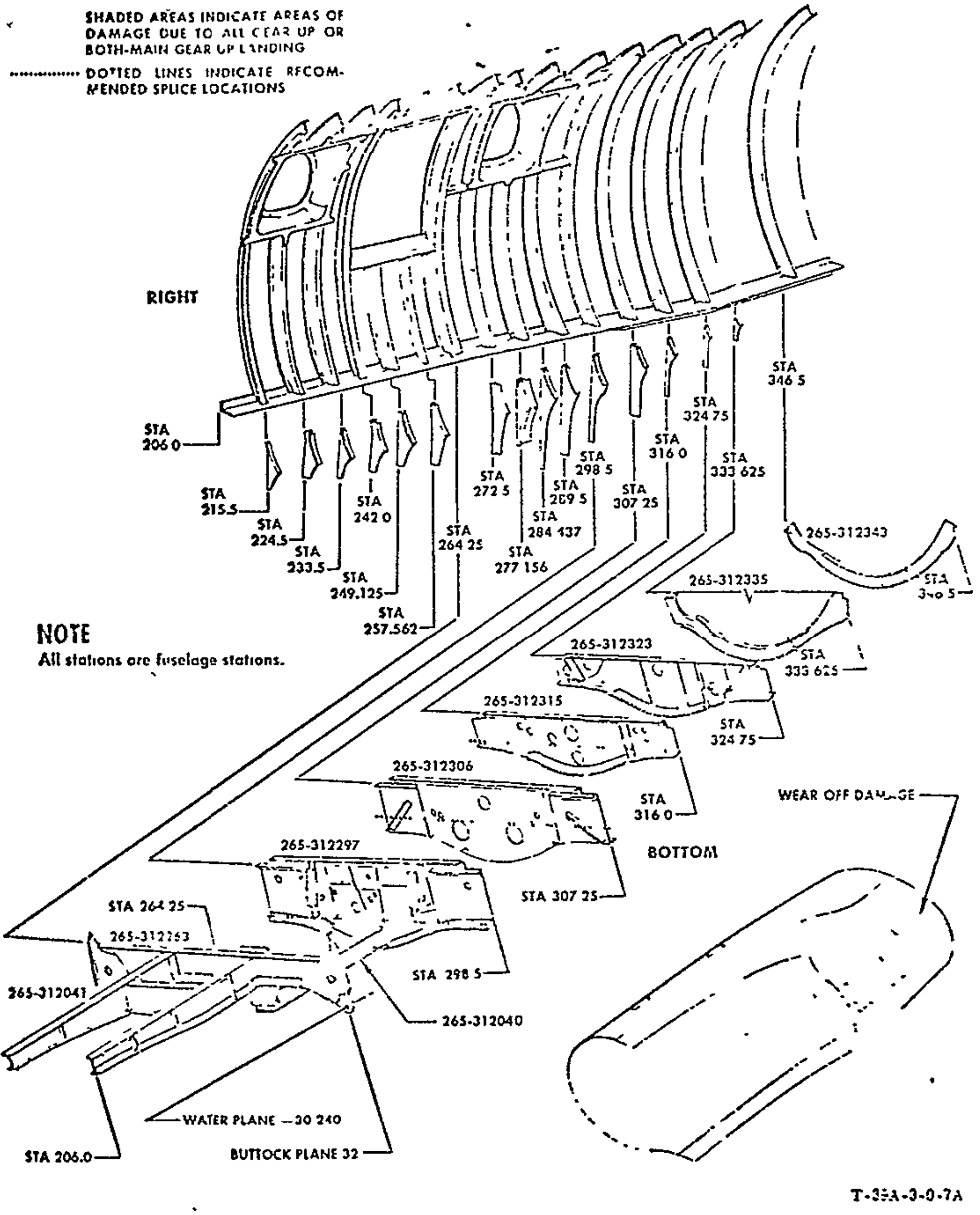

Figure 3.25 Lower Intermediate Fuselage Modification

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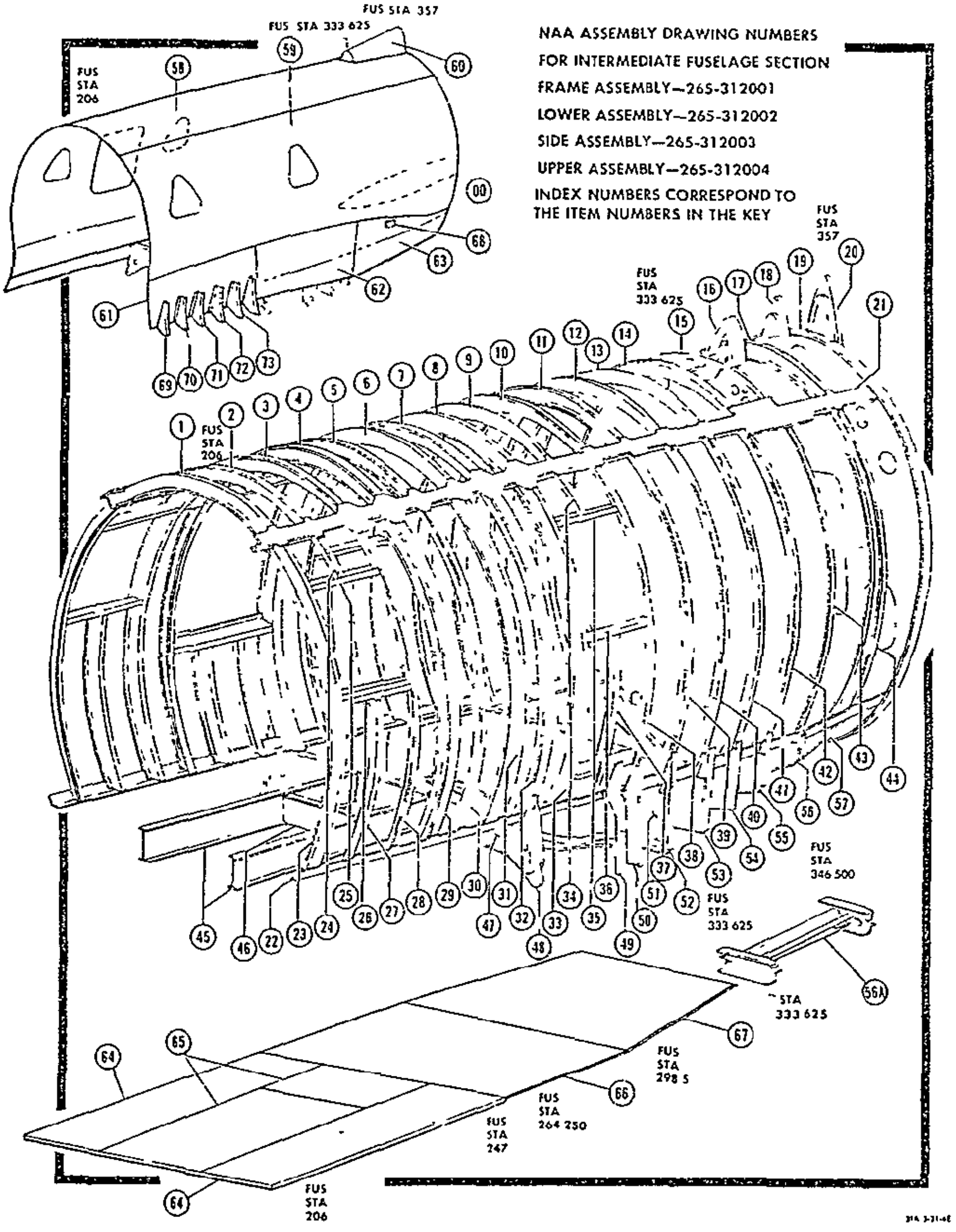

Figure 3.26 Upper Intermediate Fuselage (T-39A)

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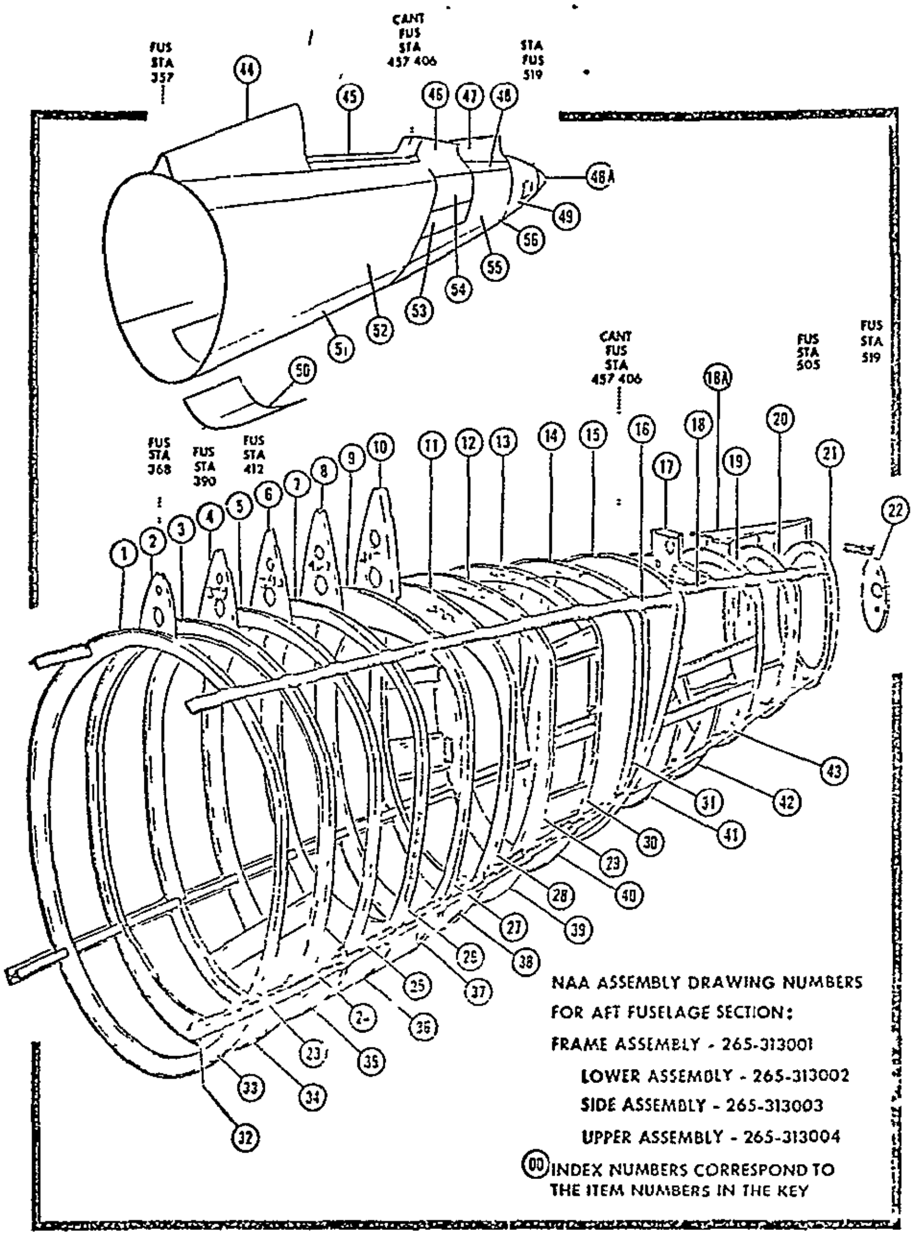

NAA ASSEMBLY DRAWING NUMBERS
FOR AFT FUSELAGE SECTION:
FRAME ASSEMBLY - 265-313001
LOWER ASSEMBLY - 265-313002
SIDE ASSEMBLY - 265-313003
UPPER ASSEMBLY - 265-313004
⓪⓪ INDEX NUMBERS CORRESPOND TO THE ITEM NUMBERS IN THE KEY

Figure 3.27 Upper Aft Fuselage (T-39A)

3.5 System Complement

3.5.1 Avionic System

The existing T-39A avionic suite will be reconfigured to remove equipments not required by the NASA research and technology program and to add equipments to support V/STOL flight operations. Existing T-39A equipments are used where possible to minimize cost but some equipments are replaced by lighter weight units to minimize weight.

Table V shows the recommended avionic suite to be installed in the modified T-39A aircraft together with a listing of the avionic equipments anticipated to be in the aircraft when received from the Air Force. The recommended system comprises minimum weight equipments and has been synthesized to accomplish the missions of the research and technology V/STOL aircraft, that is:

1. Takeoffs, VFR flight testing in the immediate vicinity of the test facility, and landings.
2. Cross country ferry flights from one test facility to another.

Voice communication is provided by installation of lightweight UHF and VHF radio units. These units will replace the existing ARC-34A UHF radio to achieve reduced weight and will permit voice communication with both military and civilian fields. The VHF unit will serve as a backup to the UHF radio and provides communication with civilian facilities during cross country ferry flights.

TACAN and IFF functions have been retained to support ferry flight operations; however, the existing T-39A equipments that accomplish these functions have been replaced with lightweight commercial units. The existing weather radar, although desirable for ferry flights, has been removed to minimize weight.

The existing T-39A Data Recorder is not considered necessary for the research and technology program and will be removed. The VOR/Localizer, glide path, marker beacon, and ADF equipments are also removed from the T-39A since the V/STOL test program will be conducted under VFR conditions.

A Low Airspeed Indicating System is added to provide low longitudinal and lateral air speed sensing and display. A lightweight radar altimeter and altitude rate adapter are added to provide display of height above terrain and vertical velocity. These equipments are of the type used on the XFV-12A V/STOL aircraft currently being designed and constructed for the Navy.

As is evident from Table V the avionic system is a minimum weight system providing basic communication, navigation (for ferry applications), and altitude/speed information necessary to support V/STOL research and technology flight testing.

Table V

AVIONIC SYSTEM CONFIGURATION FOR T-39A RESEARCH AND TECHNOLOGY V/STOL AIRCRAFT

Function	T-39A Avionics		Recommended T-39 V/STOL Avionics	
	Nomenclature	Weight	Nomenclature	Weight
UHF Communication	AN/ARC-34C	64.9	AN/ARC-159	10.5
TACAN	AN/ARC-21C	69.9	Collins TCN-40	14.0
IFF	AN/APX-46V	36.0	Collins TDR-90	4.5
Intercom	AN/AIC-10A	20.1	AN/AIC-10A (Mod)	14.0
Data Recorder Flight Director	-	23.0	-	-
Flight Director	-	49.6	Note 1	-
VOR/Localizer	51X-2B	32.5	-	-
Glidepath	51V-3	7.5	-	-
Magnetic Compass	332E-2	17.6	AN/ASN-75	10.6
Marker Beacon	51Z-3	4.1	-	-
ADF	AN/APN-59		-	-
Weather Radar	RDR-110	19.8	-	-
Low Airspeed Ind. System	-	-	Pacer/J-TEC	9.5
Radar Altimeter	-	-	AN/APN-194	7.6
Altitude Rate Adapter	-	-	Honeywell 10029940	2.0
VHF/AM Communication	-	-	Collins VHF-20B	5.0
	Uninstalled Weight	325.2		77.7

Note: 1. Course and Attitude Indicators retained as part of flight instruments complement

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3.5.2 Electrical System - The T-39 AC and DC electrical systems will be retained with the exception of the power source of the DC starter generators. The starter portion of the generator will not be used since the J-97 engine will be started pneumatically with an air turbine starter on the engine gearbox. The #1 and #2 DC generators will be attached to the left and right wing mounted fan gearboxes. Design requirements for the fan gearbox pad will be compatible with the existing DC generator requirements. The existing generator feeder lines will be replaced to accommodate the relocation of the generators. One of the two batteries will be retained as the electrical system filter and the emergency source of electrical power. Since engine start from battery power will not be accomplished, the second battery will be removed to minimize aircraft weight. The power distribution, circuit breaker, control and instrument panels will be modified as required to implement the changed configuration. A simplified schematic is shown in Figure 3.28.

The AC requirements of the modified T-39 are within the capability of the basic system. Alternating current is supplied by a DC powered main 3-phase, 1500-volt-ampere inverter and a DC-powered standby 3-phase 500-volt-ampere inverter. The two wild frequency engine driven AC generators for windshield heating were removed. External power can be supplied on the ground through the DC system.

Anti-icing systems for engines, fans, windshield and leading edge surfaces have been considered but will not be provided due to the Research and Development nature of the proposed program.

3.5.3 Environmental Control System - The T-39 environmental control system (ECS) will be retained with the exception of the bleed air supply ducting. The existing ECS utilizes an engine compressor bleed air powered simple air cycle refrigeration unit which includes an aluminum heat exchanger. Compressor bleed air pressure and temperature from the J-97 engine exceed the design limits of the refrigeration unit. An off-the-shelf precooler and pressure limiting valve will be selected to reduce bleed air pressure and temperature to levels compatible with existing ECS hardware. New ducting will be required to route the bleed air from each of the three engines to the existing refrigeration unit. The new ducting will perform a dual function by providing a cross-bleed engine air starting capability. This interface is shown on Figure 3.29.

Engine starting will be accomplished pneumatically with an air turbine starter (ATS) mounted directly on the gearbox of each J-97 engine. Air for ground starting power will be supplied from an external cart. The ground starting receptacle is located on the lower centerline beneath the fuselage mounted engine. Engine compressor bleed air ducting will be configured to route bleed air from any operating engine to the ATS for starting either of the remaining two (2) engines. Air starts of the engines require a starter boost unless the free stream mach is above 0.6, as indicated in Reference (k).

Pressurization of the T-39A followed the schedule shown in Figure 3.30. This schedule provides a comfortable environment for the cockpit and cabin area at almost a constant equivalent to 8000 feet altitude. As mentioned in the structural section, the cockpit area will be the only area pressurized. To relieve fuselage loads the recommended schedule will provide an 8,000 foot equivalent altitude to 24,000 feet and a 5 psi differential above 24,000. The aircraft is unpressurized to 8,000 feet.

3.5.4 Fuel System - The fuel system utilizes the existing T-39 fuel tankage with only those changes necessary to accommodate the third engine. The T-39 fuel tankage consists of the two integral wing tanks and a fuselage auxiliary fuel tank. The revised fuel system is depicted schematically in Figure 3.31.

The left and right integral wing tanks serve as feed tanks for the left and right engines, respectively, as on the T-39. Two electric boost pumps are added to the fuselage fuel tank and it becomes the engine feed tank for the aircraft's centerline mounted engine. The T-39 wing tanks cross-feed valve and the left and right engine supply cross-feed valve are retained. Valving provisions are added to permit cross-feeding of the centerline mounted engine. The resultant system permits any engine to be supplied from any tank by the selection of the appropriate cross-feed configuration.

The two pump configuration in the centerline engine feed tank assures fuel availability to the centerline engine with a single pump failure. With normal two pump operation the excess capacity is available to automatically supply either the left or right engine should either of the wing tanks' booster pumps fail. The placement of the left and right engines relative to the feed tanks permit satisfactory gravity fuel feed over a wide range of aircraft speed and altitude.

The venting system is modified to function properly with the changed tankage elevation relationships resulting from the high wing configuration. Each wing tank is vented to atmosphere through the wing tip by a line originating in the tank high point in the outboard portion of the wing. Fuselage tank climb and refueling vapor and air vent flow is conducted to the wing tanks and thence overboard through the wing tank's vent lines. The fuselage tank's existing syphon-break line is enlarged to assure adequate dive venting air flow during pump-down and high rate of descent.

3.5.5 Hydraulic Power System - The existing T-39 hydraulic utility system which provides pressure by an electric motor driven hydraulic pump will be retained for use in the operation of brakes and landing gear retraction. This existing hydraulic system shown in Figure 3.32 is a 3000 psi configuration utilizing standard type associated hardware such as pressure switches,

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shuttle valves, and check valves. Pump operation is controlled by DC essential bus power through a pressure switch such that any time system pressure drops below 2700 psi the pressure switch is closed and pump motor is energized. An auxiliary accumulator is available in this system which provides backup emergency operation for completion of a landing.

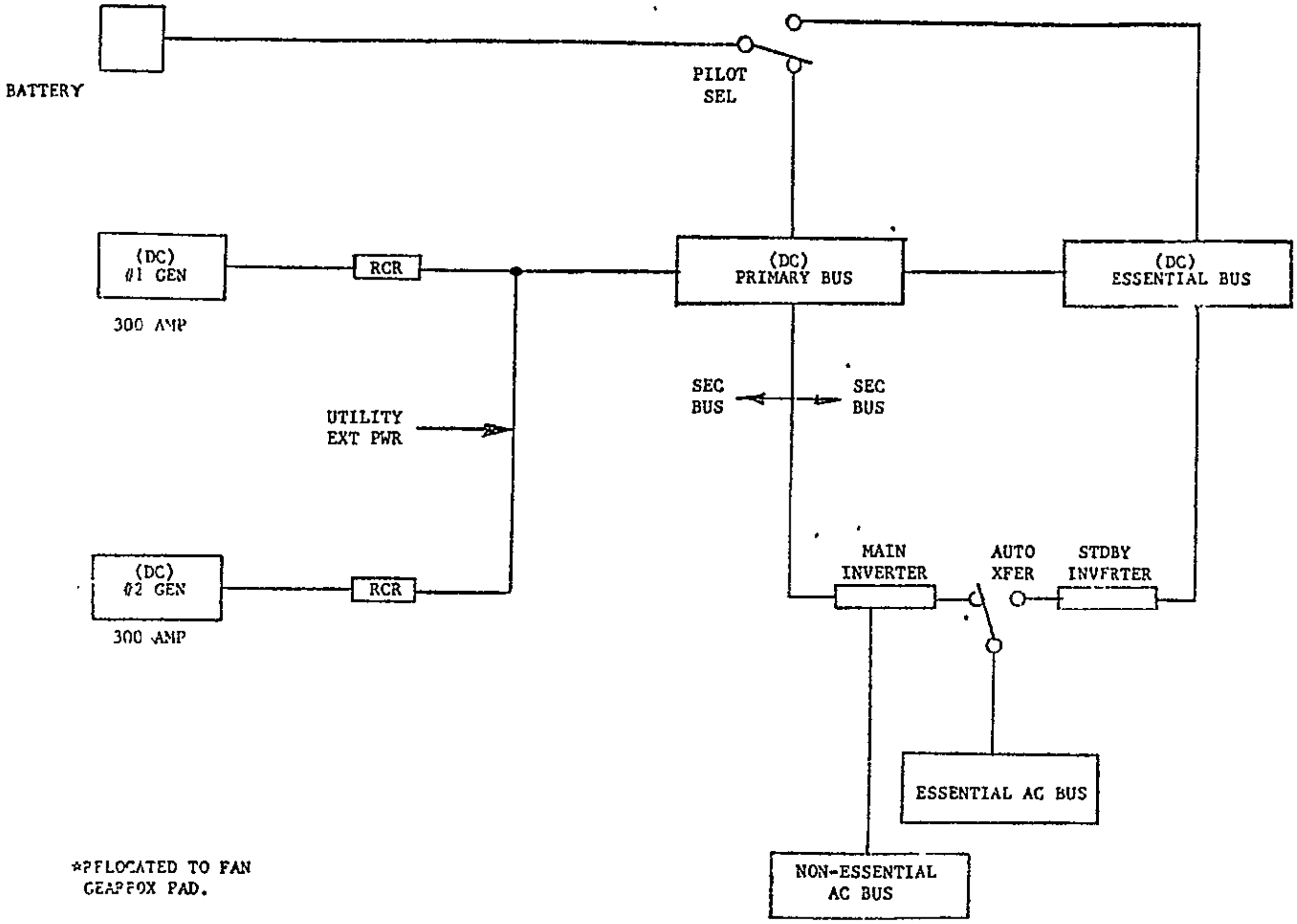
To this existing hydraulic system, modifications will be made to add two pumps, rated at 5 GPM, each one driven by one of the fans. This hydraulic system will be the prime system and used solely for flight controls, as shown in Figure 3.32. Dual line routing for redundancy will be incorporated to provide system reliability and fail safe operation. About 20 horsepower will be extracted from the pump to operate the five AFCAS type actuators.

3.5.6 Oxygen System - The existing oxygen system incorporated on the T-39 will remain as is. It is a gaseous oxygen system contained in a cylinder at 1800 PSI which is reduced to 350 PSI by a pressure reducer prior to cockpit entry. Individual demand-diluter regulators are located at the respective crewman's console. Sufficient on board oxygen exists to provide a five (5) hour supply when operated on the demand-diluter system with the aircraft under 15,000 feet, and cylinder pressure initially at 1800 PSI. Figure 3.33, a schematic of the system, shows the cabin accommodation deleted.

3.5.7 Fire Extinguishing and Detection System - The fire detection system will consist of a continuous element type alarm circuit in each of the three engine compartments to detect any engine fire or overheat condition. When an overheat condition exists a red fire warning light will come on. The existing indicating lights test circuit will be retained to monitor the overheat detection system for proper operation. Pilot selection and actuation of the fire 'T' handle will provide fire extinguishing agent to the selected engine compartment and the respective fuel shut-off valve will be closed. The existing pre-flight indication of the status of discharge of the extinguishing agent will be retained. The existing fire extinguishing system will require a three way selector valve and the necessary plumbing to each of the relocated engine compartments. See Figure 3.34.

A separate duct overheat detection system will be provided by a continuous element type alarm circuit surrounding exhaust gas ducting to detect air escaping from a ruptured duct or possible fire. The system warns of an overheat condition by turning on a caution-warning light on the instrument panel. An indicating lights test circuit will be installed to monitor proper operation of the detection system. This system is independent of the engine fire and overheat detection system.

The location of these systems and their envelopes are graphically shown on the Inboard Profile, Figure 3.35.



*RELOCATED TO FAN GEARBOX PAD.

Figure 3.28 Electrical Schematic

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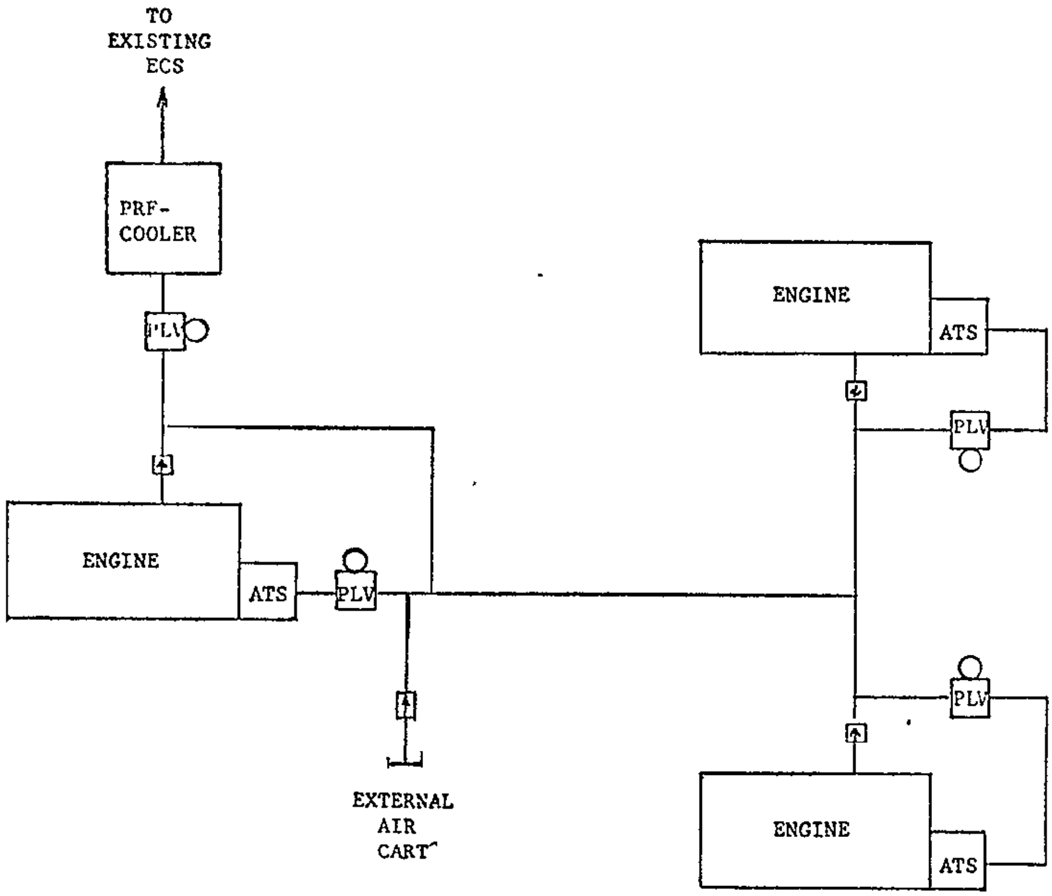

Figure 3.29 Environmental Control Schematic

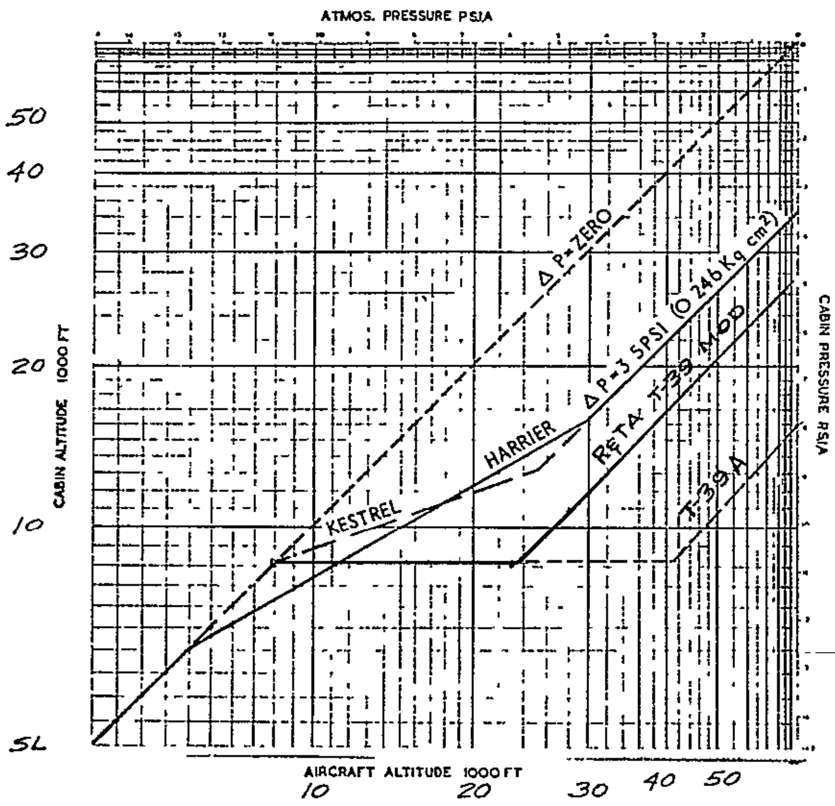

Figure 3.30. Pressurization Schedule Comparison

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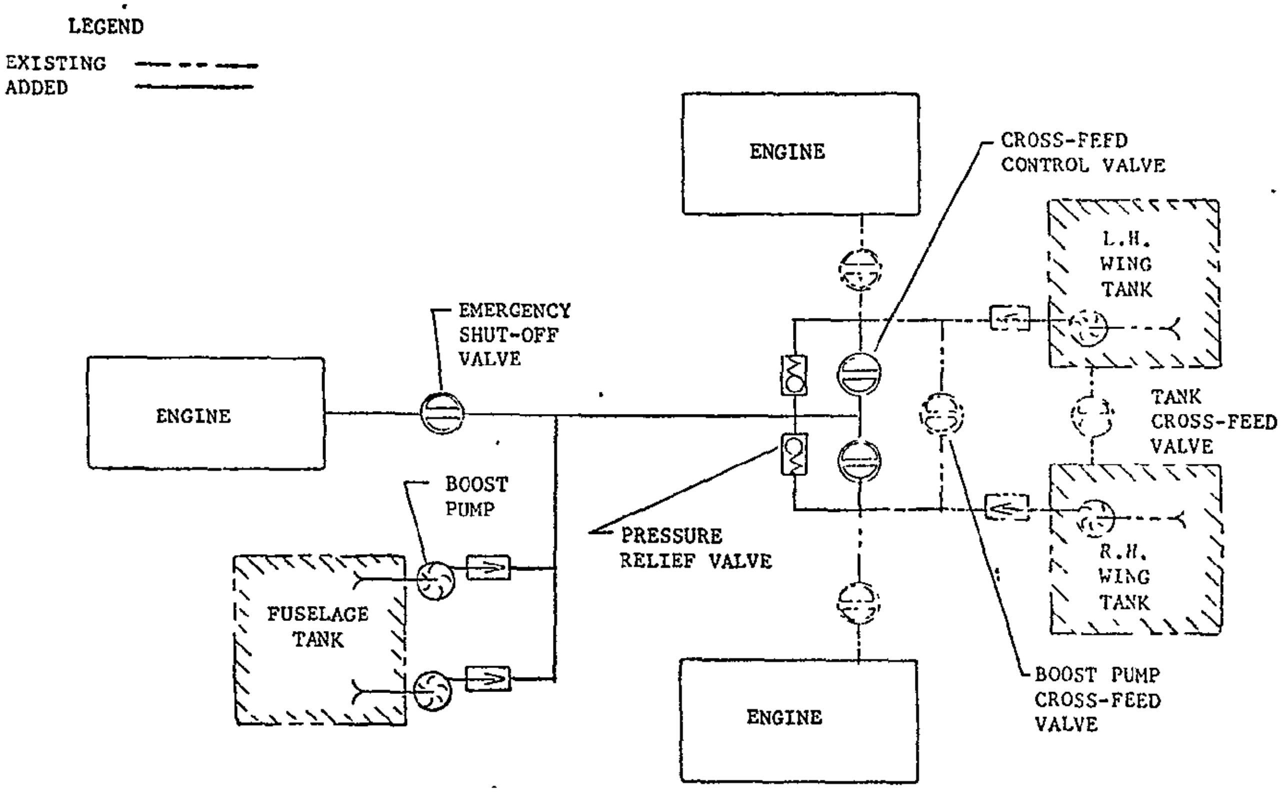

Figure 3.31 Fuel System Schematic

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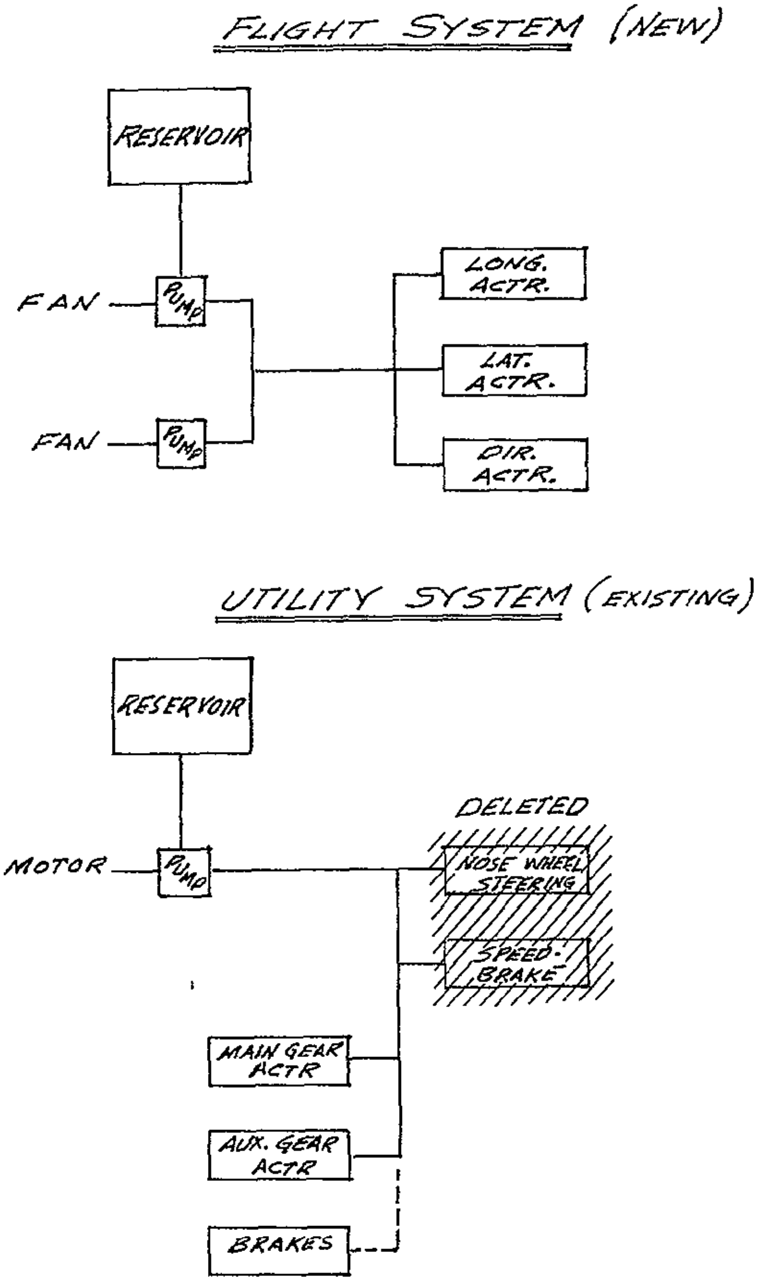
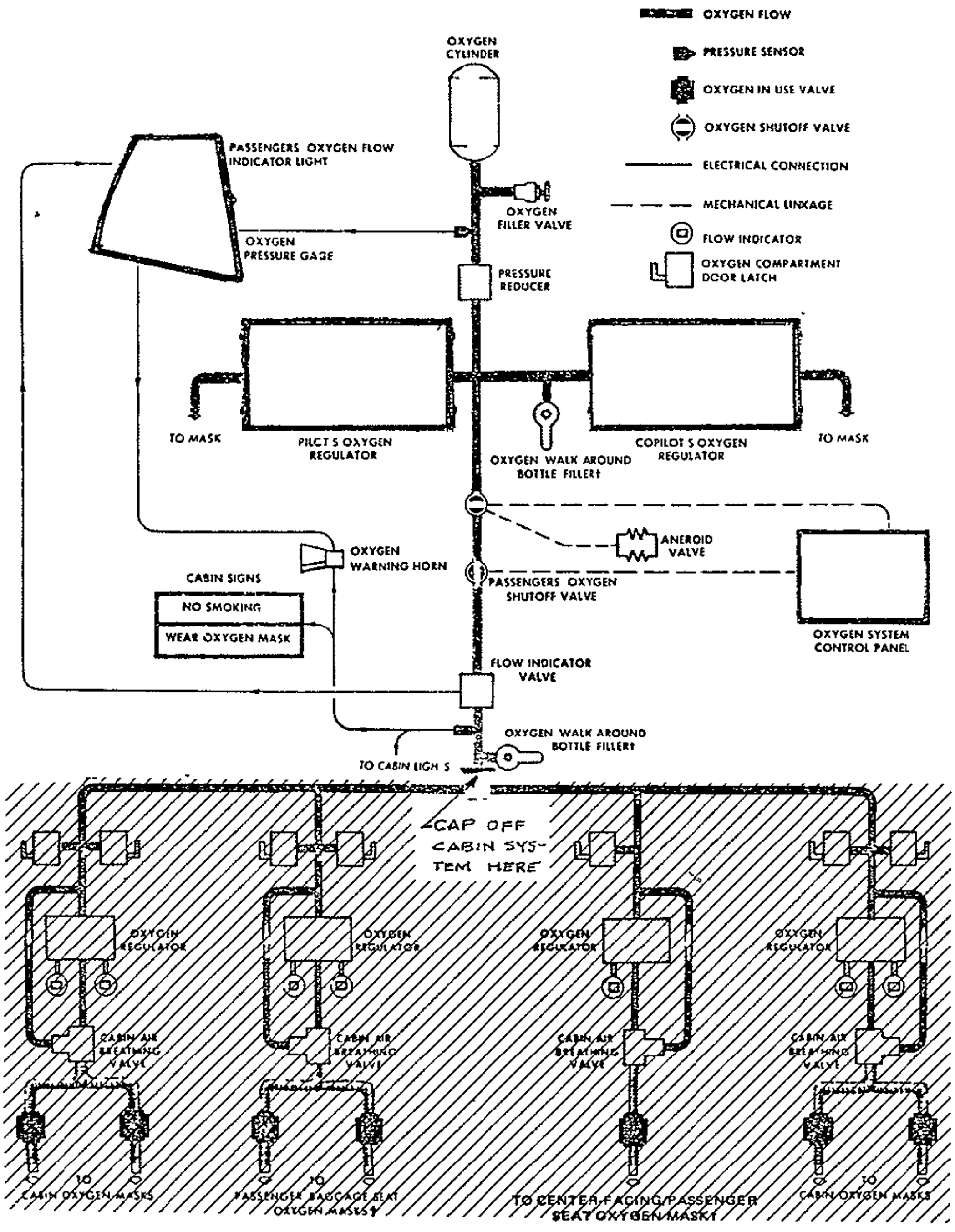


Figure 3.32 Hydraulic Systems Schematic



1 On some airplanes

Figure 3.33 Oxygen System

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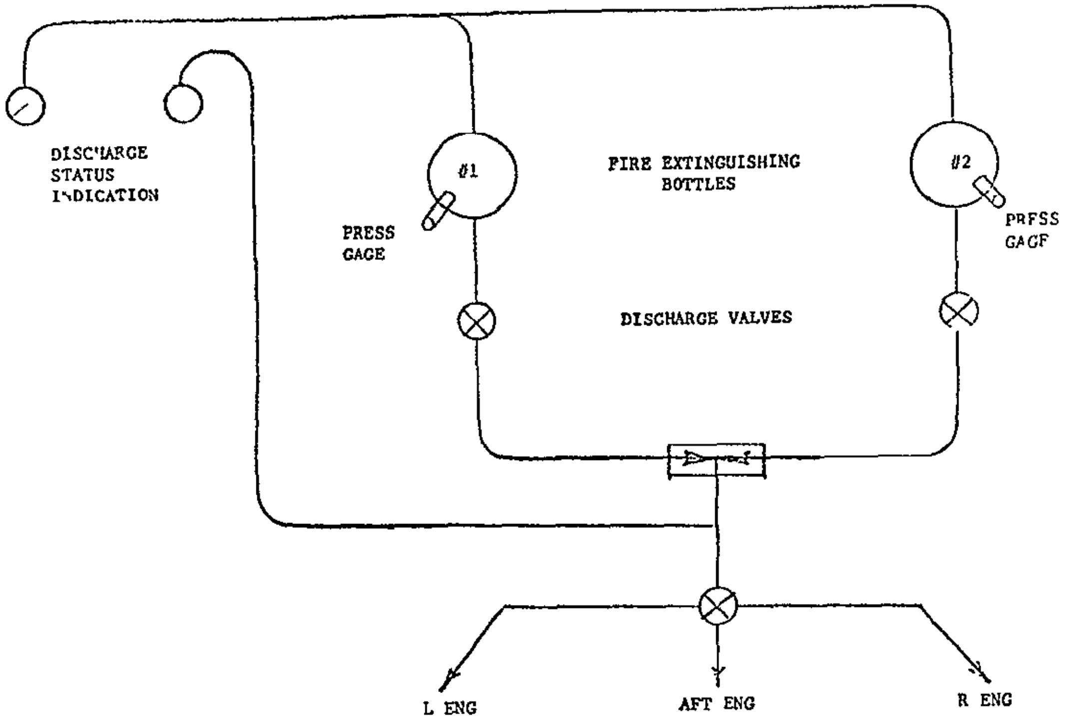

Figure 3.34 Engine Fire Extinguishing System

4.0 MASS PROPERTIES

The weight and balance has been estimated by changes over a T-39A to arrive at a T-39 lift cruise fan research aircraft. A comparison of the airplanes appears as Table VI, Weight Summary, which is in MIL-STD-1374 format.

4.1 Weight

4.1.1 Base Point

The T-39A base point is the actual weight report for the last article (#55) of the T-39A contract (NA63-1347, dated 30 October 1963).

4.1.2 Changes

The weight and balance effect of the various changes from a T-39A to a T-39 L/C research and technology aircraft have been estimated from design group descriptions and layouts. The calculations and data are presented for each of the functional groups in a MIL-STD-1374 Group Weight Statement.

4.1.3 Structure

Wing - The wing is one of the least affected components. Comparisons have been made of design loads for the T-39A and for the T-39 L/C. The most critical conditions for the T-39 L/C are the landing conditions at a landing design gross weight of 21910 pounds (TOGW of 25116# less 0.6 of 5343 lbs. fuel and water) and an operating sink speed of 12 feet per second. Both the wing to fuselage attachment loads and the wing loads at the side of the fuselage are basically within the design loads of the T-39A.

Therefore, the only changes envisioned to the wing are (1) removal of the flap and replacement with a fixed structure containing the cross-over hot gas ducting and (2) addition of attachment structure for the nacelles. The net increase to the wing is estimated to be $+\underline{\underline{80}}$ lbs.

Horizontal Tail - The horizontal tail area is increased from 77 to 90 square feet. The 2.86 PSF of the T-39A horizontal was used.

$$90 \times 2.86 = \underline{\underline{258}} \text{ lbs. for total horizontal}$$

Vertical Tail - The T-39A vertical tail was raised approximately 34 inches. The root chord was (and is) 95.69 inches.

$$\frac{95.69 \times 34}{144} = 22.6 \text{ Sq. Ft.}$$

Because part of the vertical addition will have to widen to accommodate the inlet for the aft gas generator. An increment of 3.45 PSF is used for the vertical. This should also furnish whatever stiffness may be required for flutter.

$$22.6 \times 3.45 = +\underline{\underline{78}} \text{ lbs.}$$

Fuselage - Although there will be considerable modification particularly to the upper fuselage, it is estimated the net addition of fuselage weight will be 207 pounds.

Landing Gear - The main landing gear strut and running gear will be replaced with A4 main gear mounted in the nacelle. The nose gear is replaced with a T2 nose gear. The wing skids are deleted. The net result is an addition of 268 pounds as shown below.

	Run. Gr.	Struct	Controls	Total
T-39A Main	179	148	140	467
T-39A Nose	30	68	49	147
T-39A Skid	-	15	-	15
Less	-209	-231		-440
Plus - A4 Main	199	381		+580
- T2 Nose	25	103		+128
T-39 L/C Main	199	381	140	720 lbs.
T-39 L/C Nose	25	103	49	177 lbs.

Nacelle - The area of each nacelle is 322 sq. ft. At 2.26 PSF, the nacelle weight would be

$$2.26 \times 322 \times 2 = 1453 \text{ lbs.}$$

The engine mounts are estimated at 10 lbs. for each gas generator and 20 lbs. for each fan.

$$10 \times 3 + 20 \times 2 = 70 \text{ lbs.}$$

Shrouds for the gas generators are estimated to be stainless steel of an average .045 thickness.

$$(3)\ 25\,D \times \pi \times 75\,L \times .045 \times .29 = 232 \text{ lbs.}$$

$$1453 + 70 + 232 = \underline{\underline{1755}} \text{ lbs.}$$

Air Induction - The inlets are estimated at 4.85 pounds per square foot and the ducts are estimated at 1.56 pounds per square foot.

$$\text{Inlets - Fan (2) } \frac{74 \times \pi \times 10 \times 4.85}{144} = 156 \text{ lbs.}$$

$$\text{- Nacelle Engines (2) } \frac{30 \times \pi \times 8}{144} \times 4.85 = 50 \text{ lbs.}$$

$$\text{- Aft Engine } \frac{35 \times \pi \times 20}{144} \times 4.85 = 74 \text{ lbs.}$$

Ducts - Fan (2) $\frac{62 \times \pi \times 20}{144} \times 1.56 = 84$ lbs.

- Nacelle (2) $\frac{20 \times \pi \times 13}{144} \times 1.56 = 18$ lbs.

- Aft $\frac{20 \times \pi \times 80}{144} \times 1.56 = \underline{54}$ lbs.

436

Assuming a 10% reduction for composites 436 x .9 = $\underline{392}$ lbs.

4.1.4 Propulsion

Engines - The gas generators weigh 740 pounds a piece and the fans weigh 850 pounds.

740 x 3 = 2220 lbs.
850 x 2 = $\underline{1700}$ lbs.
$\underline{\underline{3920}}$ lbs.

Exhaust - The exhaust system consists of the plenums (from the fans to the rotating nozzles), the nozzles including the yaw vanes and variable area for cruise. The temperature in the plenums and nozzles varies from 800°F to 170°F dependent upon location and nozzle position, horizontal or vertical. The material is titanium. The area of the plenum plus nozzle is 111.5 sq. ft. Allowance for an overlap of 18 inches at the bearing adds an additional 39.6 sq. ft. The added length to accommodate the vanes added 14.8 sq. ft. The total area is 165.9 sq. ft. Titanium at .070 thickness is 1.66 PSF.

165.9 x 1.66 x 2 = 551 lbs.

The centerbody area is 2872 sq. inches

2872 x .040 x 1.5 x 0.1 x 2 = 34 lbs.

The bearing is estimated at 2.85 sq. in. cross section in aluminum. The perimeter is 158.7 inches.

158.7 x 2.85 x .1 x 4 = 181 lbs.

The vanes are only in the outboard nozzles and are estimated to be 10.5" deep and 28" wide. This would give a wraparound area of 22 x 28 in. aluminum of .06 smeared thickness.

22 x 28 x .06 x .101 x 6 x 2 = 44 lbs.
Supports & Bearings 12 x 1 = $\underline{12}$ lbs.
56 lbs.

The actuation for vanes is in the surface controls group because they control yaw and roll.

The variable area nozzle outlet consists of two pieces of .06 titanium 42 inches long averaging 7 inches deep on all four nozzles.

42 x 7 x .06 x .165 x 2 x 4 = 23 lbs.
16 bearings @ 1 = 16 lbs.
Actuation & Linkage = 12 lbs. x 4 = 48 lbs.

The nozzle rotation is estimated at 20 lbs. per nozzle.

20 x 4 = 80 lbs.

Summary - Exhaust

Plenums & Nozzles	551
Centerbodies	34
Bearings	181
Vanes	56
Variable Area	87
Nozzle Rotation	80
	989 lbs.

<u>Cooling and Drains</u> - These are estimated at 10 pounds for each engine and fan

10 x 5 = <u>50</u> lbs.

<u>Engine Controls</u> - The T-39A controls are removed except for ignition and controls are added for the 3 gas generators and 2 fans. <u>50</u> lbs.

<u>Starting</u> - The T-39A circuitry (13 lbs.) is removed and the following is added.

Air Turbine Starters	12.5 x 3 =	37.5 lbs.
Valves	7.0 x 3 =	21.0
Lines - 2 x π x .020 x .29 = .036 lbs./Inch		
Nac. Engines to Fuse ℄	330	
Front Spar to Aft Engine	190	
	520	
520 inches x 1.15 = 598 x .036		21.6
Couplings .65# x 598/48		8.1
Supports .065# x 598/24		1.6
Bellows 1.4 x 598/60		14.0
Ext Fitting		1.5
Circuitry (21.7) + Controls (9)		30.7
		136 lbs.

One half the lines (23 lbs.) are removed and integrated with air conditioning system

136 lbs. - 23 = <u>113</u> lbs.

Lubrication - The oil tanks and lines are estimated at 5 lbs. per gas generator

5 x 3 = 15 lbs.

Fuel System - Two fuel pumps at 8 lbs. each and 19 lbs. for distribution are added to the T-39A system and the dump system at 10 lbs. is removed.

T-39A	195
Pumps	+16
Distribution	+19
Dump	-10
	220 lbs.

Hot Gas Ducting - The hot gas ducting is in 3 sizes: 18.5" coming off the gas generators, 16.8" for cross ducting and 11.25" for the pitch pipe. The temperature of 1400°F requires that .020 Rene 41 (or equivalent) be used. Thermo analysis indicates 1/4 inch Min K insulation will be sufficient to protect the structure from heat. The weight of couplings, flanges, valves, bellows, and tee ducts are estimated from data in General Electric Report R71-AEG325 dated 3 Nov. 1971. The pitch pipe nozzles are estimated at 40 lbs. each.

	Duct Size				
	11.25	16.8		18.5	
RENE 41 @ .045 (lbs/ft.)	5.69				
RENE 41 @ .02 (lbs/ft.)	2.54	3.80		4.18	
Insul/Ft @ .476 PSF	1.41	2.10		2.30	
Wt of Flange	1.17	1.7		1.9	
Wt of Coupling	2.25	3.5		3.9	
Wt of Elbow		17.5			
Wt of Coupling		3.5			
Wt of Insulation		4.6			
		Reg.	Thin	Reg.	Thin
Wt of Control Valve	19.0	34.4	28.5	40.0	33.1
Wt of Coupling	2.3	3.5	3.5	3.9	3.9
Actuation	5.0	5.0	5.0	5.0	5.0
Wt of Insulation	1.5	3.4	2.0	4.1	2.4
Wt of Tee Duct	17.0	31.0		39.0	
Wt of 2 Couplings	4.5	7.0		7.8	
Wt of Insulation	4.7	10.5		12.7	
Wt of Socket	23.4	38.4		44.0	
Wt of Coupling	2.3	3.5		3.9	
Wt of Insulation	2.0	4.3		5.3	
Wt of Bellows	22.8	29.7		33.3	
Wt of Coupling	2.3	3.5		3.9	
Wt of Insulation	2.0	2.7		3.1	

Based upon the above data, the weight of the fuselage components is estimated to be as shown below.

	Unit Wt	Quan	Total
(2) Nozzles for Pitch	40	2	80
(2) Ends .045, No Insul., 11.25 Diam			
210 - 12 x 5.69	99.6	1	205
Center Section .020 Insulated $\frac{312}{12} \times 2.54$	66.0		
4 Flanges + 2 Couplings	9.2		
Insulation (261/12) 1.41	30.7		
Tee Duct + 2 Couplings	21.5	1	22
Tee Duct Insulation	4.7	1	5
Duct 2.5 Ft + 2 Flange & Coupling	10.9	1	11
Duct Insulation	3.5	1	4
Bellows + Coupling	25.1	2	50
Insulation-Bellows & Socket	2.0	2	4
18.5" Tee Duct + 2 Couplings	46.8	1	47
Insulation-Tee Duct	12.7	1	13
18.5" Control Valve + Coupling	42.0	2	84
Insulation-Control Valve	4.1	2	8
18.5" Socket + Coupling	47.9	1	48
Insulation-Socket	5.3	1	5
Coupling & Flange	5.8	1	6
Total Fuselage			592

The weight of the wing components is as follows:

18.5" Tee Duct + 2 Couplings	46.8	1	47
Insulation-Tee Duct	12.7	1	13
16.8" Duct 6.25' Long + 2 Flanges + Coupling	30.7	2	62
Insulation	13.1	2	26
Socket + Coupling	41.9	4	168
Insulation	4.3	4	17
Elbow + Coupling	21.0	2	42
Insulation	4.6	2	9
Total Wing			384

The weight of nacelle components is as follows:

16.8" Control Valve + Coupling	37.0	1	37
Insulation	2.0	1	2
Tee Duct + 2 Couplings	38.0	2	76
Insulation	10.5	2	21
Control Valve + Coupling	42.9	2	86
Insulation	3.4	2	7
Bellows + Coupling	33.2	4	133
Insulation	2.7	4	11
Duct + 2 Flanges + Coupling 2.5'	16.4	2	33
Insulation	5.3	2	11
Elbow + Coupling	21.0	2	42
Insulation	4.6	2	9
Control Valve + Coupling	42.9	2	86
Insulation	3.4	2	7
Socket + Coupling	41.9	2	84
Insulation	4.3	2	9
Coupling	3.5	2	7
			661
Total			1637

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On the basis of information from a vendor which indicated a weight 5% under 1637 pounds, a 2.6% reduction was made in hot gas ducting to 1595 lbs.

Water Injection - The engine mounted components are included in the engine weight. In addition, a 19 gallon capacity tank is estimated at 11 lbs. since the requirement is for 2.52 lbs. per second x 30 seconds x 2 engines (required for one engine out only). The pump is estimated at 28 lbs. and solenoid valves (3) at 2 lbs. each. The plumbing is estimated to be 150 inches of 1.0 O.D. steel at 0.0301 lbs/inch and 400 inches of 3/4 O.D. at 0.0223 lbs/inch. The factor for fittings is 1.0 x line weight. The estimate for electrical circuitry is 5 lbs.

Summary

19 Gallon Tank	11	lbs.
Pump	28	lbs.
(3) Solenoid Valves	6	lbs.
Plumbing	27	lbs.
Circuitry	5	lbs.
	77	lbs.

4.1.5 Fixed Equipment

Flight Controls

	T39A	Delete	Add	T39 L/C
Cockpit	88	-69	+35	54
Aileron	41			41
Elevator	90			90
Rudder	23			23
T.E. Flaps	23	-23		--
Speed Brakes	28	-28		--
Stab. Adj.	33			33
Computer Install			+41	41
Long. Mech.			+49	49
Lateral Mech.			+31	31
Yaw			+26	26
Total (lbs.)	326	-120	+182	388

Cockpit - The control columns are removed and two control sticks plus interconnect are added based upon T-2 and OV-10 data.

Trailing edge flaps and speed brake controls are removed.

Computer Installation

Computer (3) @ 3 lbs.	9 lbs.
Rate Gyros (9) @ 1 lbs.	9 lbs.

4.1.5 Fixed Equipment (cont'd)

Flight Controls

Computer Installation (cont'd)

Position Sensor - Stick (6) @ 1 lb.	6 lbs.
- Pedals (3) @ 1 lb.	3 lbs.
- L/C Nozzle (2) @ 1 lb.	2 lbs.
- Scroll Valve (2) @ 1 lb.	2 lbs.
Supports & Circuitry	10 lbs.
Total	41 lbs.

Longitudinal

Hydraulic Actuator (5 lbs) + Motor (3 lbs)	8 lbs.
Mechanical (Equivalent of Aileron)	41 lbs.
	49 lbs.

Lateral

Feel Bungee	5 lbs.
Hyd Actuators (2) @ 5 lbs + (2) Motors @ 3 lbs.	16 lbs.
Circuitry	3 lbs.
Plumbing	4 lbs.
Linkage	3 lbs.
	31 lbs.

Yaw

Hyd Actuators (2) @ 5 lbs. + (2) Motors @ 3 lbs.	16 lbs.
Circuitry	3 lbs.
Plumbing	4 lbs.
Linkage	3 lbs.
	26 lbs.

Instruments

Added Engine Instruments	+10 lbs.
Added Circuitry	+ 4 lbs.
	+14 lbs.

Hydraulic & Pneumatic - T39A hydraulic system weighs 145 pounds. It is estimated that 51 pounds of plumbing and circuitry will have to be rerouted. In addition, (2) 5 gallon per minute hydraulic pumps will be added to actuate T39 L/C hydraulic actuators. The pumps and circuitry will weigh about 20 pounds.

$$145 - 51 + 51 + 20 = 165 \text{ lbs.}$$

Electrical - The wild frequency generators (75 lbs.) which supply power for windshield deice and one of the two batteries (53 lbs. + 4 lbs. installation) removed.

$$924 - (75 + 57) = 792 \text{ lbs.}$$

Avionics - All the T39A avionics are removed and replaced with 78 pounds of black boxes and 22 pounds of installation.

464 - 464 + (78 + 22) = 100 lbs.

Furnishings - The following items are removed from the T39A.

T39A Furnishings		877 lbs.
Less:	Pilot & Co-Pilot Seats	-86
	Passenger Seats	-92
	Hear Rest	- 4
	Relief Tubes	- 4
	Passenger Oxygen	-10
	Portable Oxygen	- 8
	Windshield Wiper	-12
	Consoles	-81
	Control Stands	- 9
	Furnishings	-392
	Remove Fire Ext. (Partial)	-27
		152 lbs.

The items added are as follows

Plus	(2) Fire Ext in Nacelles	+54 lbs.
	Added Fire Detect	+ 8
	(2) Ejection Seats	+280
T39 L/C		494 lbs.

Air Conditioning - The following changes are made to the T39A-System

T39A		333 lbs.
Less:	Air Induct Anti-Icing	-23
	Bleed Lines (Partial)	- 5
Plus:	Pre Cooler (11	+18
	Prov for Pre Cooler	+ 8
	Eng Bleed Line, Bellows, etc.	+46
T39 L/C		377 lbs.

4.2 Center of Gravity and Inertia

The take-off gross weight c.g. is at 17.5 percent MAC with inertia values as shown below and in Figure 4.1 along with data for a condition with fuselage fuel only remaining.

		C.G.		(Slug Feet^2)	
Condition	Weight	(% MAC)	Pitch	Roll	Yaw
TOGW	(25,116)	17.5	35,400	27,400	68,800
Fuse. Fuel Only	(20,659)	16.4	34,800	27,200	58,900

The changes in DCPR weight (AMPR weight) are shown in Table VII.

A summary of weights for all the various aircraft, mission and structural conditions discussed in various portions of this report are tabulated in Table VIII. This list notes the fuel and payload on board.

TABLE VI

COMPARISON T39A VS T39 L/C

WEIGHT SUMMARY

MIL-STD 1374

	T39A	Less	Plus	T-39 LC Lbs	T-39 LC Kg	
TOTAL STRUCTURE	(4753)	(-1234)	(+3680)	(7199)	3265.39	
WING GROUP	1661	-94	+174	1741	789 70	
TAIL GROUP-HORIZONTAL	220	-150	+188	258	117 03	
-VERTICAL	91		+78	169	76 66	
BODY GROUP	1780	-178	+385	1987	901.28	
ALIGHTING GEAR GROUP--MAIN	467	-327	+580	720	326.58	
-NOSE	147	-98	+128	177	80.29	
-~~ARREST~~SKIDS	15	-15		-		
ENGINE SECTION OR NACELLE GROUP	343	-343	+1755	1755	796.05	
AIR INDUCTION SYSTEM	29	-29	+392	392	177 81	
PROPULSION GROUP	(1272)	(-1058)	(+6815)	(7029)	3188.28	
ENGINE (AS INSTALLED)	980	-980	+3920	3920	1778.07	
GEAR BOXES AND DRIVES						
EXHAUST SYSTEM	28	-28	+989	989	448.60	
COOLING AND DRAIN PROVISIONS	16	-16	+50	50	22.68	
ENGINE CONTROLS	30	-20	+40	50	22.68	
STARTING SYSTEM	22	-13	+104	113	51 26	
LUBRICATING SYSTEM	1	-1	+15	15	6 80	
FUEL SYSTEM	195		+25	220	99.79	
THRUST DIVERTER						
THRUST TRANSFER	-		+1595	1595	723.48	
WATER INJECTION SYSTEM	-		+77	77	34 93	
FIXED EQUIPMENT	(3238)	(-1720)	(+981)	(2499)	1133.52	
FLIGHT CONTROLS GROUP	326	-120	+182	388	175.99	
INSTRUMENT GROUP	166		+14	180	81 65	
HYDRAULIC AND PNEUMATIC GROUP	145	-51	+71	165	74.84	
ELECTRICAL GROUP	924	-332	+200	792	359.24	
AVIONICS GROUP	464	-464	+100	100	45.36	
ARMAMENT GROUP						
FURNISHINGS GROUP	877	-725	+342	494	224.07	
AIR CONDITIONING GROUP	333	-28	+72	377	171.00	
HANDLING GROUP	3			3	1.36	
TOTAL WEIGHT EMPTY	9263	-4012	+11476	16727	7587 20	
CREW	(340)			(340)	154 22	
FUEL	(5988)			(5363)	2432 60	
UNUSABLE	170			170	77.11	
WING	5818			4307	1953 61	
FUSELAGE	-			886	401.88	
WATER INJECTION	-			(150)	68.04	
OIL	(24)			(36)	16.33	
ARMAMENT						
PASSENGERS	(680)			-		
BAGGAGE	(420)			-		
PAYLOAD	-			(2500)	1133 98	
EQUIPMENT						
TOTAL USEFUL LOAD	7452			8389	3805.17	
TAKE-OFF GROSS WEIGHT	16715			25116	11392.37	
FLIGHT DESIGN GROSS WEIGHT	16527					
LANDING DESIGN GROSS WEIGHT	13000					

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TABLE VII

COMPARISON - DCPR WEIGHT

WEIGHT SUMMARY

MIL STD 1374

	DCPR T-39A	Less	Plus	T-39 LC Lbs	T-39 LC Kg	
TOTAL STRUCTURE	(4544)	(-1024)	(3445)	(6965)	3159.25	
WING GROUP	1661	-94	+174	1741	789.70	
TAIL GROUP-HORIZONTAL	220	-150	+188	258	117.03	
-VERTICAL	91		+78	169	76.66	
BODY GROUP	1780	-178	+385	1987	901.28	
ALIGHTING GEAR GROUP-MAIN	288	-147	+380	521	236.32	
-NOSE	117	-68	+93	142	64.41	
-ARRESTSKIDS	15	-15			796.05	
ENGINE SECTION OR NACELLE GROUP	343	-343	+1755	1755	177.81	
AIR INDUCTION SYSTEM	29	-29	+392	392	1379.37	
PROPULSION GROUP	(262)	(-78)	(2857)	(3041)	448.60	
ENGINE (AS INSTALLED)						
GEAR BOXES AND DRIVES						
EXHAUST SYSTEM	28	-28	+989	989	22.68	
COOLING AND DRAIN PROVISIONS	16	-16	+50	50	22.68	
ENGINE CONTROLS	30	-20	+40	50	34.02	
STARTING SYSTEM	22	-13	+66	75	6.80	
LUBRICATING SYSTEM	1	-1	+15	15	86.18	
FUEL SYSTEM	165		+25	190	723.48	
THRUST DIVERTER						
THRUST TRANSFER	-		+1595	1595	34.93	
WATER INJECTION SYSTEM			+77	77	917.16	
FIXED EQUIPMENT	(2043)	(-1255)	(+874)	(2022)	175.99	
FLIGHT CONTROLS GROUP	326	-120	+182	388	36.74	
INSTRUMENT GROUP	77		+4	81	74.84	
HYDRAULIC AND PNEUMATIC GROUP	145	-51	+71	165	248.11	
ELECTRICAL GROUP	547	-200	+200	547	9.98	
AVIONICS GROUP	139	-139	+22	22	224.07	
ARMAMENT GROUP						
FURNISHINGS GROUP	877	-725	+342	494	146.06	
AIR CONDITIONING GROUP	289	-20	+53	322	1.36	
HANDLING GROUP	3			3	5455.78	
TOTAL WEIGHT EMPTY	7209	-2357	+7176	12028		
CREW						
FUEL						
UNUSABLE						
OIL						
ARMAMENT						
EQUIPMENT						
TOTAL USEFUL LOAD						
TAKE-OFF GROSS WEIGHT						
FLIGHT DESIGN GROSS WEIGHT						
LANDING DESIGN GROSS WEIGHT						

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Table VIII

Research and Technology Aircraft
T-39 Modification

Weights for Basic Configurations

	TOGW Kg (lbs)	Fuel Kg (lbs)
Maximum TOGW Full Fuel	12,009 (26,477)	3041 (6704)
Maximum TOGW No Fuel Outer Section	11,447 (25,237)	2478 (5464)
STOL Mission (11 Circuits)	11,392 (25,116)	2423 (5343)
Cruise Mission (2 Hours Aloft)	11,258 (24,820)	2289 (5047)
VTOL Mission (5 Circuits)	10,600 (23,370)	1631 (3597)
VTOL Lift Off (5 Circuits)	10,393 (22,913)	1424 (3140)
VTOL (Fuel for 2 Circuits)	9,584 (21,130)	615 (1357)
VTOL with Reserve Remaining	9,372 (20,663)	403 (890)
STOL with Reserve Remaining	9,189 (20,259)	220 (486)
Operating Weight Empty	8,968 (19,773)	-
OWE with No Payload	7,834 (17,273)	-
Empty Weight with No Payload	7,587 (16,727)	-
Flight Design (60% STOL Fuel Remaining)	10,423 (22,979)	1454 (3206)
Landing Design (40% STOL Fuel Remaining) 952 Kg Payload	9,938 (21,910)	969 (2137)

All configurations have 1134 Kg (2500 lbs.) payload unless noted.

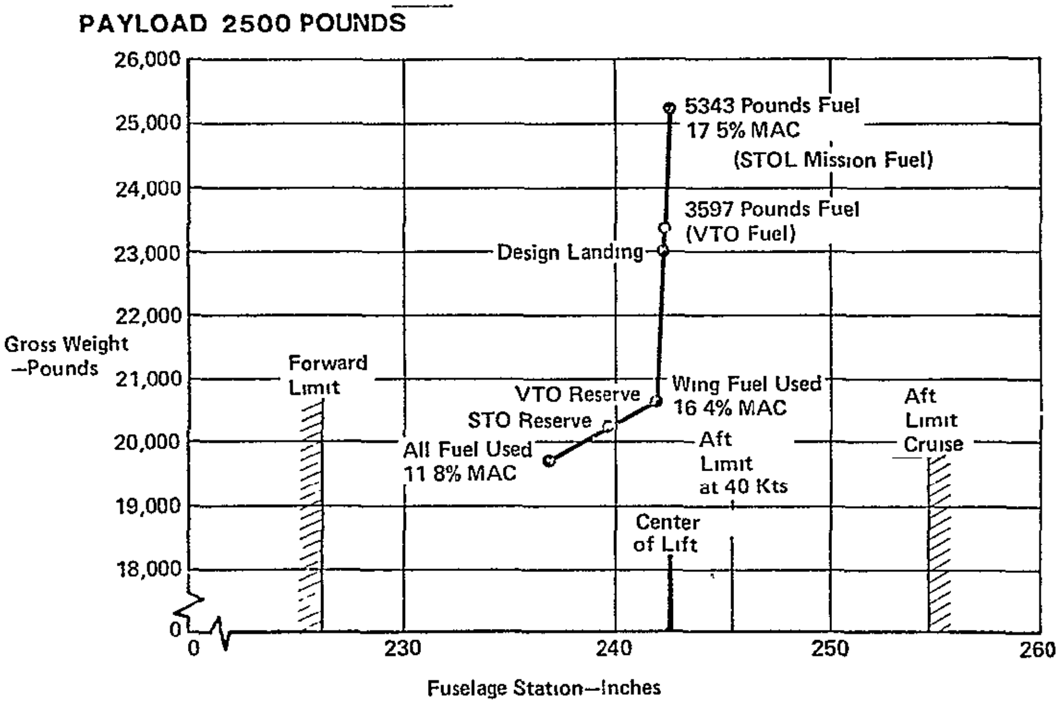

Figure 4.1 Center Of Gravity Travel

5.0 AERO-THERMODYNAMIC ANALYSIS

5.1 Performance Summary

The basic performance in the VTOL mode is measured by the excess lifting capacity for the prime mission and the elimination of an avoidance curve for Level 2 operation. This research and technology vehicle will provide a lift to weight ratio of 1.32 after trim and control allowances are made. This figure is based on a tropical day with no water used. The vertical thrust to weight requirement for normal operation is 1.1; this can be met with 84 per cent of the 1 minute VTO rating. The duct temperature at reduced power is 129 degrees below 1 minute. VTO temperature of 1909°R. The pressure is 10 per cent less. For the same five circuit VTOL lift off weight of 22,913 lbs., the thrust to weight for Level 2 operation (i.e., tropical day, water injection) is 1.05.

The study missions for VTOL and STOL are summarized in Figure 5.1. The track is approximately 6.6 miles in circumference flown at 1000 feet of altitude with the terminal maneuvers performed for each cycle. The takoff allowance was not specified but was arbitrarily set at two minutes of operation at intermediate power (i.e., for three engine operation; 457 pounds). The reserves were given in the guidelines and required four minutes of hover for the five circuit "V" mission and 10 per cent of the 11 circuit STOL mission. The total fuel requirements are 3597 and 5343 pounds, respectively, for the "V" and STOL missions. These fuel requirements are based on the minimum mission time for the circuits required.

The V/STOL vehicle has a cruise operation capability that has been estimated on the requirement for two hours aloft. The range at best cruise altitude within the two hour restriction is 844 nmi. Best cruise altitude is approximately 45,000 feet and flown at a Mach number of 0.75. If the two hours aloft were flown primarily at 25,000 feet, the minimum altitude suggested in the guidelines, the range would be 600 nautical miles and require 5749 pounds of fuel. The envelope, Figure 5.43 of the research and technology vehicle is similar to the basic T-39; approximately 0.77 Mach above 20,000 feet and a dynamic pressure of 305 psf below 20,000. The power portion of the envelope shows a hovering capability up to 13,000 feet. These numbers are based on standard day conditions.

5.2 Propulsion System

5.2.1 Background - The proposed propulsion system for the aircraft consists of three YJ-97-GE-100 gas generators and two GE LCF 459 lift cruise fans. The high pressure YJ97 exhaust flow is used to drive the tip turbine of the lift cruise fan. Fan exhaust flow exiting through a vectorable exhaust nozzle provides the aircraft propulsive force for both VTO and cruise flight modes. All gas generators and fans are interconnected through a system of ducting and valves. The duct system permits flight with one gas generator out and, in conjunction with a lower fuselage mounted pitch pipe and variable exit vanes in the lift fan exhaust nozzle, permits longitudinal, lateral and directional control forces. A phantom sketch of the propulsion system installed in the T-39 airframe is shown in Figure 5.2.

5.2.2 Level 1 VTO Operation - In normal VTO operation, each of the wing mounted gas generators drives its adjacent fan, as shown in Figure 5.3. Gas generator 'B' drives Fan 1 and gas generator 'C' drives Fan 2. Gas generator 'A' is isolated from the lift fan system by closing Valve e, and the entire exhaust is diverted through the pitch pipe system. Flow from the pod mounted gas generators is turned 180° through large diameter ducts of large radii to minimize losses (See Figure 5.4). At VTO airflows, losses from gas generator exit to lift fan tip turbine entry are estimated to be 5.6%. A summary of installed thrust with associated assumptions and estimates are shown in Table IX.

Flight control forces in the normal VTO mode are supplied through propulsion system variations. Pitch forces are supplied by the pitch pipe system. Variable area nozzles forward and aft are modulated to yield constant total exit area with variable percentages forward and aft. Roll control is obtained by closing the roll control valve (Valves b or g in Figure 5.3 on the side of the aircraft where the wing down moment is desired. Increased fan flow to the opposite side of the aircraft produces higher fan RPM and thrust. Constant lift is maintained by decreasing the fan thrust on the low flow side with fan nozzle spoilers. Yaw control is supplied by differential vector of the thrust by means of the LH and RH nacelle louvers in the fan swivel nozzles.

5.2.3 Level 2 VTO Operation - The third gas generator and associated ducting system allows safe aircraft operation with any one generator inoperative. Figure 5.3 shows system valve arrangement with one wing gas generator inoperative. The isolation valve at the inoperative engine closes to isolate the gas generator from the propulsion system (Valve f). Valve e opens simultaneously and the variable pitch pipe nozzles adjust to allow approximately 10% of the flow from gas generator A through the pitch control system. Portions of the fan scroll area are closed off by valves a and h, such that fan flow requirements are reduced by 5%. Fan 2 now receives 90% of gas generator A flow and 5% of gas generator B flow. System thrust is augmented by a 4% water injection.

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Operation with loss of the fuselage installed gas generator, "A", is essentially the same, with the inoperative engine being isolated from the system and 5% flow from each of the remaining engines being ducted to the pitch system. In either case, control forces are generated in the same manner as in the normal operational mode.

A summary of the installed thrust with one gas generator out is shown with associated assumptions and estimates in Table X.

A lift budget for Levels 1 and 2 for various conditions and power setting is shown in Table XI. Note that the thrust to weights for Level 1 are in excess of the guidelines of Reference (i).

The gas generator exhaust conditions for the conditions listed in the lift budget are shown in Table XII.

Table IX

J-97-GE-100/LCF 459 Propulsion Package, Level 1 Performance

1 minute VTO - Tropical Day - Sea Level Static

Gas Generator Inlet Total Pressure Loss	1%
Fan Inlet Total Pressure Loss	1%
Gas Generator Bleed Air Extraction	11 lb/min.
H.P. Extraction	20 h.p.
Gas Generator Exhaust Duct Pressure Loss	5.6%
Fan Tail Pipe Total Pressure Loss	4%
Fan Nozzle Thrust Coefficient	0.98
Installed Fan Thrust (per Fan)	12,120 lbs.

Table X

J-97-GE-100/LCF 459 Propulsion Package, Level 2 Performance

1 minute VTO with 4% H_2O - Tropical Day - Sea Level Static

Gas Generator Inlet Total Pressure Loss	1%
Fan Inlet Total Pressure Loss	1%
Gas Generator Bleed Air Extraction	11 lb/min.
H.P. Extraction	20 h.p.
Gas Generator Exhaust Duct Pressure Loss (Fuselage Gas Generator to Wing Fan Turbine Inlet)	9.25%
Fan Tail Pipe Total Pressure Loss	4%
Fan Nozzle Thrust Coefficient	.98
Installed Fan Thrust (per Fan)	11,800 lbs.
Pitch System Thrust	600 lbs.

Table XI

Lift Budget for VTO Takeoff Gross Weight (22,913)

Condition	Total Lift Kn (Lbs.)	Total Lift/Weight (incl. yaw control)*
LEVEL 1		
1 Min. VTO		
Standard	137.99 (31,023)	1.35
Tropical	134.51 (30,241)	1.32
Intermediate		
Standard	129.87 (29,197)	1.27
Tropical	125.97 (28,321)	1.24
LEVEL 2		
1 Min. VTO		
Standard	112.04 (25,190)	1.100
Tropical + H_2O	107.59 (24,189)	1.055
Tropical - Dry	99.49 (22,367)	0.976
Intermediate		
Standard	109.13 (24,535)	1.070
Tropical + H_2O	97.26 (21,866)	0.954
Tropical - Dry	95.94 (21,569)	0.941

*Maximum yaw control lift less = 213 N (48 lbs) Level 1, 106 N (24 lbs.) Level 2

Table XII

Installed Propulsion System Parameters

Condition	Thrust$_{\text{Fan}}$ (Lbs.)	Temp.$_{\text{GG}}$ (^{o}R)	Pres$_{\text{GG}}$ (psia)	Airflow$_{\text{GG}}$ (lbs/sec)	RPM$_{\text{GG}}$ (%)	Thrust$_{\text{GG}}$ (lbs.)
LEVEL 1						
1 Min. VTO						
Standard	12,868	1909	53.3	69.7	102.7	5,312
Tropical	12,120	1909	50.9	66.5	103.5	5,000
Intermediate						
Standard	12,544	1842	52.4	69.2	101.5	5,178
Tropical	11,748	1875	50.1	65.6	101.5	4,850
LEVEL 2						
1 Min. VTO						
Standard	12,284	1909	55.2		101.1	
Tropical + H_2O	11,800	1909				
Tropical	10,908	1909	50.9		100.0	
Intermediate						
Standard	11,965	1875	54.3		99.8	
Tropical + H_2O	10,664	1875				
Tropical	10,519	1875	49.6		99.4	

5.2.4 Installation Losses - The propulsion system performance is based on the following equation:

$$F_{NPE} = F_N - F_{ADD}$$

where: F_{NPE} - Net Propulsive Effort

F_N - Installed Net Thrust

F_{ADD} - Inlet Additive Drag

$$F_N = C_{fg} \cdot F_g - F_D$$

C_{fg} - Nozzle Gross Thrust Coefficient

F_D - Ram Drag of Fan and Gas Generator

F_g - Isentropic Gross Thrust corrected for inlet pressure recovery, bleed, horsepower extraction, connecting duct loss, and exit duct loss

$$F_{ADD} = K_{ADD} F_{TADD}$$

F_{TADD} - Theoretical Additive Drag

K_{ADD} - Additive Drag Correction Factor

The inlet pressure recovery curve is presented in Figure 5.5. 11.0#/min. of bleed air is taken from the engine and 20 horsepower is extracted from the fan for all flight conditions. The nozzle gross thrust coefficient is 98%. The theoretical additive drag is calculated at each flight condition and the K_{ADD} factor is obtained from Figure 5.6. The exit duct pressure loss is presented in Figure 5.7.

5.2.5 Duct Losses - Gas generator ducting system losses from the turbine exit to the fan tip turbine inlet are minimized by using the most direct duct routing practical based on configuration restraints and maintaining duct Mach numbers at approximately 0.3 or less. Conventional gas flow methods and data were used in determining the duct losses along with considerable flow system experience with aircraft systems. Applicable pressure loss data were obtained from various reliable sources such as SAE Aerospace Applied Thermodynamics Manual (1969 Edition). Pertinent flow ducting system experience has been obtained on various programs such as the XFV-12A VTOL aircraft and the A-5 aircraft boundary layer control system. The pressure loss and associated duct Mach numbers are shown for the Level 1 and 2 flow paths in Figures 5.8 and 5.9.

5.2.6 V/STOL Installed Performance - Installed V/STOL propulsion system performance is shown in Figures 5.10 through 5.13. Figure 5.10 contains data for the one minute VTO power setting. The remaining curves are for Intermediate power setting at various altitudes. All data shown are for a single fan/gas generator combination. For the three engine operation, fuel flows should be tripled to arrive at total aircraft fuel flow.

5.2.7 Cruise Performance - Estimated installed engine performance for a standard day, single fan are shown in Figures 5.14 and 5.15. Figures 5.16 through 5.22 show cruise performance at various altitudes. All thrusts and fuel flows are to be doubled for total propulsion system performance. Third engine fuel flow at idle power may be added if engine remains in operation, See Figure 5.23.

The estimated installed propulsion system performance for this study was calculated with an engine cycle computer deck supplied by the General Electric Company. References (i) and (m) give pertinent details on the program.

5.2.8 Roll Control - V/STOL roll control forces are generated by modulation of propulsion system thrust. Increased thrust is obtained on one wing fan by increasing the flow and flow temperature through the fan scroll. The increased flow is achieved by partially closing the roll control valve just upstream of the fan scroll on the opposite side of the aircraft. Figure 5.24 shows the roll control available as a function of power setting. These data are from Reference (n) which presents thrust available with an uninstalled J97-GE-700 gas generator. The data are presented in ratio form and are representative of installed ratios.

In normal operation, fan engines will operate with a full 360° of scroll arc open and without water injection. For this configuration it may be seen from Figure 5.24 that the control margin is about 10% of the fan thrust when operating at the one minute VTO power setting. For a one minute VTO thrust of 12,100 pounds, a maximum increase of 1210 pounds may be expected with roll control valve actuation. To maintain constant total thrust, spoilers are employed in the opposite fan nozzle.

For one engine out operation, the fan airflow is decreased by 5.1%. This requires an adjustment of flow area in the scroll. For this case, 342 degrees of the total 360 degrees remains open. Reference (n) contains thrust available for roll control for the 360 and 240 degree arc cases. These data have been linearly interpolated to construct a 342-degree with water injection control line. At one minute VTO power setting, approximately 8% control is available for this case.

A qualitative time history is shown in Figure 5.25 that represents the variation in engine parameter during a roll command to the roll control valve. These data appear in Reference (n). Fan performance data are shown in Figure 5.26

Comparisons of roll control capabilities vs control requirements are shown in Figures 5.42 and 5.46.

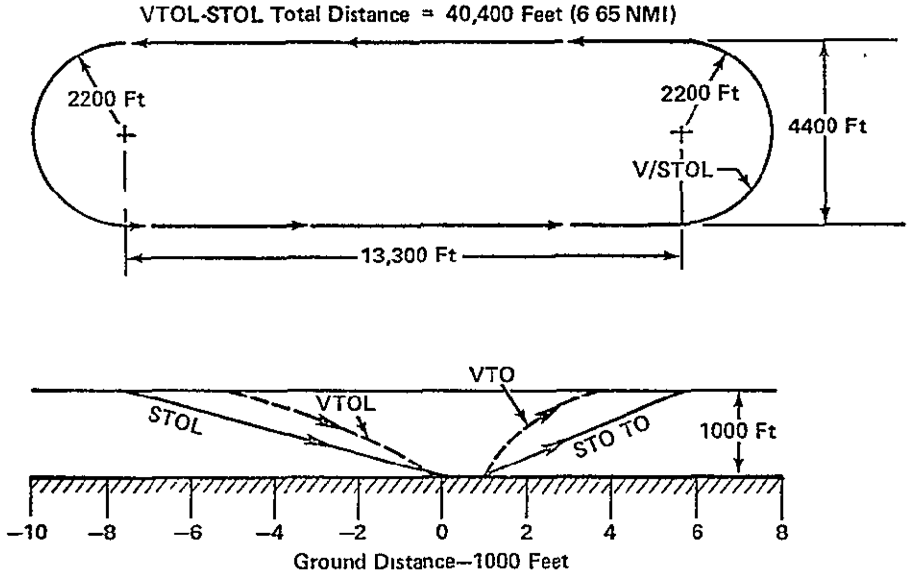
5.2.9 Inlet Selection - All aircraft engine inlets have been designed to minimize pressure losses to the compressor and fan faces at vertical takeoff. Both fan and gas generator wing mounted inlets will be straight walled ducts with no internal divergence. Inlet leading edges will be simple semi-circular fairings. Straight walled ducts will minimize design and fabrication effort and resulting program costs. Pressure recovery levels at static conditions of 99% have been assumed for all estimated thrusts in this report. Performance levels of open-nosed inlets have been well documented. CAD experience with such inlets was obtained, most recently, in the OV-10Z program. A pylon mounted inlet recovery of 99.6% was recorded during the initial flight test program.

The fuselage mounted rear facing gas generator requires an inlet system capable of high performance from static conditions to 300 knots. A simple constant area straight inlet as used in the wing installations would necessarily also be rear facing. Performance estimates of a rear facing inlet in 140 knots airflow indicate recovery levels of less than 80%. Resulting propulsion system thrust with one engine out would not be adequate to support the transition to vertical landing. Therefore, the inlet design incorporates a forward facing inlet delivering air to the engine face through a smooth 180° bend. The internal lines include a slight convergence from inlet to engine face. The elliptical inlet allows a turning radius to diameter ratio of 1.1. Estimated pressure recovery for the static case is 99%.

5.2.10 High Flow Pitch Pipe Option - With three engines operating, thrust available from the fuselage mounted engine exceeds thrust required for pitch control. To attenuate this thrust while maintaining high engine RPM, the pitch pipe system nozzle area will be adjusted to an area larger than required for maximum thrust. Figure 5.27 shows the effect of increasing nozzle area on uninstalled engine thrust and is representative of area adjustment required. The figure also shows that lower gas temperatures and resulting lower footprint may be anticipated with the larger nozzle area. For TOGW of 22,913 lb. and L/W = 1.1, intermediate thrust of the pitch pipe system can be reduced to 1704 lb., 35% of maximum available thrust by increasing nozzle area by 100%. Exhaust temperature from the pitch pipe nozzles at this condition is reduced to less than 535°F.

Although not included in the present design, an optional use of the area variation in the pitch pipe system is to achieve quick response for height control if needed.

5.2.11 Temperature Control - The presence of 1400°R gas temperature throughout this vehicle requires various methods of controlling the temperature. These temperatures are present in the nacelle over the wing fuel tank, in the fuselage engine and duct compartment, in the wing fairings aft of the rear spar and in the external pitch pipe on the lower shoulder of the airplane as shown in Figure 5.28. The primary methods of protecting the aluminum structure is with duct insulation, compartment forced air cooling and radiation.



FUEL REQUIREMENTS

VTOL 5 Circuits		STOL 11 Circuits
457	Warm-up	457
2250	Circuits	4400
890	Reserve	486
3597 Pounds 553 Gallons	Total	5343 Pounds 822 Gallons

Figure 5.1 V/STOL Test Missions

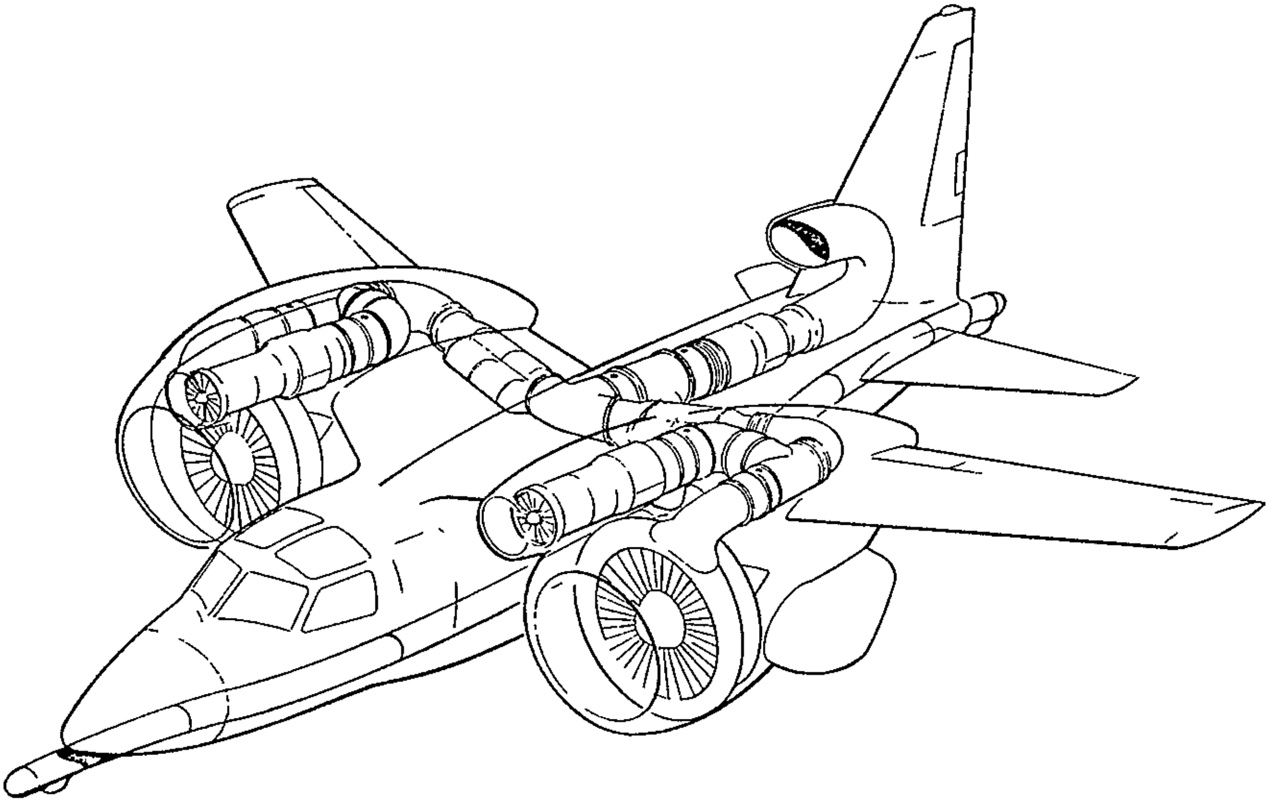
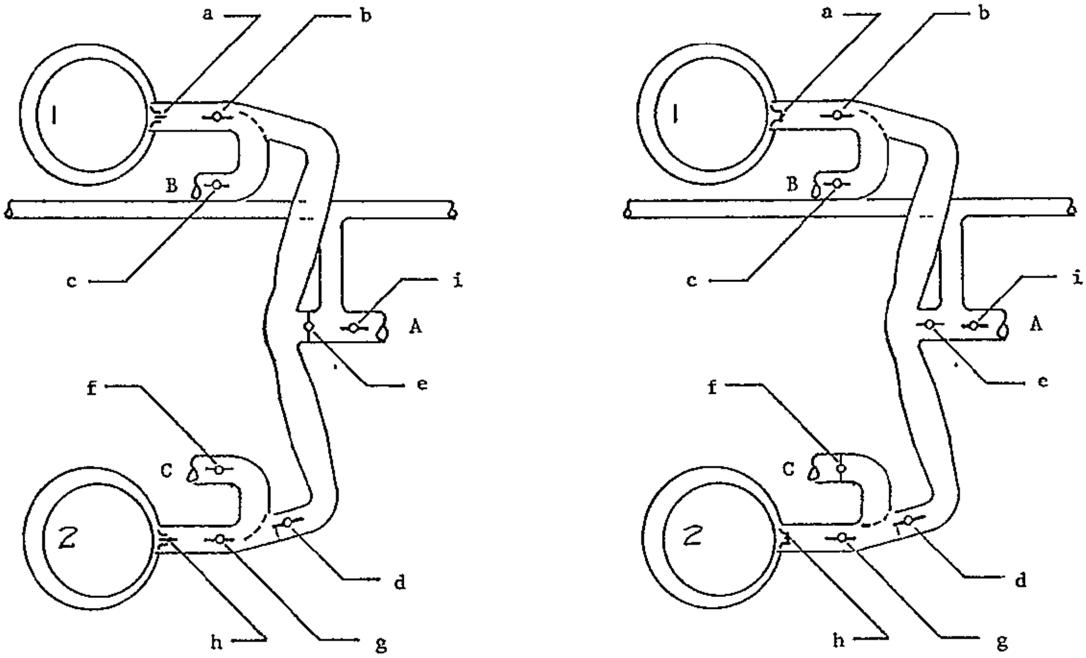


Figure 5.2 Lift Cruise Fan Propulsion System



NORMAL OPERATION

ENGINE OUT OPERATION
Assume to be Gas Generator C

NOMENCLATURE

A	Gas General, Fus
B	Gas Generator, R.H.
C	Gas Generator, L.H.

a	scroll valve
b	backflow valve
c	control valve
d	isolation valve
e	isolation valve
f	control valve
g	backflow valve
i	backflow valve

Figure 5.3 Propulsion System Schematic J97/L CF 459, Normal Operation and Engine Out Operation

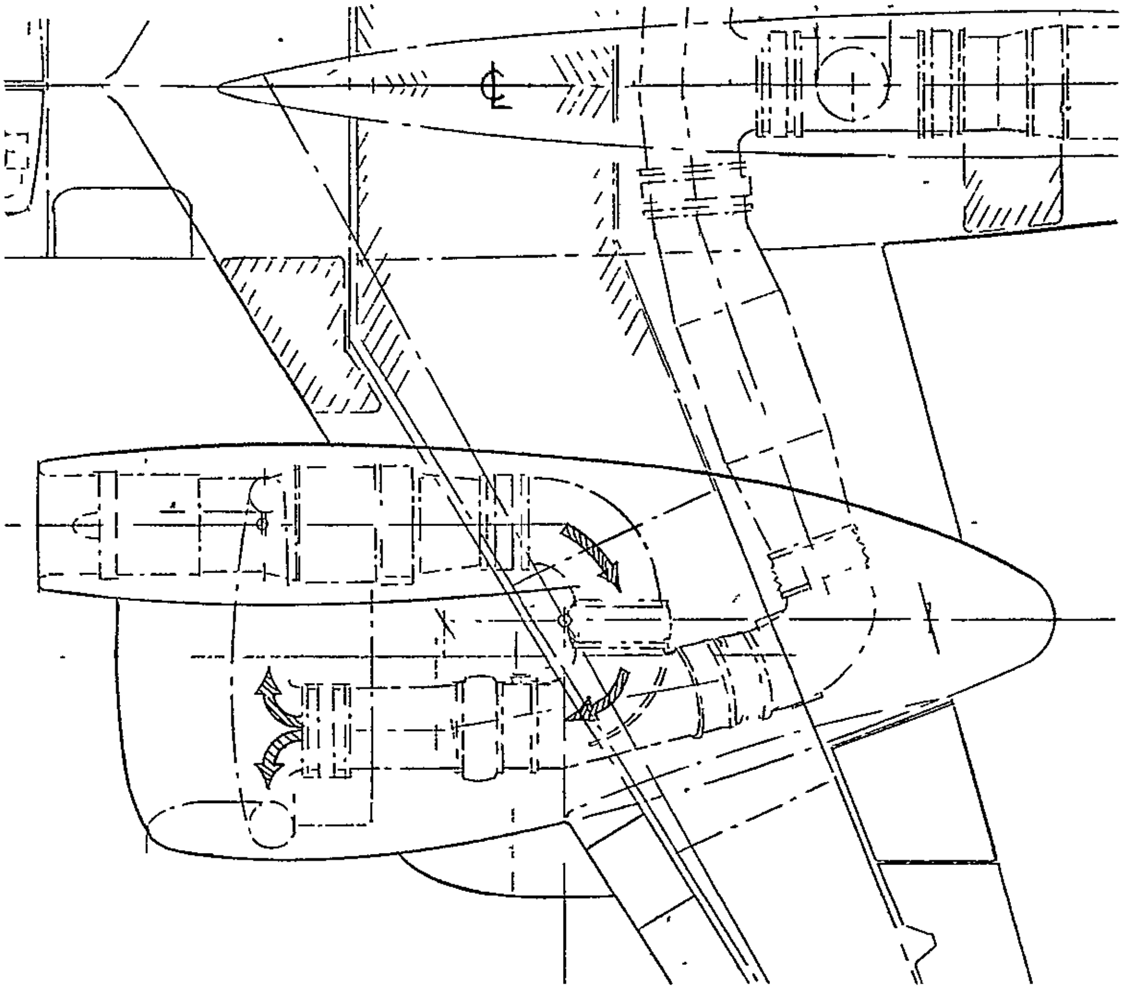


Figure 5.4 YJ97/LCF459 Duct Interconnect for Normal Operation

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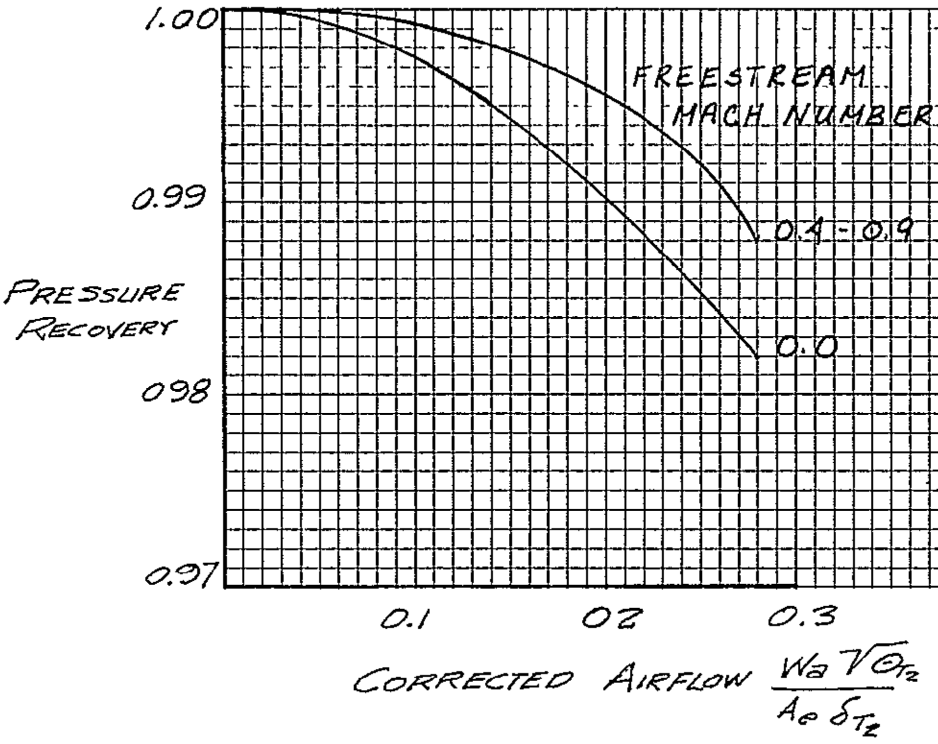

Figure 5.5 Inlet Duct Pressure Recovery

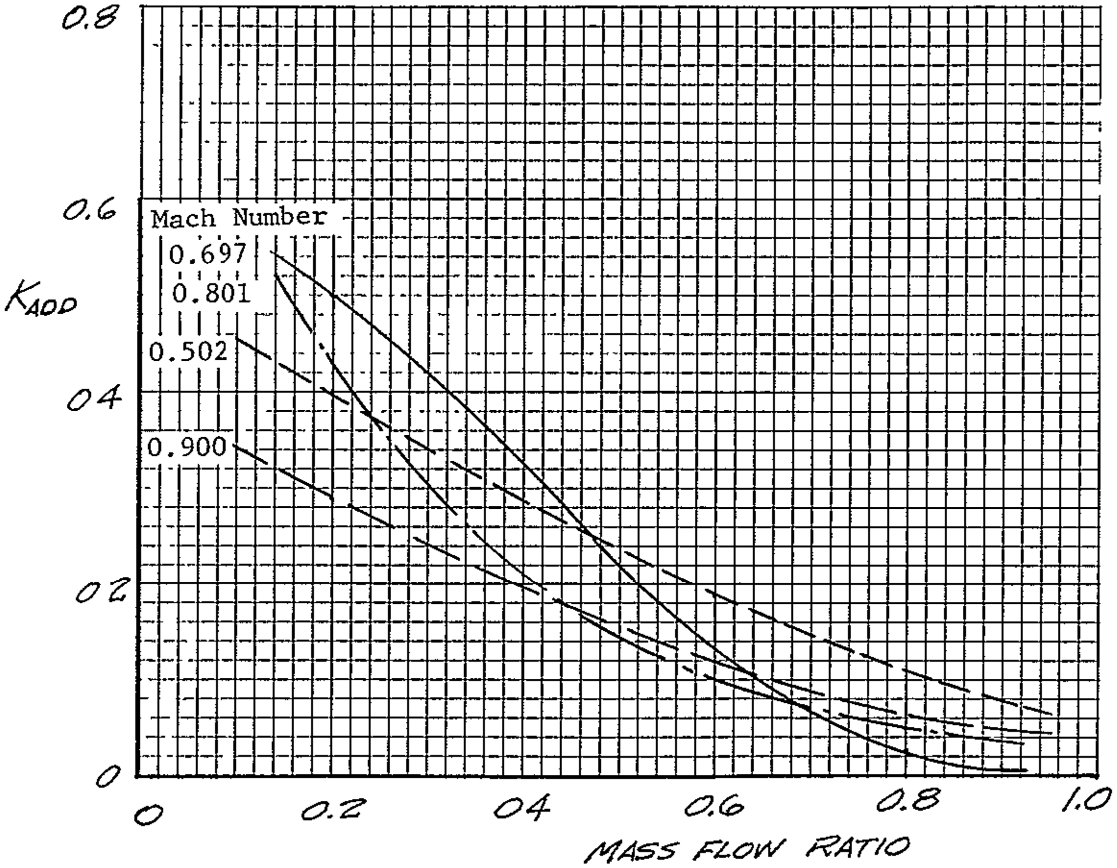

Figure 5.6 Additive Drag Correction Factors

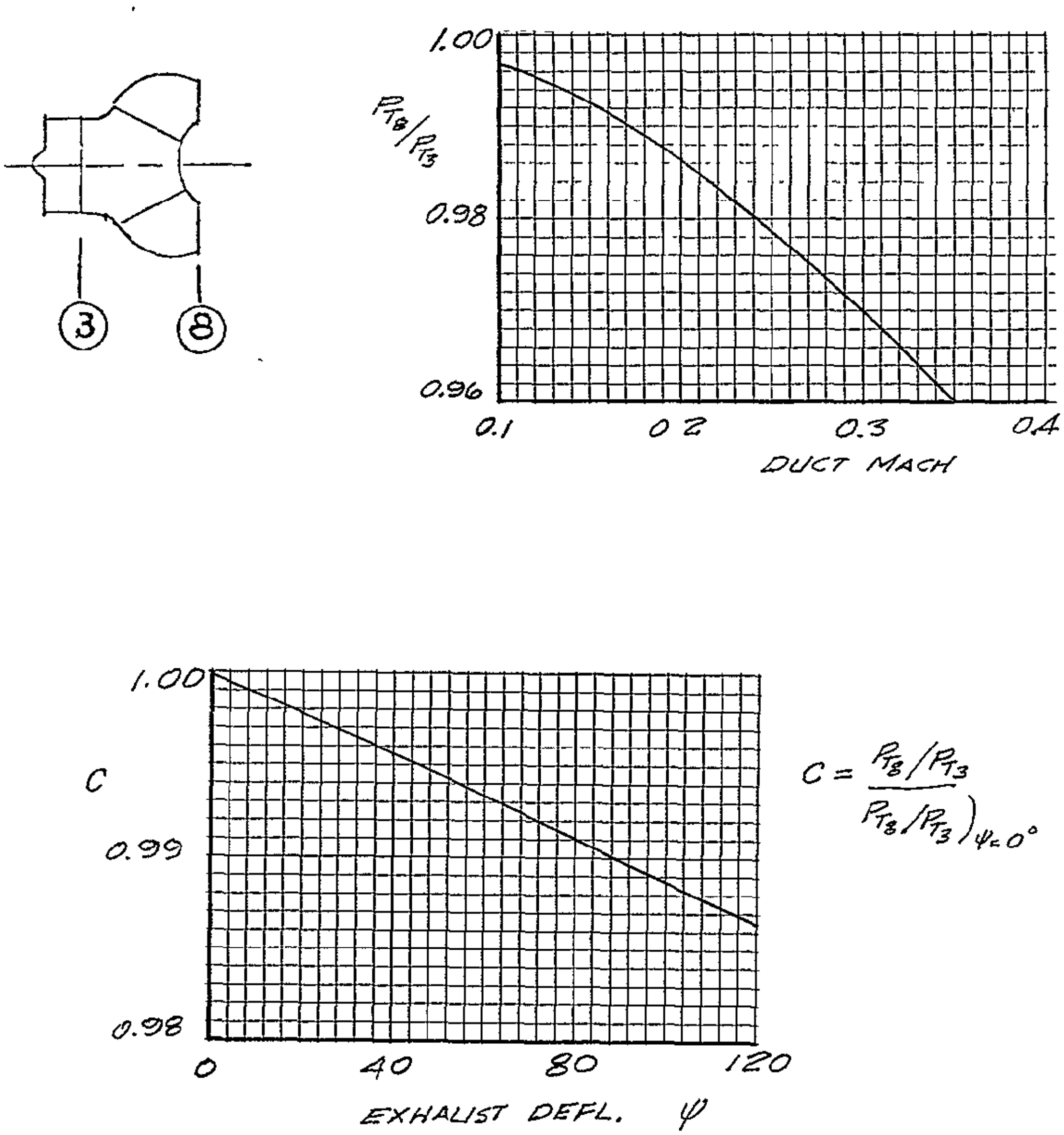

Figure 5.7 Exhaust Swivel Nozzle Pressure Losses

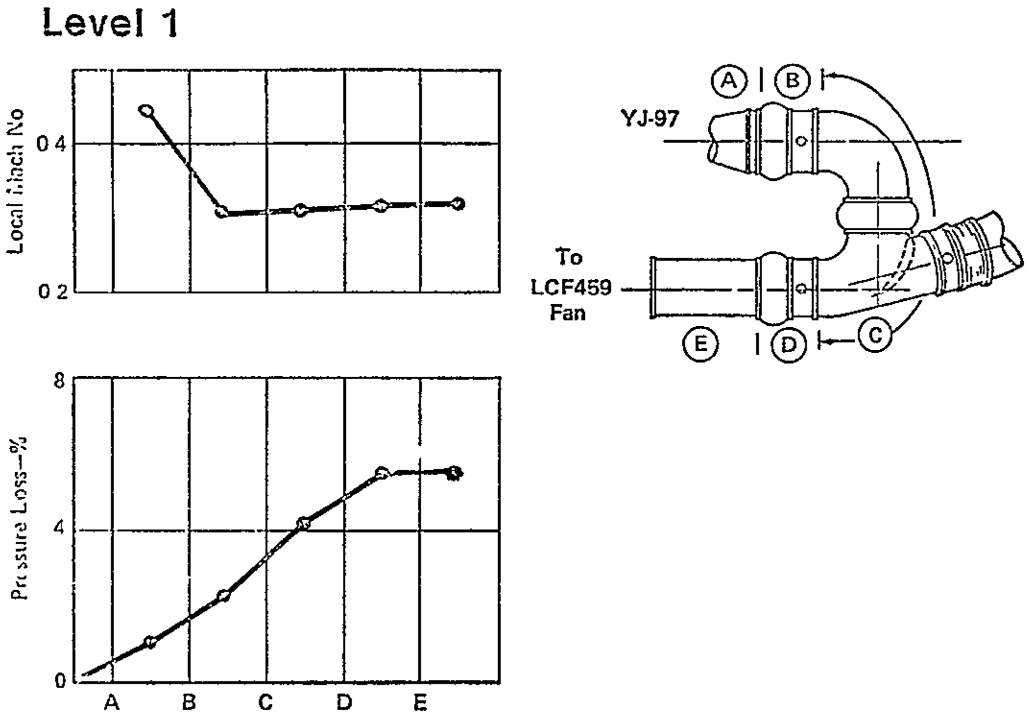

Figure 5.8 Duct Losses - Level 1

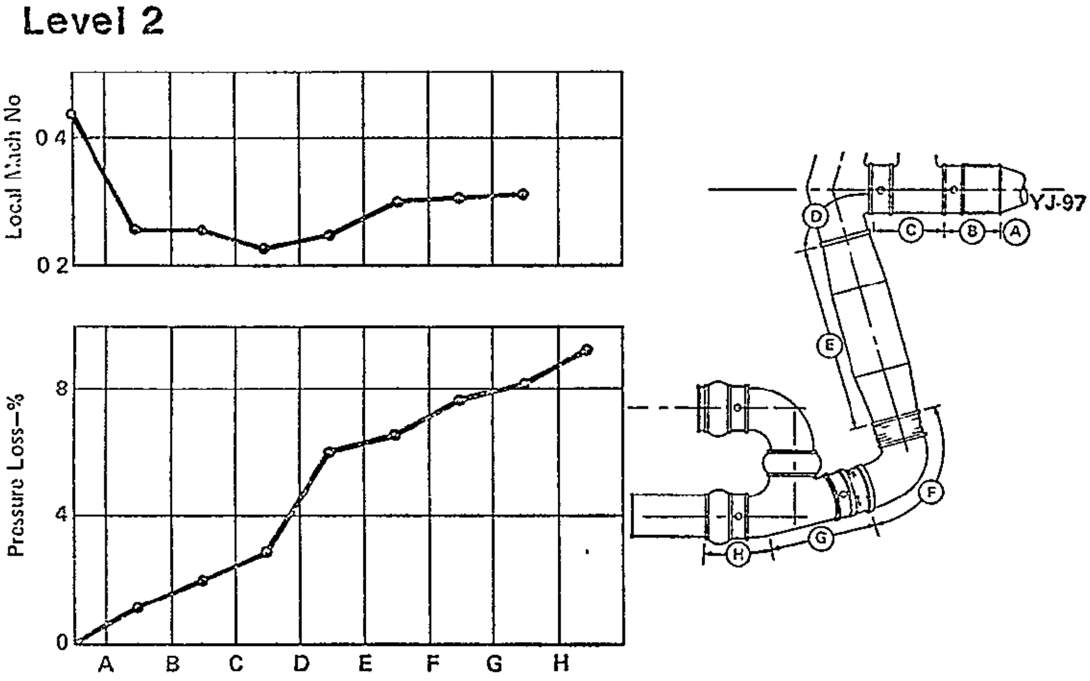

Figure 5.9 Duct Losses - Level 2 (Engine out)

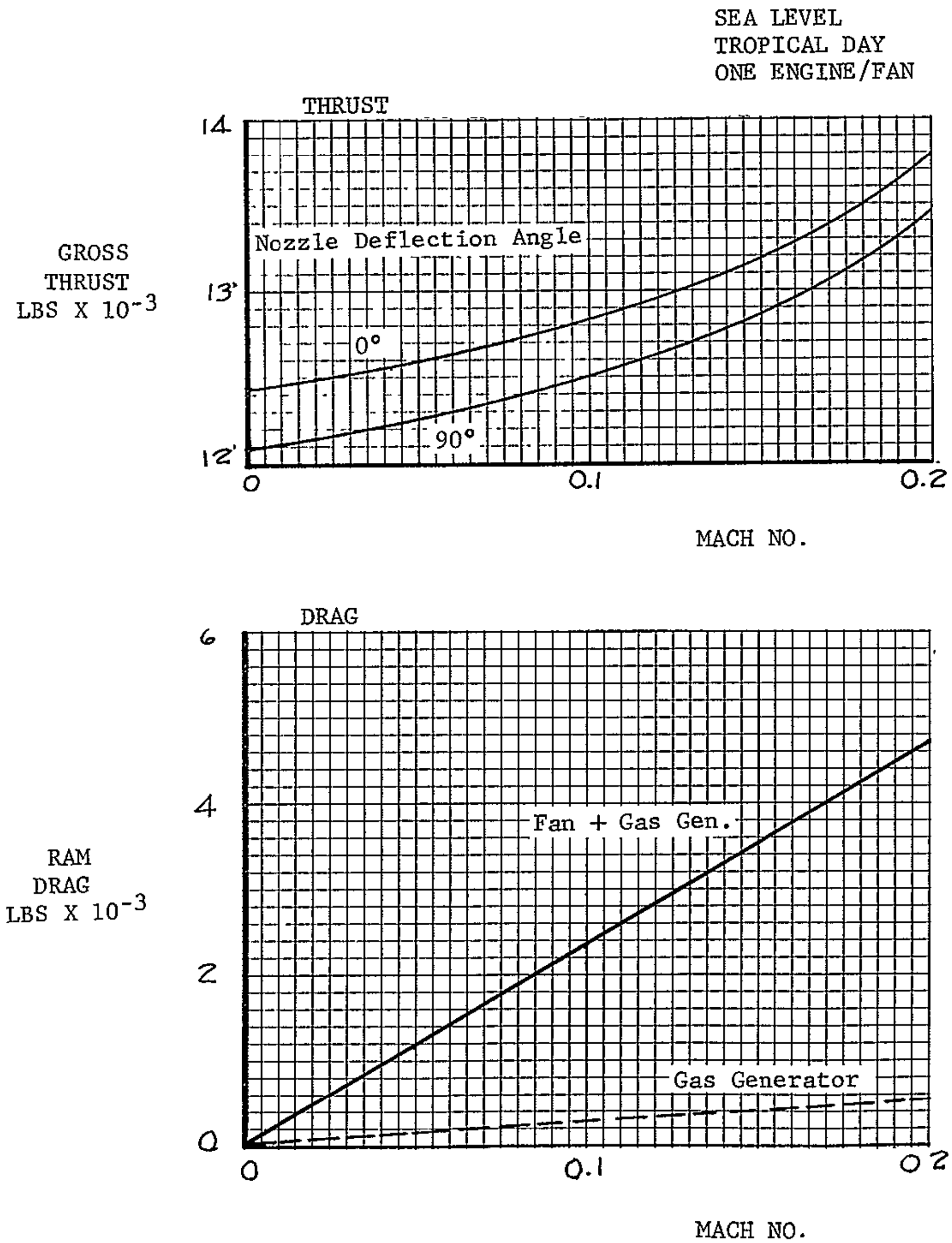

Figure 5.10 LCF45/9YJ97 Installed Performance, 1 Min VTO

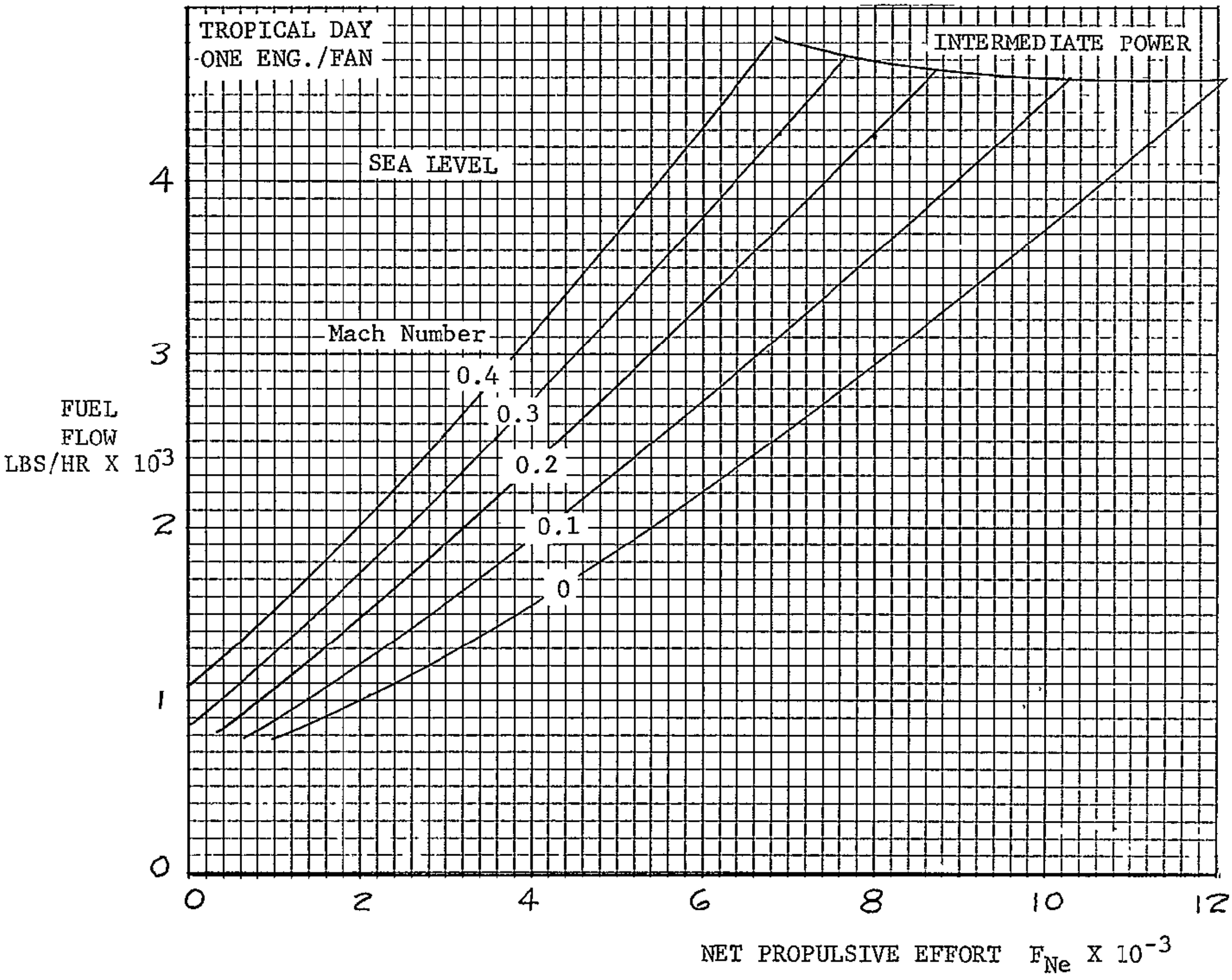

Figure 5.11 LCF459/YJ97 Installed Performance, Sea Level

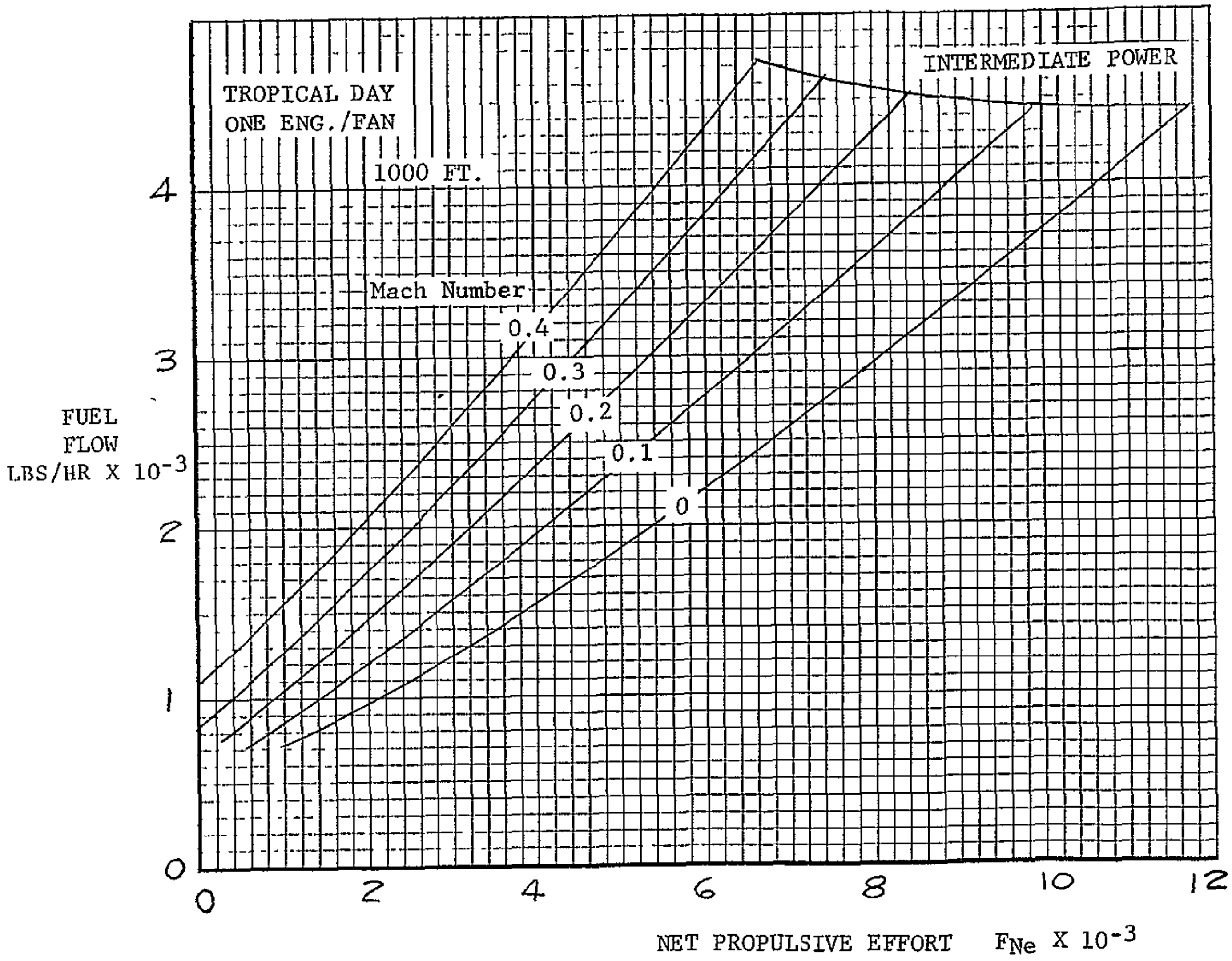

Figure 5.12 LCF459/YJ97 Installed Performance, 1000 Ft. Altitude

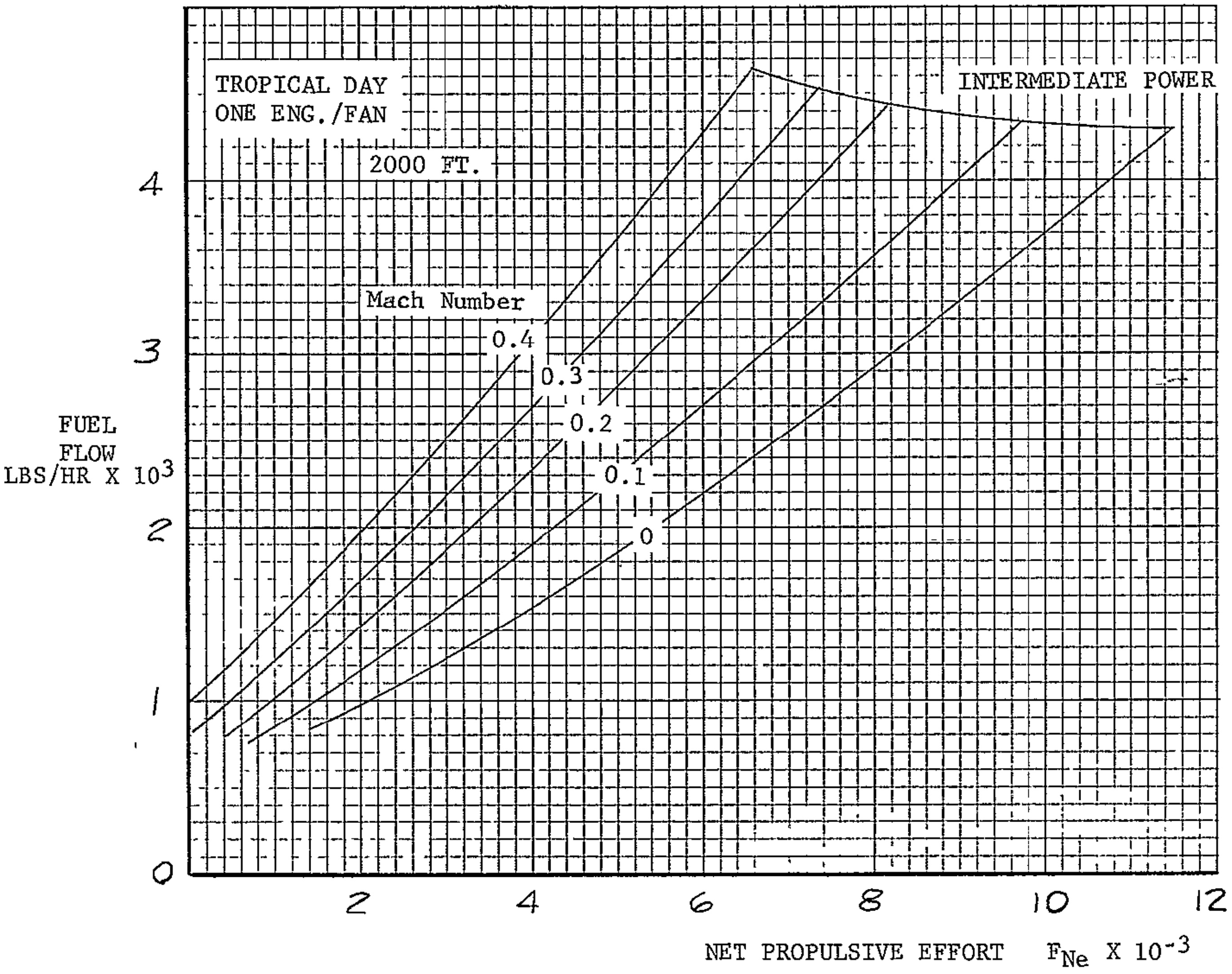

Figure 5.13 LCF459/YJ97 Installed Performance, 2000 Ft Altitude

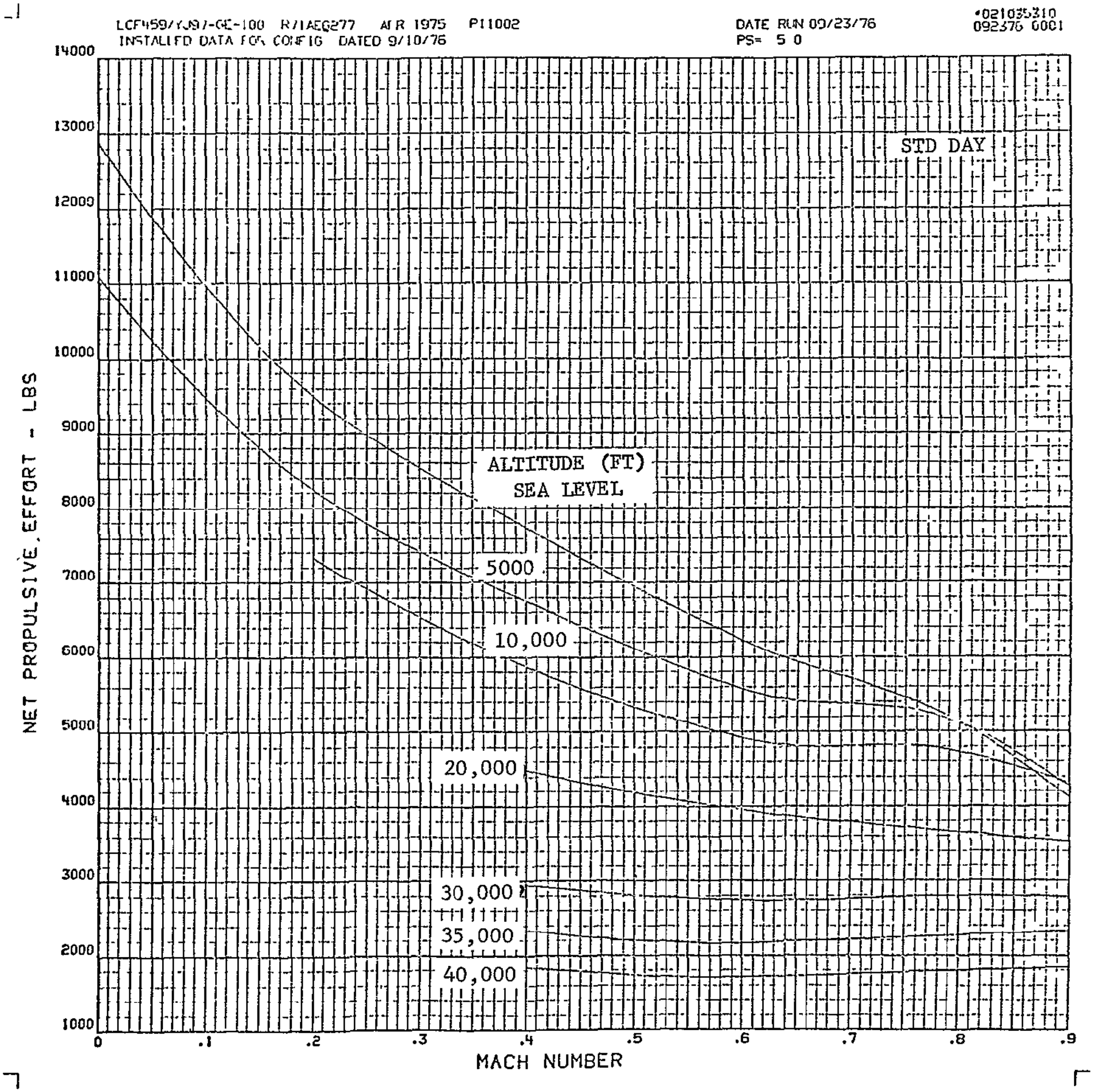

Figure 5.14 LCF459/YJ97 Installed Performance, Fn e vs Mn

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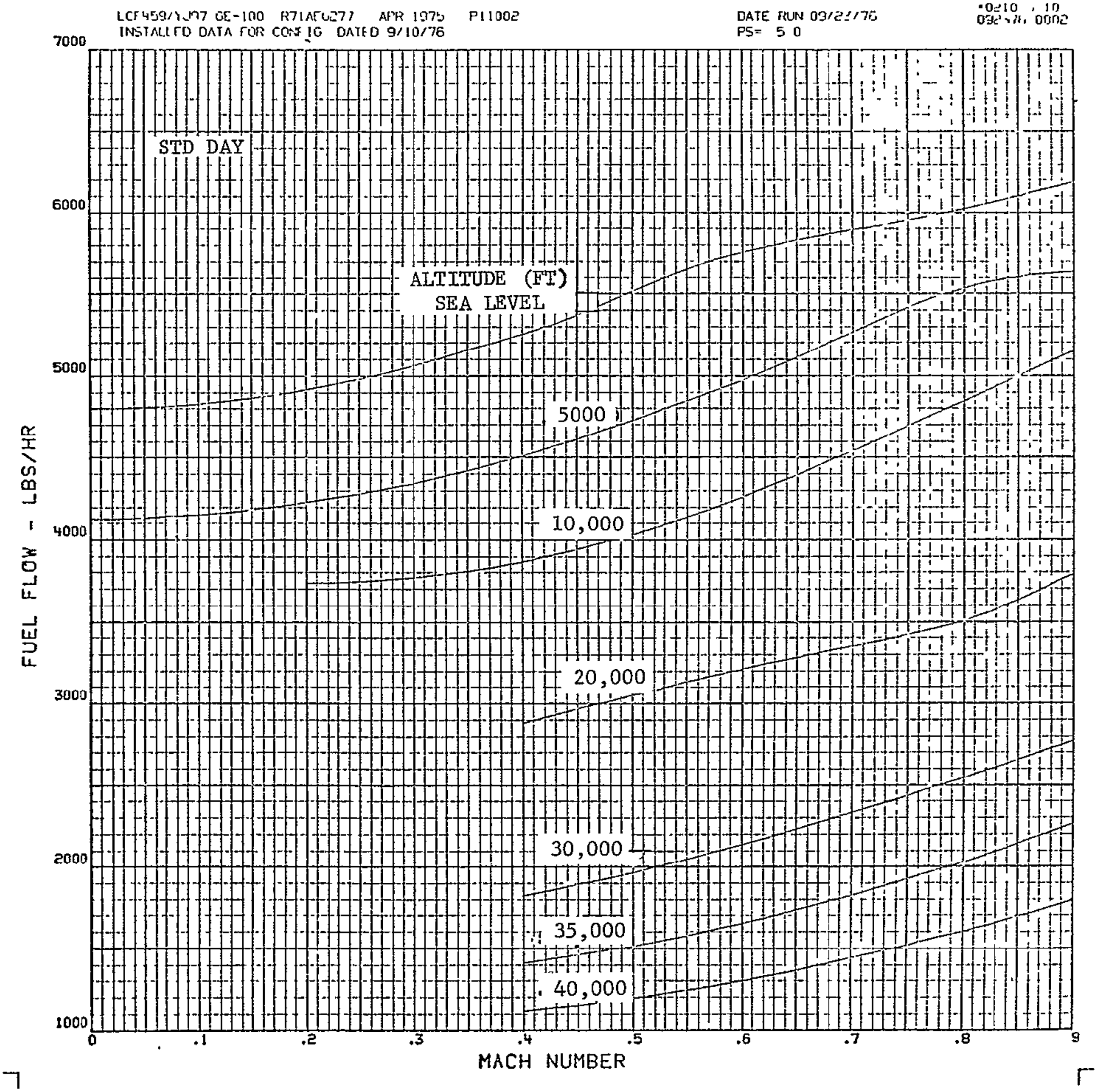

Figure 5.15 LCF459/YJ97 Installed Performance, W f vs Mn

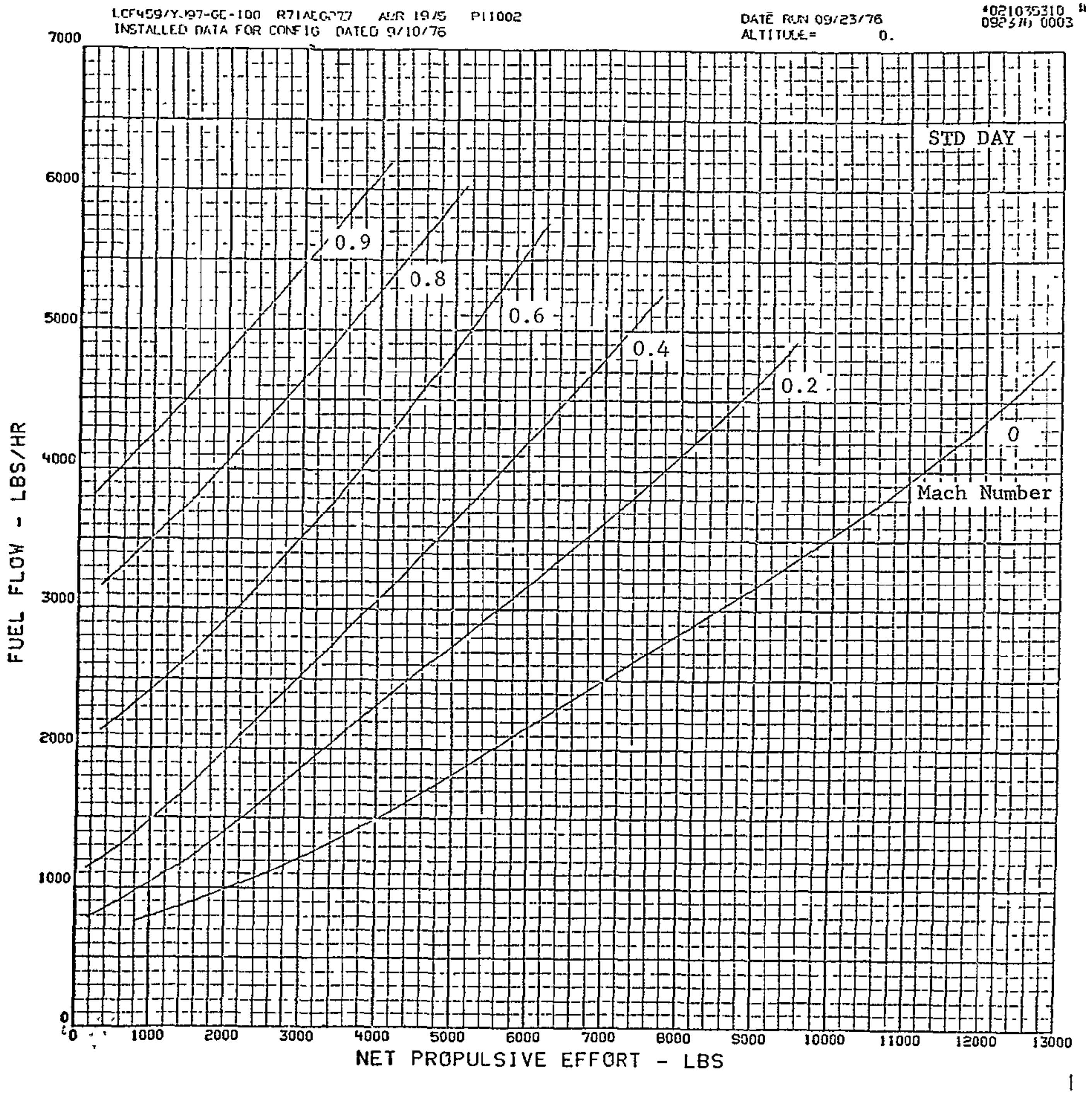

Figure 5.16 LCF459/YJ97 Installed Cruise Performance, Sea Level

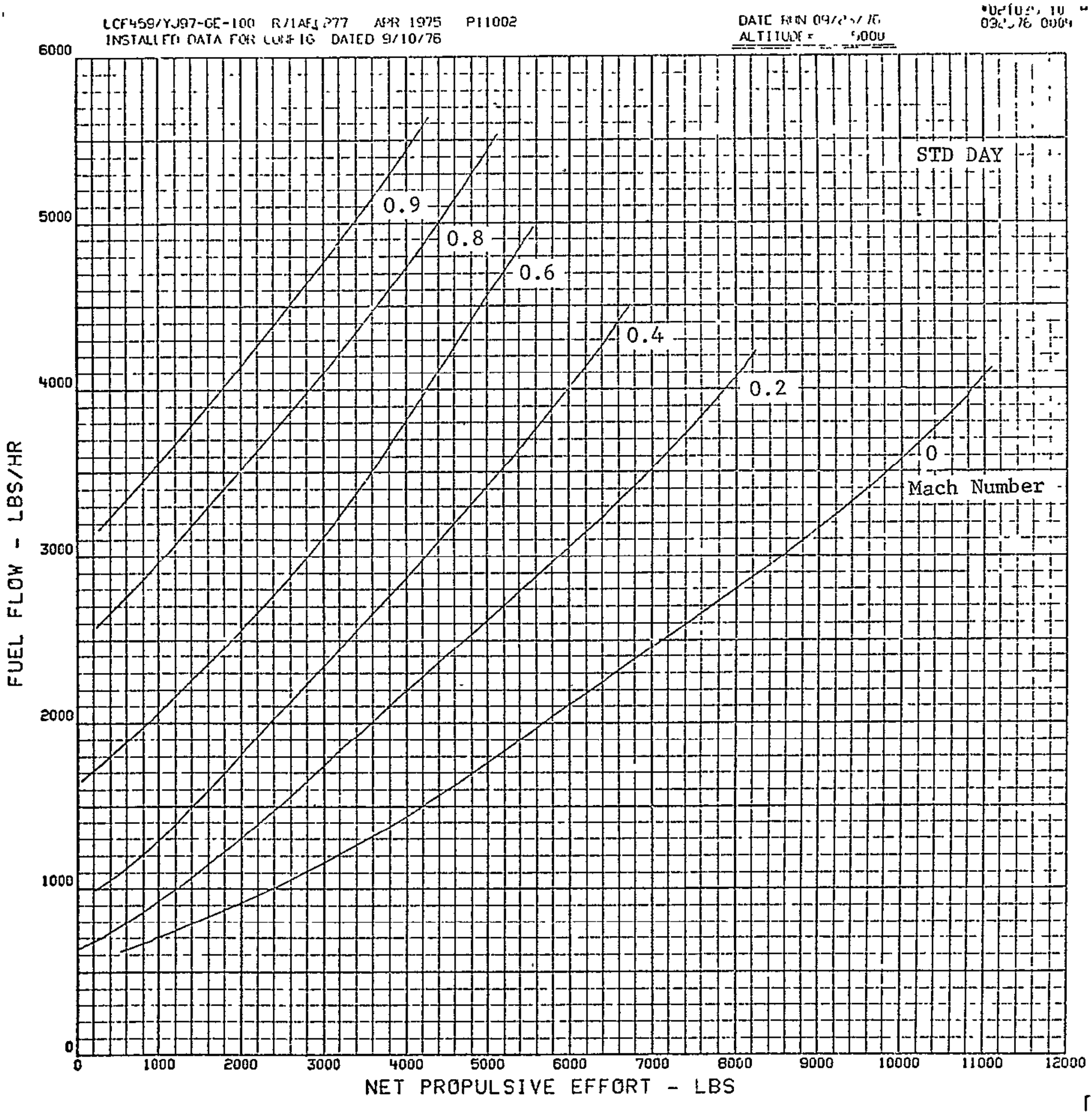

Figure 5.17. LCF459/YJ97 Installed Cruise Performance, 5000 Ft.

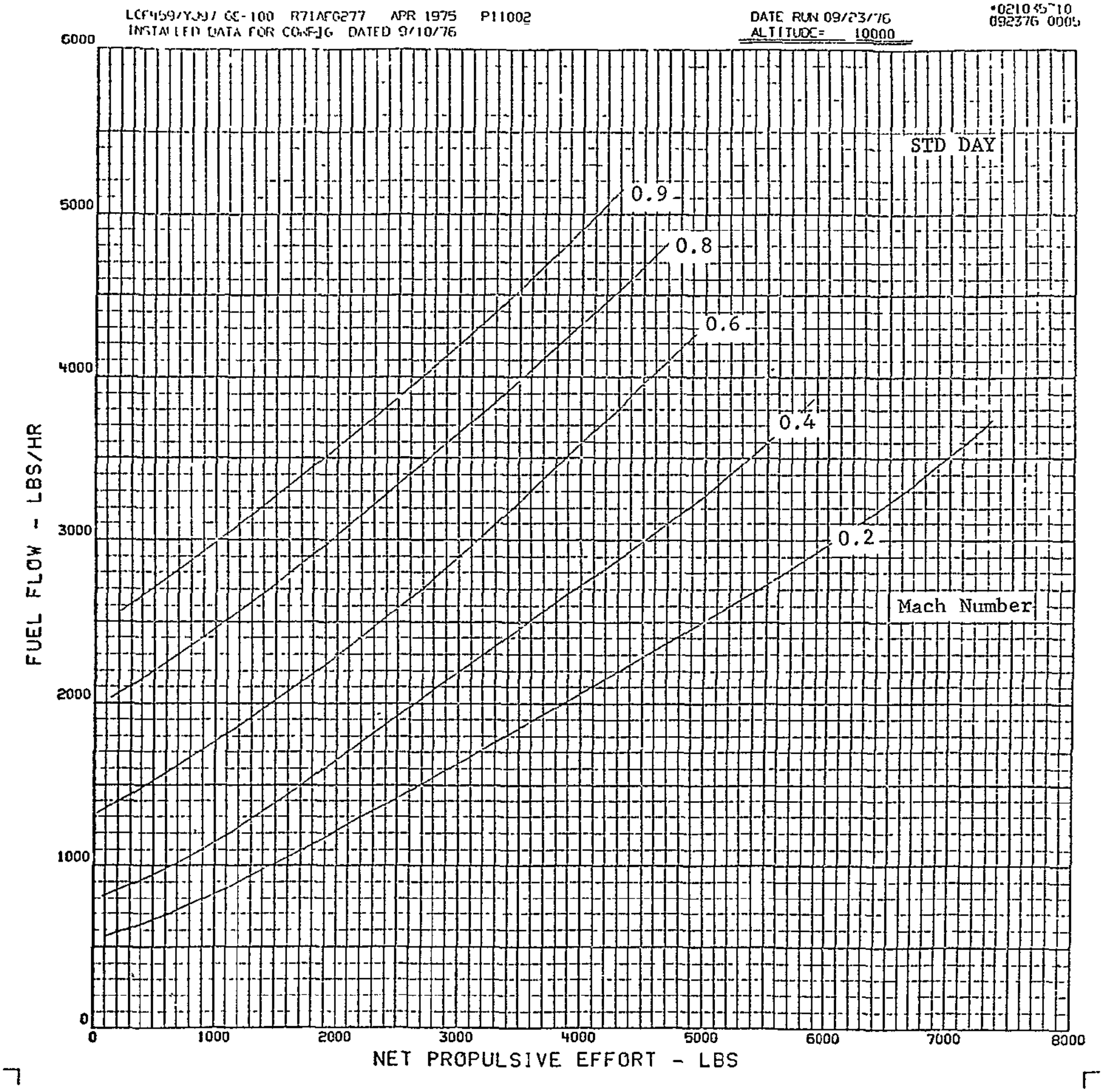

Figure 5.18 LCF459/YJ97 Installed Cruise Performance, 10,0 00 Ft.

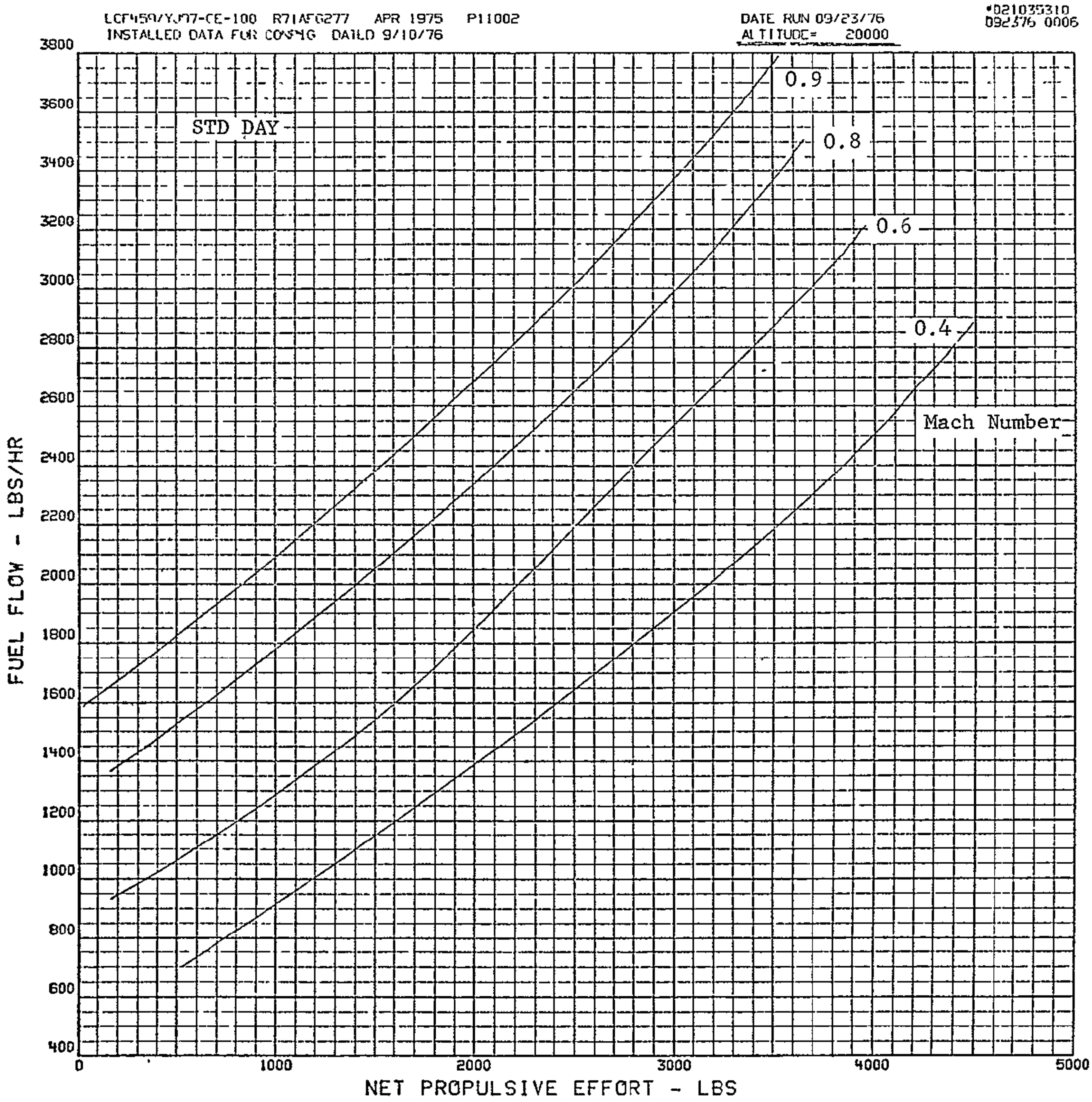

Figure 5.19 LCF459/YJ97 Installed Cruise Performance, 20,000 Ft.

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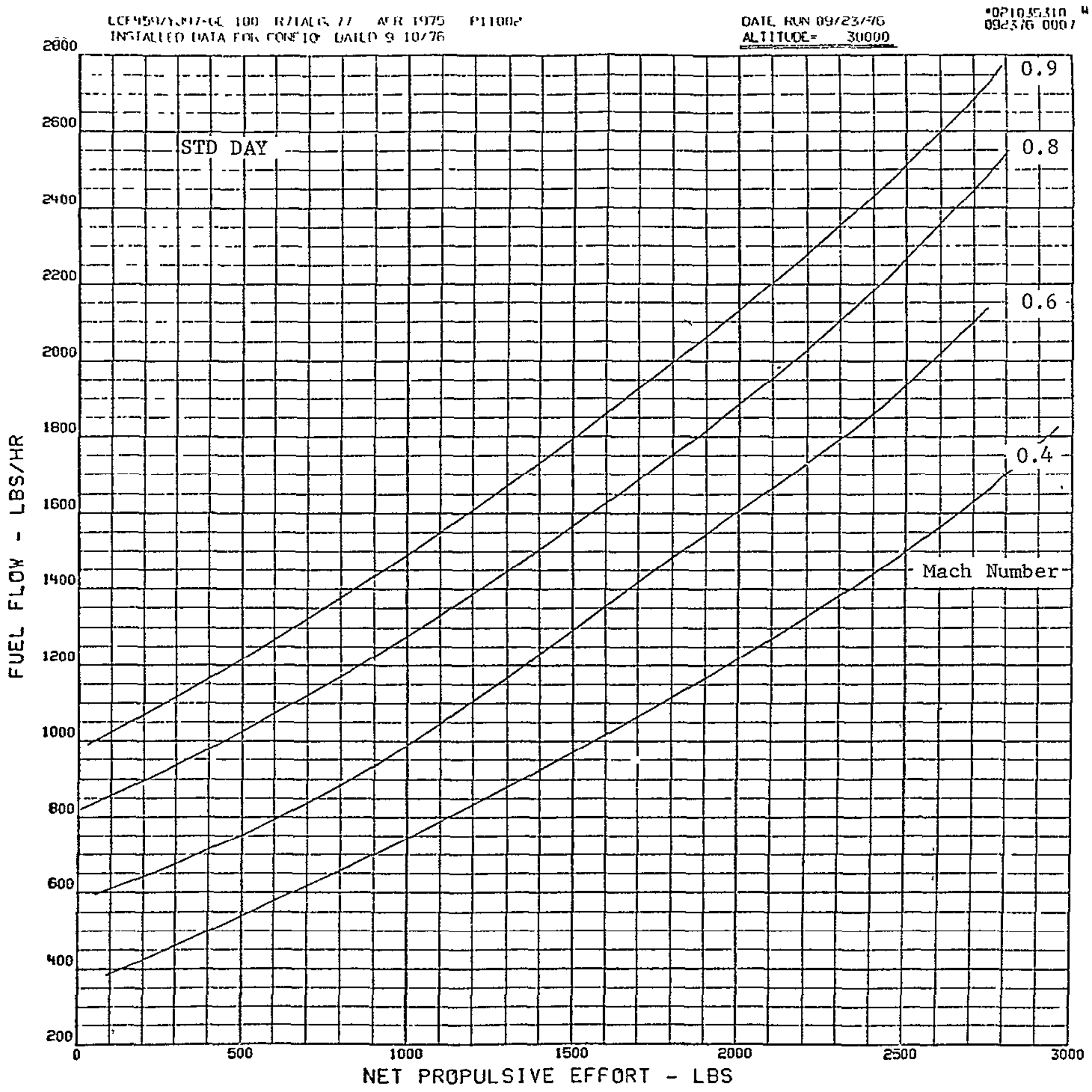


Figure 5.20 LCF459/YJ97 Installed Cruise Performance, 30,000 Ft

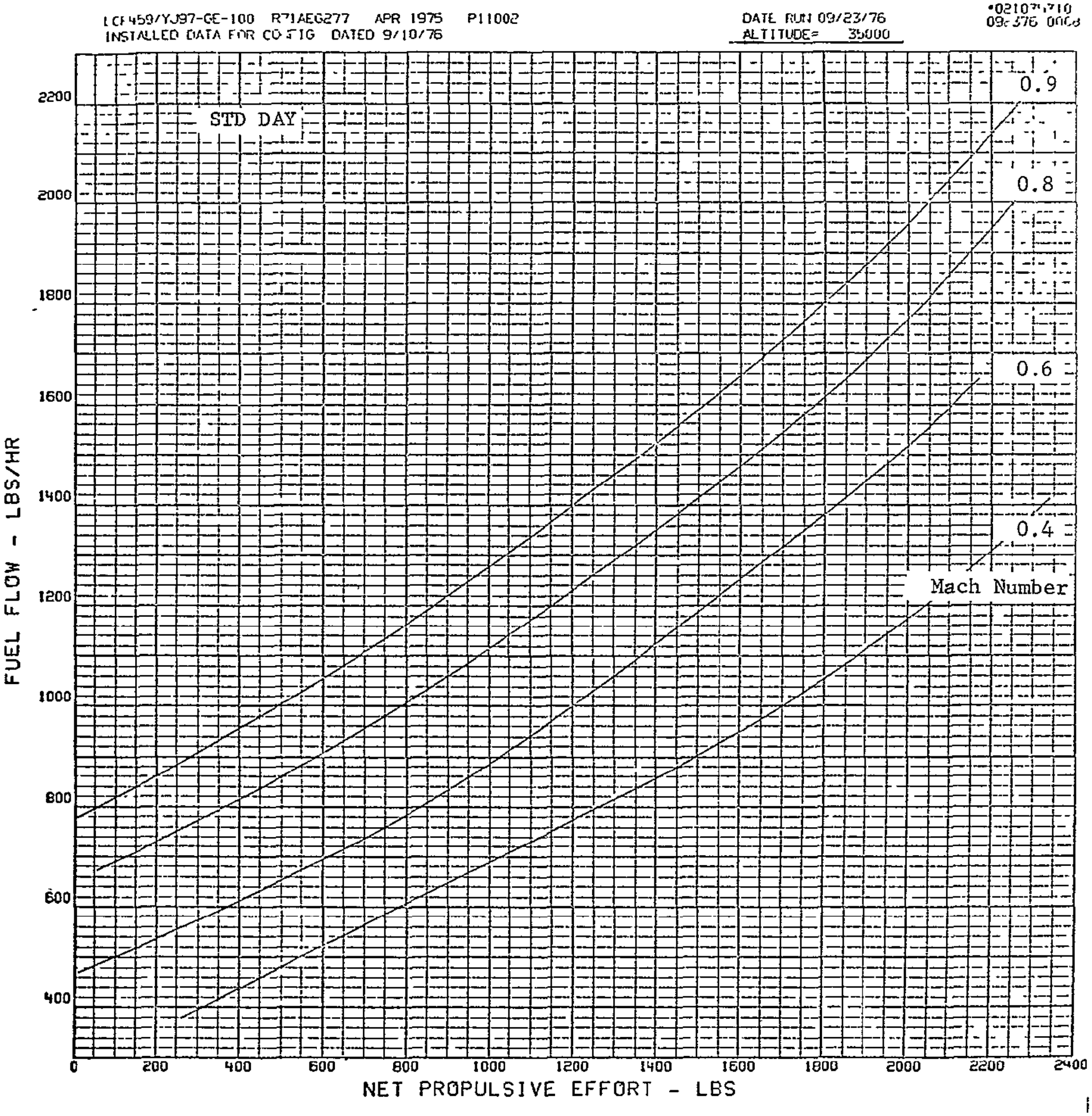


Figure 5.21 LCF459/YJ97 Installed Cruise Performance, 35,000 Ft.

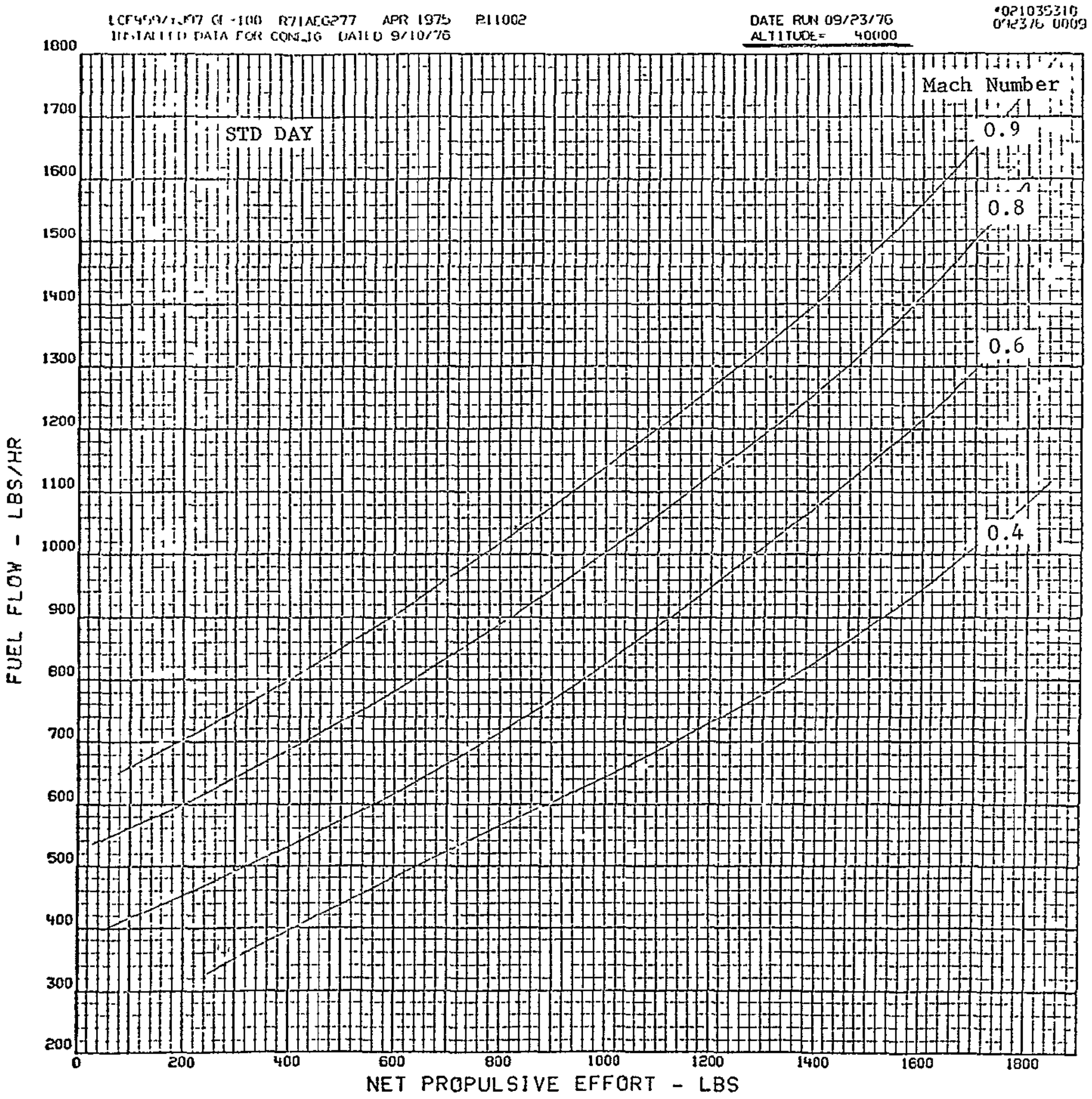


Figure 5.22 LCF459/YJ97 Installed Cruise Performance, 40,000 Ft.

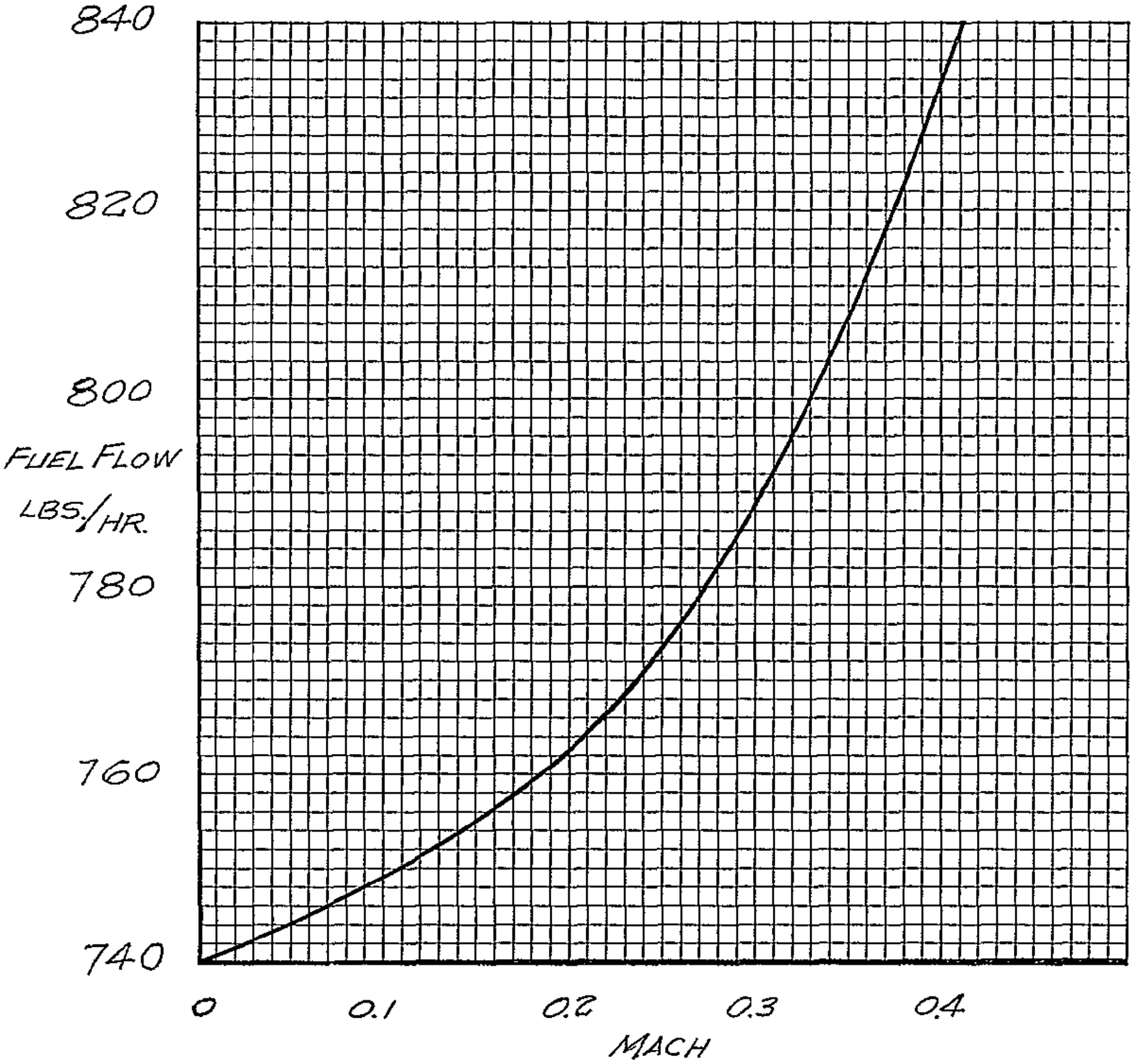
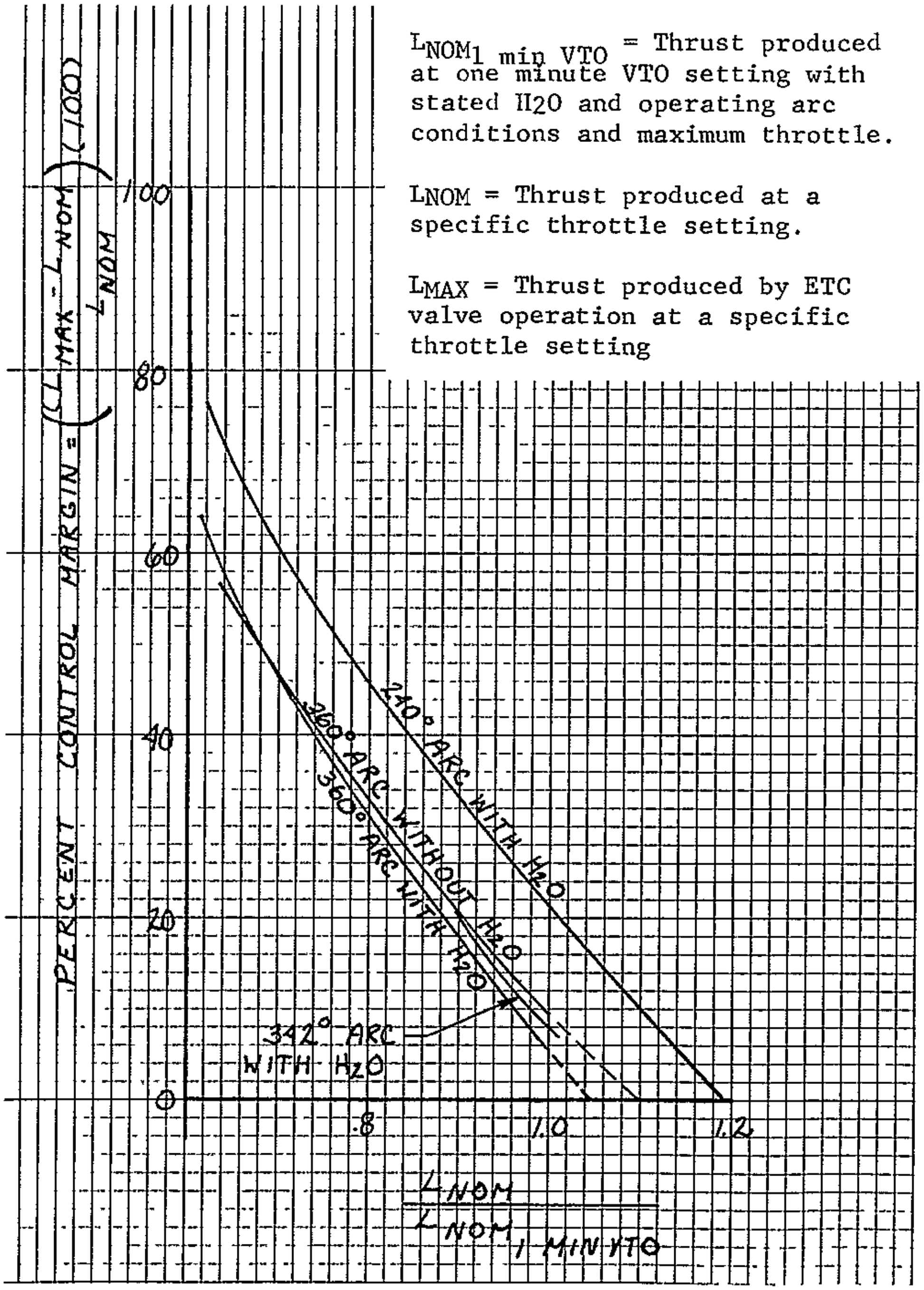


Figure 5.23 YJ97 Gas Generator Idle Power Fuel Flow



$L_{NOM_1\ min\ VTO}$ = Thrust produced at one minute VTO setting with stated H_2O and operating arc conditions and maximum throttle.

L_{NOM} = Thrust produced at a specific throttle setting.

L_{MAX} = Thrust produced by ETC valve operation at a specific throttle setting

Figure 5.24 Control Characteristics, LCF459/YJ 97

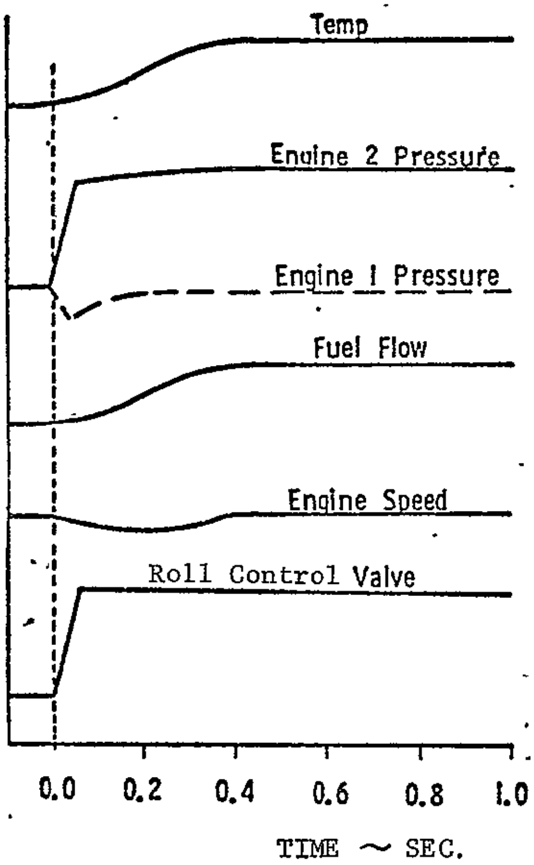


Figure 5.25 Engine Transients During Roll Control

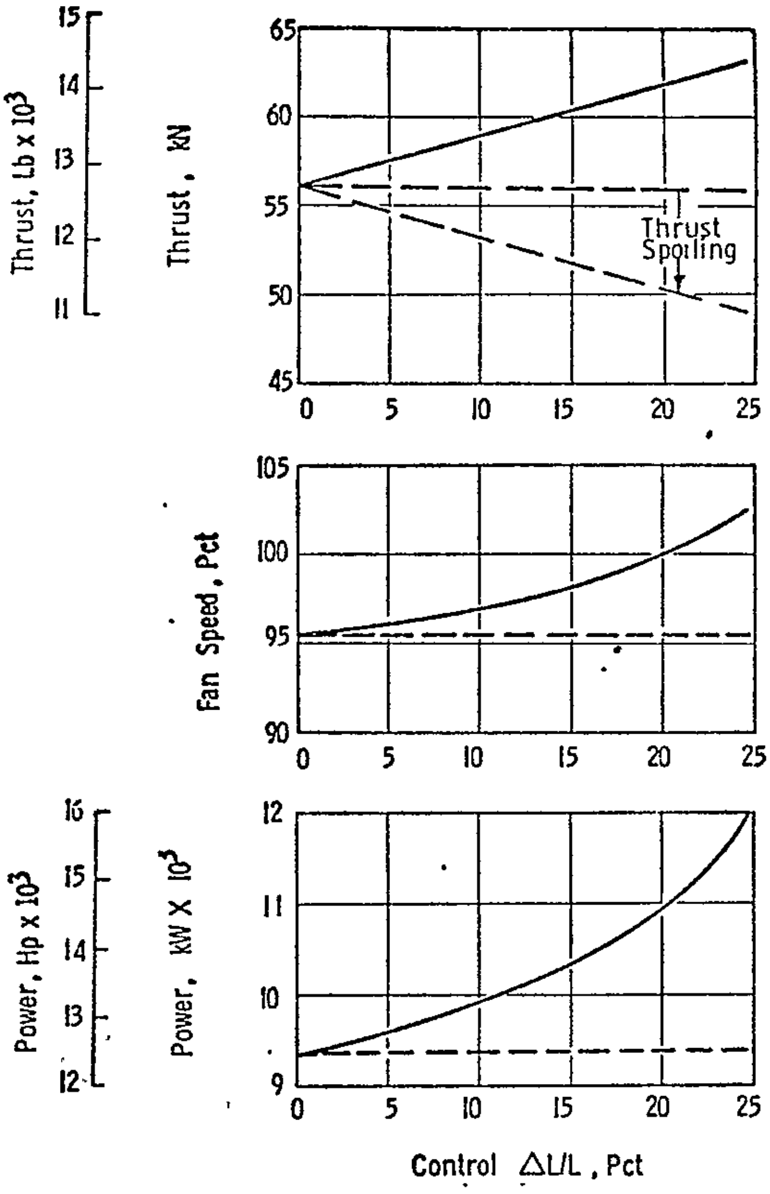


Figure 5.26 Fan Condition During Roll Control Inputs

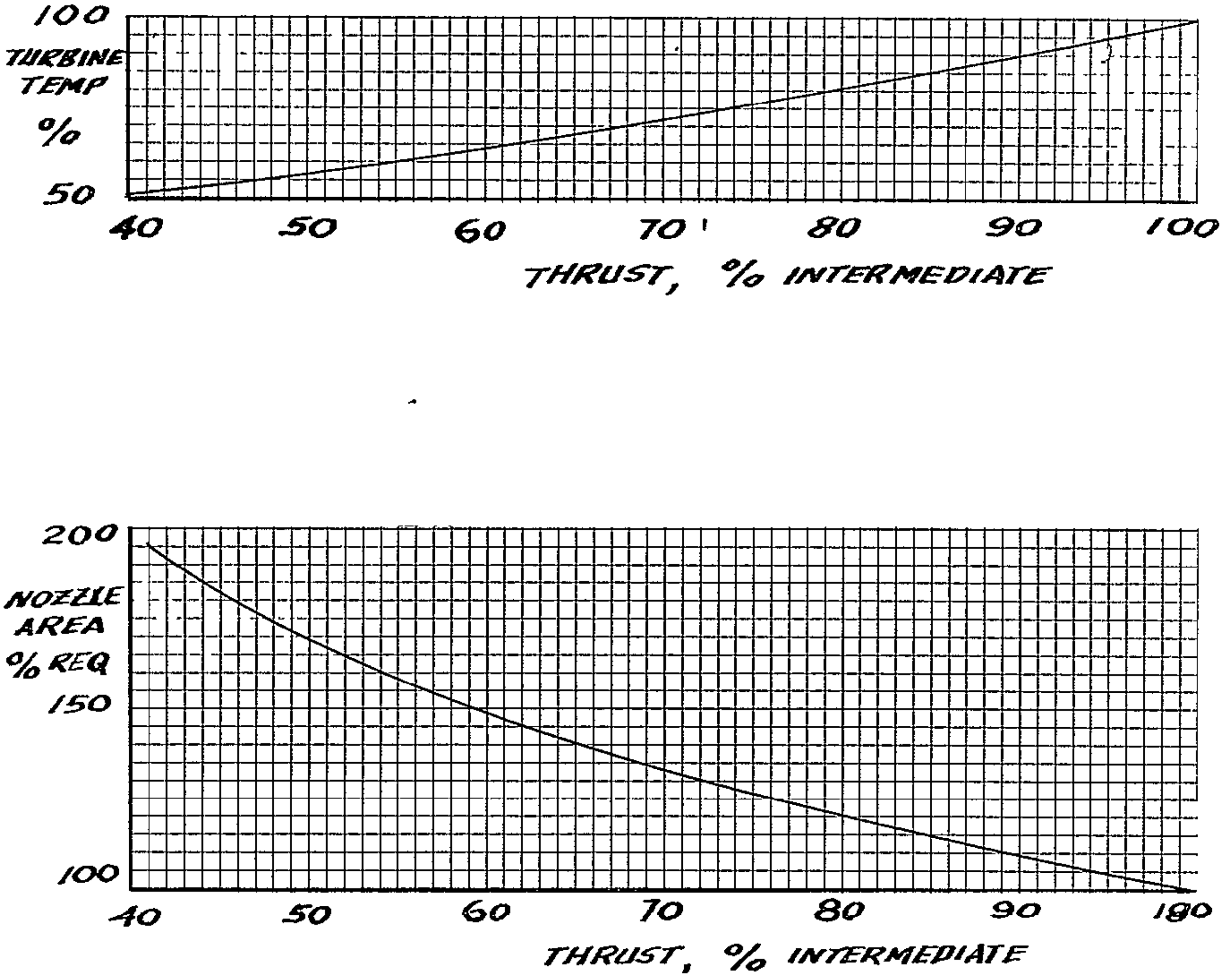


Figure 5.27 Effect of Increasing Engine Nozzle Area

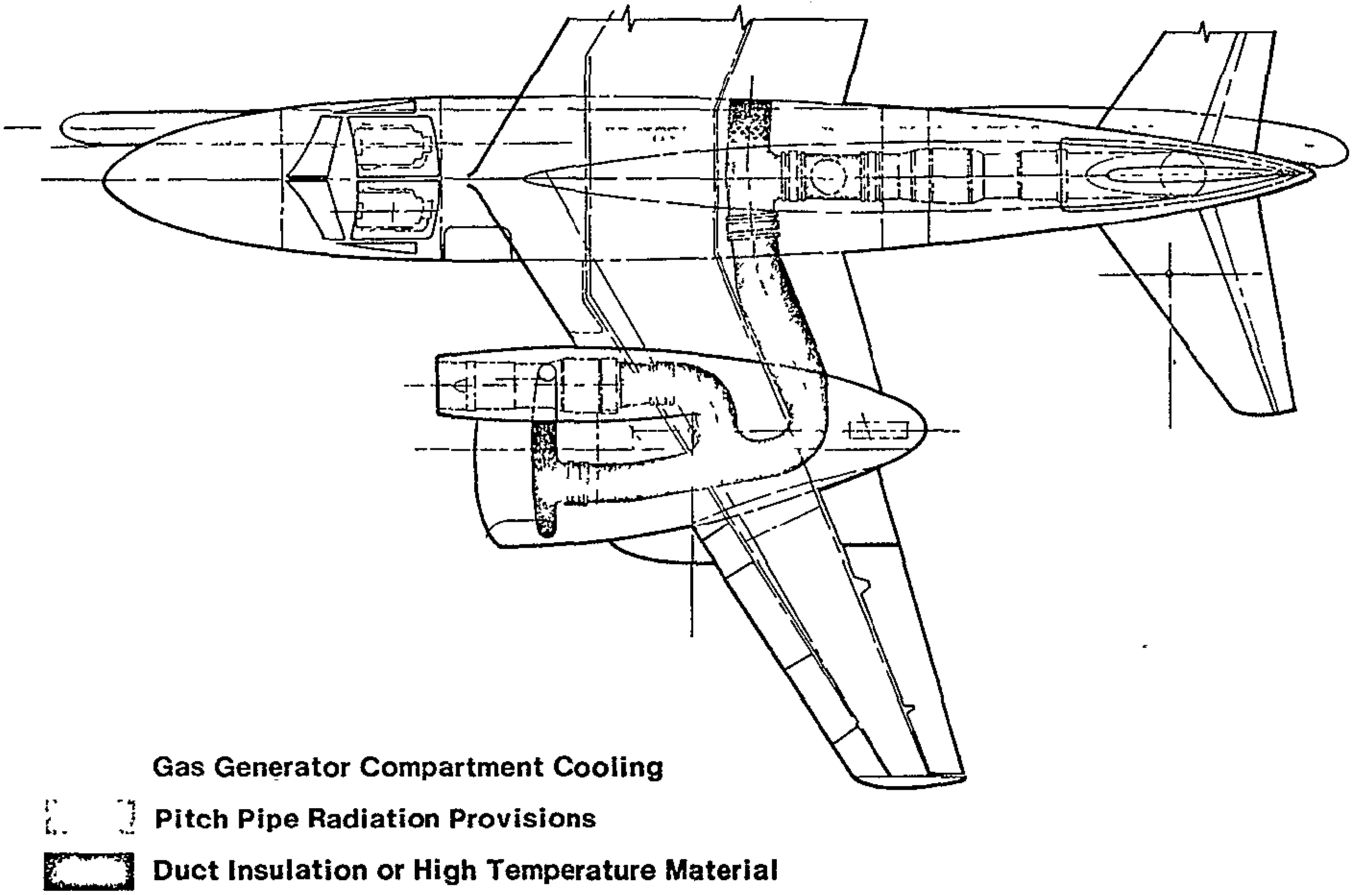
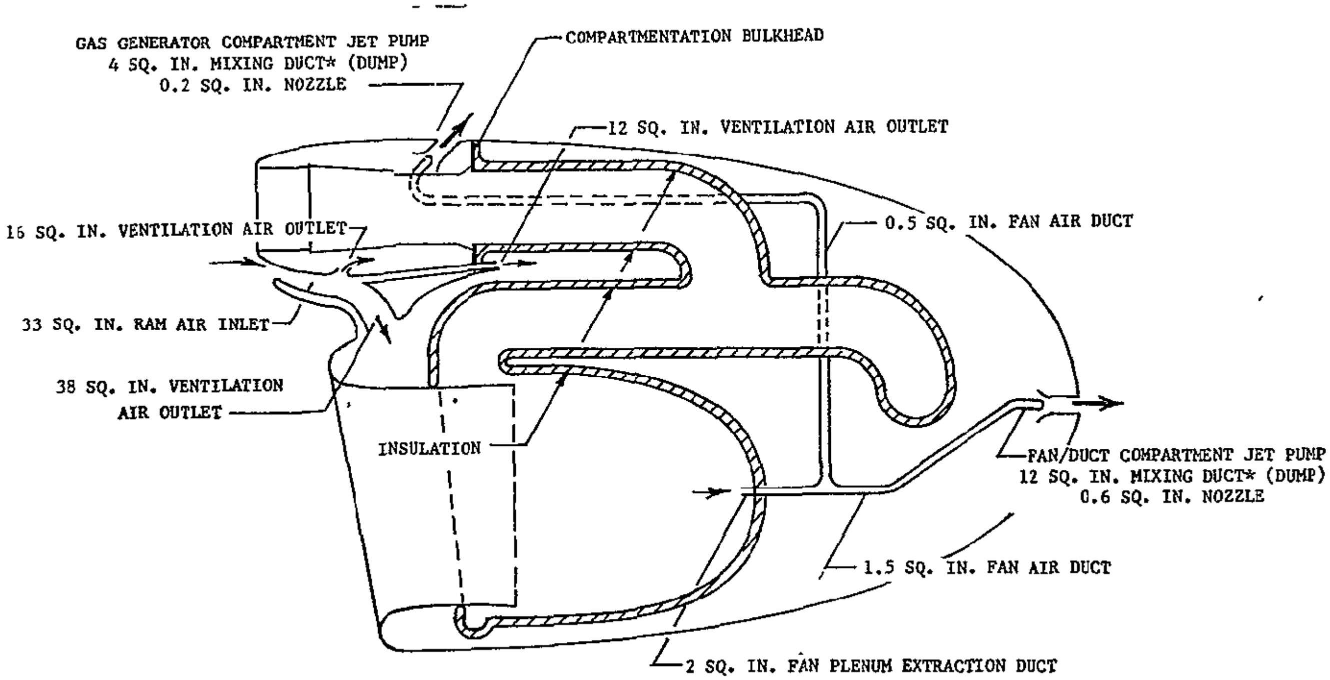


Figure 5.28 Temperature Control



* MINIMUM REQUIRED MIXING DUCT L/D IS THREE

Figure 5.29 Nacelle Ventilation Schematic

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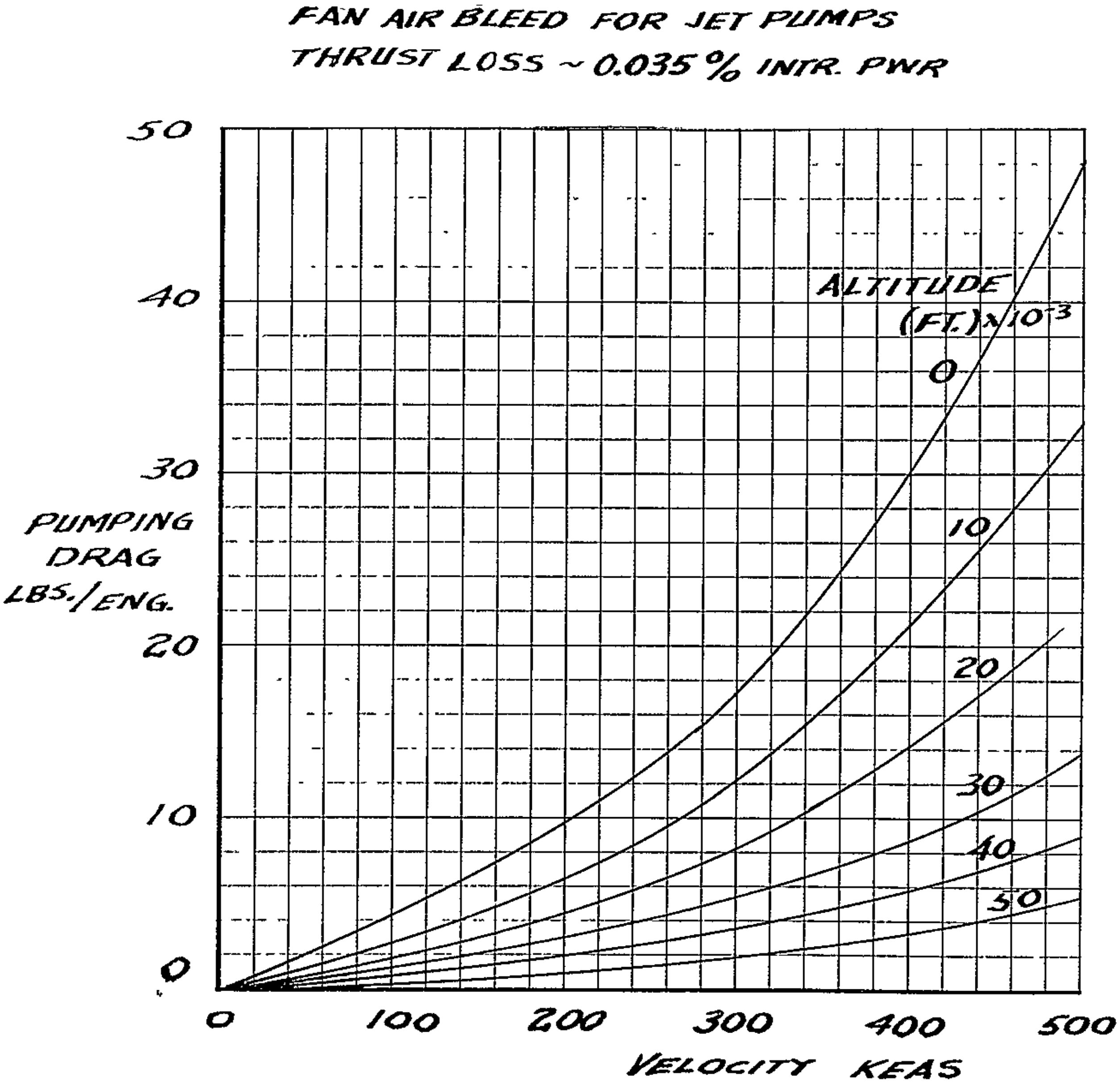


Figure 5.30 Performance Penalties from Nacelle Ventilation

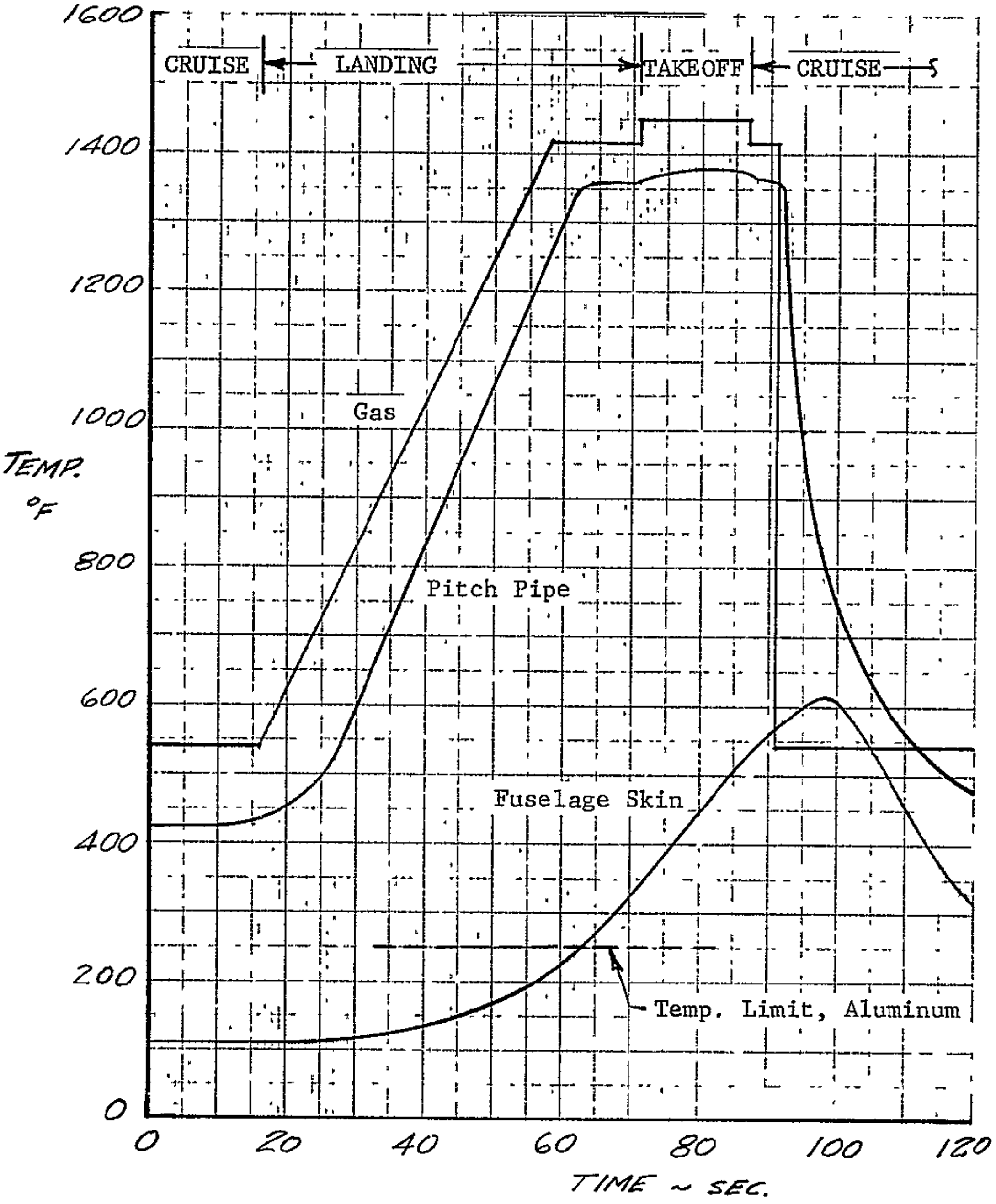
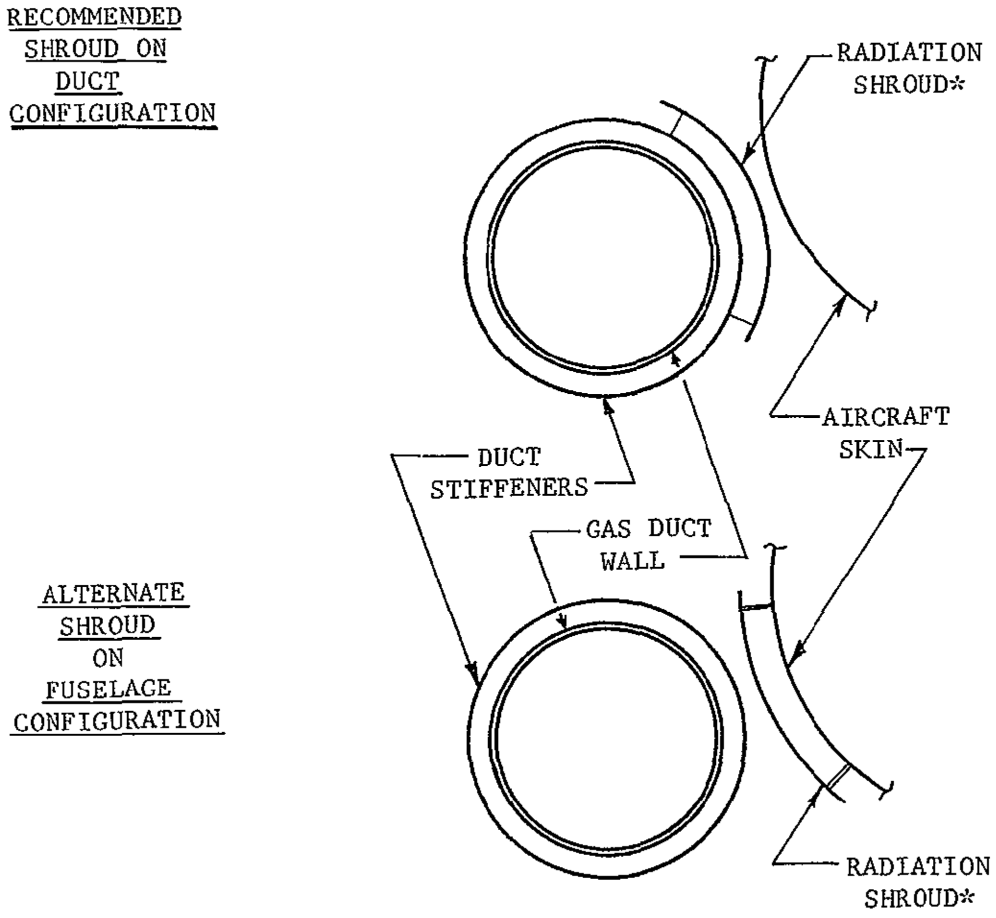


Figure 5.31 Pitch Pipe Temperature Estimates



* SHROUD COULD BE TITANIUM OR CRES AND SHOULD BE GOLD COATED ON BOTH SIDES TO SUPPRESS RADIATION HEAT TRANSFER (PROCESS SPEC. ST0108HA0004 OR ST0109HA0027)

Figure 5.32 Pitch Pipe Shroud Installations

Insulation is provided for all the hot gas ducting. Analysis for the actual aircraft operating profiles indicate that 1/4 inch MIN-K or 1/2 inch E-FLET blanket are adequate to carry out the takeoff/150 knot go-around/land missions continuously and permit 2 minutes of static operation at intermediate power (or 5 minutes if this is followed by 5 minutes at idle to cool the insulation). A five minute idle cool-down would always be desirable prior to shut-down with this aircraft.

As a precautionary measure, an insulation blanket will cover the wing skin directly below the ducting run in the nacelle. Also a radiation shroud will be placed between the rear spar and the cross ship ducting in the region between the nacelle and fuselage.

The nacelle ventilation provisions are shown in Figure 5.29. This arrangement would provide 3 air changes per minute in the gas generator compartment and 1 air change per minute in the rest of the nacelle at idle, and it would provide more than 3 air changes per minute throughout the nacelle when the engines are developing any significant thrust. The performance penalties due to these ventilation provisions are small, as shown in Figure 5.30.

Ventilation provisions for the third engine and fuselage hot gas ducting similar to that shown for the nacelle are incorporated. Jet pumps in the fuselage are powered by third engine compressor bleed air (with jet pump nozzles sized appropriately for the pressure source).

Figure 5.31 shows aircraft fuselage skin temperatures exceeding the limit for aluminum structure would be obtained near the pitch pipe without any thermal control provisions. Therefore, a radiation shroud is provided between the duct and fuselage as shown in Figure 5.32. Although the shroud could be attached to the duct or fuselage, mounting on the duct appears to be preferable. Heating of the fuselage structure to temperatures above 200°F will not occur with the shroud thermal protection.

5.3 Aerodynamic Characteristics

5.3.1 Configuration Characteristics - The modified T-39 is fitted with two wing-mounted tip driven lift-cruise fans and engines. A third engine is mounted in the fuselage to provide engine out capability and connected to a pitch pipe for longitudinal control. The full thrust of the third engine is directed vertically and used to provide additional lift in the VTOL and STOL operation of the configuration. The aerodynamic lift and drag are presented in Figures 5.33 through 5.37 . The cruise configuration drag buildup is presented in Table XIII. The estimated lift interference effect of the engine nozzle arrangement is presented in Figure 5.38 . A small negative effect is estimated for the forward location of the nozzles.

The estimated minimum drag coefficient is 0.0320 with a $C_{F_{eff}}$ of 0.0051 reflecting the interference of the nacelle on the wing and fuselage. The drag divergence Mach number is higher than the required flight speeds.

Table XIII

C_{D_0} Estimation Summary

Configuration· Lift Cruise Fan R&T Aircraft S_{Ref}: 342

Component	S_{Wet} Ft^2	L or $\bar{c}$ Ft	$R_N \times 10^{-6}$	C_f	M.F.	C_F	C_{D_0}
WING	Ex 201.5 410	$\lambda = .32$ 8.38' Æ = 5.77	22.57	.00254	t/c = .12 1.375	.00349	.00419
TAIL HORIZ.	Ex 60.7 123.5	S = 77. $\lambda = .30$ Æ = 4 4.81	12.96	.00277	t/c = .10 1.385	.00384	.00138
VERT.	Ex 38.5 78.3	S = 42.3 $\lambda = .30$ Æ = 1.5 5.82	18.83	.00188	-	.00260	.00059
FUSELAGE	618.0 68.8 93.6 780.4	$A_x \cong 39\ Ft^2$ 42.58 $D_e = 7.05$	114.71	.00201	L/D = 6.04 1.74	.00349	.00798
NACELLES	(2)x385	17.5 $D_e = 8.41$	47.14	.00228	L/D =2.1 2.9	.00661	.01489
OTHER -							
MISC. & NACELLE INTERFERENCE							.0030
TOTAL	2162	$C_{F_{EFF}}$ = .0051					.0320

$RN_{250\ KN\text{-}SL} = 2.694 \times 10^6 \times L_{Ft}$

$1/\sqrt{C_f} = 3.46 \log RN - 5.6$

$$C_{F_{EFF}} = \frac{C_{D_0} \times S_{Ref}}{S_{Wet}}$$

5.3.2 V/STOL Performance - A short takeoff analysis is presented in Figure 5.39. A minimum takeoff speed of 40 knots was utilized as a low end cut off for the STO analysis. The minimum speed of 40 knots for the takeoff was utilized as a logical speed break point between vertical and STO operation. At lesser speeds the vertical control options must be considered, while, above 40 knots, the aerodynamic controls exert considerable forces. The takeoff performance shown in Figure 5.39 includes an allowance for ground effect and thrust lift interference.

The transition time history for a vertical takeoff is presented in Figure 5.40 . The data show the transition to wing lift to be complete in 14 seconds at approximately 135 knots at which time the third engine can be retarded to idle thrust and the acceleration continued to 155 knots with the two wing-mounted lift fans. 155 knots was chosen as the speed for the go-around missions. Table XIV presents the time and fuel usage for the vertical takeoff and go-around mission at 155 knots. The data are computed with ailerons and slats deflected and a $C_L = 0.92$ for level flight and .95 for the turn. The drag is approximately the same with or without ailerons deflected for the mission and with the slats open the speed is 1.25 V_{stall} in the turns.

A transition time history for a vertical takeoff with one engine inoperative is shown in Figure 5.41. The takeoff is similar to the three engine takeoff shown in Figure 5.40, and was performed with fuel for two go-arounds and all reserves.

The conversion from level flight to the landing is presented in Figure 5.42. The configuration can descend at a constant nozzle deflection of 102^o with the control input limited to thrust variations. The airplane is on an 8^o glide slope with a speed reduction of approximately 3 knots per-second. The thrust of all three engines is applied in a continuous manner starting at the thrust required for the second turn ($\sim$ 5000 lbs.) and ending at the landing with thrust to weight = 1.0 and at slightly below intermediate thrust. Excess thrust is available during the descent for waveoff or for altitude changes. At landing, the excess thrust can develop a Δg of approximately 0.3 with 3 engine operation.

Stopping distances with a 40 knots approach speed are 325 feet with normal breaking and no reverse thrust.

5.3.3 Cruise Performance - The flight envelope of the modified configuration is presented in Figure 5.43. Minimum cruise flight speed requirements for the airplane as specified in Reference (i) are V = 300 knots at sea level, M = .7 at 25,000 feet and a cruise/endurance mission of 2 hours is required at best cruise altitude. As seen in Figure 5.43 the minimum speed can readily be met. Also presented in Figure 5.43 is the powered flight envelope. The envelope is arbitrarily cut off at 200 KEAS which is a reasonable flaps down speed limit. The mission breakdown for the two hour cruise are presented in Table XV. The mission shows a speed of 430 knots at 47,000 feet, a range of 840 NMI and fuel usage of 5050 lbs.). The fuel includes two minute warm-up and takeoff and 20 minute reserve.

Table XIV

Mission Fuel Usage

VTO Go-Around   Weight = 23,000 Lb.

Leg	Time (Sec.)	Engine	Power	Distance (Ft.)	Fuel (Lbs.)
VTO to Transition	14.0	3	VTO	1215	56
to 155 Kts.	2.0	2	VTO	490	6
Climb to 1000'	3.7	2	Intermediate	812	10
Front Stretch	16.1	2	F_N = Drag	4240	20
1st Turn	26.4	2	F_N = Drag	6911.5	42
Back Stretch	51.9	2	F_N = Drag	1360.0	60
2nd Turn	26.4	2	F_N = Drag	6911.5	42
Approach	52.0	3	Variable	6800.	140
V Landing	13	3	F_N = Weight	0	46
1 Engine Idle	126.5	1	Idle	-	27
Vertical Go-around			205 Sec.		450

Table XV

Mission Performance

BCAV Mission 5050# Fuel

Radius = 421.8 NMI Fuel = 5047.1 Lbs. Time = 120.0 Min. TOGW = 22824. Lbs.

Range = 843.6 NMI

Operation	Alt-Ft.	Wt-Lbs.	F-Lbs.	D-NMI	T-Min	CD-CTS	SR-NMI/LB	VT-Kts.
W-UP-T.O.	0.0	22504.0	320.0	0.0	2.0	0.0		
Climb Out	47788.3	21718.6	785.4	77.4	11.4	0.0		
1st Cruise Leg	47890.7	21718.6	0.0	0.0	0.0	0.0	0.2317	428.1
2nd Cruise Leg	47762.3	20280.6	1438.0	344.4	48.4	0.0	0.2395	426.7
Return Cruise	48536.1	18642.8	1637.8	421.8	59.8	0.0	0.2575	423.1
Reserve	0.0	17776.9	865.9	0.0	20.0	0.0	1840.1	140.6

5.3.4 Stability and Control - The Research and Technology Aircraft T-39 Mod. has been designed as a low cost technology demonstration vehicle. V/STOL and conventional flight are achieved with a relatively simple combination of cruise fan engines, flow diverters and a pitch pipe on an existing T-39 airframe. In the vertical flight mode, the cruise fan swivel nozzles are rotated to the vertical about an axis close to the airplane center of gravity. Pitch control is developed by an external pitch pipe with forward and aft nozzles at fuselage stations 0 and 528. A total of 5000 pounds of gas generator thrust is available at these nozzles. In practice, one nozzle is closed or partially closed while the other is simultaneously opened to achieve longitudinal control and trim.

Roll control and trim is generated by increasing thrust on one outboard nacelle nozzle and spoiling thrust on the opposite outboard nozzle. Yaw control is obtained by small forward and aft differential deflection of thrust with vanes in the outboard nozzles. Figure 5.44 describes the V mode (powered lift) control system.

Transition is achieved by gradually rotating the main cruise fan nozzles aft. As forward speed is developed, control authority is gradually transferred to the conventional flight controls of elevators, ailerons, and rudder. Stabilizer deflection range of ± 9 degrees is provided to assure adequate control over the expected range of downwash variation.

The stability and control characteristics presented are for the conditions tabulated below.

Conditions for Stability and Control Analysis		
Gross Weight		23,370 Lbs.
Center of Gravity	Station	241.93
Center of Gravity	Water Line	18.8
Roll Inertia		31,750 Slug-Ft^2
Pitch Inertia		35,200 Slug-Ft^2
Yaw Inertia		63,250 Slug-Ft^2

5.3.4.1 Vertical Flight Mode - During normal V mode operation, Level 1, the full output of one gas generator is diverted through the pitch pipe and is directed fore and aft in proper proportion to provide longitudinal trim and control. The extent of control available is determined by the thrust modulation capability of the nozzles.

With one gas generator inoperative, Level 2, sufficient thrust from the remaining two gas generators is diverted to the pitch pipe to assure 0.3 rad/sec^2

pitch acceleration in combination with the most adverse trim requirement.

Figures 5.45 and 5.46 present the simultaneous roll and yaw control available for Level 1 and 2 operation. The simultaneous control capability while maintaining a pitch acceleration of 0.5 radian per sec.^{2}, Level 1, exceeds the single axis roll and yaw control requirements defined in the guidelines. Similarly, Level 2 simultaneous capability exceeds those specified in the guidelines. Lateral control is achieved by speeding up a fan on one side while spoiling the thrust on the other side. The propulsion system time constant and control system dynamics are shown in Figure 5.47 for height control (thrust control) and Figure 5.48 for roll control (fan speed).

5.3.4.2 STOL Flight and Transition - The elements of the stability and control system that change between vertical flight and conventional flight are the deflection angles of the thrust nozzles, the valve schedule of the pitch pipe thrust diverters, and the mode of the stability augmentation system. As the airplane develops forward speed, the conventional flight controls become aerodynamically effective and add to the propulsive control forces. The rotational acceleration capability generally increases with speed as shown in Figures 5.49 and 5.50. The reduction in roll and yaw accelerations in the vicinity of 15 to 30 knots is due to the dropoff in propulsive control effectiveness as the main thrust nozzles are rotated aft toward the normal cruise position. Transition is completed at 140 and 128 for Levels 1 and 2, respectively. The abrupt reduction in control acceleration at transition completion corresponds to the termination of all propulsive control. Note that at all speeds during transition, the single axis STOL control guidelines are exceeded.

A stability and control augmentation system is provided to reduce the pilot's work load during hover and transition. Three axis motion sensing will be provided by rate gyros. Control authority for cruise flight always exists with the fly-by-wire system providing dual failure operative during vertical flight.

5.3.4.3 Conventional Flight Mode - The T-39 modified Research and Technology aircraft is in conventional flight mode when the thrust nozzles are pointing aft. Stability and control is provided by conventional aerodynamic surfaces. The vertical and horizontal tail have been sized to provide static stability in conventional flight. The arrangement of three gas generators driving two fans results in symmetrical roll and yaw forces even when one gas generator is inoperative. Except for the reduction in total thrust, there is no critical asymmetry or transient that is introduced when one engine fails. The aileron and the vertical fin and rudder are adequate for Level 2 operation.

5.3.4.4 Static Longitudinal Stability - The proposed test configuration is shown with the low horizontal tail of the T-39, but the tail size corresponds to the Sabre 75. This tail position was selected to minimize cost. The proximity of the jet exhaust to the horizontal tail may reduce the tail input to longitudinal stability. If the wind tunnel tests indicate a stability problem, the horizontal tail can be moved up or the fan nozzles can be deflected down a small amount to minimize the jet induced downwash gradient with angle of attack. It is not anticipated that the magnitude of downwash will be a problem. Figure 5.51 shows the downwash measured on a 0.10 scale V/STOL lift-fan model at the NASA Langley Research Center. This model was generally similar to the modified T-39, but it had a high tail, and the downwash is shown for flaps deflected 50°. The modified T-39 does not have flaps. The combination of zero flap deflection and low tail of the modified T-39 is estimated to experience a variation in downwash with lift and nozzle deflection angle similar to that of the test model.

The downwash angle does not become significant until the nozzles are deflected more than 60°. This deflection would only be used at high thrust levels and at low speeds during conversion, as shown on Figure 5.52. The effective angle of attack of the horizontal tail can be reduced 9° by the variable incidence capability provided.

5.3.4.5 Longitudinal Neutral Point - Figure 5.53 presents the longitudinal neutral point as a function of airspeed for the configuration at full throttle. With the aft center of gravity position at 19.5% MAC, positive static stability is realized down to approximately 66 knots.

5.3.4.6 Directional Stability - The variation of directional stability as a function of speed for the configuration with full throttle is presented on Figure 5.54. Positive static stability is maintained down to approximately 76 knots.

5.3.4.7 Roll Characteristics - Figure 5.55 presents the conventional flight roll characteristics of the modified T-39 at sea level. The modified T-39 ailerons extend inboard to the nacelle thus providing a larger aileron to compensate for the increased roll inertia. Figure 5.55 shows that, at a speed of 140 knots, the configuration will bank approximately 28 degrees in the first second. This level of roll performance is satisfactory for the conventional flight mode.

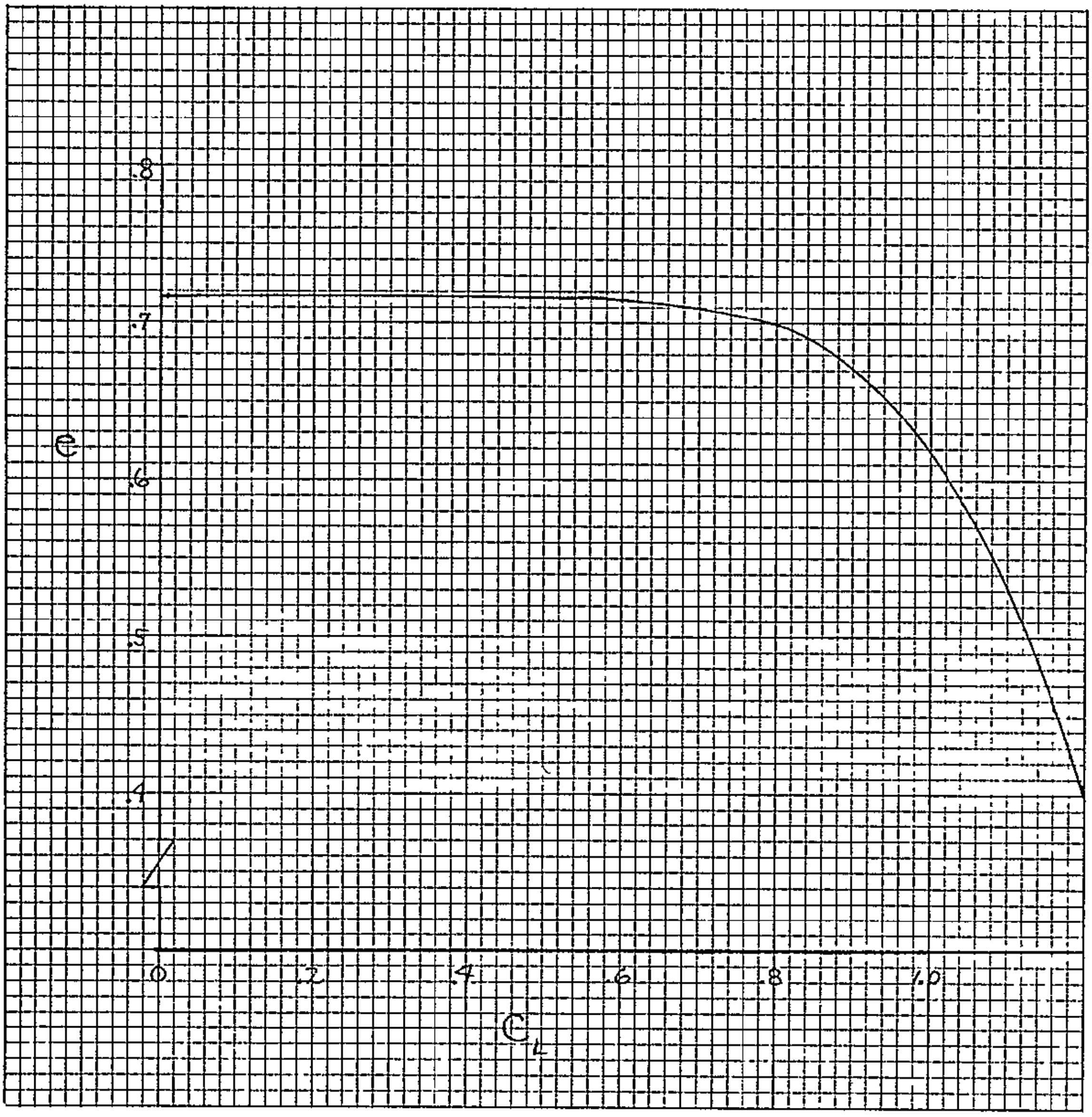


Figure 5.33 Aerodynamic Efficiency

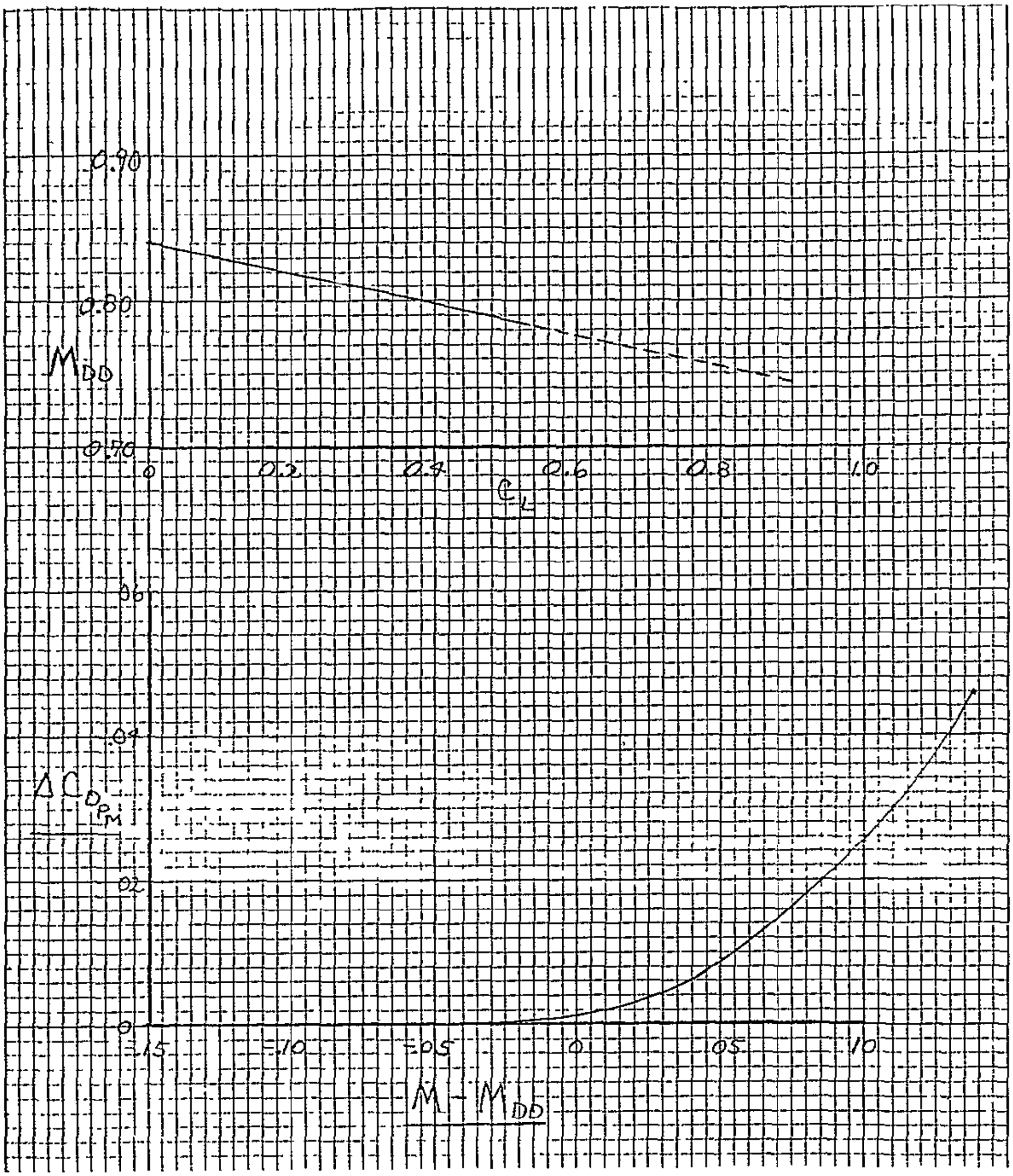
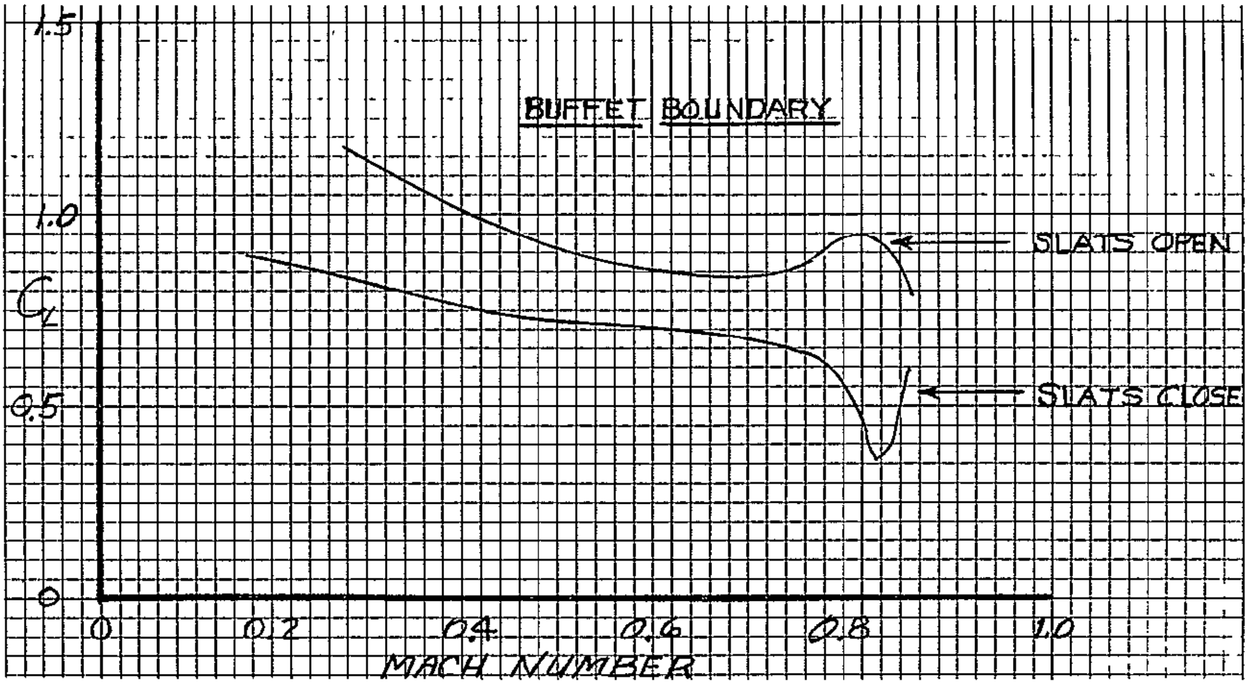


Figure 5.34 Drag Divergence



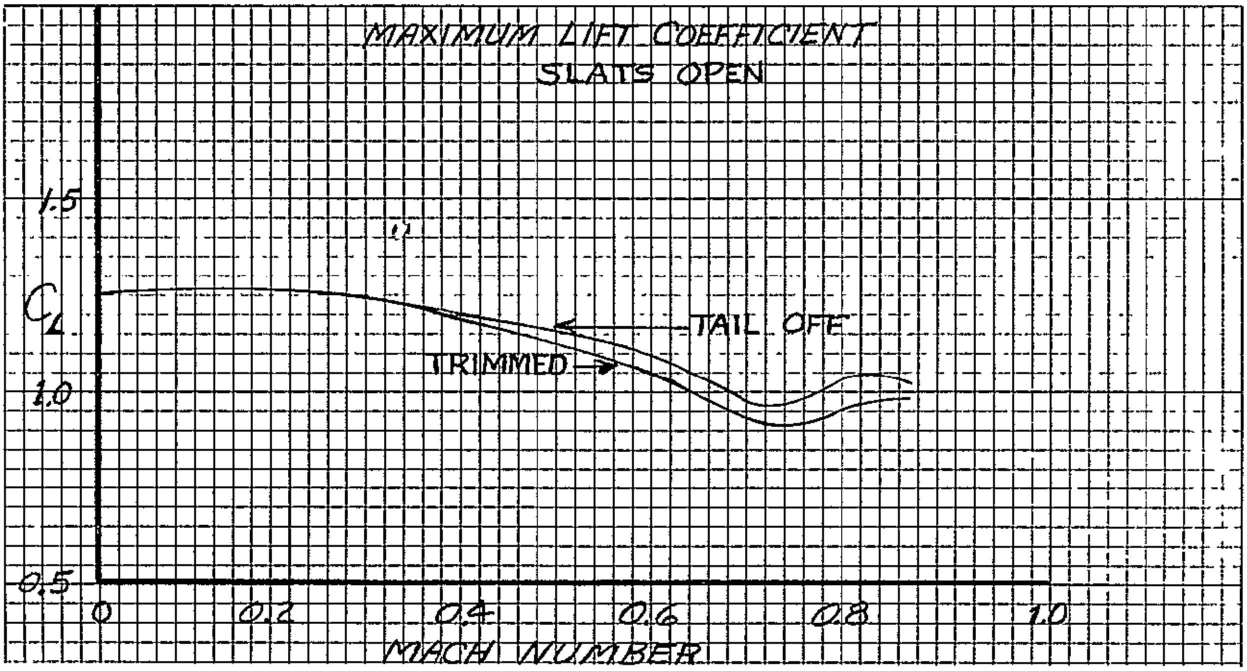


Figure 5.35 Buffet Boundary

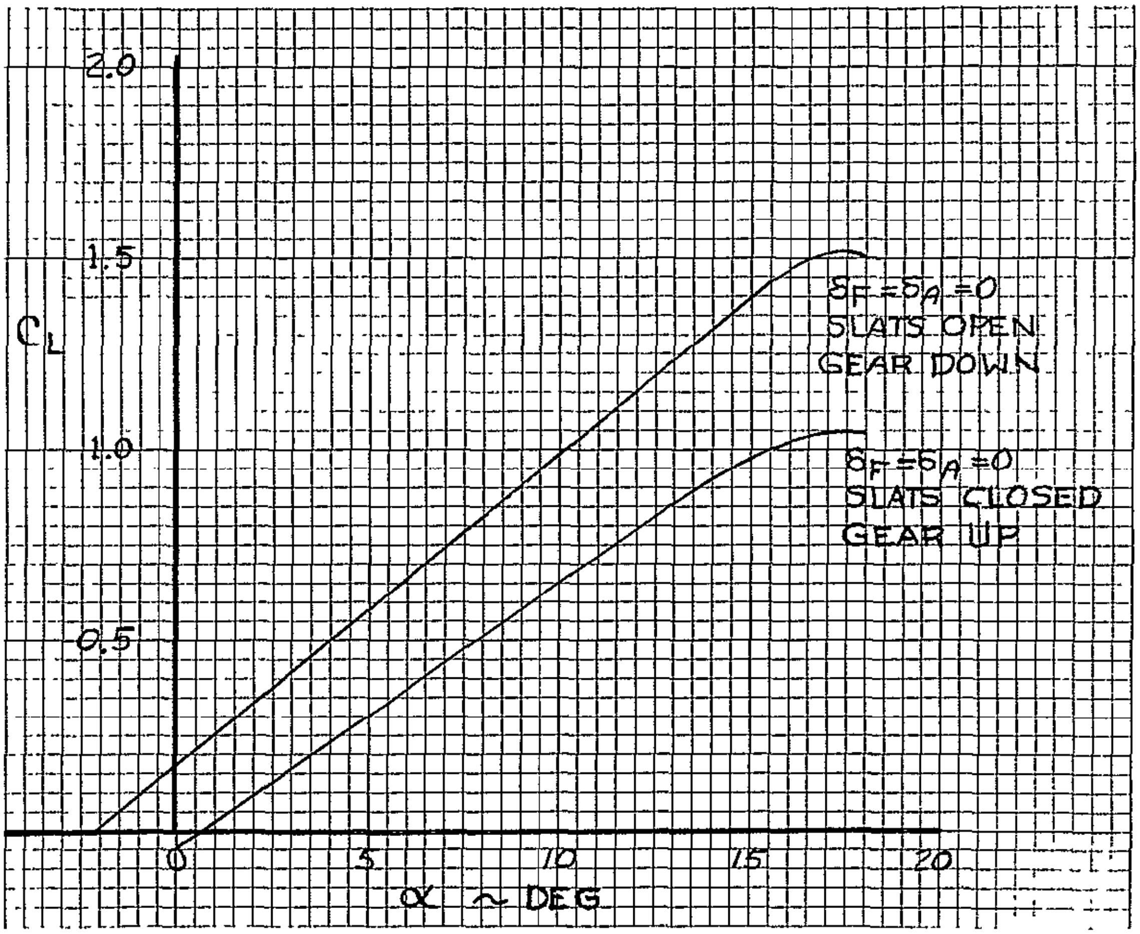


Figure 5.36 Lift-Coefficient Vs Angle of Attack

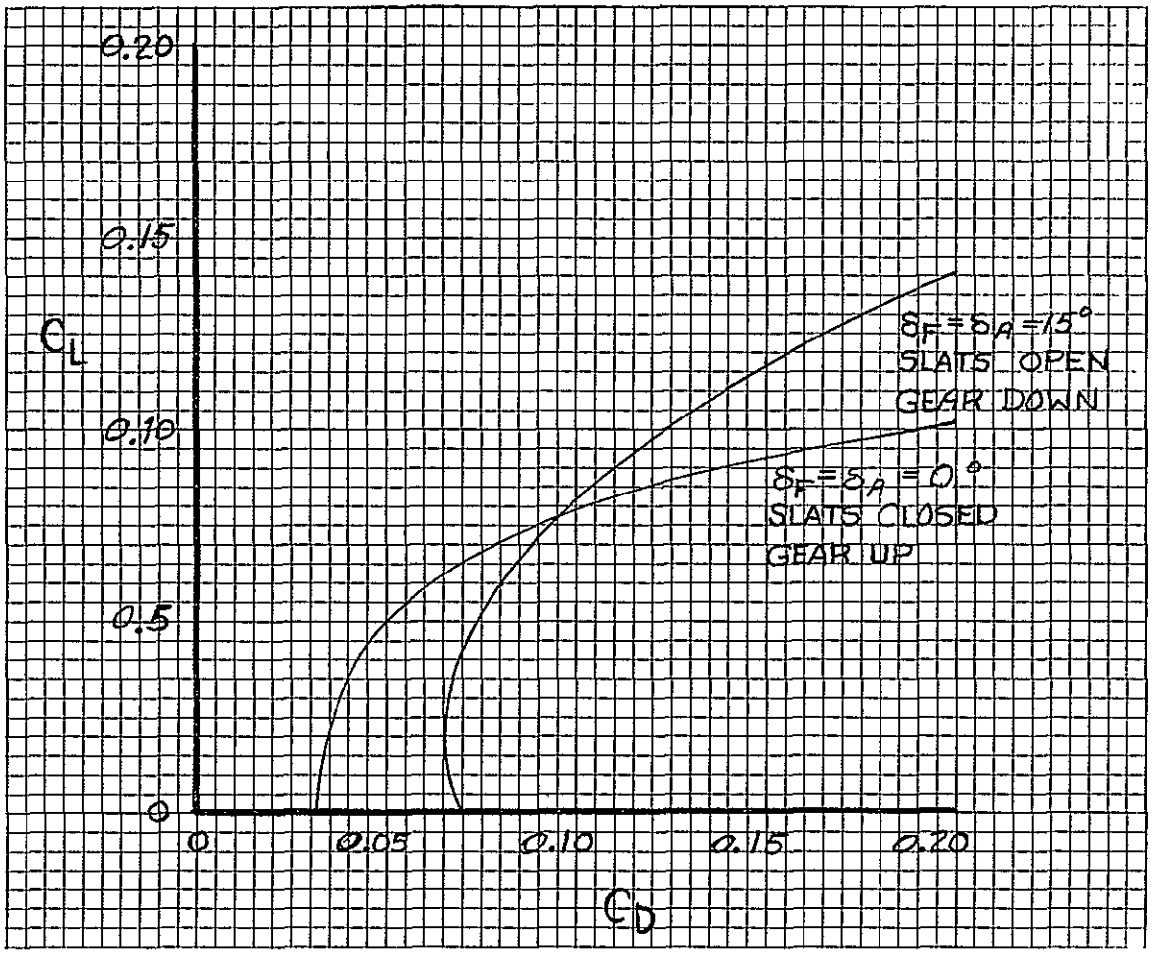


Figure 5.37 Drag Polars, TO & L

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0.10 Scale V/STOL Model

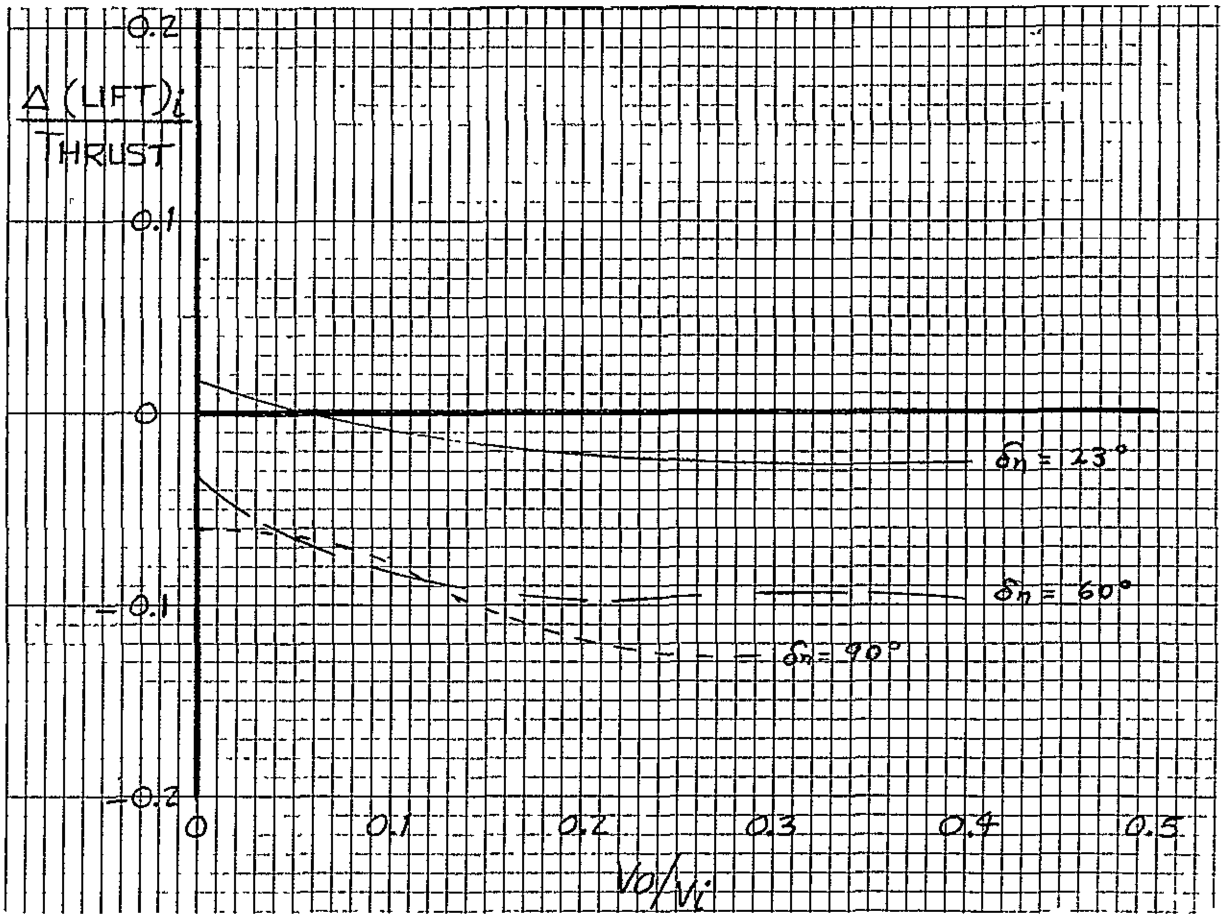


Figure 5.38 Interference Lift

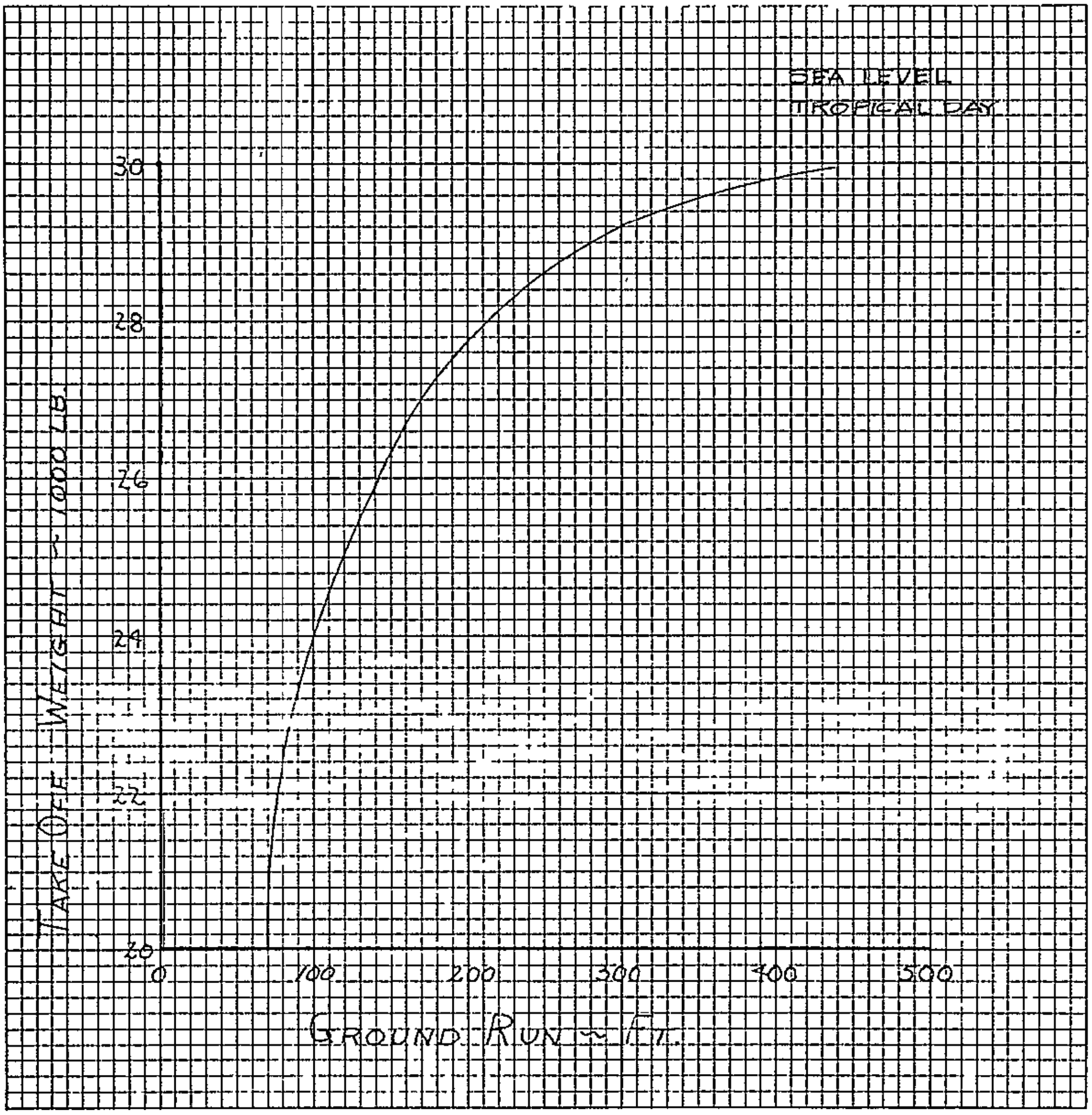


Figure 5.39 Take-off Performance

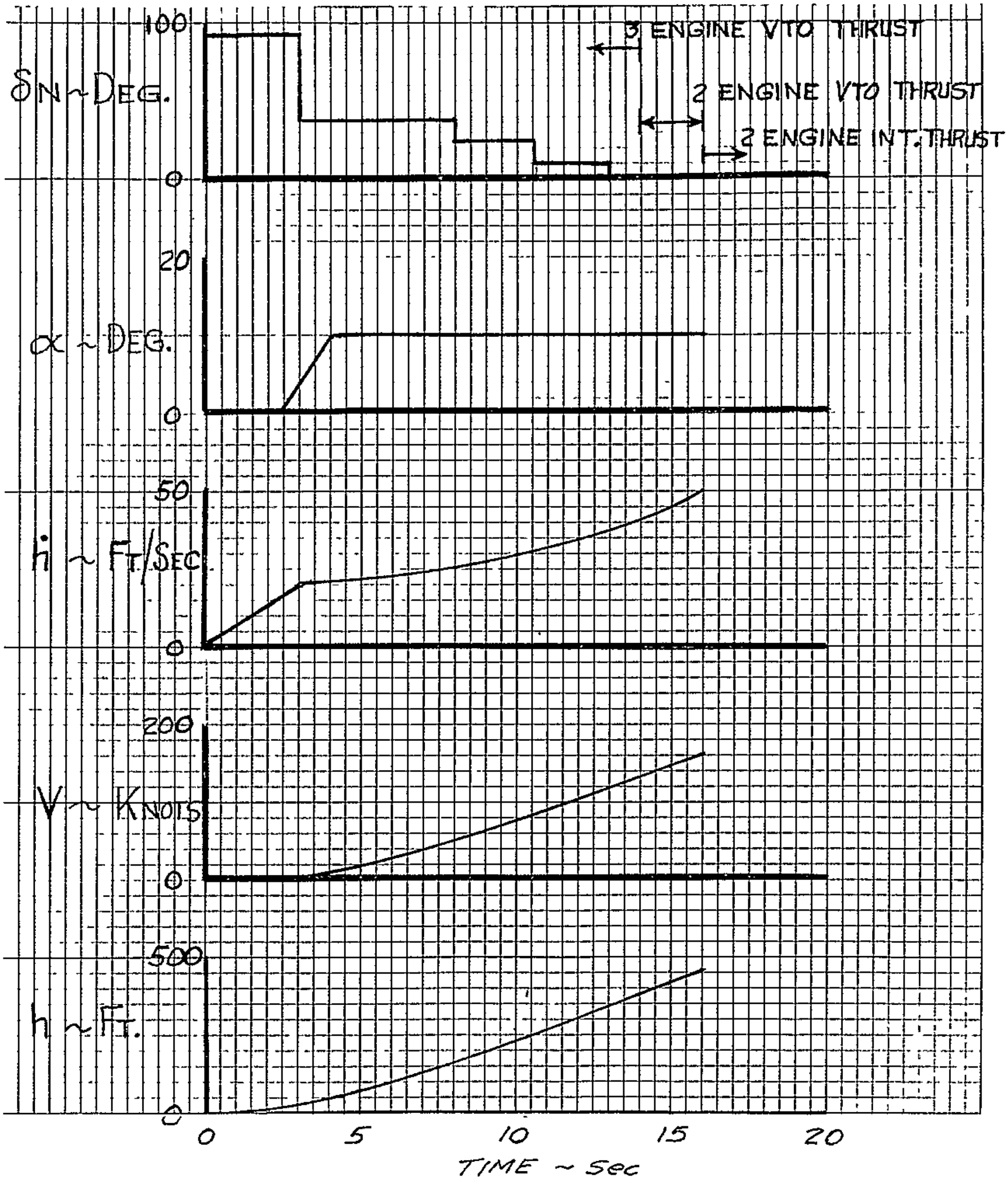


Figure 5.40 Time History of a Vertical Take-Off and Conversion

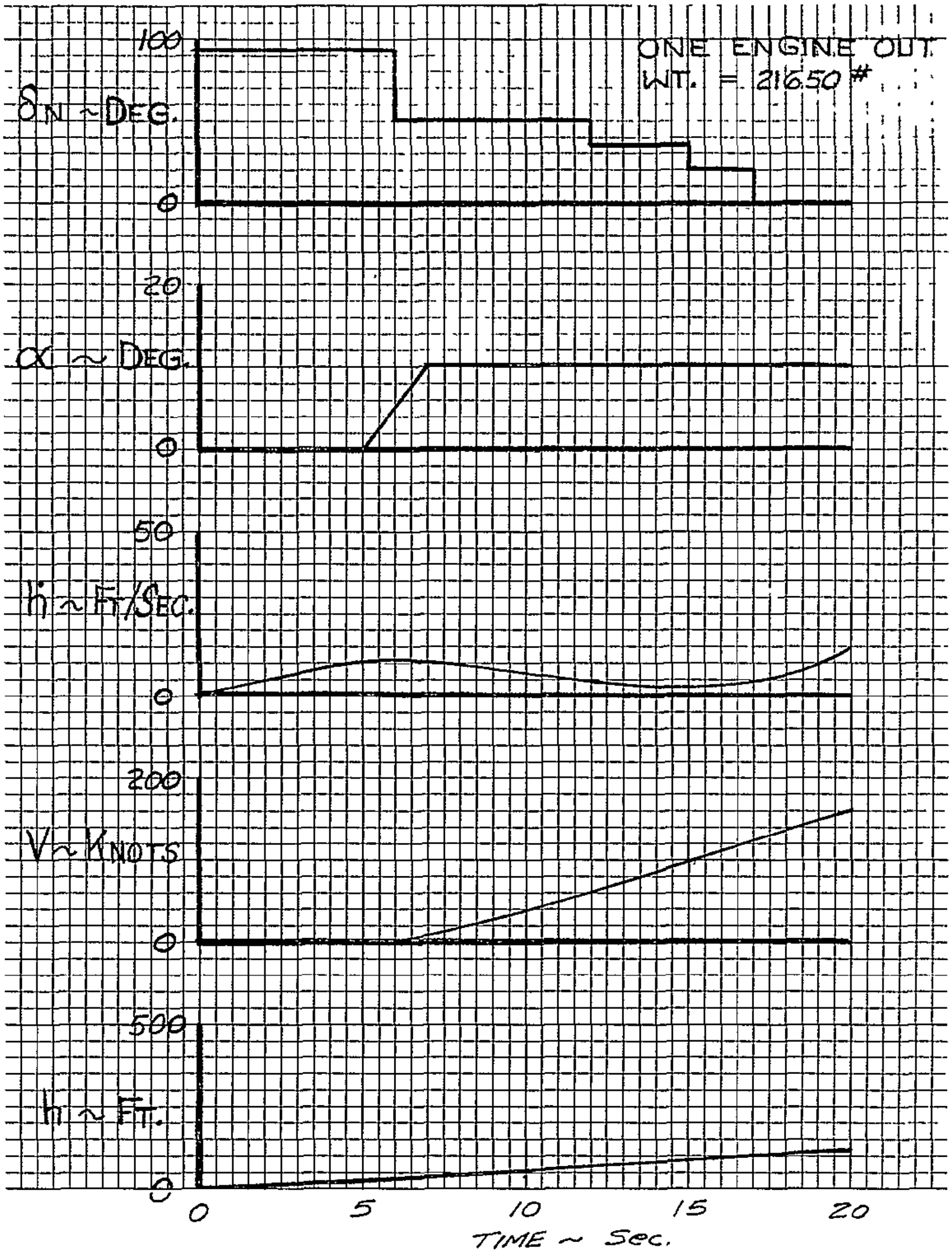


Figure 5.41 Time History of a Vertical Take-Off and Conversion, Engine Out

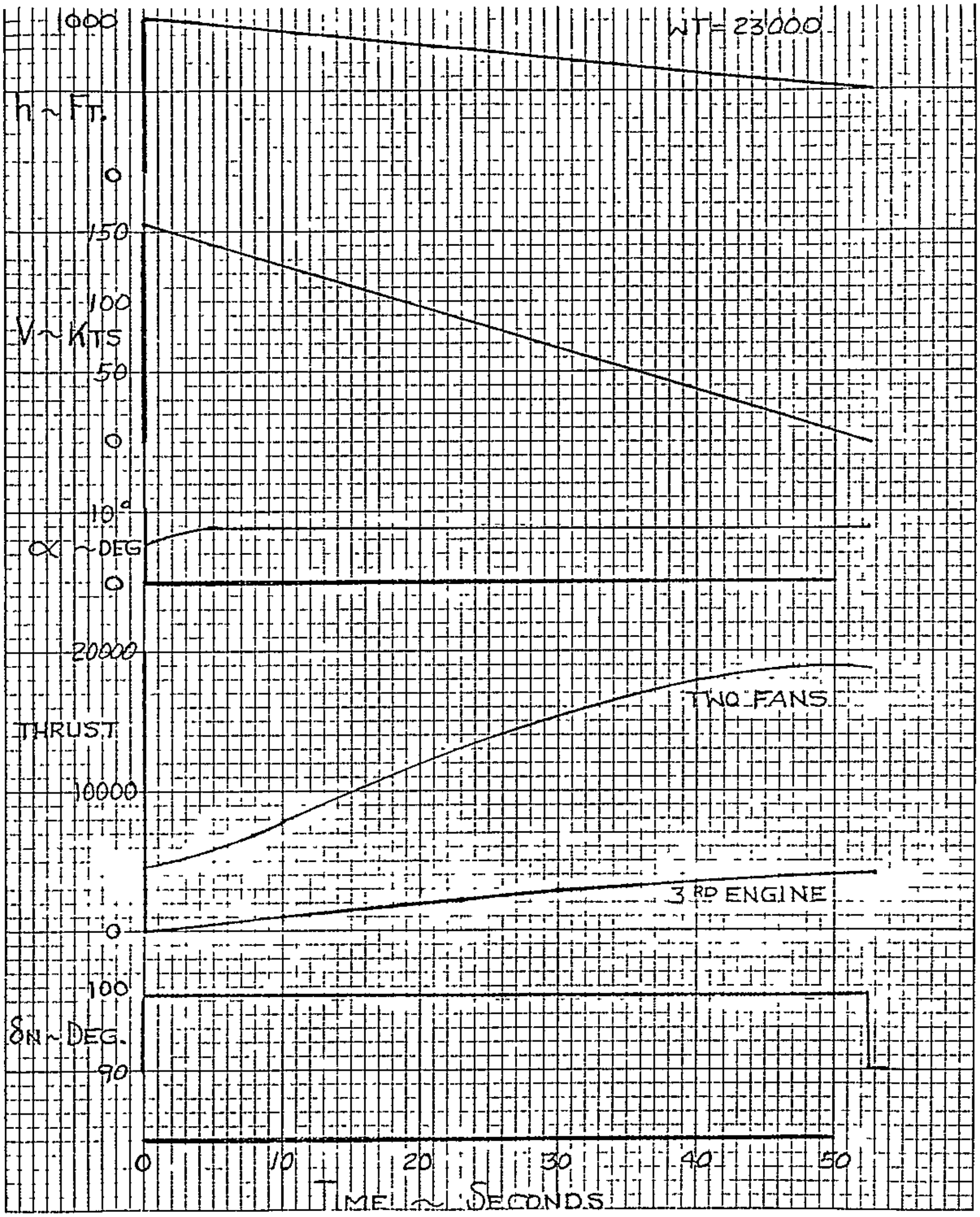


Figure 5.42 Time History of a Descent

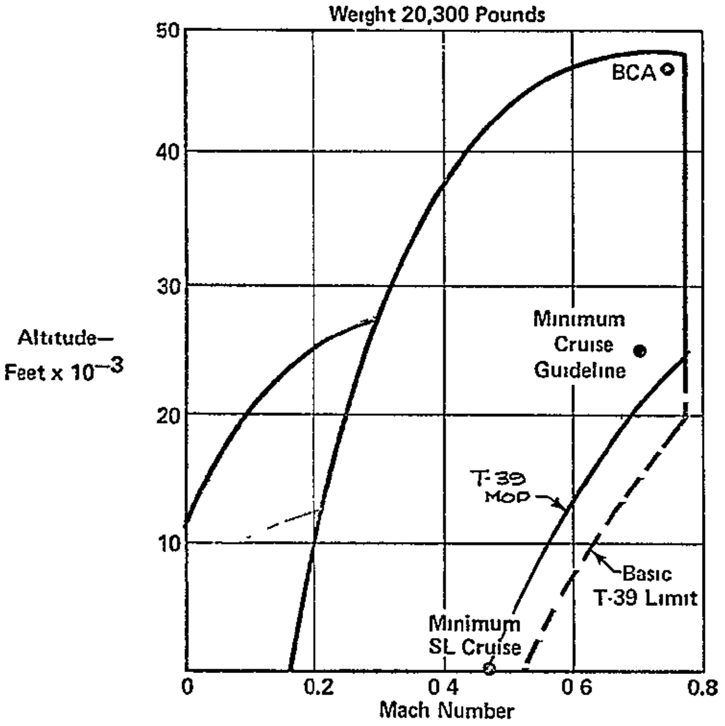
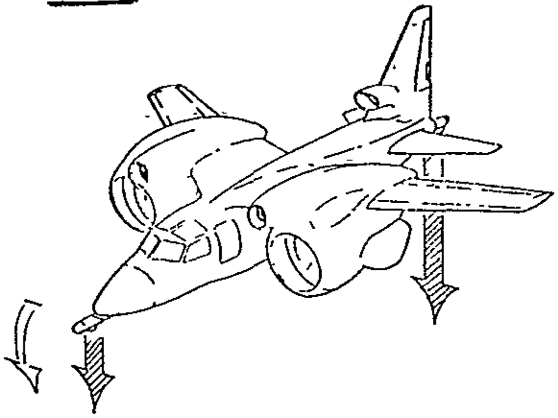


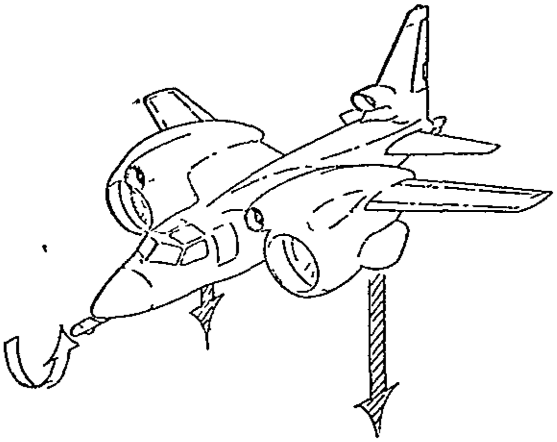
Figure 5.43 T-39 Mod Flight Envelope

PITCH (Modulated Lift from Variable Nozzle Area)



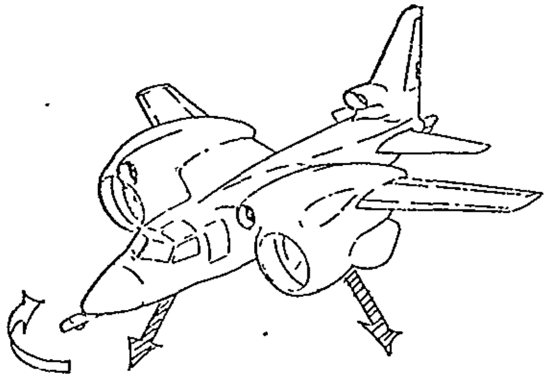
	Level 1	Level 2	
$\ddot{\theta}_{reqd}$	0.5	0.3	(rdn/sec^2)
l_{yy}	35,000		slug ft^2
M_{reqd}	17,600	10,560	ft lbs
$\ddot{\theta}_{ava}/\ddot{\theta}_{reqd}$	>5	2.5	

ROLL (Differential Lift from Thrust Transfer and Spoiling)



$\ddot{\psi}$	0.3	0.2
l_{zz}	53,250	
M_{reqd}	18,974	12,660
$\ddot{\psi}_{ava}/\ddot{\psi}_{reqd}$	2.67	2.0

YAW (Deflected Lift from Exhaust Vanes)



$\ddot{\phi}$	0.9	0.4
l_{xx}	31,750	
M_{req}	28,576	7,696
$\ddot{\phi}_{ava}/\ddot{\phi}_{reqd}$	1.10	1.75

Figure 5.44 Hover Control Concept

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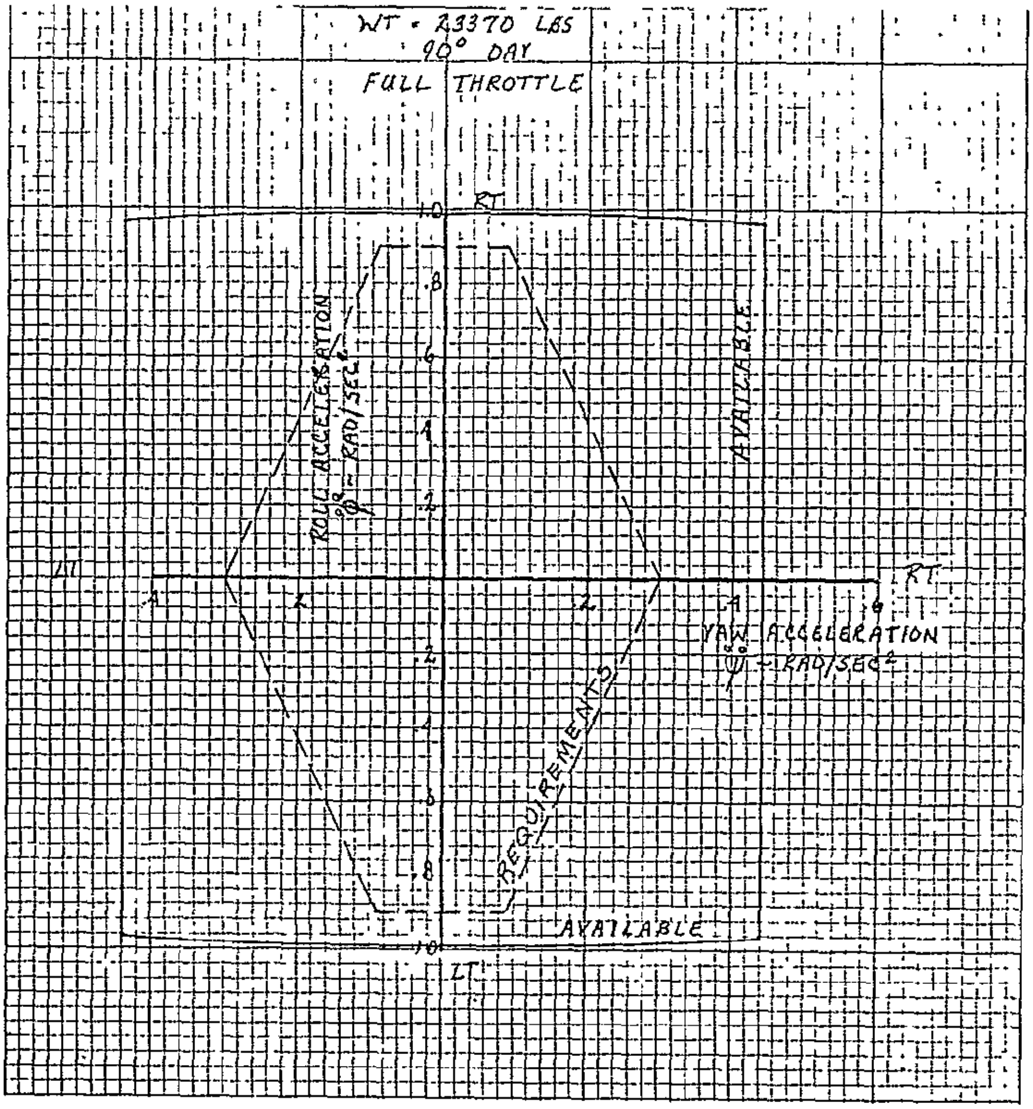

Figure 5.45 Roll Yaw Control Capability, Level 1

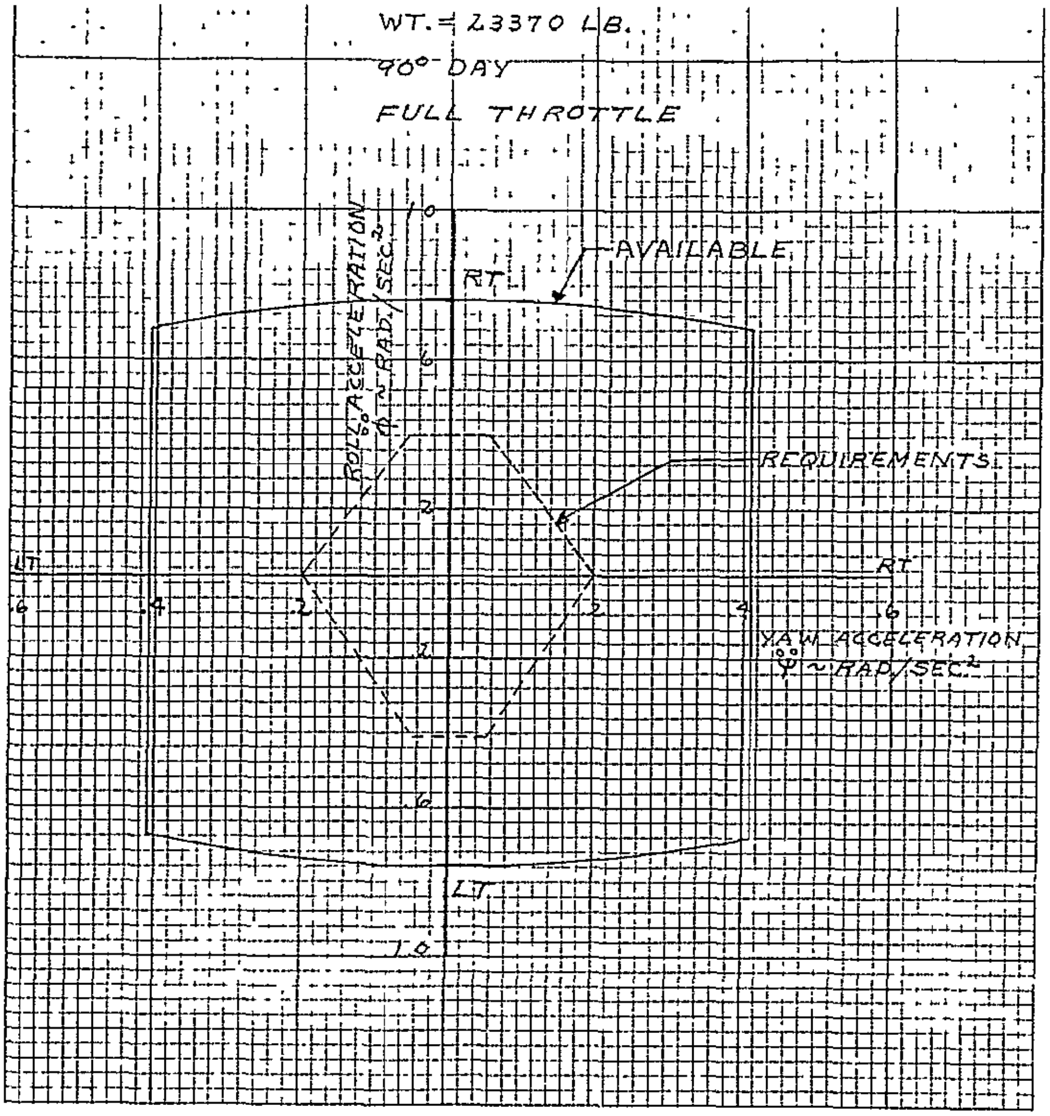

Figure 5.46 Roll Yaw Control Capability, Level 2

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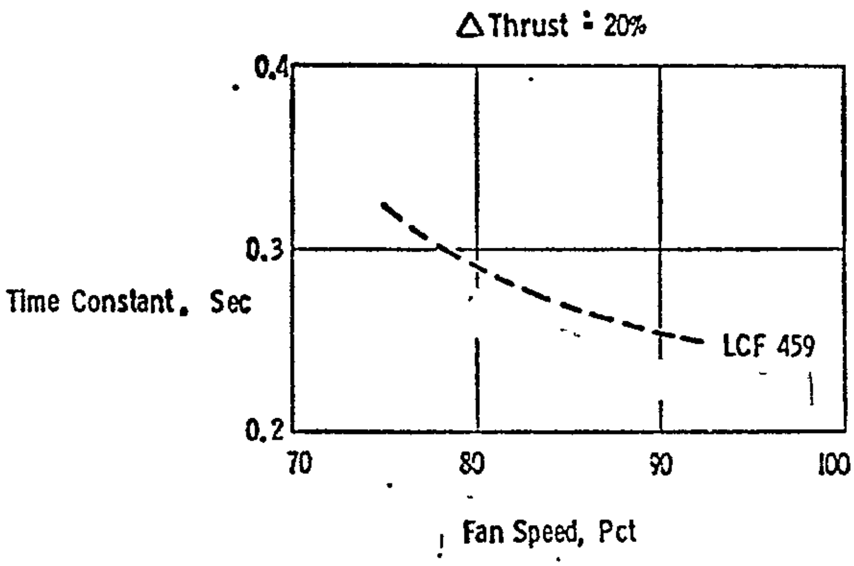

Figure 5.47 Fan Transients Response for Vertical Acceleration

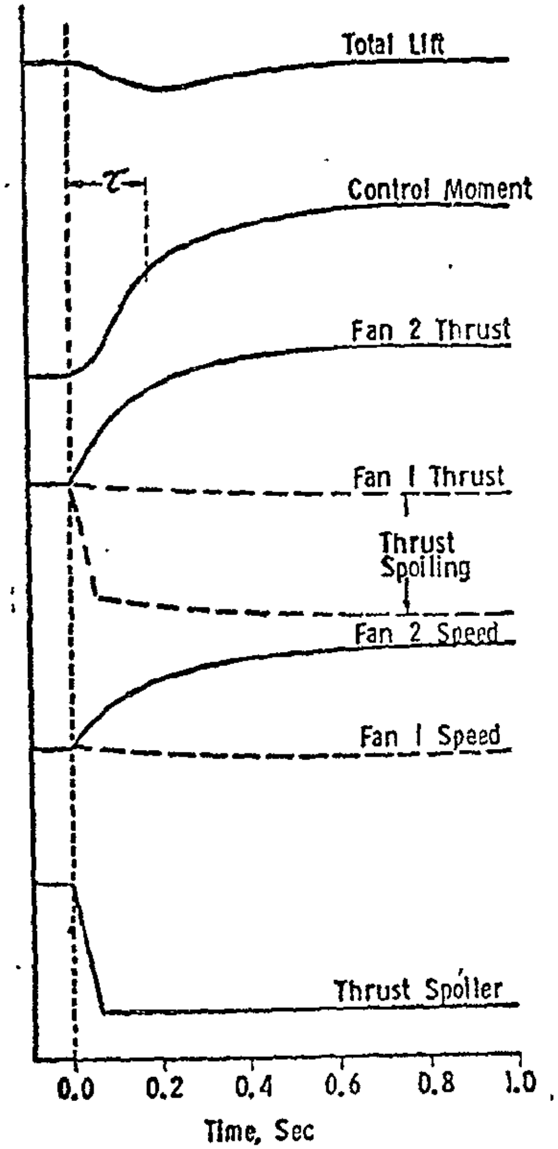

Figure 5.48 Fan Transients during Roll Control

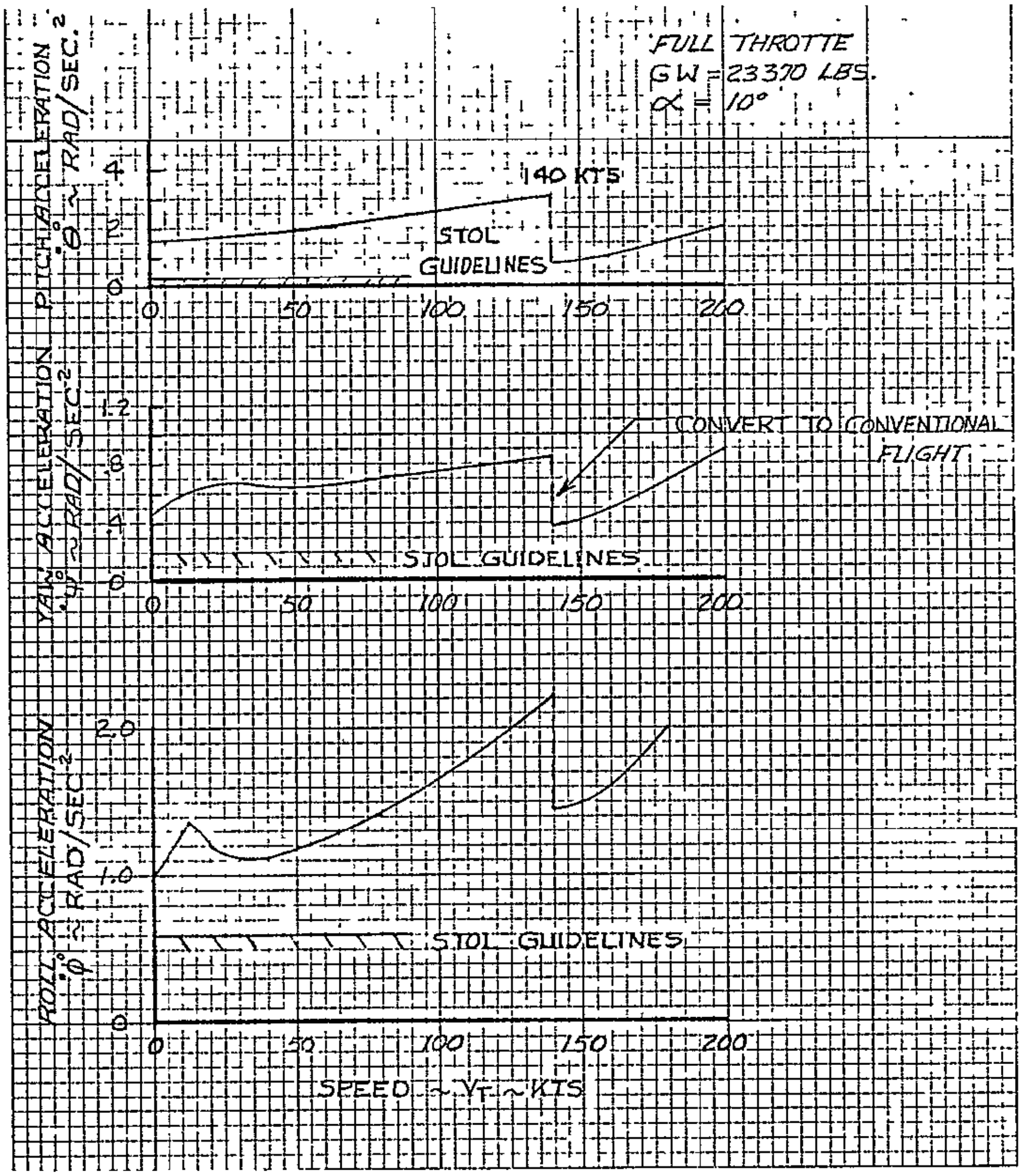

Figure 5.49 Single Axis Control Capability vs Speed, Level 1

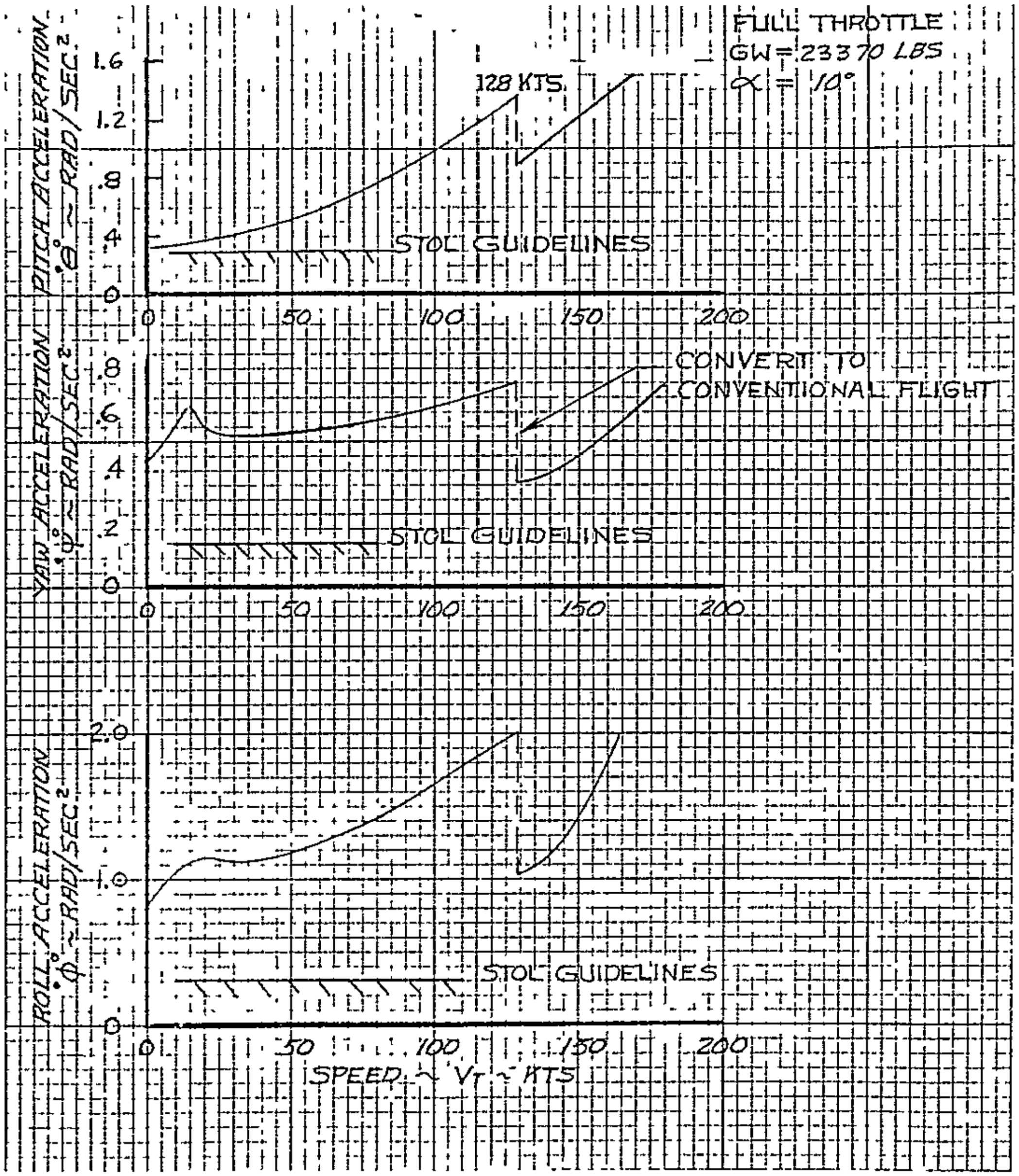

Figure 5.50 Single Axis Control Capability vs Speed, Level 2

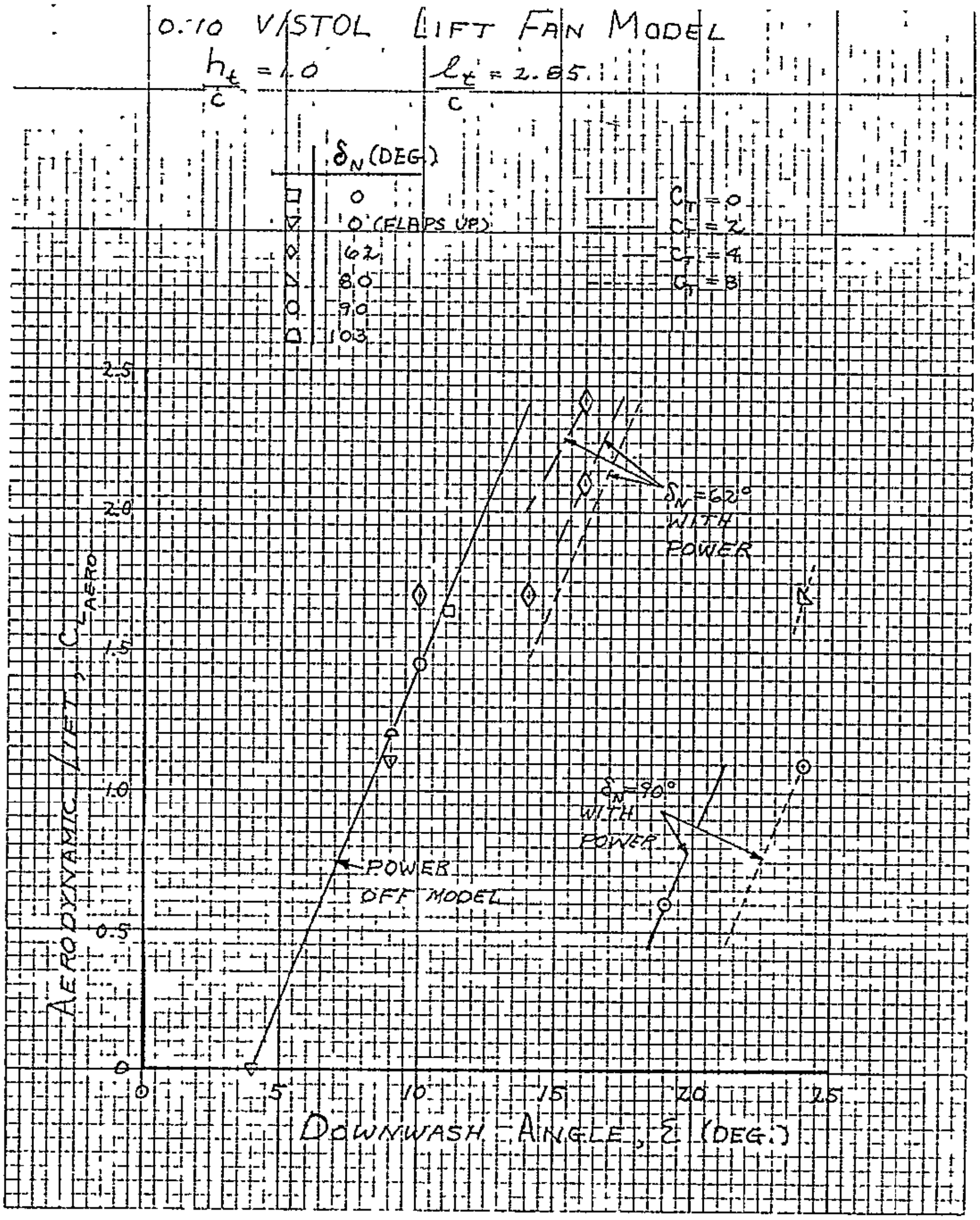

Figure 5.51 Downwash vs Circulation Lift

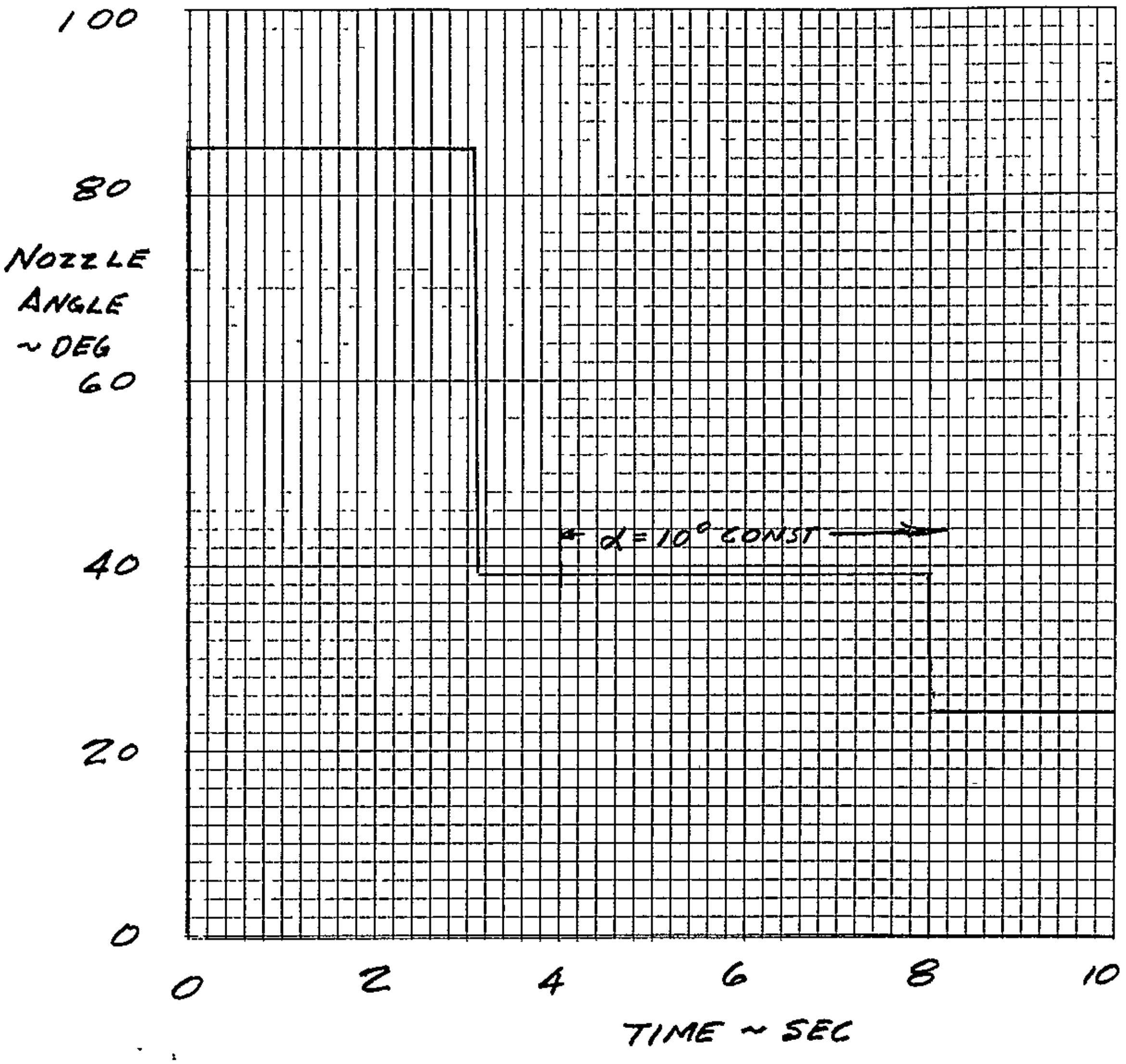

Figure 5.52 Time History of Nozzle Deflection during Transition

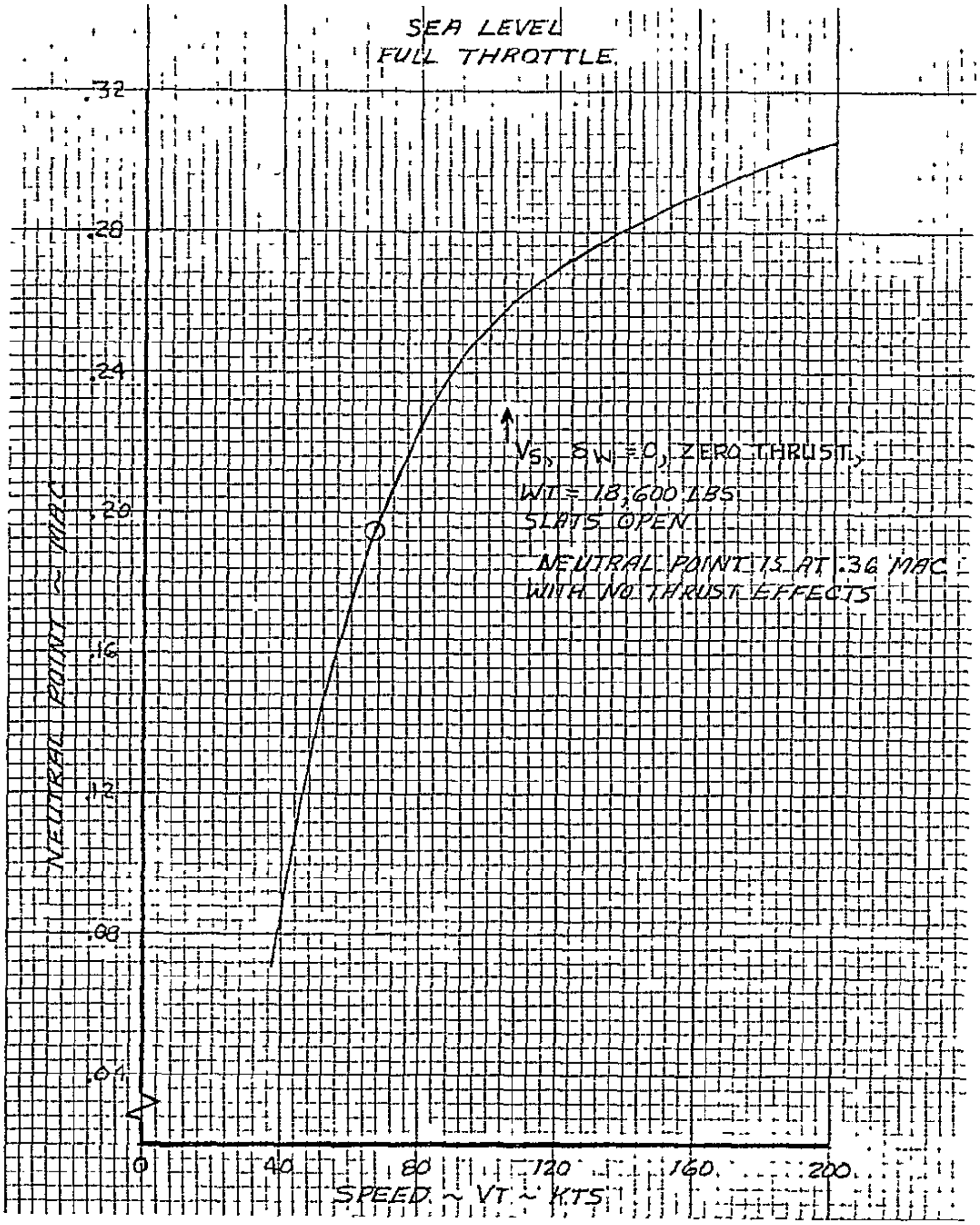

Figure 5.53 Variation of Longitudinal Neutral Point with Speed

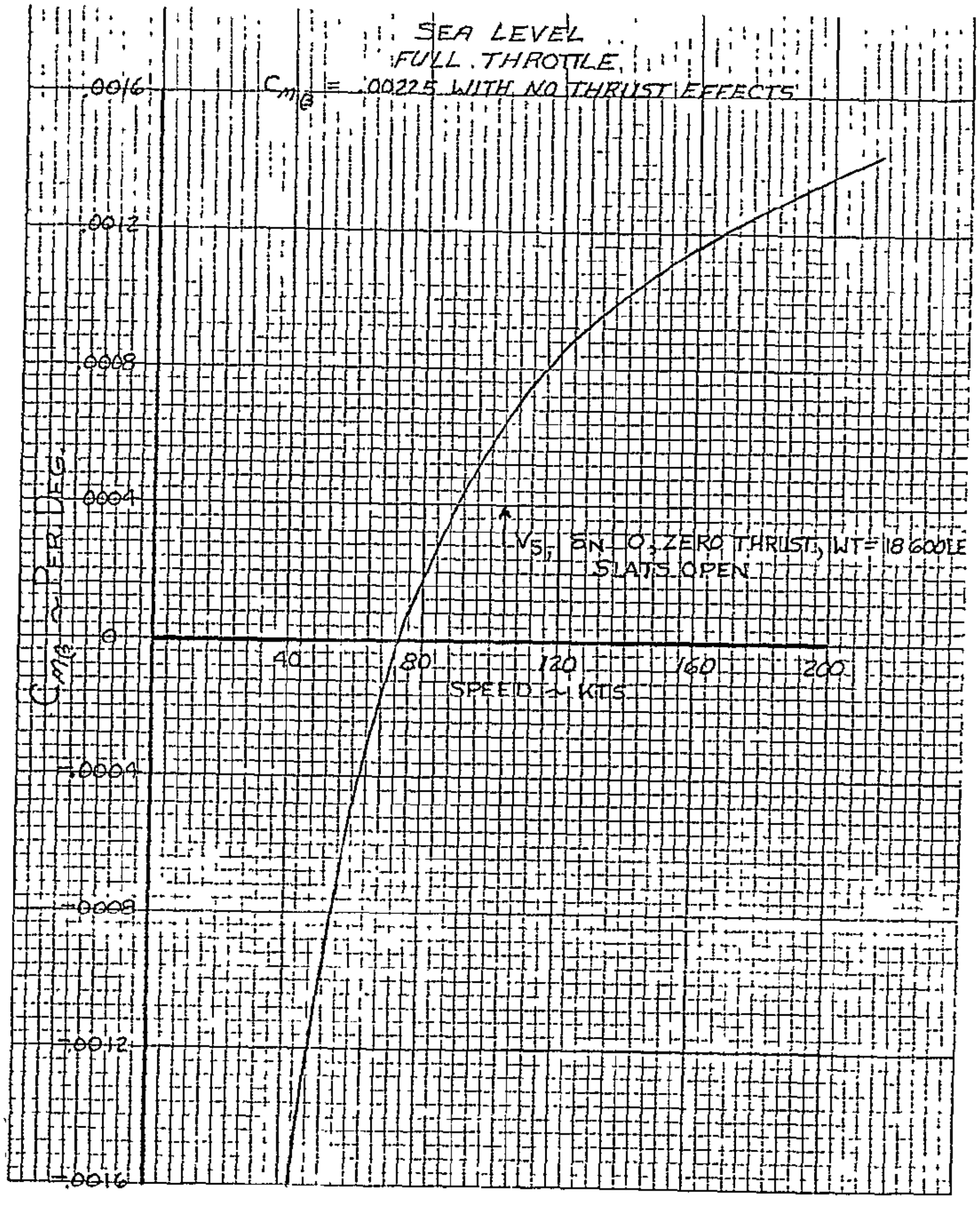

Figure 5.54 Variation of Directional Stability with Speed

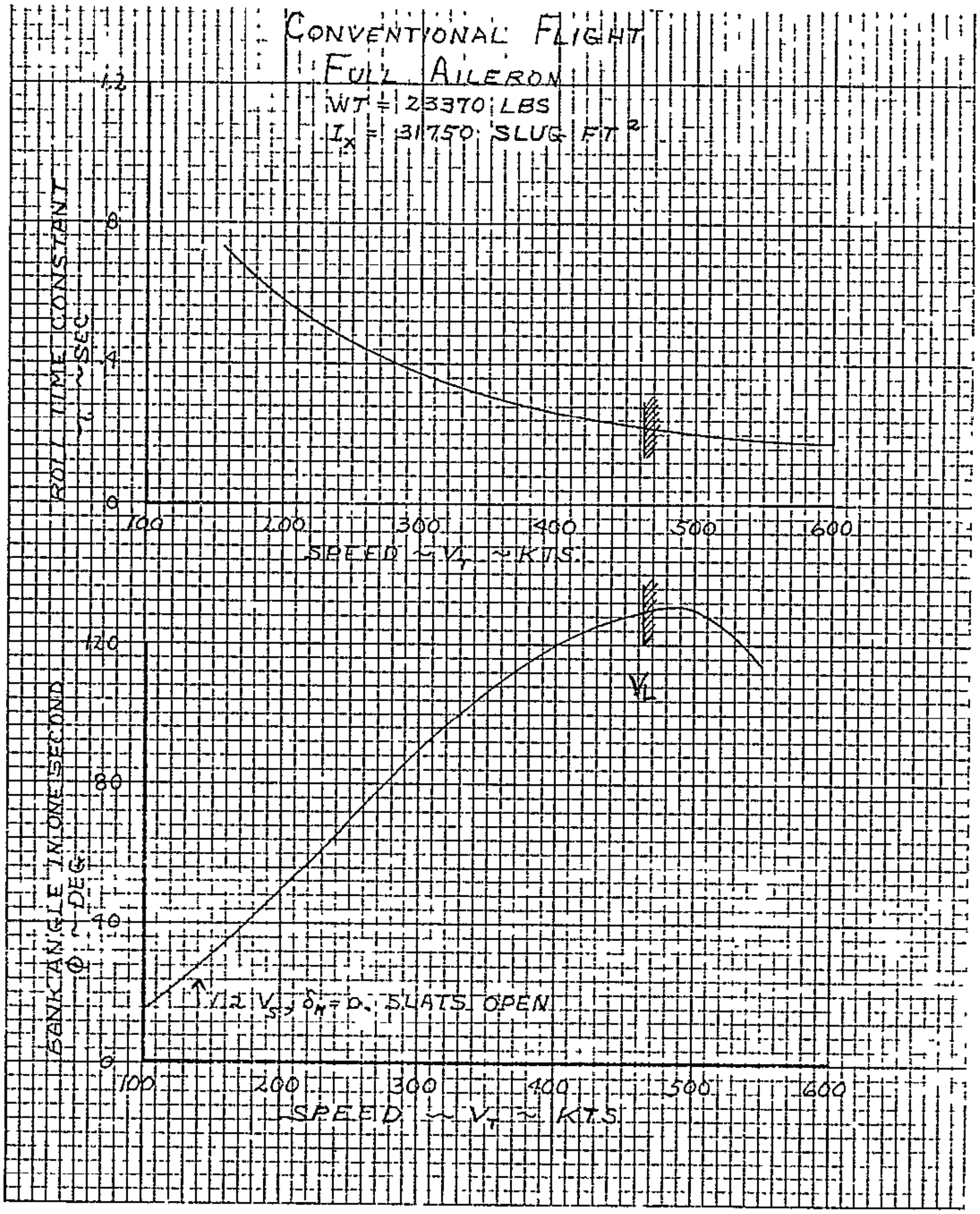

Figure 5.55 Roll Performance

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6.0 POWER TRANSMISSION

The power transmission is a system of hot gas ducting providing a path from the prime gas generator to the two fans; an optional connection, coupling an additional gas generator to these two fans in the event of a failure and finally a coupling from fan to fan for roll control. The hot gas ducting is shown in Figure 6.1. The components of the hot gas ducting include:

7 Valves
6 Bellows
7 Universals
5 Tees
2 Nozzles
Ducting (60 feet)

The rotating machinery consists of three YJ-97-GE-100 gas generators and two LCF459 gas up driven fans. The conditions of the exhaust from the gas generators during a vertical takeoff is as follows:

	Tropical Day 1 Minute VTO	Tropical Day Intermediate	Tropical Day
Lift/Weight	1.32	1.24	1.10
Thrust (pounds)	12,120	11,743	10,177
Pressure (psia)	53.3	50.1	46
Temperature (°R)	1909	1875	1780
Gas Flow lbs./sec.	69.7	65.6	

The VTOL mission consists of five circuits in a 30 minute time period. Each circuit includes 1/2 minute of three engine operation at takeoff power where exhaust gas temperature is 1873°R with very short term temperature spikes up to 2060°R followed by 2 minutes with two engines at cruise power with exhaust gas temperature at 1099°R and, subsequently, a 1/2 minute period with three engines at landing power. Figure 6.2 presents a time temperature profile for this mission. The hot gas system components will be designed to accommodate thermal cycling to the 1273°R level. The duration of the 2060°R spikes is too short to produce a severe influence on the high side and the two minute cruise period is too short to provide any significant relief on the low side. The STOL mission thermal cycles will not be as severe as those produced by the VTOL mission. The 500 hour life requirement for new hardware produces 1700 thermal cycles. The ducting and valving would be designed to accommodate 2500 operating cycles. Since this type of hardware would normally be designed for 10,000 to 20,000 cycles for a production program, the 500 hour life requirement does not impose any significant development risk.

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Material selection for the various components in the hot gas power transmission system represents one of the more critical aspects of this development program. Candidate materials would include Inconel 600, 601 and 625, Haynes 25 and 188. Rene 41 and Alloy N-155. Materials selection will consider such characteristics as elevated temperature strength, oxidation resistance, creep and creep rupture resistance, producibility (cost and manufacture), impact resistance and wear resistance. Moving parts may require inserts such as certain carbon compounds which will not gall or seize under operating conditions.

The valve complement includes three backflow valves that, when closed, prevent exhausting gas backwards through a disabled gas generator. The location of the valve, in all cases, is just down stream of the engine. The valves are of the butterfly type with an internal diameter of 16.8 inches. The valves are electrically operated and are automatically closed (within the power management system) when they sense a dying gas generator. The sensor could be EGT, compressor outlet pressure, or RPM as long as a reference to where it should be is evaluated. These valves are two position only and need not provide a perfect seal.

Two isolation valves are used for starting to provide a fixed exhaust area and isolation from the dynamics of another engine. The valve in the fuselage mounted engine system remains closed throughout Level 1 operation and is only opened when either prime engine fails. The isolation valve in the prime system must be opened during all operations, except starting, to provide passage of air demanded during a roll input. The isolation valves are also two position butterfly type identical to the backflow valves. These are electrically actuated with the third gas generator valve being tied into the automatic engine out sequence.

The remaining two butterfly valves are identically constructed but are hydraulically actuated since they are primary control (roll) valves. These valves are symmetrically located just upstream of the fans and are infinitely adjustable; vice the two positions of the isolation and backflow valves. The roll control valves need not be closed; their operation is primarily "full open" to "partially closed."

The bellows (6 required) absorb a longitudinal expansion or contraction but no angular deviation. These have been located to absorb longitudinal motions. All bellows are 16.8 inches in diameter and identical. Although the length required varies, cost saving can result from identically fabricating all units.

The ducting is manufactured from a two ply tube; the inner tube being smooth and the other tube with external convolutions. The primary inside diameter of the main ducting is 16.8 inches. The pitch pipe nozzles are designed to provide 2500 lbs. of thrust per nozzle plus the maximum trimming moment and maximum pitch control. The total thrust capability of one nozzle is 3600 lbs., however, during Level 2 this could drop to zero from a maximum of 600 lbs. The nozzles have been conceptually designed similar to those used on the Harrier. These type nozzles have rectangular nozzle exits covered by visors. The cross-section sketch shows a gentle throat approach incorporated into the visor. The

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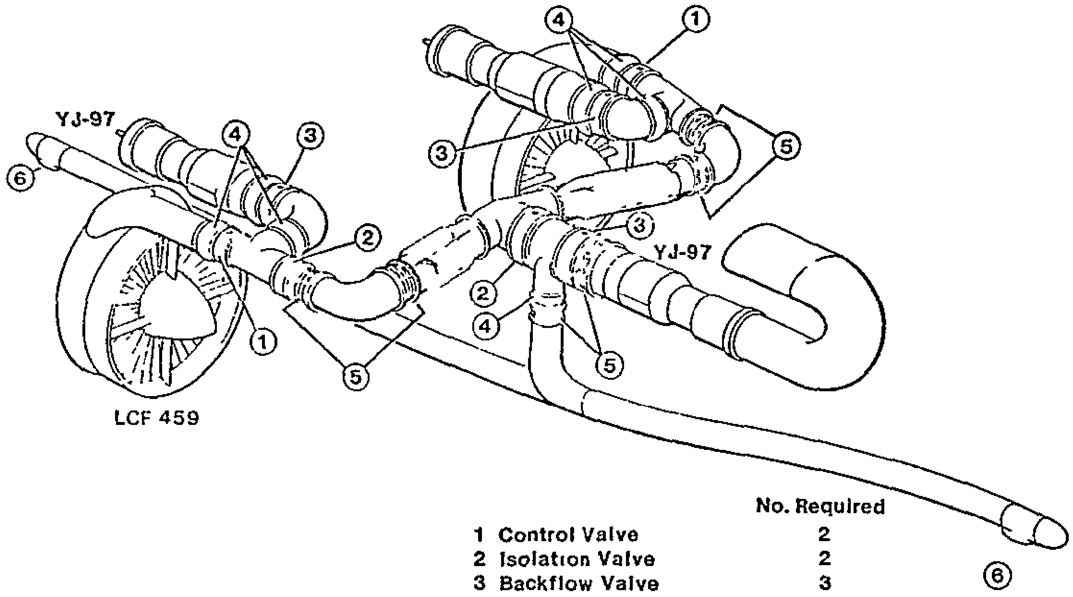
flow requirements of the pitch pipe require an inside diameter of 11.25 inches. Conceptual sketches of these nozzles are shown in Figure 6.3.

The temperature control of this system and the surrounding aircraft structure is of prime importance since, in most cases, the ducting is adjacent to aluminum structure and inside the nacelle adjacent to the fuel cell. Min-K insulation is used over all of the ducting, including the fan scrolls. The engine compartments must be purged and cooled. Since the operation involves periods of static or very low forward velocities, forced flow is provided by means of fan powered jet pump and forward facing inlet scoops. This scheme is used for cooling and purging the nacelle cavity and the gas generator compartment. The fuselage mounted engine can be handled similarly, using bleed air for the jet pumps. The pitch pipe is uninsulated and stands off from the fuselage with a radiation shroud to protect the fuselage.

The propulsion transmission system (i.e., the hot gas ducting) and insulation and mounting attachments, excluding the rotating machinery, weighs 1595 lbs. The duct restraint system is schematically shown in Figure 6.4 and indicates four fixed points; one on centerline, two symmetrically mounted on the elbows, and one on the pitch system prior to exiting the cabin area. The remaining anchors will restrain the ducting in only one or two planes as the system requires.

Special attention has been paid to minimizing the ducting losses. These efforts have resulted in keeping the runs as short as possible, turns with $r/_D > 1.0$ and low internal Mach numbers (0.3 max.). The interior finish and fitting of components is of high quality with the same loss goals used for valve, bellows, and universal joint design. The pressure losses for Level 1 were calculated to be 5.6 percent from the gas generator to the fan, an additional five percent loss through the fan scrolls, and four percent in the swivel nozzle. The nozzle coefficient is calculated to be 0.98. Comparable losses in Level 2 are 8.8 percent from the third gas generator to the fan scroll. These losses are discussed item by item in Section 5.0.

The hot gas ducting system is considered state-of-the-art even though no valves or expansion components of this diameter or temperature capability have been fabricated. Temperatures higher than those required for this program have been handled, and ducting and components of this size have been fabricated; however, the two have not been combined. Two years are required to provide qualified ducting and components subsequent to the establishment of a detail design. The design incorporates a pair of double-bubble ducts just aft of the wing rear spar due to mold lines restraints, however, the remainder of the design is circular and planer in order to simplify the fabrication and minimize the risk. The essentially external location of this system was maintained to reduce the rework to the existing structure, minimize the ducting runs and most importantly position the ducting away from the cockpit. This routing also provides ready access to the total system for ease of inspection, adjustment and monitoring temperature related deflections with respect to structural and system components.



	No. Required
1 Control Valve	2
2 Isolation Valve	2
3 Backflow Valve	3
4 Universal Joint	7
5 Bellows	6
6 Reaction Control Valves	2

Figure 6.1 Hot Gas Transmission Systems

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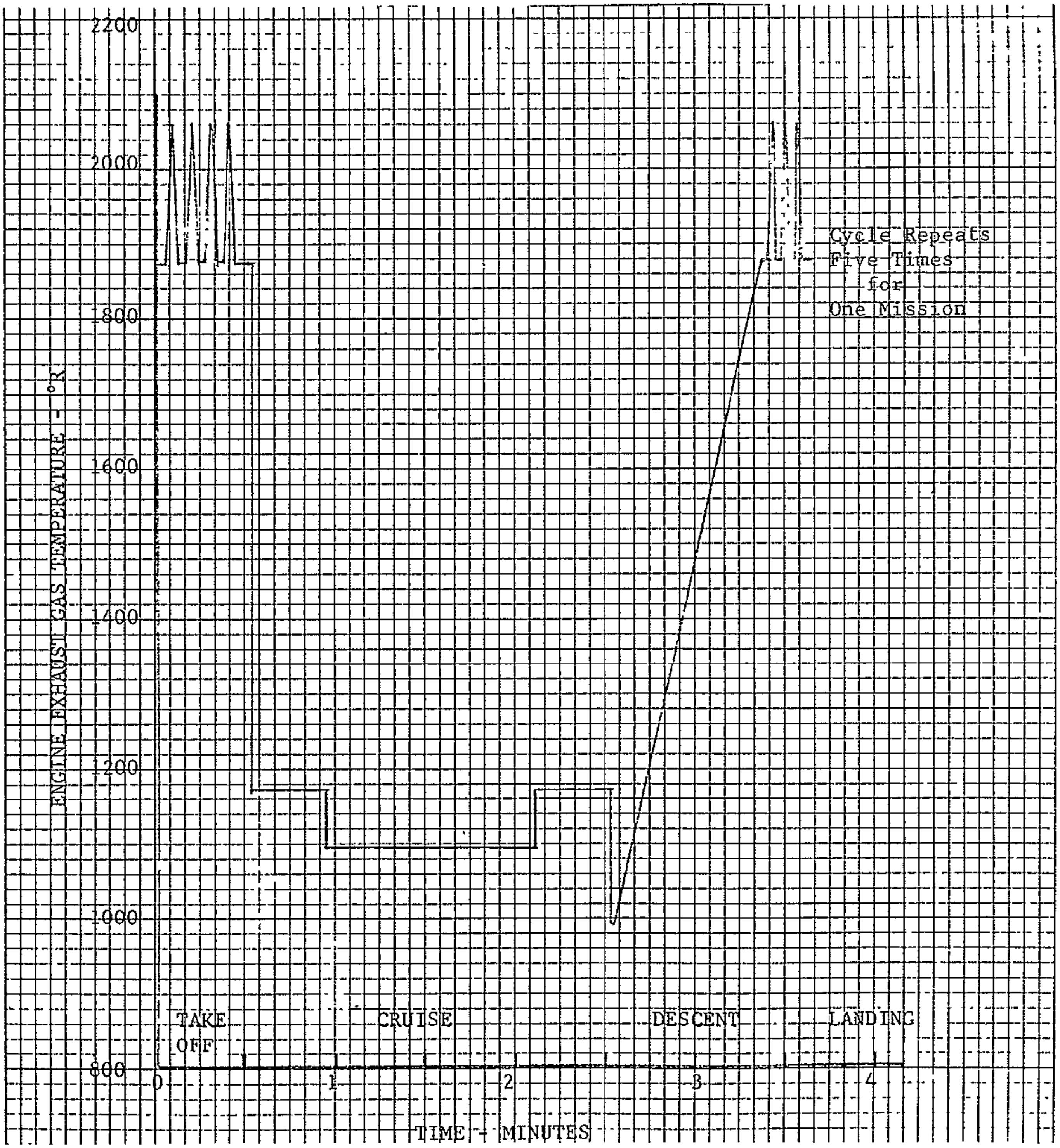

Figure 6.2 Time History of Temperature Variations

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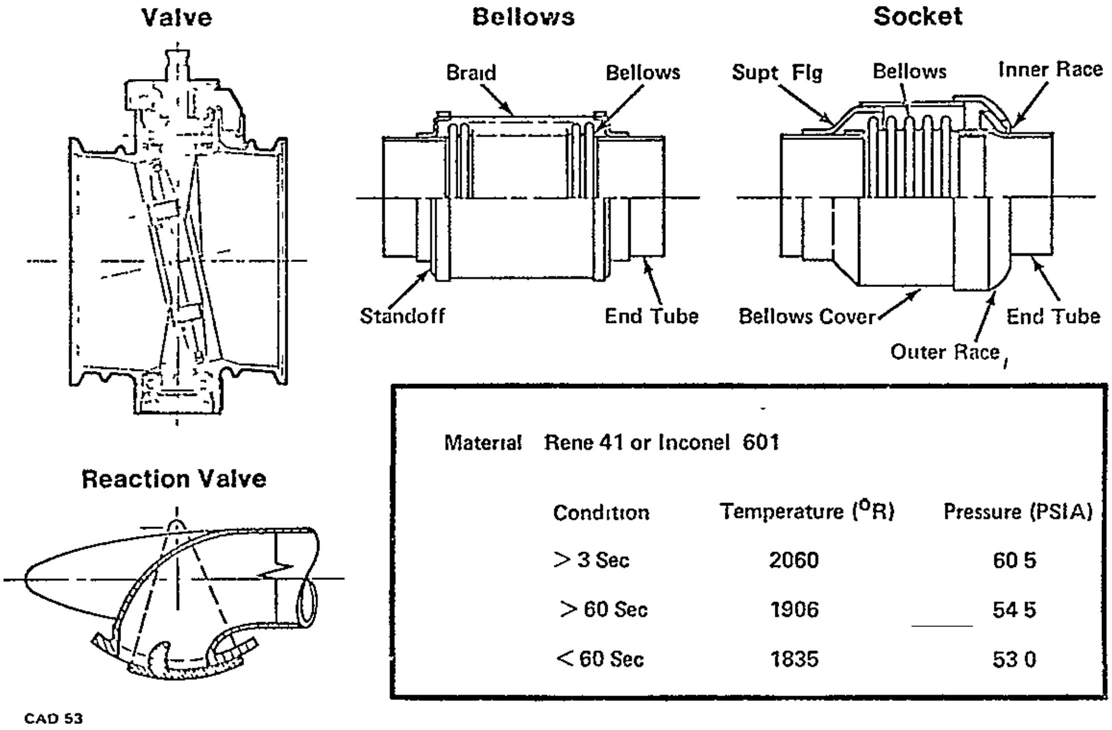
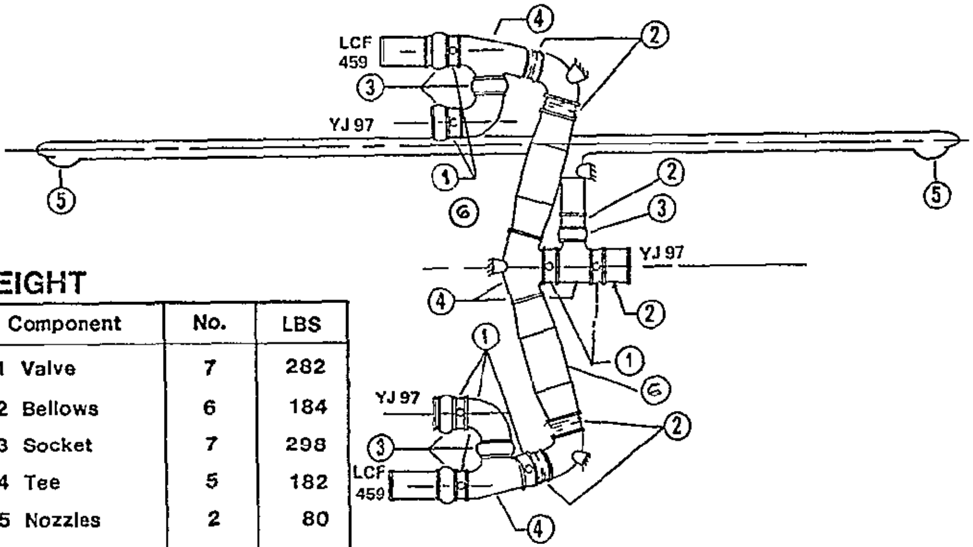


Material Rene 41 or Inconel 601

Condition	Temperature (°R)	Pressure (PSIA)
> 3 Sec	2060	60 5
> 60 Sec	1906	54 5
< 60 Sec	1835	53 0

Figure 6.3 Hot Gas Ducting Hardware



WEIGHT

Component	No.	LBS
1 Valve	7	282
2 Bellows	6	184
3 Socket	7	298
4 Tee	5	182
5 Nozzles	2	80
6 Oval Duct		61
Round Duct		294
Insulation		214
		1595

CAD 55

Figure 6.4 Hot Gas Ducting Weight Breakdown

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7.0 REFERENCES

(a) Cavage, Robert L.; "Conceptual Design Study of a Military Oriented Remote Lift-Fan V/STOL Transport." NASA CR 114753, July 1974

(b) Cavage, Robert L.; "Design Definition Study of NASA/Navy Lift/Cruise Fan V/STOL Aircraft, Volume I, Summary Report of Navy Multi-Mission Aircraft," NASA CR 137695, June 1975

(c) Cavage, Robert L.; Chaloff, David; and Renselaer, Dirk J.; "Design Definition Study of NASA/Navy Lift/Cruise Fan V/STOL Aircraft, Volume III - Addendum Report for the Navy Multi-Mission Aircraft," NASA CR 137741, September 1975

(d) Cavage, Robert L.; "Design Definition Study of NASA/Navy Lift/Cruise Fan V/STOL Aircraft, Volume II - Summary Report of Technology Aircraft," NASA CR 137696, June 1975

(e) Cavage, Robert L.; "Design Definition Study of NASA/Navy Lift/Cruise Fan V/STOL Aircraft, Volume II - Summary Report of Technology Aircraft," NASA CR 137696, June 1975

(f) Schlundt, Donald W.; "Testing of Lift/Cruise Fan Exhaust Deflector," NASA CR 137682, March 1975

(g) Anon; "Small Scale Nozzle Test." Report to be published per Contract NAS2-8972.

(h) Schlundt, Donald W.; "Pretest Information for Test of a 0.15 Scale Swivel Nozzle Lift/Cruise Fan Exhaust Thrust Deflector Model at Trisonic Wind Tunnel Flow Calibration Room," NA76-345, 12 March 1976

(i) Anon; "Guideline of Lift/Cruise Fan V/STOL Aircraft Conceptual Design." Attachment I to NAS2-9307, July 1974.

(j) Anon; "Lift Cruise Fan V/STOL Aircraft Conceptual Design Study T-39 Modification, Volume II, Schedules and Budgetary Data," CR 151926, November 1976

(k) Anon; "Model Specification E-1155 Engine, Aircraft, Turbojet YJ97-GE-100 G.E.," Spec. No. E1155, 15 October 1969

(l) Anon; "Remote Lift Fan System, LF400/YJ-97-GE-100" R61AEG277, General Electric Co., September 1971

(m) Anon; "Remote Lift Fan System, LCF459/YJ-97-GE-100," R71AEG277, General Electric Co., April 1975

(n) Smith, E. G.; Dors, J. C.; "LC459/J97 Estimated Performance," R75AEG413, General Electric Co., July 1975

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18 SUPPLEMENTARY NOTES

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20 ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

A conceptual design to modify two T-39's to a tip driven lift cruise fan powered V/STOL research and technology aircraft are described. The areas of investigation include structural and system modification, control concept, aerodynamic configuration and lift cruise propulsion complement. The propulsion complement include three YJ-97's and two LCF 459 gas tip driven fans. Fans are fixed and oriented with axis horizontal; vertical powered lift components are obtained with two bifurcated swivel nozzles. Longitudinal control during powered lift (vertical) is obtained with fore and aft pitch

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pipes; lateral and directional control are obtained at the lift-cruise nozzles. The configuration is a high wing, twin nacelle modification to the basic T-39 airframes. The study design meets or exceeds the guidelines set forth. A 45 month program is projected and described to design, fabricate, test and fly (both VTOL and STOL) two aircraft. Cost and schedules are included in NASA CR 151926