A1
X-24A/2 [illegible]

IFM X-24A-1-1

INTERIM

A1
X-24A/[illegible]

X-24 A

FLIGHT MANUAL

15 April 1968

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Hq Aeronautical Systems Division (ASZV), Wright-Patterson Air Force Base, Ohio.

Prepared For

Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

PREPARED BY Edward E. Bleyeh [signature]	**MARTIN MARIETTA**
APPROVAL:	BALTIMORE, MARYLAND
LOGISTICS Edward E. Bleyeh [signature]	21203
ENGINEERING R. E. Boss [signature]	
QUALITY ______	

173 pp

LIST OF EFFECTIVE PAGES

Insert Latest Changed Pages - Destroy Superseded Pages

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONT)

LIST OF ILLUSTRATIONS (CONT)

LIST OF TABLES

FOREWORD

Information in this report is embargoed under the Department of State International Traffic in Arms Regulations. This report may be released to foreign governments by departments or agencies of the United States Government subject to approval of the Aeronautical Systems Division (ASZV), Wright-Patterson Air Force Base, Ohio, or higher authority within the Department of the Air Force. Private individual of firms require a Department of State export license.

SECTION I

DESCRIPTION

1-1. GENERAL.

1-2. The X-24A PILOT (PILoted LOw-speed Test) aircraft, (See Figure 1-1), built by Martin Marietta Corporation, is a low speed manned lifting body configuration that provides aerodynamic maneuverability from orbital to touchdown speeds. The X-24A is capable of simulating a re-entry vehicle from approximate speed of Mach 2.0 to tangential landing.

1-3. The X-24A is designed to be launched from a modified B-52 at altitudes of 40,000 to 45,000 feet. The launch will be at Mach 0.8 and the X-24A will be capable of attaining aburnout speed of Mach 2.0 and altitude of 100,000 feet or greater.

1-4. STRUCTURE. The body of the X-24A is basically a semi-monocoque structure of aluminum alloy, it is wedge shaped with the bottom flat and the top a curved airfoil surface with three vertical fins, the outboard fins provide support for the upper and lower rudders. The aft end of the body provides support for the upper and lower flaps. The landing gear is a typical retractable aircraft tricycle landing with co-rotating wheels on a steerable nose gear. The cockpit consists of typical aircraft instrument panels, stick and pedal surface controls, zero-zero pilots ejection seat and bubble jettisonable canopy.

1-5. OVERALL DIMENSIONS. The dimensions of the X-24A in position on the landing gear are as follows: (See Figure 1-2).

	Inches	Feet	Inches
Width at tip of outboard fins	164	13	8
Height at tip of outboard fins	124	10	4
Length (less nose boom)	294	24	6
Incidence (leading edge inboard)	. 4 degrees		
Dihedral (angle with respect to vertical)	16 degrees		
Leading edge sweep (side view)	55 degrees		

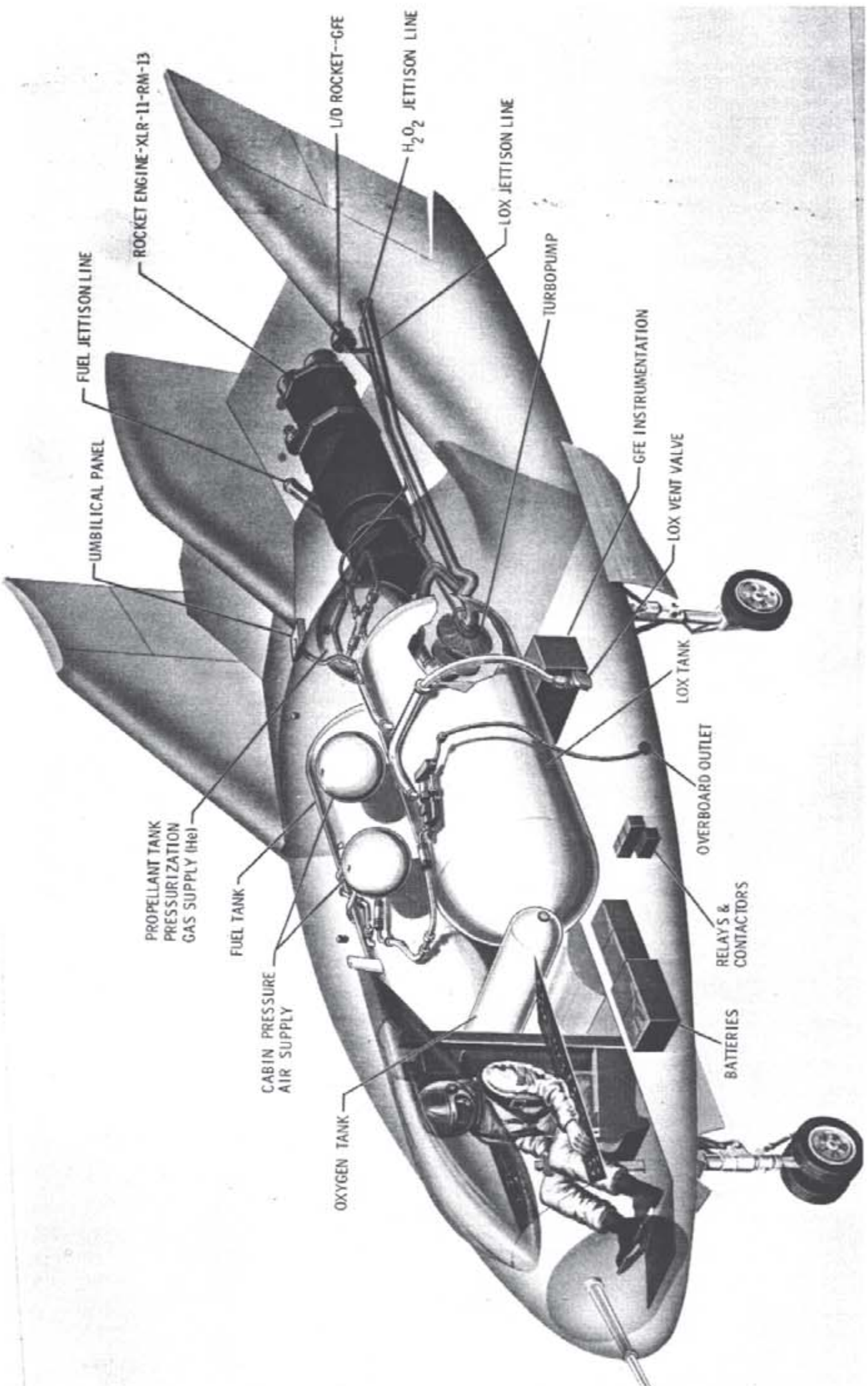


Figure 1-1. X-24A.

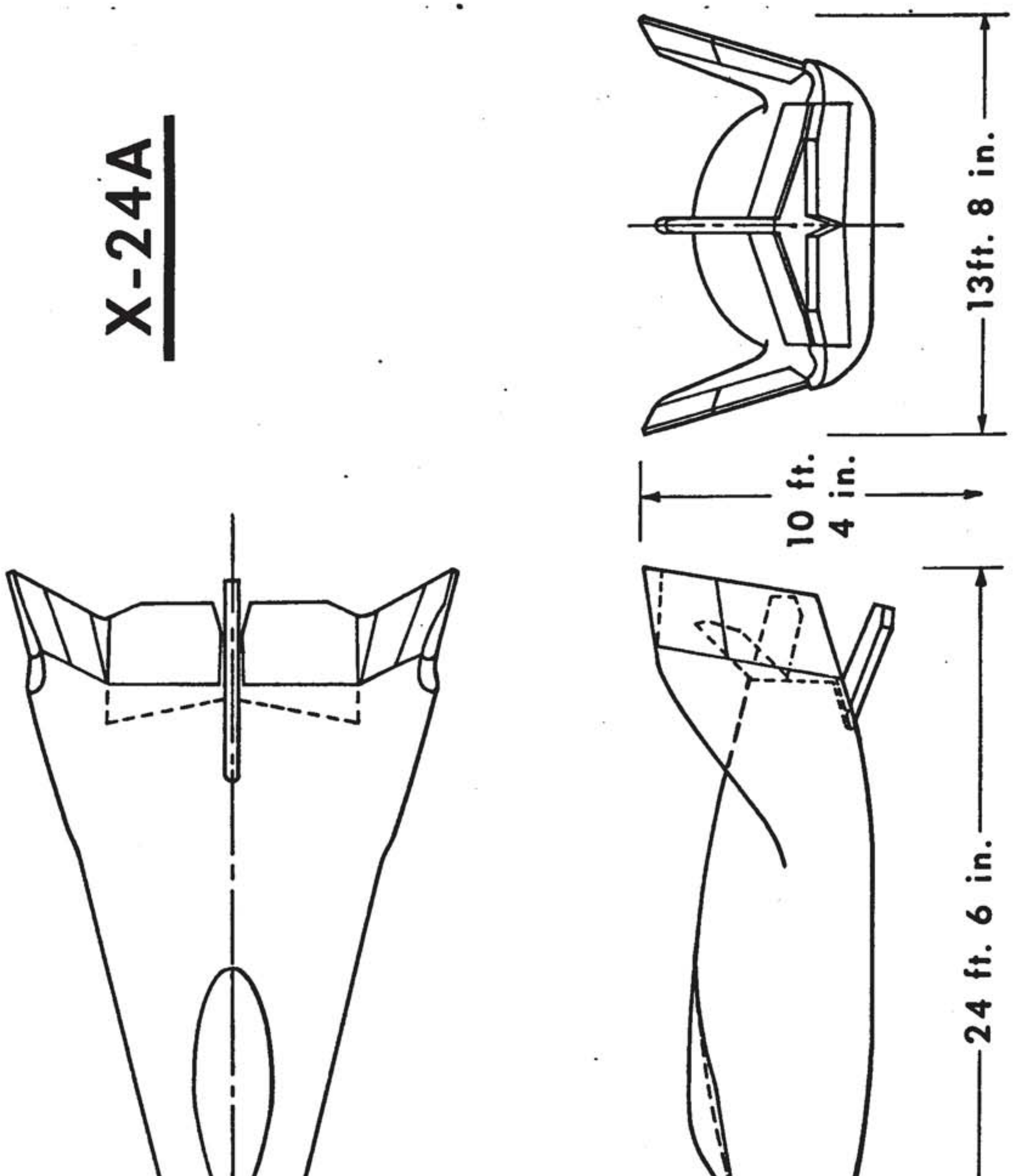


Figure 1-2. Overall Dimensions.

1-6. **PROPULSION.** The Propulsion System used for powered flights consists of the XLR11-RM-13 Liquid Propellant Rocket Engine with turbopump assembly and the Lift/Drag (L/D) monopropellant motors with their respective associated fuel and oxidizer tanks. (See Figure 1-3.) Unpowered flights use a substitute set of fuel and oxidizer tanks filled with water to attain the desired center of gravity condition.

The X-24A rocket propulsion system serves two functions. After release from the B52, the rocket engine (XLR11-RM-13), which uses as its propellants; alcohol/water, liquid oxygen and hydrogen peroxide, provides thrust to boost the X-24A to an altitude of approximately 100,000 feet and a speed of mach 2.0

It is bi-propellant, pump-fed engine of four regeneratively cooled thrust chambers. Each thrust chamber has its own igniter system and propellant control valves and can be operated individually. The engine can operate on one or four chambers, however, operation of an opposite pair (1 and 3, or 2 and 4) or all four preferred. Normally, chambers 1 and 3 are ignited after 5 seconds from the drop of the B-52; then within an additional 5 seconds, thrust chambers 2 and 4 are to be ignited. The total burn time for the engine 139 seconds with 137 seconds at full thrust. The propellants are forced into the combustion chamber by the turbopumps driven by a gas turbine. The gas turbine is driven by decomposed hydrogen peroxide.

The glide portion of the powered or unpowered flight uses the L/D motors, which provide an impulse to stretch the glide or reduce the rate of descent by increase in the Lift/Drag ratio. Thrust for the L/D system is provided by two monopropellant rocket motors that use peroxide only as their propellant.

1-7. **FLIGHT CONTROL SYSTEM.**

1-8. **GENERAL.** The X-24A Flight Control System is comprised of the control surfaces, the stability augmentation system, the hydraulic system, the biasing system and the mach sensing system. These systems working together stabilize and control the vehicle during flight. The pilot has the capability of controlling and maneuvering

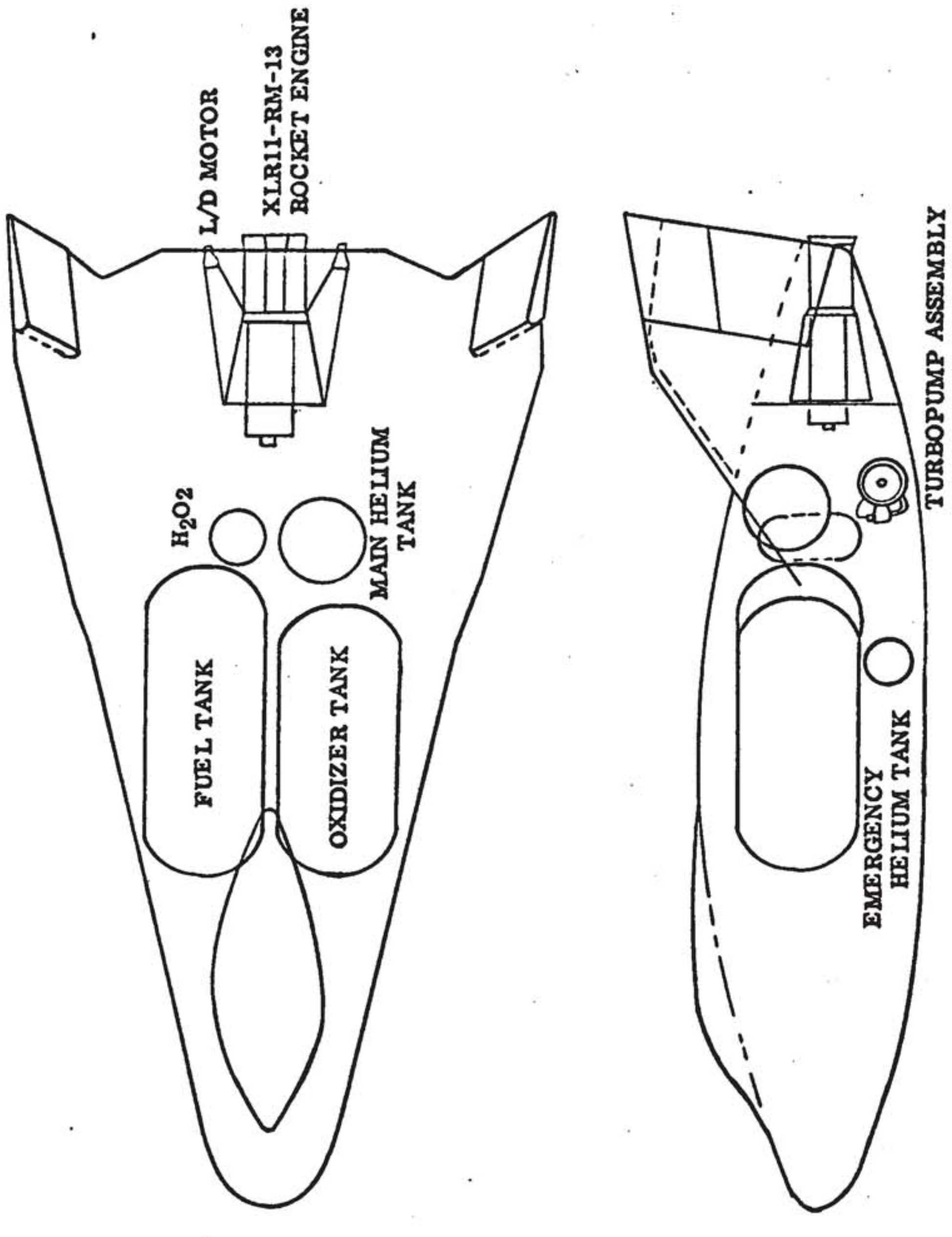


Figure 1-3. Propulsion System.

the vehicle by use of a control stick and rudder pedals. Those controls will position six of the eight control surface located on the aft end of the vehicle (See Figure 1-4). The lower rudders are used to a bias condition and are positioned by the stability augmentation system as a function of mach number. The control surfaces are used in various combinations and degrees of deflection as shown in Figure 1-4, for the subsonic, transonic, and supersonic flight regimes.

The effectiveness of the upper and lower flaps are a function of mach number, vehicle attitude and flap deflection. At high mach numbers, the lower flaps are more effective. As the X-24A decelerates through the transonic speed regime, there is a transfer of authority from the lower to the upper flaps.

1-9. Control in all axes of flight is attained through the symmetrical deflection of the flaps for pitch, differential deflection of the flaps for roll and symmetrical (actually they operate symmetrically to each other) for yaw control.

1-10. Pitch control is attained by different methods for different speeds. Below Mach No. 0.6 the lower flaps are maintained in the stowed position and pitch control is attained from symmetrical operation of the upper flaps. From Mach No. 0.6 to Mach No. 1.9 Pitch Control is obtained by symmetrically deflecting the lower flaps while the upper flaps are maintained in a biased up deflection. This upper flap bias varies with Mach numbers above Mach No. 1.9. The upper flap bias remains constant and pitch control is obtained by symmetrical deflection of the lower flaps.

1-11. DEFLECTION LIMITS. The deflection limits of the control surfaces are as follows:

Rudder deflection limits (from faired position):

Upper	$\pm$ 25.0°
Lower	$\pm$ 10.0°

Flap deflection limits:

Upper	3 to 60° up
Lower	0 or faired position to 40° down

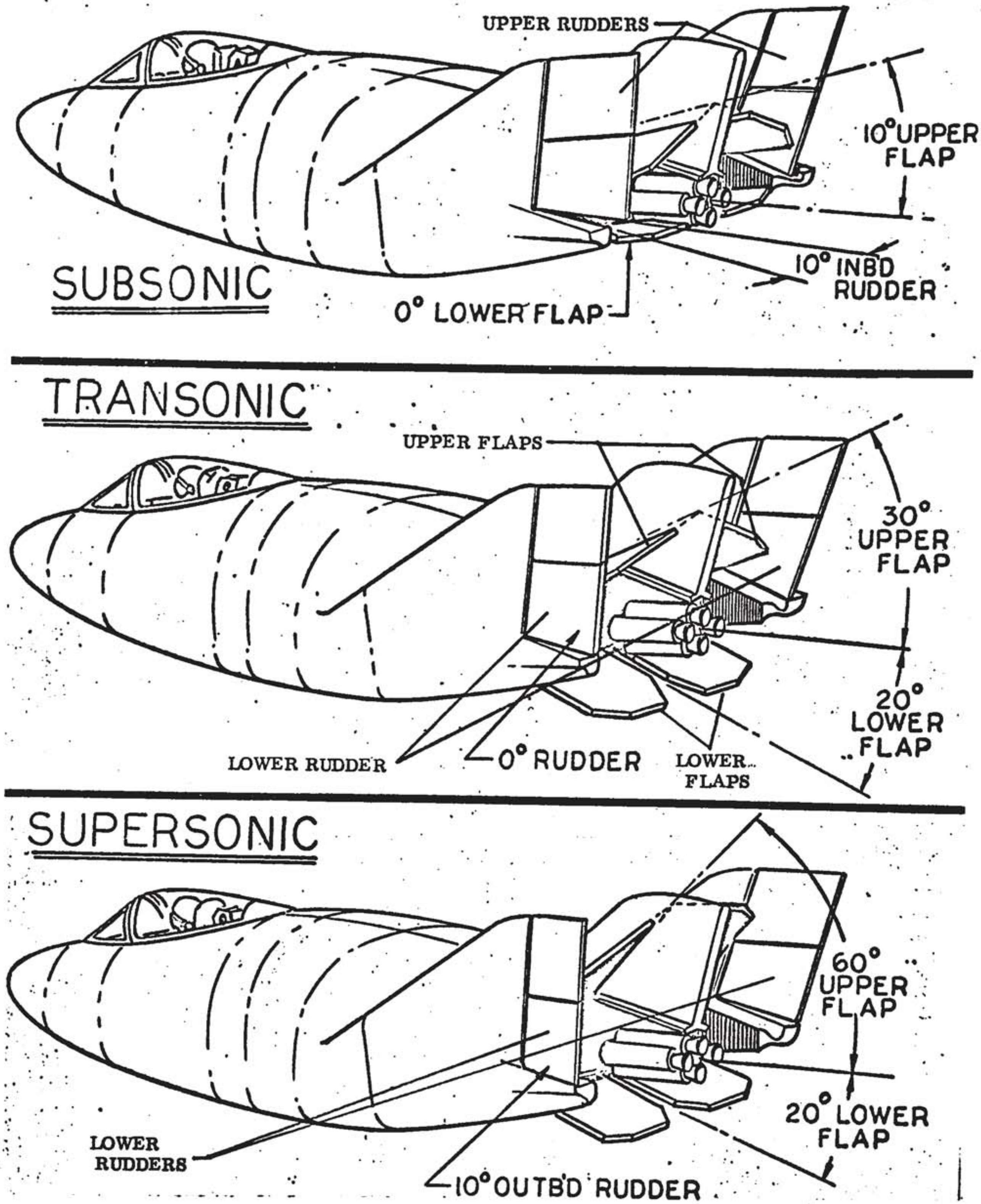


Figure 4-1. Control Surfaces

1-12. HYDRAULIC SYSTEM. The X-24A is equipped with redundant 3000 psi hydraulic systems (See Figure 1-5.). Each system provides power to all four flaps, to both upper rudders, and to the servo actuators used to power the pitch and roll command channels. Each of the redundant systems are powered by two electric motor-driven pumps. An accumulator is used in each system to provide fast pressure response to servo commands and to sustain power during severe transients. The pressure line in each system is connected to the return line through a check valve to provide filling capability and prevent induced loads and fluid aeration in the event of an external force driving a dead system. Filters are included in the system to provide contamination protection to the pressure lines which feed the actuators.

The hydraulic system contains pressure sensors and transducers which provide the pilot with a visual indication of the condition of the hydraulic system.

1-13. ELECTRICAL SYSTEM.

1-14. DC Power System. The 28 vdc power required by the X-24A vehicle is supplied by one of three means, depending on the operating conditions at the time of need. An external ground power source is used for operational checkouts and tests when the aircraft is on the ground. During captive flight, power is supplied from the B-52 electrical system through umbilical connections. While in free flight, power is supplied by four silver-zinc batteries. See Figures 1-6 and 1-7 for a schematic representation of the circuits and Figure 107 for the general location of significant components.

1-15. Regardless of the source, power is controlled by the DC POWER SELECT switch on the R.H. Pilot's Console. Rotation of the switch from OFF to the desired power source position (EXT, B-52, or BAT) energizes four relays incorporated in each individual power source circuit thereby activating the circuits to the four distribution buses, viz., the hydraulic system No. 1 bus, the hydraulic system No. 2 bus, the equipment bus, and the instrumentation bus, located on the power distribution panels on the aft side of the bulkhead at Station 84.

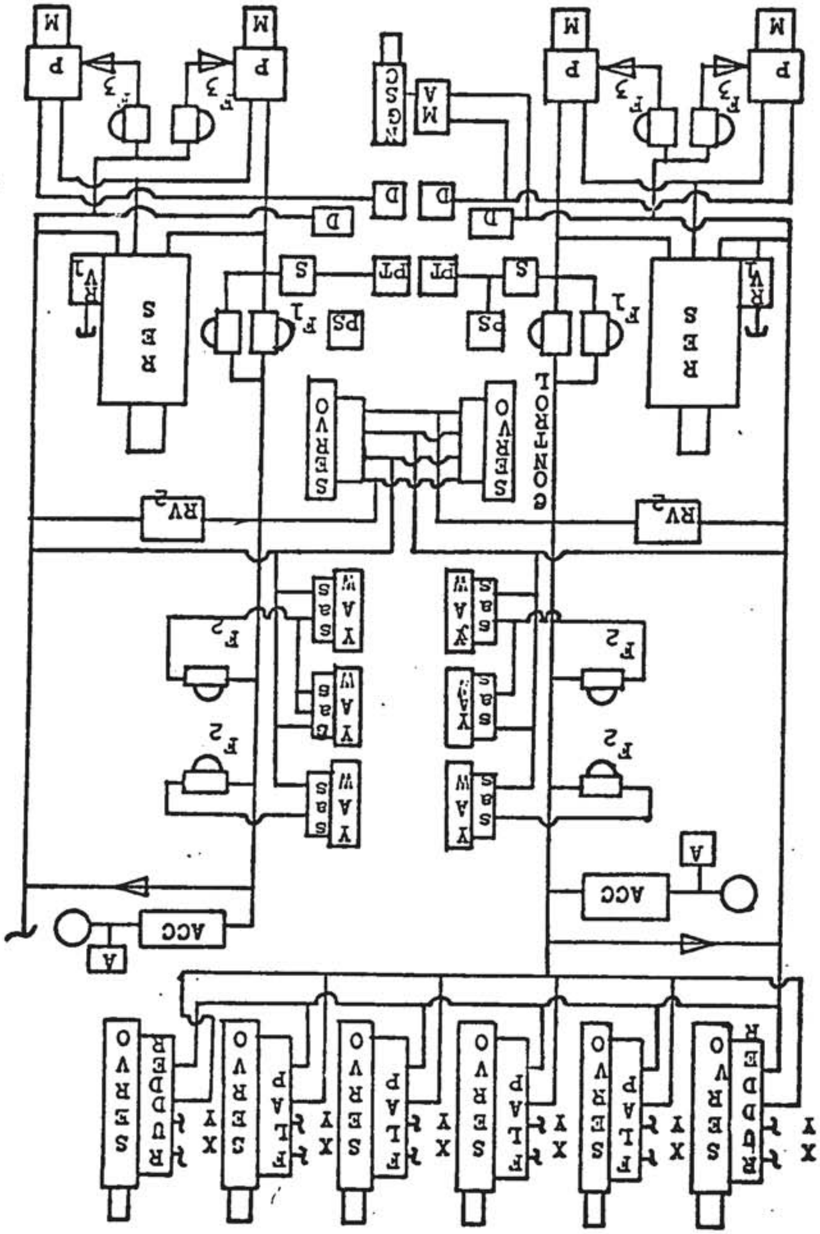


Figure 1-5. Hydraulic System.

1-16. The current supplied to each bus is measured at shunts in the power supply circuit and reflected on corresponding ammeters located on the right side of the pilot's instrument panel. Fuses are provided in the ammeter circuit to protect the buses from short circuits. The fuses and shunts are located on the power distribution panels.

1-17. ELECTRONIC SYSTEM. The X-24A Electronic System is comprised of two separate systems, (1) the "S" Band Radar Beacon System which allows tracking of the vehicle by communicating a radar signal to the ground station, and (2) the Pilot's Intercom and Radio System which provides air to ground voice communication, and intercom between the X-24A and the B52 during captive flight.

1-18. "S" BAND RADAR BEACON SYSTEM.

1-19. The "S" Band Radar Beacon System is designed to generate and transmit a radar beacon signal for inflight tracking of the X-24A. (See Figure 1-8.) The Radar Beacon System is essentially comprised of the following:

a. Transponder - Vega Model 204S

b. Antenna - Mictron C5-6TNC

c. Radar on-off Switch MS-25306-212

d. Associated Wiring

1-20. FUNCTIONAL OPERATION OF "S" BAND RADAR BEACON SYSTEM.

1-21. In operation with the RADAR on-off switch in the ON position 28 VDC is supplied to the Vega Model 204S transponder. The applied current enables the transponder to create a beacon signal which is transmitted through the Mictron C5-6TNC antenna to the receiving station. See Figure 1-9. System shut-off is accomplished by placing the RADAR on-off switch in the OFF position.

1-22. PILOT'S INTERCOM AND RADIO SYSTEM

1-23. The Pilot's Intercom and Radio System is a redundant air to ground communication system, incorporating an intercom system which permits communication with the B52 during captive flight. The Pilot's Intercom and Radio System is essentially comprised of the following:

a. Antenna - AT256A/ARC

b. Circuit Breakers - MS25244-5

c. Transceiver - Model TR31

d. Radio Select Switch MS 25308-232

e. Radio Interphone Switch MS25308-232

f. Transformer TRIAD-45643

g. Associated Wiring

1-24. Redundancy is provided by incorporating two identical Model TR31 Transceivers, two AT256A/ARC Antenna and associated circuit. This redundancy requires that the Pilot select either the No. 1 or No. 2 Transceiver prior to system operation. Selection of the desired transceiver is accomplished as follows:

a. Engage both the No. 1 and No. 2 transceiver breakers located on L.H. Console.

b. Place the RADIO-INTERPHONE switch located on R.H. Console, in RADIO position.

c. Place RADIO select switch located on R.H. Console in RADIO No. 1 or RADIO No. 2 position whichever is desired.

1-25. FUNCTIONAL OPERATION OF PILOT'S INTERCOM AND RADIO SYSTEM.

1-26. In operation with the transceiver circuit breakers engaged, 28 VDC is supplied to each of the Model TR31 Transceivers from the 28 VDC bus. See Figure 1-10. Selecting the desired transceiver (Refer to Para. 1-24) completes the circuit necessary for system operation. After selecting the desired transceiver the system is operated as follows:

a. Turn the applicable transceiver power switch ON.

b. Turn the CHANNEL SELECTOR switch to the proper channel.

c. Adjust the GAIN control to the desired level.

d. To transmit press the push to talk switch and speak into microphone at a normal voice level.

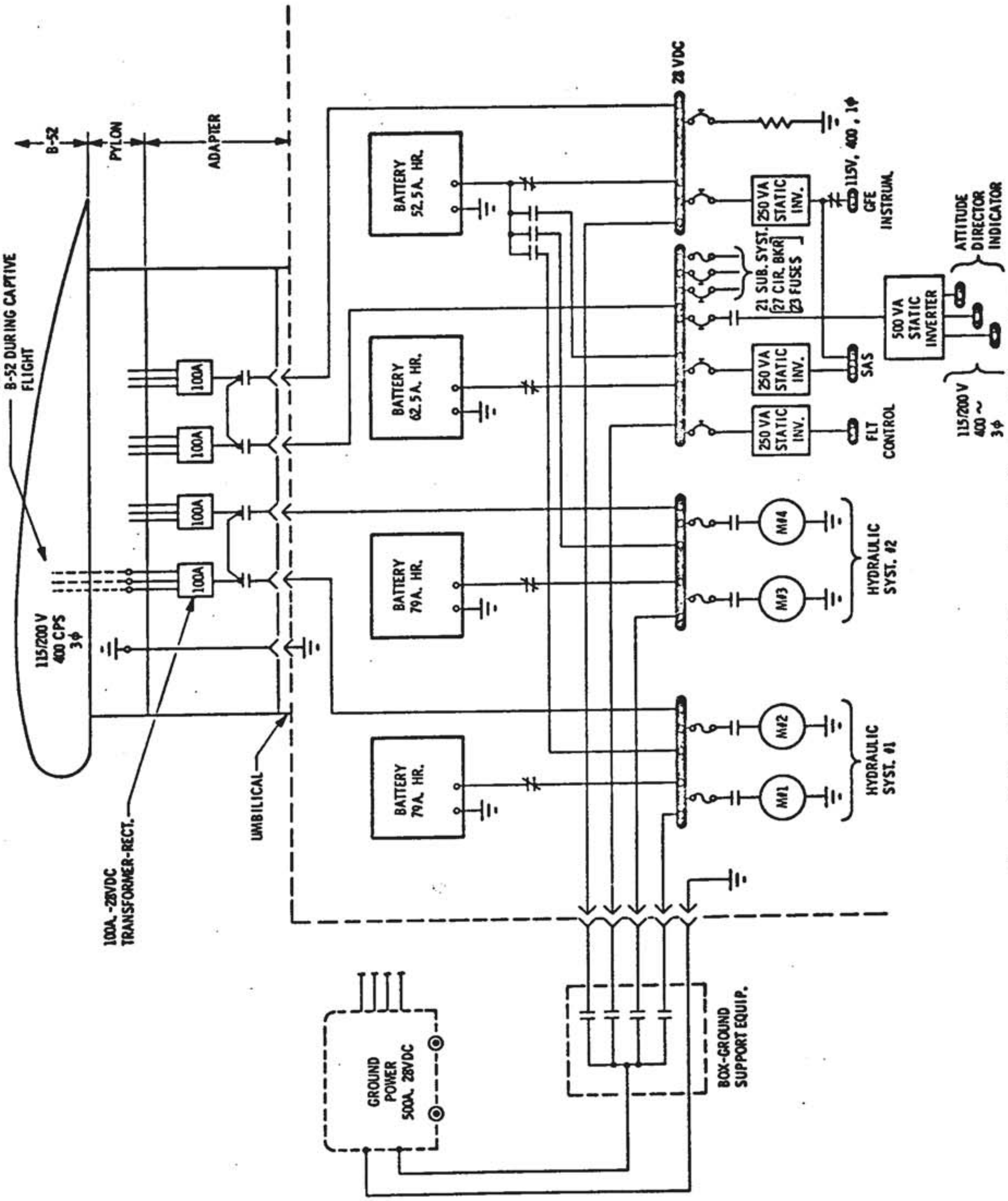


Figure 1-6. Electrical Power Supply System Schematics.

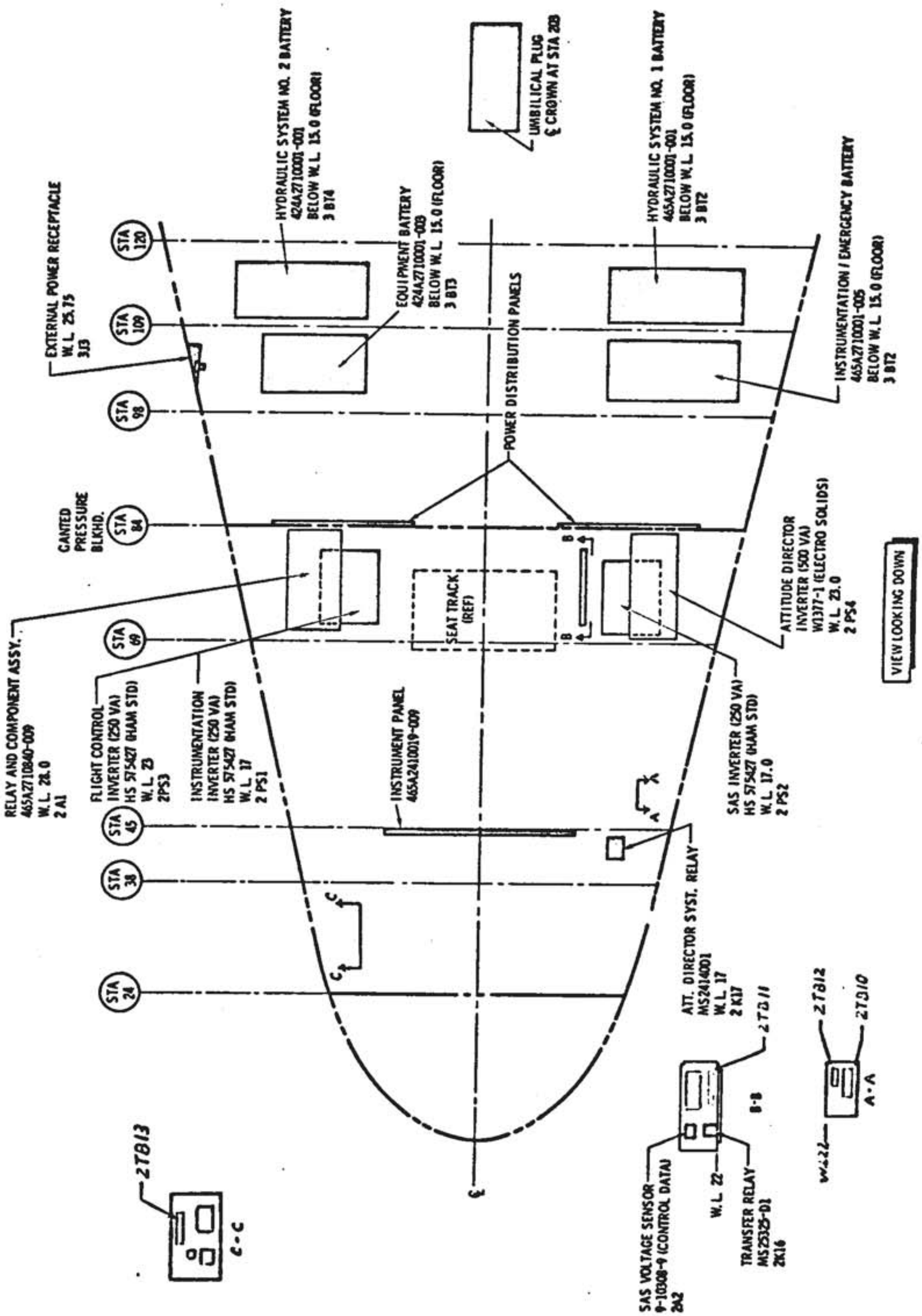


Figure 1-7. Location of Electrical Supply System Components.

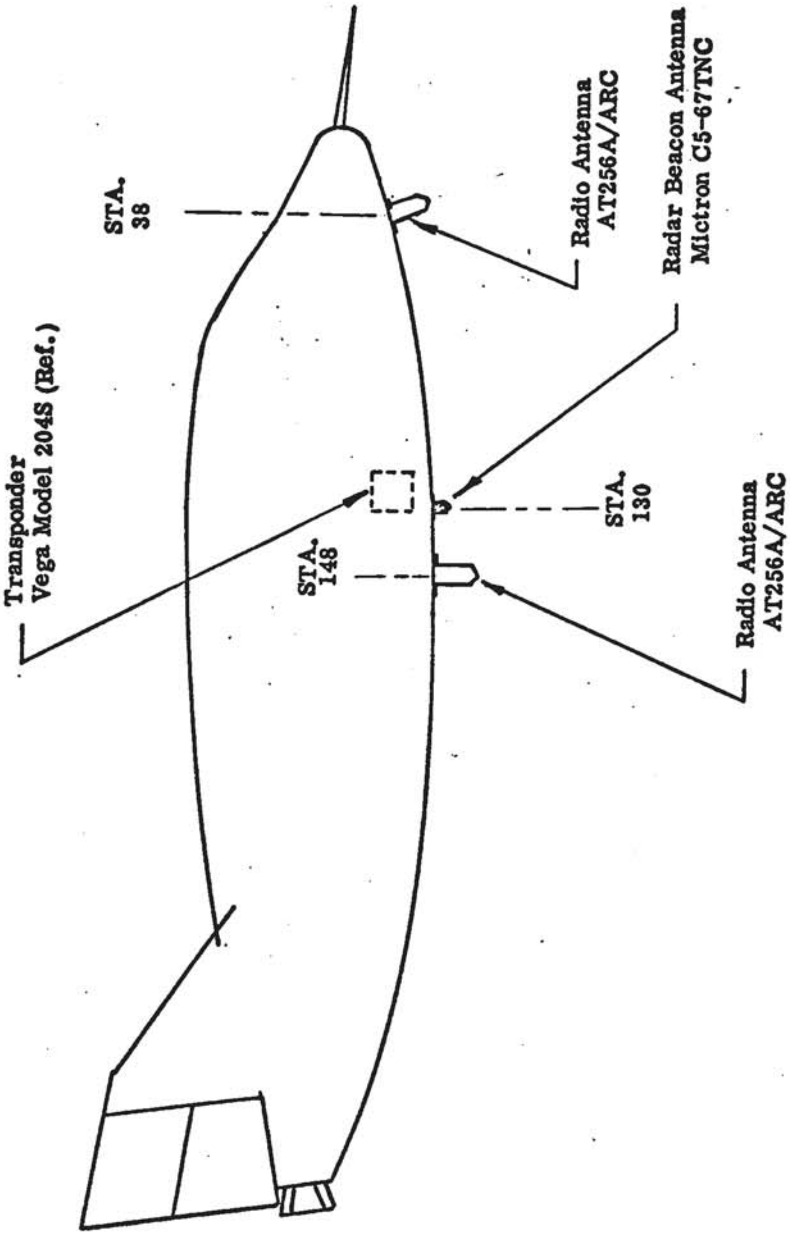


Figure 1-8. Antenna Installation-Radar Beacon and Radio.

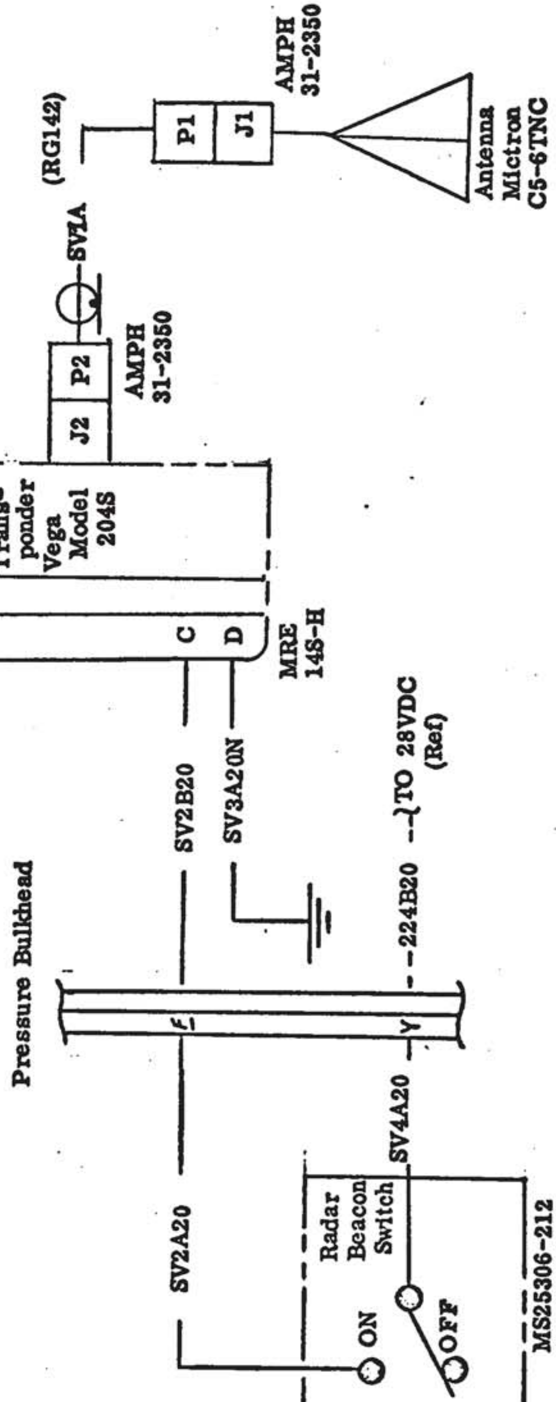


Figure 1-9. Radar Beacon System-Schematic.

e. To use intercom system place RADIO-INTERPHONE switch in INTERPHONE position.

NOTE

A TRIAD 45643 transformer is incorporated in the intercom system to match microphone impedance of the X-24A with the B52 communication system.

1-27. FIRE WARNING AND EXTINGUISHING SYSTEM. The X-24A Fire Warning and Extinguishing System utilizes helium gas to drench the interior of the aircraft aft of the pressure bulkhead if a fire is sensed by any of the six flame detectors located in the engine area. The fire extinguishing portion of the system is essentially a multi-purpose network, that provides an emergency supply of helium under high pressure (approximately 4200 psi) that can be utilized to extend the landing gears should the primary landing gear system become inoperative. The helium gas can also be employed as a means of propellant jettison in case of emergency. System particulars associated with the landing gear and fuel jettison systems are covered in their respective maintenance manuals.

1-28. FIRE WARNING SYSTEM. The fire warning system (See Figure 1-11) is an electrical system utilizing a Control Amplifier (P/N 30-303 A) and six flame detectors (P/N 30-212), a cockpit indicator, a control switch, and a fire warning test switch. In operation, the flame detectors will sense infrared radiation from a fire and cause an increase in detector output voltage. This increase will trigger a relay circuit in the control amplifier which in turn activates the cockpit warning light system.

1-29. The Detectors are strategically located in the engine area and are rigidly mounted to the structure. When any one of the detectors sense the infrared radiation of a fire, the warning light system is activated. Upon elimination of the fire, the entire system instantly recycles to normal and is ready to detect again.

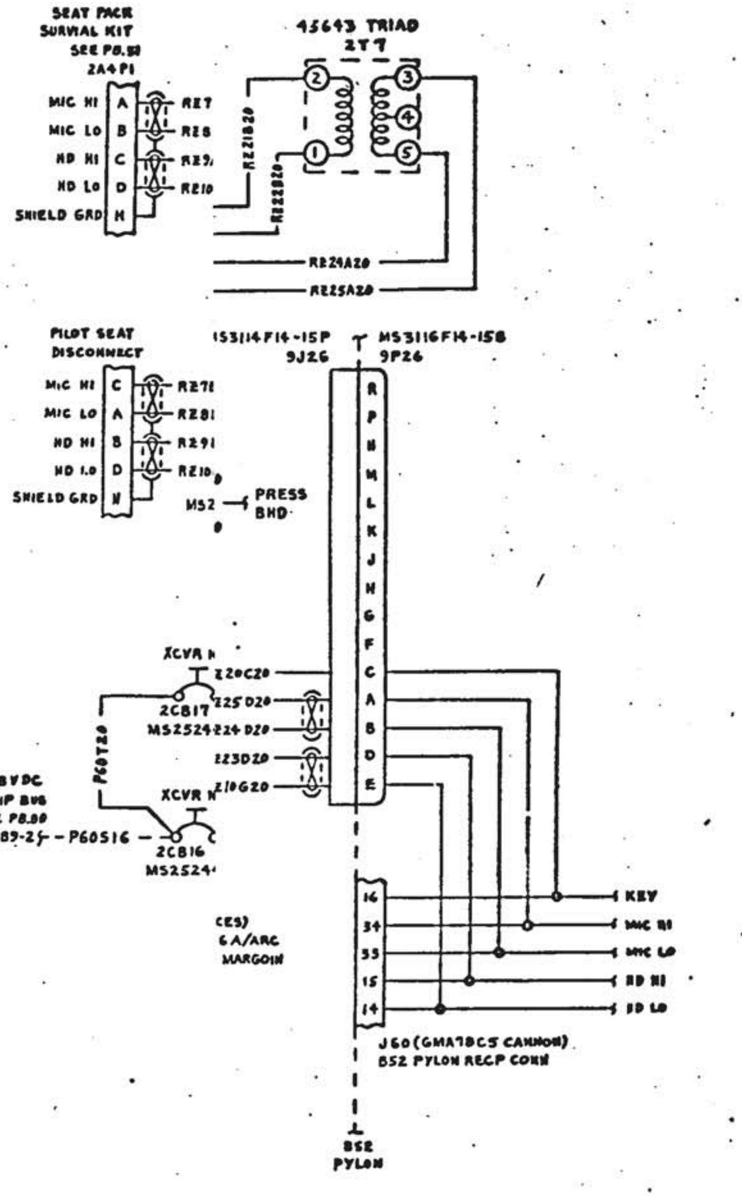


Figure 1-10. Wiring Diagram - Pilot's Intercom and Radio Systems.

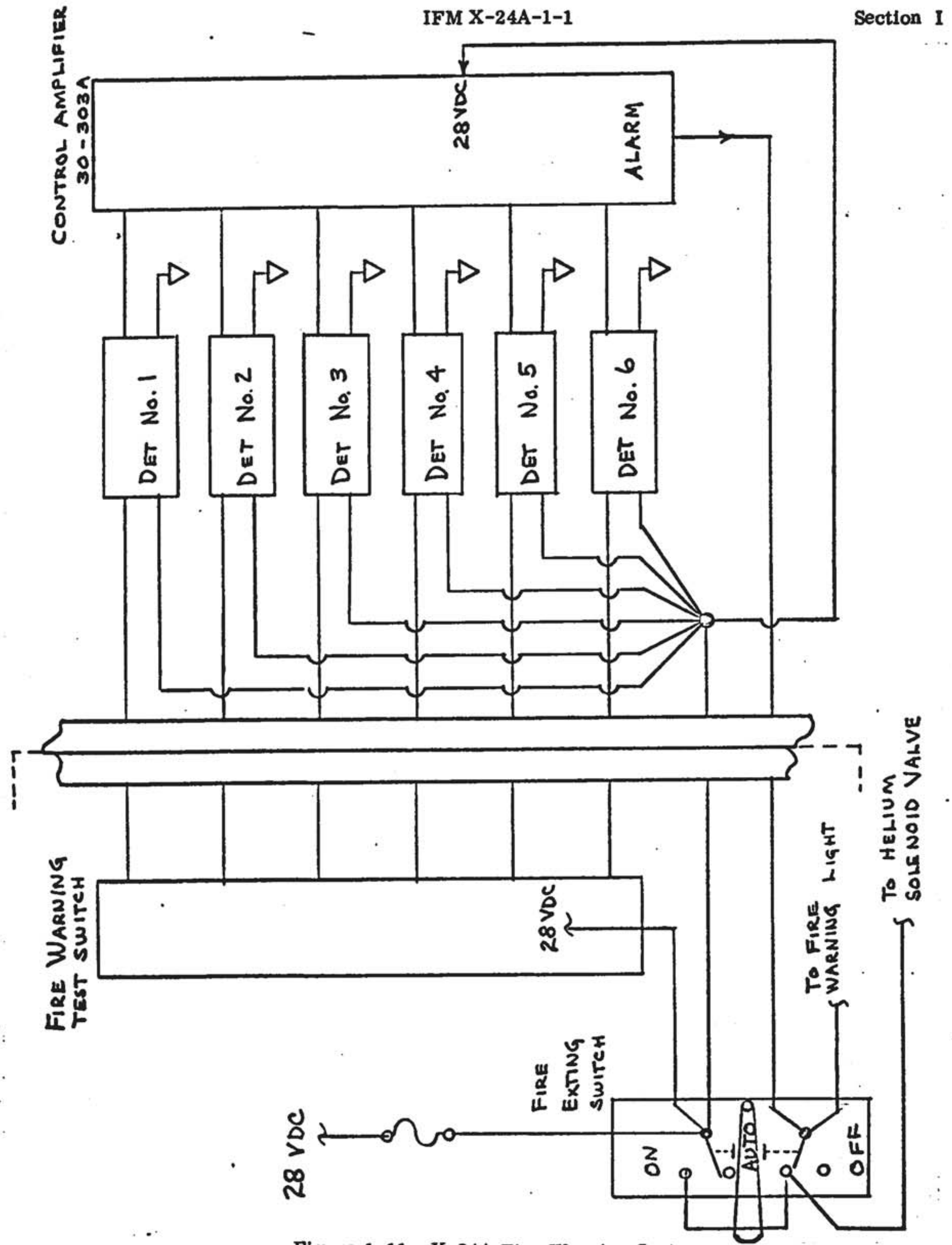


Figure 1-11. X-24A Fire Warning System.

1-30. FIRE EXTINGUISHING SYSTEM. The fire extinguishing system utilizes a high pressure helium system to drench the engine area if a fire is detected on the X-24A. The system consists of a helium tank, P/N 23711740, which is charged during ground servicing to approximately 4200 psi; a Carleton valve P/N 2011001-11 which is electrically controlled by the FIRE EXTING switch on the left hand side of the pilot's glare shield. When the FIRE EXTING switch is in AUTO position, any of the six detectors can (through the control amplifier) activate the Carleton valve and release helium at full pressure through the extinguisher nozzle. With the FIRE EXTING switch in the OFF position, it is the pilot's responsibility to manually activate the extinguishing system by placing the FIRE EXTING switch to ON.

1-31. ENVIRONMENTAL CONTROL SYSTEM. The X-24A aircraft environmental control system is essentially comprised of three sub-systems; (1) Cabin pressurization and ventilation system, (2) suit ventilation and pressurization system and (3) canopy seal pressurization system. Figure 1-18 of this manual shows the entire environmental control system and the interfaces between the three subsystems. During captive flight, air for the environmental control system is supplied from four tanks located in the X-24A pylon adapter. Each tank has a capacity of 3000 cubic inches and is charged to 3000 psi at 70°F. When flying independently of the B-52, air is supplied to the environmental control system from two tanks located on the crown access door of the X-24A. Each of the on board tanks have a capacity of 1500 cubic inches and are charged to 3000 psi at 70°F.

1-32. X-24A PYLON/ADAPTER AIR SUPPLY. The environmental control air supply during captive flight (See Figure 1-12) is provided from four compressed air cylinders (P/N 23711666) located in the X-24A pylon/adapter. These cylinders, connected in parallel, are serviced during ground operations through a common charging valve (P/N 238136). Since the cylinders are connected in parallel, a single pressure gage (P/N 2445-5000) is used to indicate pressure in the pylon/adapter air supply system. This system is protected by a relief valve

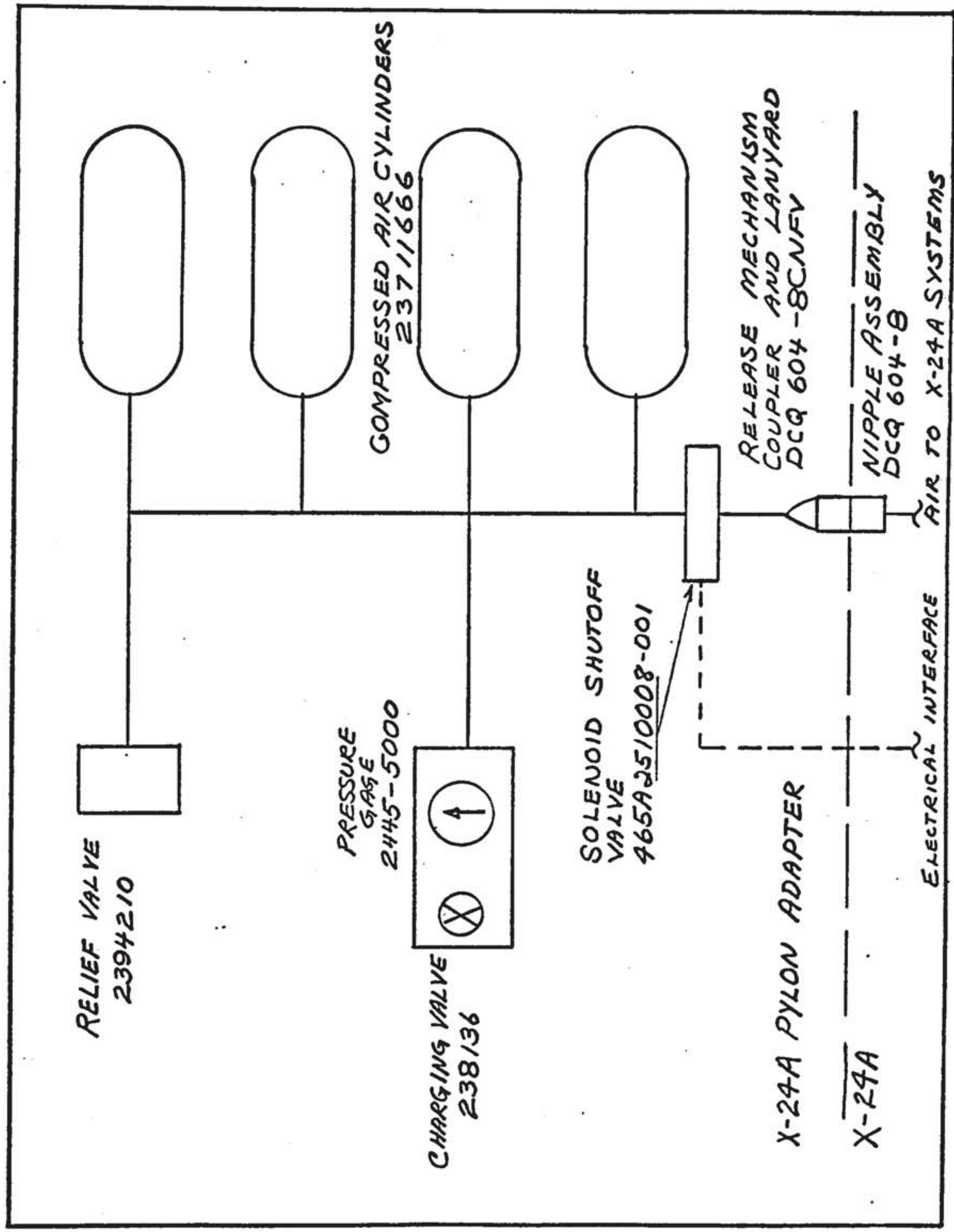


Figure 1-12. X-24A Pylon Adapter Air Supply.

(P/N 2394210) that opens between 3300 and 3500 psi and will reclose when the pressure decreases to 3100 psi. A solenoid shutoff valve (P/N 465A2510008-001) which is electrically controlled from the pilot's right hand console, when opened will allow pressurized air to flow to the X-24A. The pylon/adapter air supply contains the necessary release and seal mechanism to prevent pressurized air from excaping into the atmosphere after separation of the X-24A from the B-52.

1-33. X-24A AIR SUPPLY SYSTEM. During both unpowered and powered flights of the X-24A, air is supplied to the environmental control system from the two on-board tanks, connected in parallel, are charged through a common charging valve during ground servicing of the vehicle. The on-board system contains a relief valve (P/N Z394210) which opens between 3300 and 3500 psi and resets when the X-24A tanks is maintained between 61 and 69°F by use of a thermostat controlled heater blanket. Power for this heater blanket (115VAC) is supplied by the B-52 during captive flight. After separation, heat is no longer applied to the tanks by the blanket. A check valve (P/N 299A-8BB) in the air line from the pylon/adapter prevents the back flow of air from the on-board tanks after separation.

1-34. CANOPY SEAL PRESSURIZATION AND VENTING SYSTEM. The canopy seal pressurization and venting system supplies air pressure at 15 $\pm$ 1.5 psi to the canopy seal when the canopy is closed and locked. The system also vents the air from the seal when the canopy is unlocked. The system essentially consists of the following components: (See Figure 1-14.)

a. Pressure Regulator PN 14281

b. Two pressure fittings PN AN832-4

c. Canopy seal connector

d. Canopy seal

e. Tubing

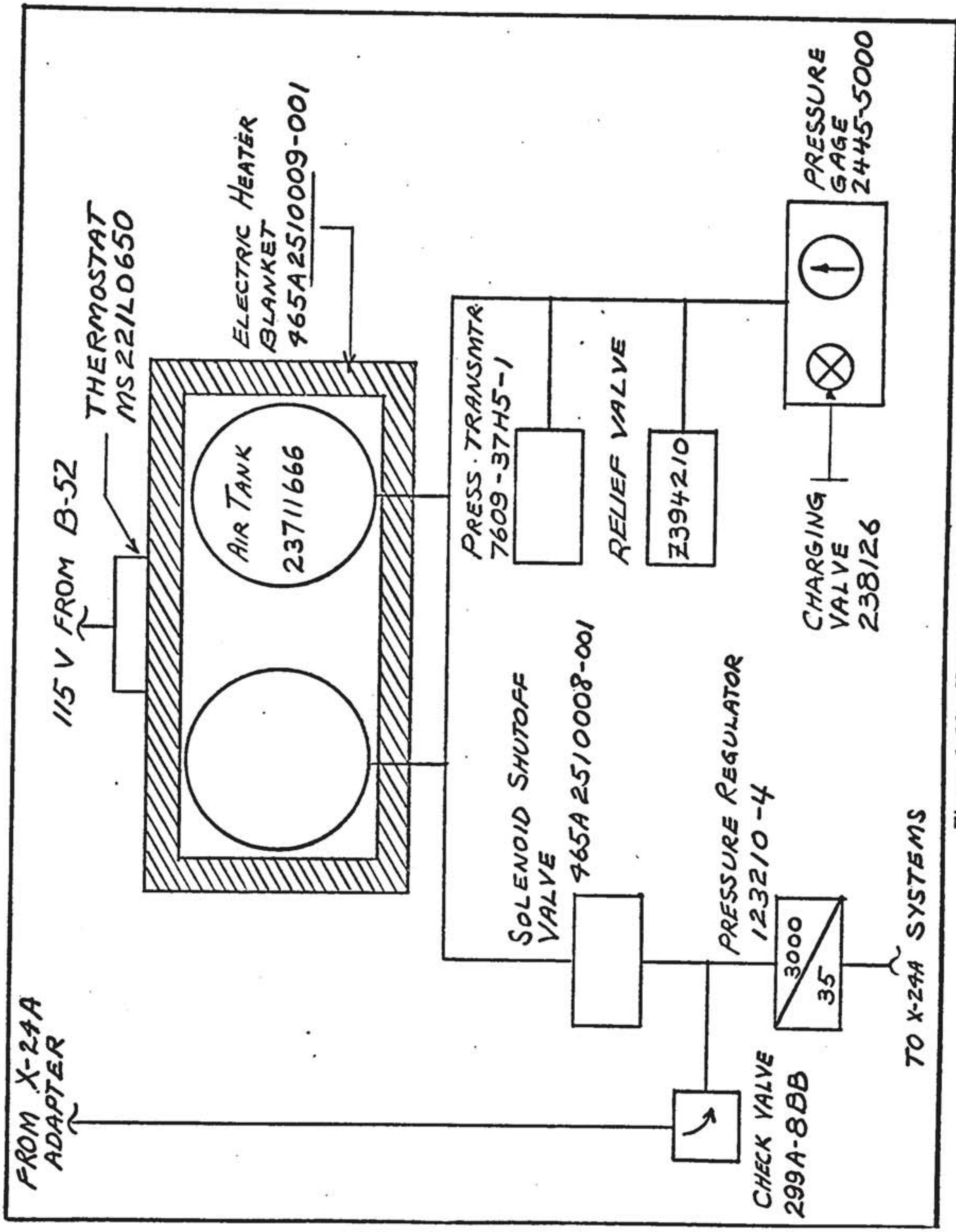


Figure 1-13. X-24A On-Board Air Supply.

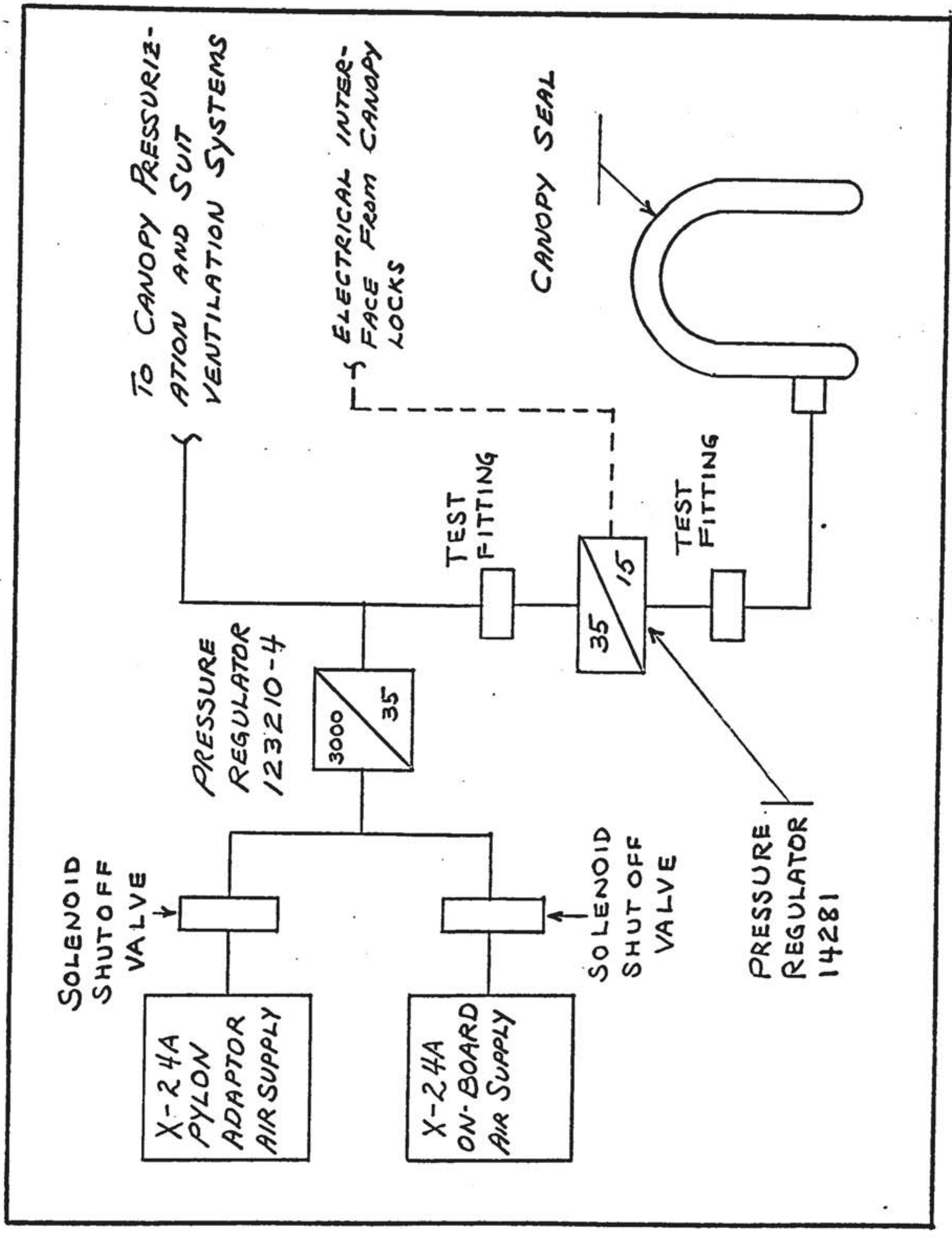


Figure 1-14. X-24A Canopy Seal Pressurization.

In operation, the system is initially activated by placing the CABIN AIR SOURCE switch on the pilot's right hand console to either the X-24A or B-52 position. This allows air pressure at 3000 psi to flow to the Pressure Regulator (P/N 123210-3) which reduces it to between 33 and 39 psi. When the canopy is closed and locked, an electrical signal from the canopy locks will activate pressure regulator (P/N 14281) which allows pressure between 13.5 and 16.5 psi to inflate the canopy seal. When the canopy locks are released, the electrical signal to the pressure regulator is removed and the regulator allows the air to be vented from the canopy seal.

1-35. CABIN PRESSURIZATION SYSTEM. The cabin pressurization system (See Figure 1-15) provides clean dry air at approximately 0.29 pounds per minute for discharge directly into the cabin through a sonic orifice (P/N 465A2510012-013). Airflow in excess of cabin pressure requirements passes through the cabin pressure regulator P/N 123210-4 which maintains an unpressurized cabin up to 5000 feet (flight altitude); a 5000 foot isobaric cabin altitude and a 3.5 ± 0.15 psi differential cabin pressure above approximately 13,700 feet. The cabin safety valve provides positive pressure relief at 4.0 psig. The safety valve may be energized by the dump switch on the pilot's right hand console or by opening the ram air scoop. Either of these two methods are considered emergency procedures.

1-36. SUIT VENTILATION AND PRESSURIZATION SYSTEM. The suit ventilation and pressurization system (Figure 1-16) provides temperature and pressure controlled air to the pilot's pressure suit during powered flights of the X-24A aircraft. As previously stated, air is flowing from either the X-24A adapter tanks or the X-24A on board tanks depending on the position of the CABIN AIR SOURCE switch. With the SUIT HEAT selector switch in the ON position, power is applied to the Temperature selector setting. A temperature sensor BYLF 8436 provides feedback to the controller to maintain a stable air temperature. The heated air flows through the suit air pressure regulator which reduces the pressure from 35 psi to 3.0 below

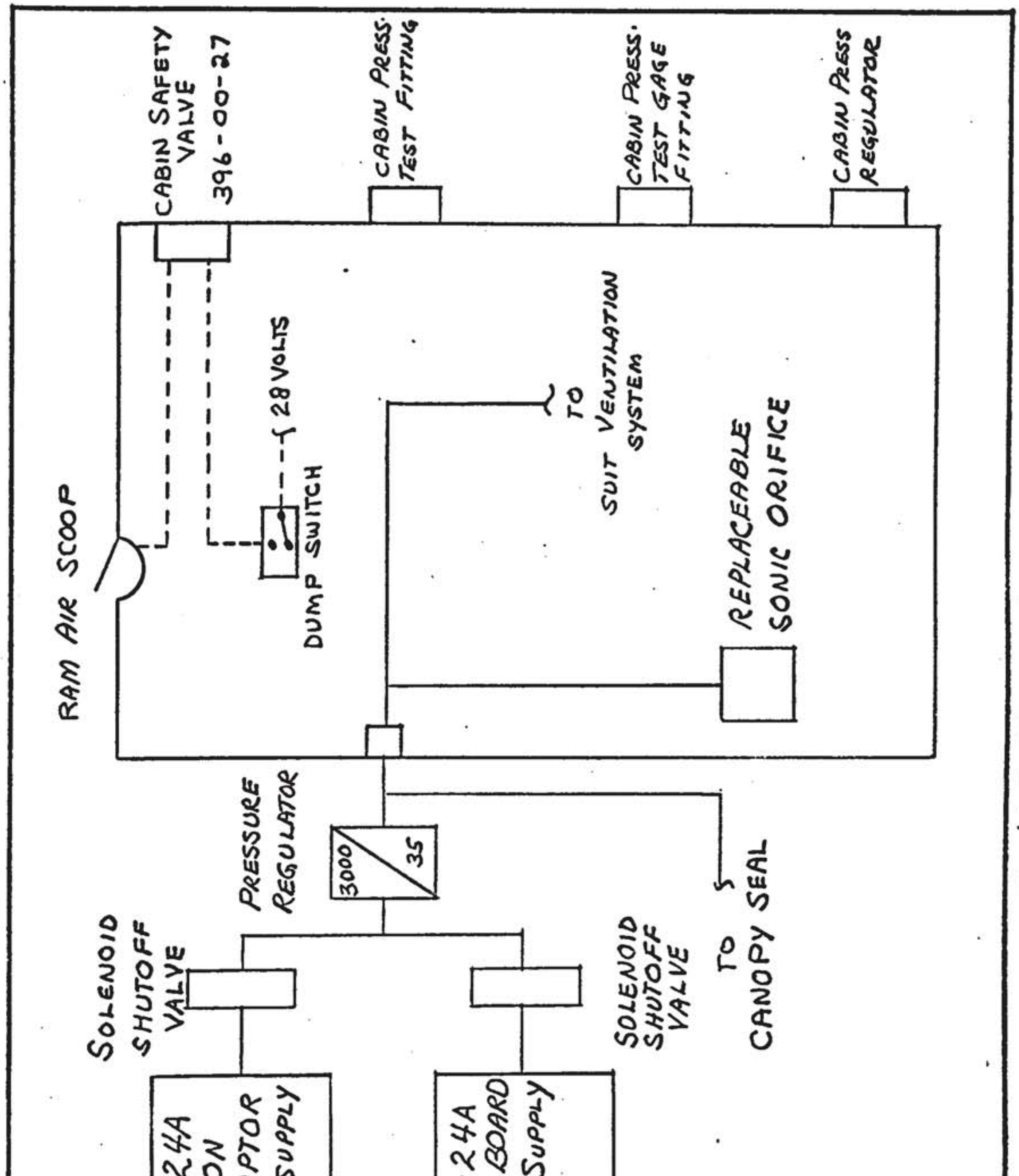


Figure 1-15. Cabin Pressurization System.

an altitude of 35000 ft. and 6.5 above 35000 ft. This reduced pressure is supplied to a special "T" fitting which contains orifices (See Figure 1-17). This fitting serves as a by-pass around the suit vent air flow control valve (465A2510012-001) and provides the minimum air flow requirement for cabin pressurization. The suit vent flow control valve provides the pilot with the means of controlling the flow of air into the pressure suit. (4.5 scfm to 9.2 scfm).

During unpowered flights of the X-24A, the full pressure suit will not be worn. In this case, the vent air supply hose will be disconnected from the ejection seat disconnect and the hose is restrained so that the air can discharge directly into the cabin.

1-37. CANOPY DEFOG SYSTEM. The X-24A Canopy Defog System is essentially comprised of a blower, a heater, two thermostats and the associated tubing required to maintain the canopy in a clear transparent condition during the entire flight of the X-24A. The system (Figure 1-19) has the capability of providing 80 cubic feet of air per minute within a temperature range from ambient cockpit temperature up to approximately 190°F. The system utilizes cabin air, forced through the blower and heater for discharging parallel to the inner surface of the canopy through two distribution nozzles.

1-38. With the CANOPY DEFOG switch in the OFF position, the Janco heater and the blower are inoperative; in either the AIR or HEAT positions, power is applied to the blower to force cabin air through the system (See Figure 1-20). In the HEAT position, power is also applied to the heater circuit. When the temperature of the duct thermostat exceeds 187 $\pm$ 4°F or the canopy surface thermostat exceeds 163 $\pm$ 4°F, the specific thermostat will open thus removing power from the heater. The heater itself contains both a thermal switch and a thermal fuse connected in series to protect the heater against an overheat condition.

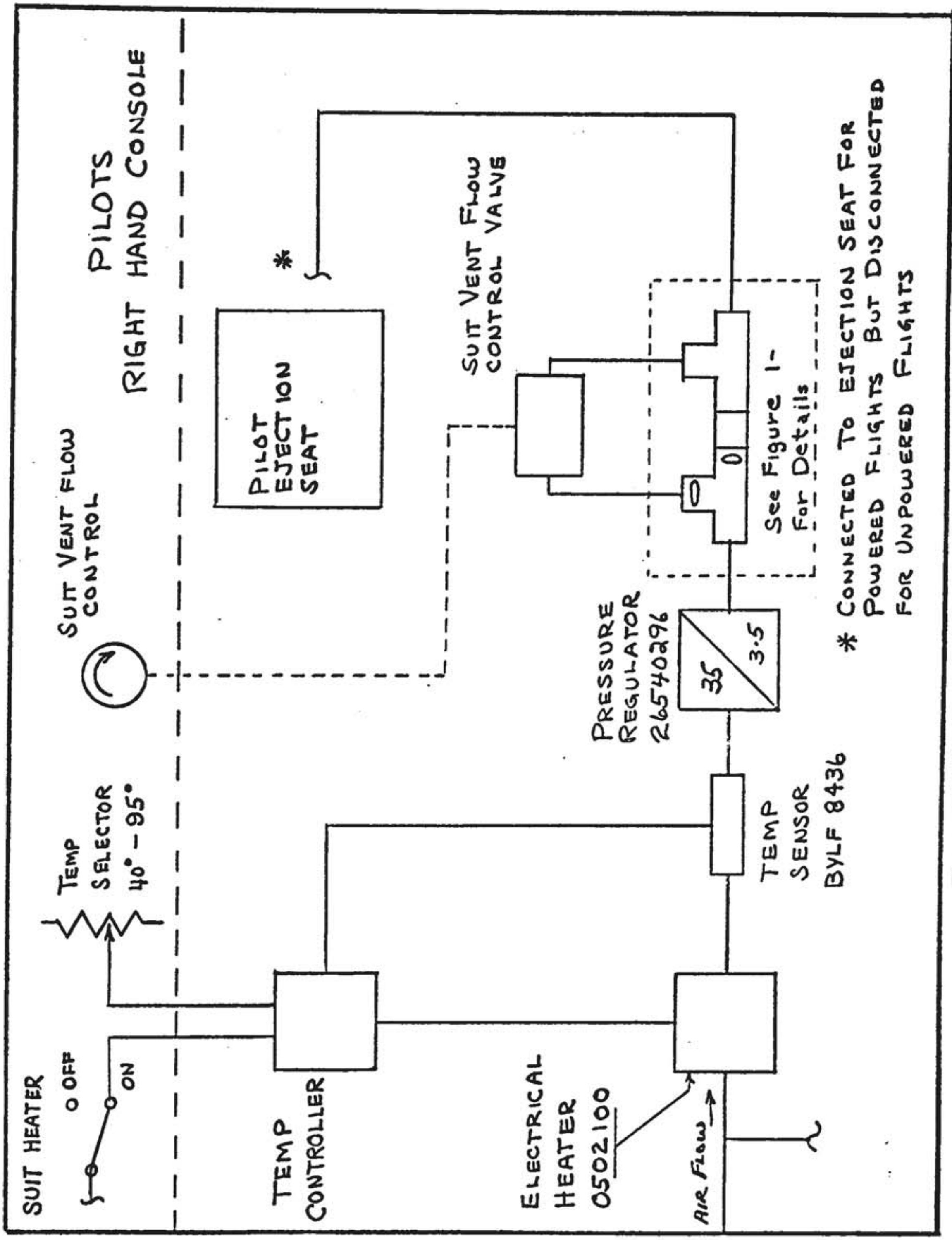


Figure 1-16. Suit Ventilation and Pressurization System.

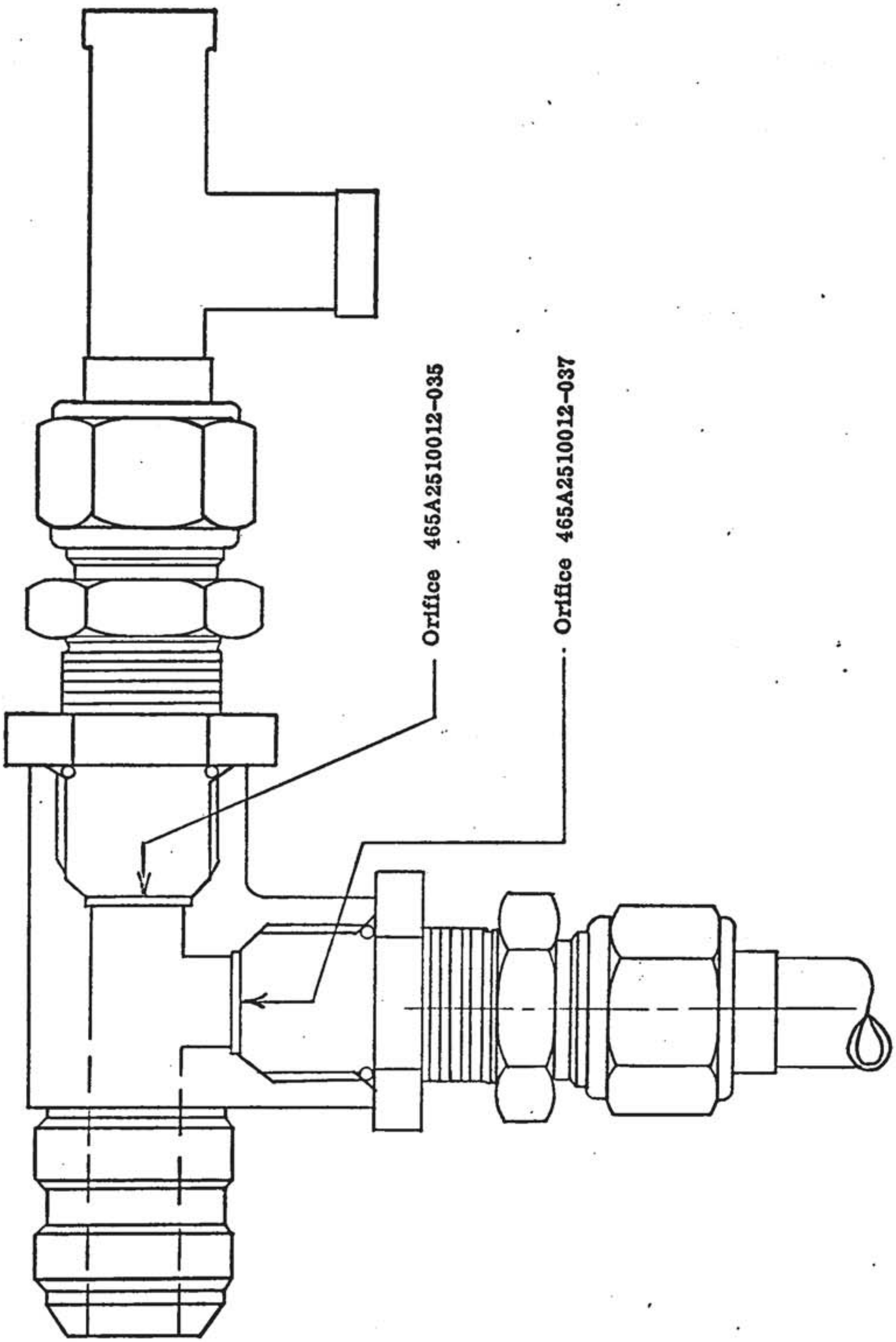


Figure 1-17. Suit Vent Orifice Assembly.

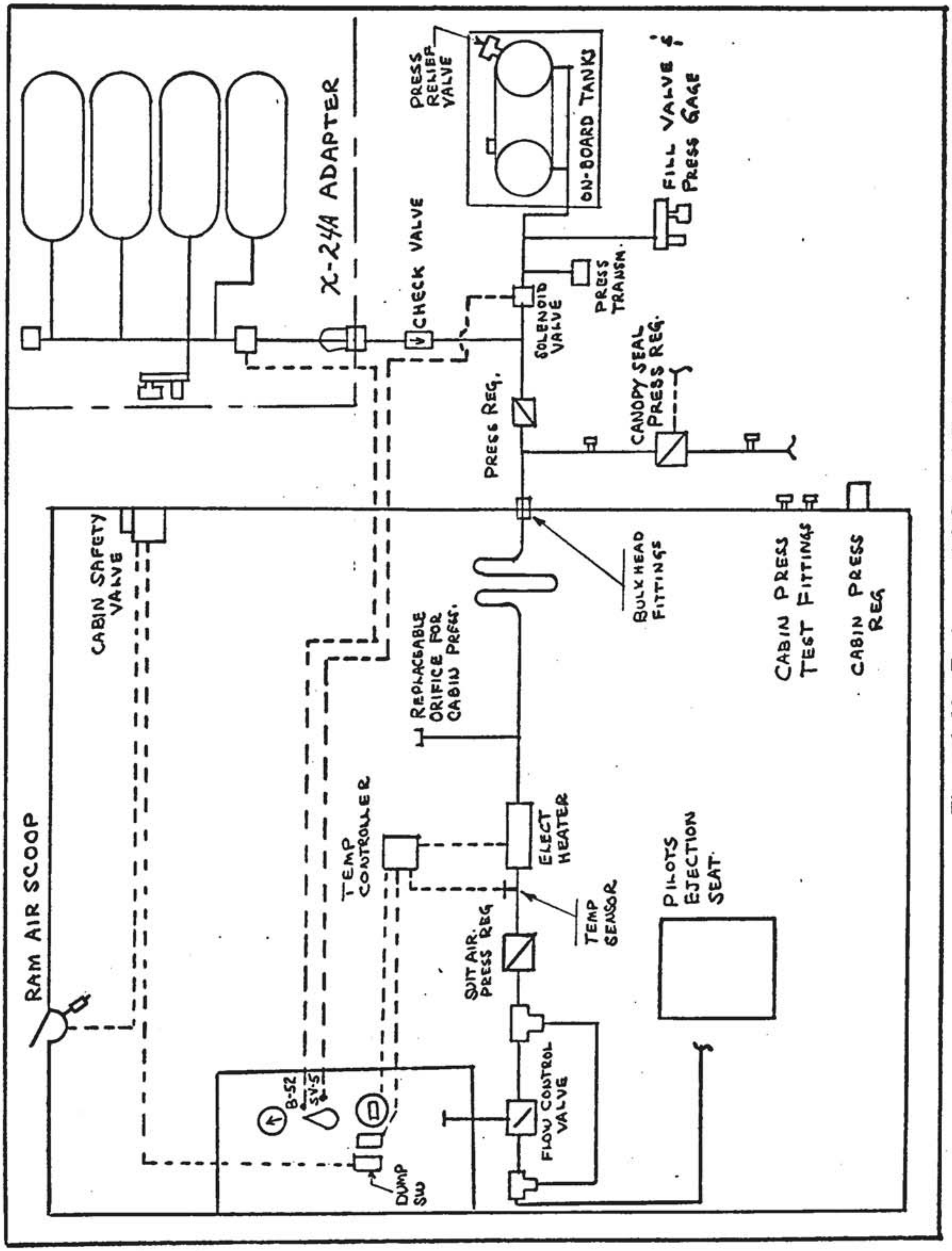


Figure 1-18. Environmental Control System.

1-39 The thermal switch opens the heater control circuit when the static air temperature reaches between 237.5°F and 262.5°F. If the thermal switch should fail, the thermal fuse will open the control circuit when the temperature of the heater housing reaches between 380°F and 420°F. After once opening, the thermal fuse must be replaced.

1-40. BREATHING OXYGEN SYSTEM. The X-24A aircraft utilizes a gaseous oxygen system supplied by a single oxygen cylinder located at Station 84. Fully serviced, this cylinder contains 15.2 cubic feet of oxygen at 1800 psi. The system is serviced through a high pressure filler valve located at Station 46. An emergency oxygen supply is provided which is used for both powered and unpowered flights and is part of the ejection seat survival kit. The survival kit will be serviced by the personnel equipment shop in accordance with existing procedures.

The particular X-24A mission configuration will determine the source of oxygen supplied to the pilot (See Figure 1-21). During captive flight, breathing oxygen will be provided to the pilot from the B-52. After separation of the X-24A from the B-52, oxygen will be supplied to the pilot from the on board system.

1-41. X-24A CAPTIVE FLIGHT CONFIGURATION. During captive flight, breathing oxygen is supplied to the pilot from the B-52; and is routed through the X-15 pylon, through the X-24A pylon adapter to the aircraft. The oxygen passes through low pressure lines made of aluminum alloy to a selector valve (F851000-3). The selector valve control knob is located on the right hand pilot console and allows the pilot to select the desired source of oxygen (either B-52 or X-24A). During captive flight, the OXYGEN SELECT switch is in the B-52 position and allows oxygen to flow to the pilot's ejection seat.

1-42. X-24A FLIGHTS AFTER SEPARATION. After separation of the X-24A from the B-52 there are two possible missions, 1) powered flight and 2) unpowered. During powered flights, the pilot must wear a full pressure suit while for unpowered flights

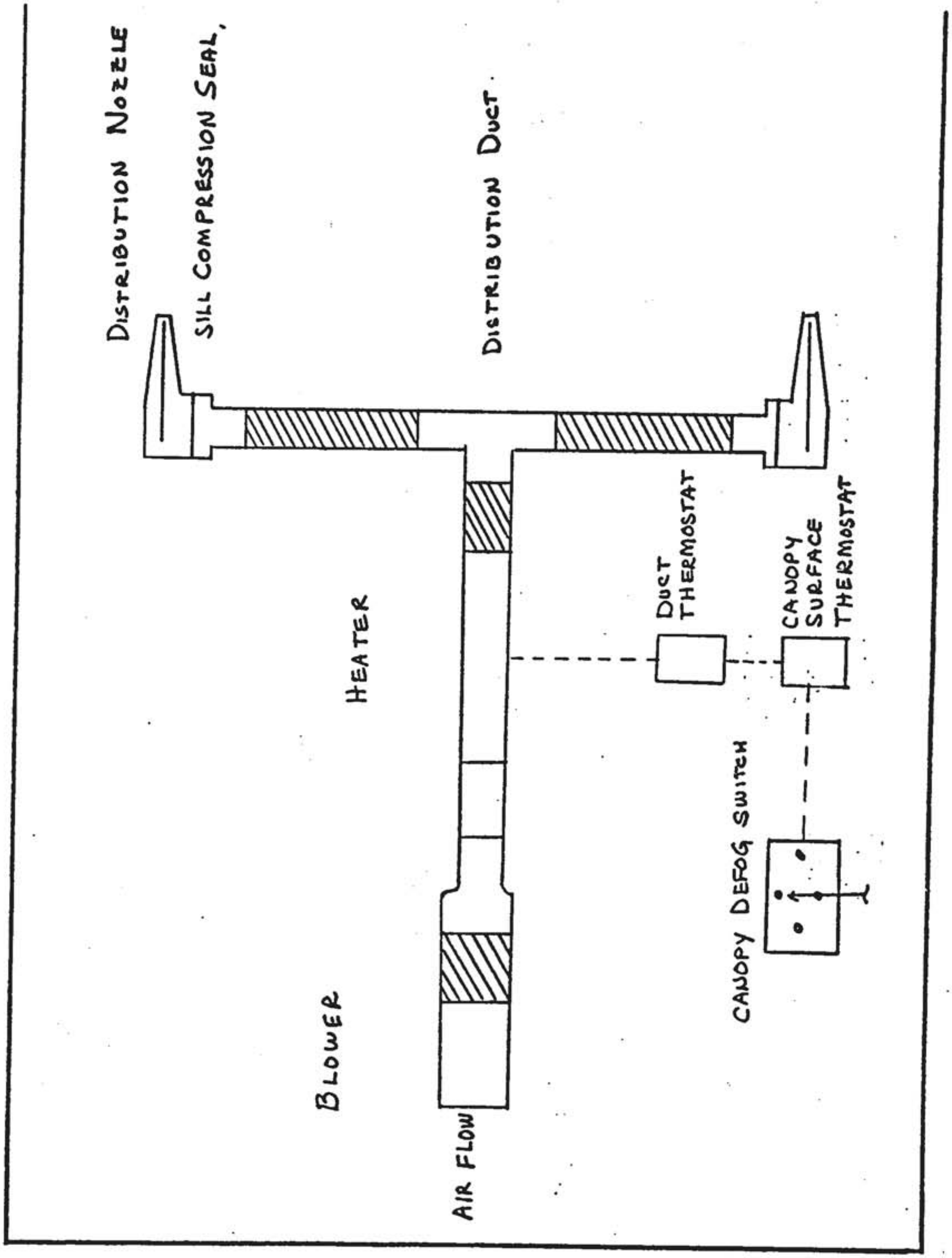


Figure 1-19. X-24A Canopy Defog System.

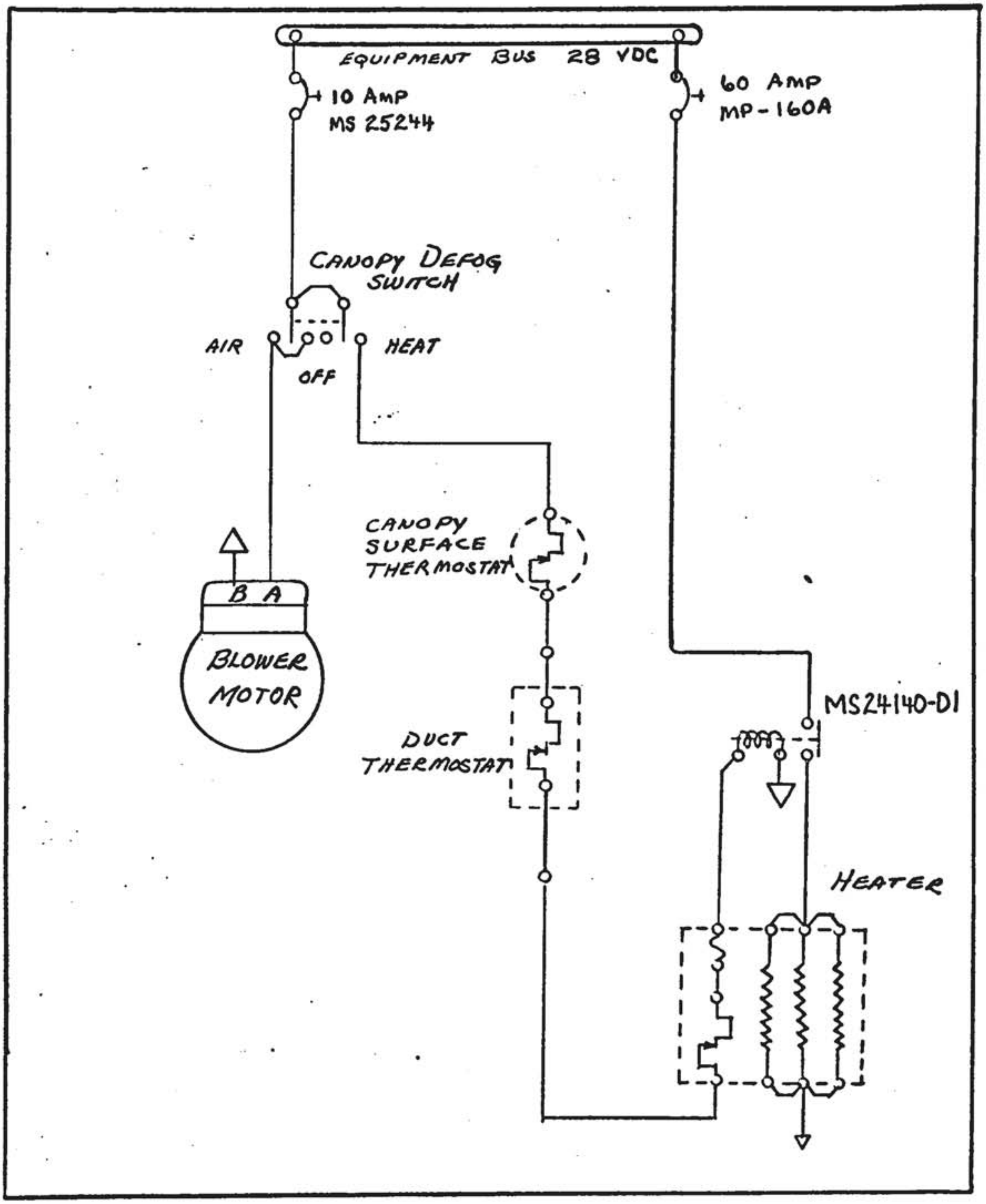


Figure 1-20. Canopy Defog Schematic.

a standard flight suit may be worn. Oxygen to the pilot is provided by the on-board system when the OXYGEN SELECT switch is placed in the X-24A position. Now, oxygen is provided from the cylinder ZC268-15-7 located on the aft side of the canted bulkhead through high pressure lines made of seamless copper alloy tubing, to the pressure reducer F17130-5 where the oxygen pressure is reduced from 1800 psi to 80 $\pm$ 10 psi. The oxy en then goes to the pilot's ejection seat.

During powered flights of the X-24A, a full pressure suit will be worn by the pilot. The pressure suit contains a firewell mini-regulator that provides a proper mixture of oxygen/air to the pilot's face mask. During unpowered flights, the pilot will wear a standard flight suit. The oxygen mask used during unpowered flights will include the mini-regulator, thus eliminating the need for a more bulky means of providing the proper air/oxygen mixture.

1-43. EMERGENCY OXYGEN SUPPLY. The survival kit seat pack is the means of providing emergency oxygen. If the X-24A aircraft oxygen system is depleted or inoperative the pilot will utilize the survival kit by pulling the green OXYGEN SUPPLY handle at the right side of the seat. This automatically prevents oxygen flow, back through the on board system. In the event of pilot ejection, the on-board system is disconnected through a lanyard arrangement as the ejection seat leaves the aircraft.

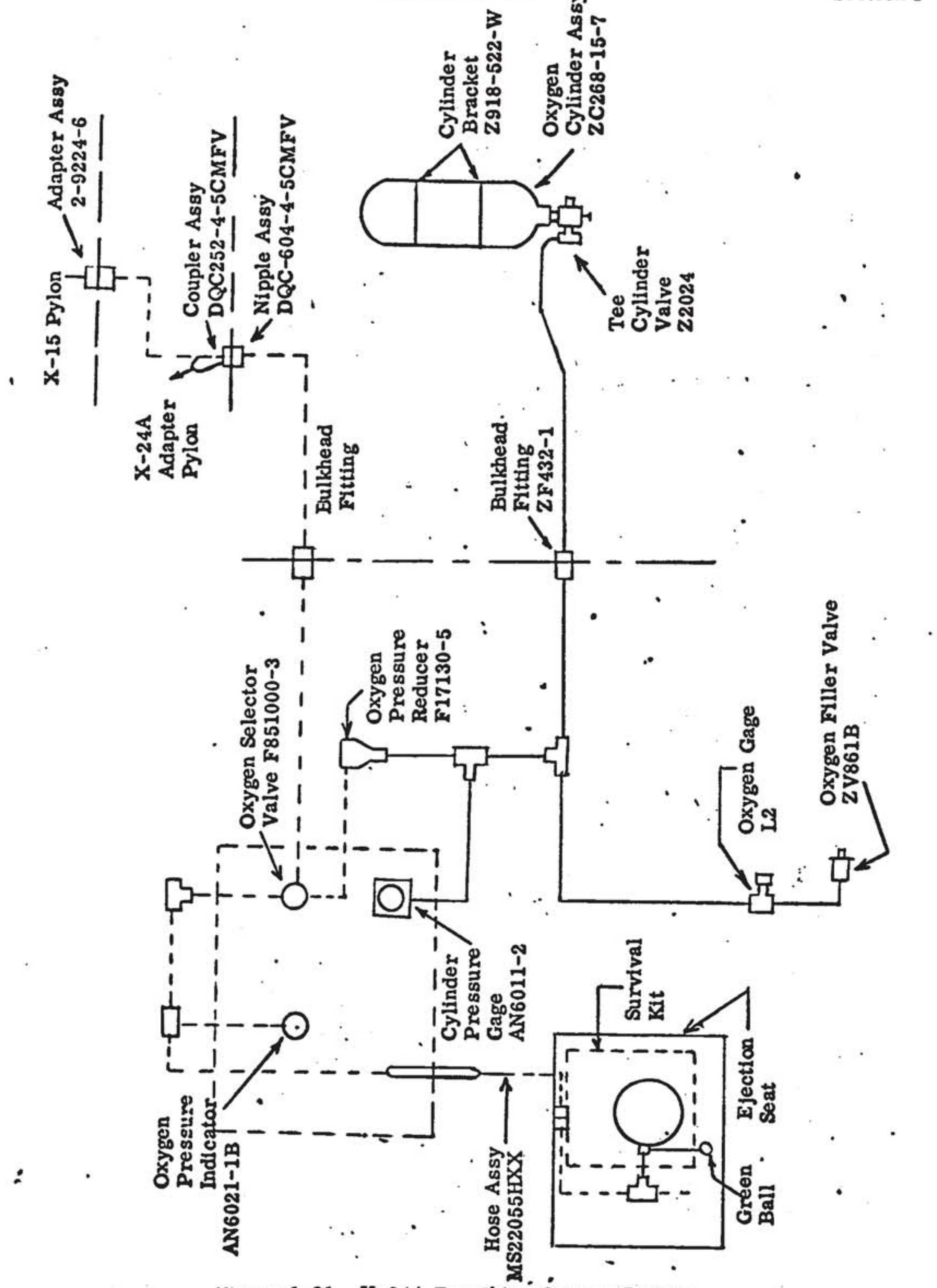


Figure 1-21. X-24A Breathing Oxygen System.

SECTION II

NORMAL OPERATING PROCEDURES

2-1. GENERAL.

2-2. This section contains the normal operating procedures for preflight checkout, takeoff, climb, prelaunch, launch-powered flight, landing and post landing of the X-24A.

2-3. The procedures contained in this section assumes that the X-24A is installed on the pylon adapter and that all the interconnections from the pylon to the X-24A have been completed. Also that the tires, brake hydraulic system, landing gear struts have been properly serviced, the seat and canopy explosives are installed, and that all functional system tests have been satisfactorily completed on the X-24A and the pylon adapter.

2-4. PREPARATION FOR FLIGHT.

2-5. FLIGHT RESTRICTIONS. Refer to Section V for detailed aircraft limitations.

2-6. FLIGHT TEST. The flight test of the X-24A will be conducted by NASA Flight Research Center at Edwards Air Force Base, California. A B-52 aircraft, modified by additon of the pylon adapter to the existing X-15 pylon will be used to carry the X-24A to launch altitude. The flight test program will consist of two phases:

- Unpowered/glide flight, the X-24A (with ballast/system) will be dropped from the B-52 and glide to tangential landing. The X-24A drop weight can vary from Burnout weight to 9720 lbs by use of the ballast system.
- Powered flight, the rocket engine XLR11-RM-13 turbopump and propellant tanks will be installed in place of the ballast system. Within five seconds after release from the B-52, two of the four thrust chambers will be ignited, after an additional five the remaining two thrust chambers will be ignited.

The X-24A will climb to altitude and glide to a tangential landing. See Figure 2-1.

2-7. SERVICING. The servicing of the X-24A consists of two parts; that which is accomplished prior to installation of the X-24A onto the pylon adapter and that which is accomplished prior to or after installation. The servicing is further affected by the type of mission planned i.e.; an unpowered flight or powered flight. The mission effectivity for each procedure is designated in Table 2-1. The panel locations in the cockpit are shown on Figure 2-2. The detailed servicing procedures are covered in MIM X-24A-2-11 Servicing Manual.

TABLE 2-1

SERVICING

System	Unpowered	Powered	Installation	
			Prior	After
Environmental control system pylon storage tanks	X	X	X	
Release tanks, pylon adapter	X	X	X	
Environmental control system X-24A storage tanks	X	X	X	
Landing gear helium storage tank	X	X	X	
Main (LOX and Fuel pressurization) Helium storage tank	X	X	X	
Emergency (landing gear, fire extinguisher, and LOX and fuel tank pressurization backup) helium storage tank	X	X	X	
Pilot's breathing oxygen tank	X	X	X	
Batteries	X	X	X	
Fuel System		X	X	X
Lox System		X	X	X
Ballast	X		X	

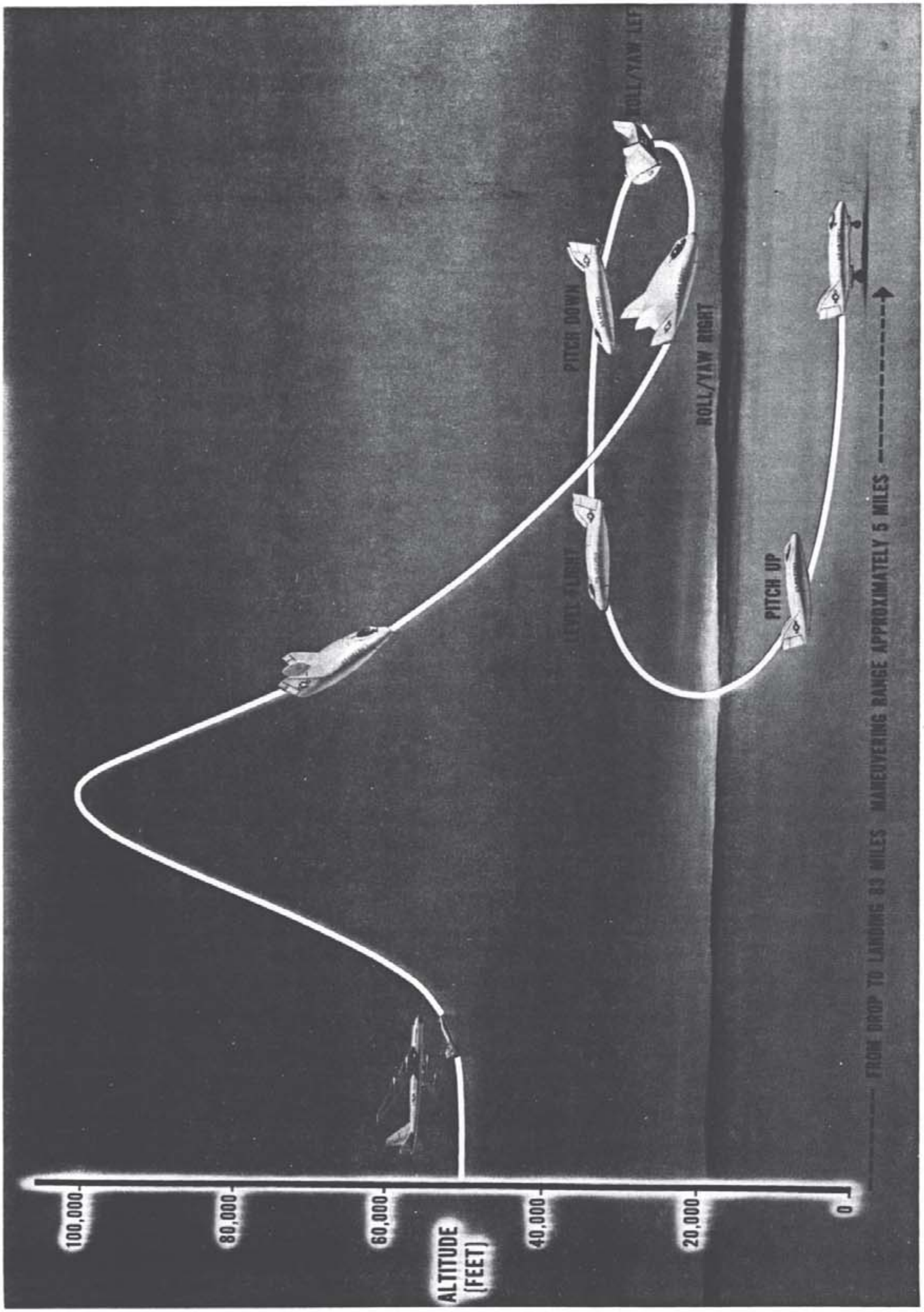


Figure 2-1. X-24A Flight Profile.

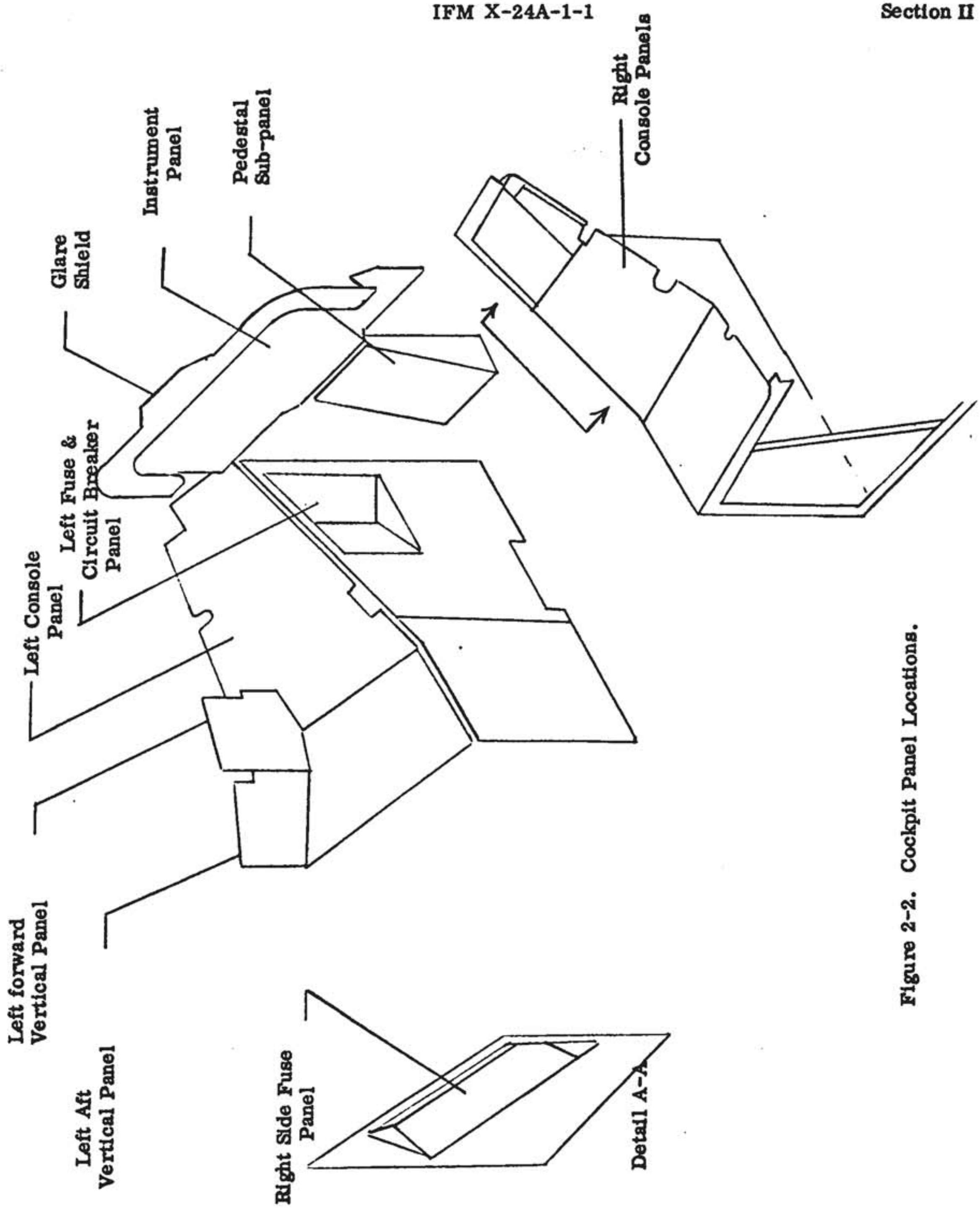


Figure 2-2. Cockpit Panel Locations.

2-8. X-24A FLIGHT CHECK LISTS:

A. PRIOR TO TAKEOFF

NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
1.	Crew entry	B-52 crew entry	Crew entry
2.	Perform cockpit chk with inspector ref. Para. 2-13.		Perform launch panel chks
3.	Radio Chk:		
	RADIO INTERPHONE sw--INTERPHONE	Interphone chk	Interphone chk
	RADIO INTERPHONE sw--RADIO		
	RADIO NO. 1 & NO. 2 sw--NO. 2	Chk aux & prim freqs	Radio chk
	RADIO NO. 1 & NO. 2 sw--NO. 1	Chk aux & prim freqs	Radio chk
	RADIO INTERPHONE sw--INTERPHONE		
4.	OXYGEN SELECT sys chk:		
	B-52 supply		
	X-24A supply		
	Return to B-52 supply		
5.	Cockpit ground safetypins--removed		
6.	FIRE DETECT sw--mom ON		
	Position 1-6		
	Fire indic light--ON each pos.		
7.	FIRE EXTING sw--AUTO		
8.	CABIN & PILOT AIR cb--in		
9.	CANOPY cb--in		
10.	CANOPY sw--CLOSE		
11.	CABIN AIR SOURCE sw--B-52		
12.	SUIT VENT FLOW val--as desired		
13.	SUIT HEAT:		
	Switch--ON		
	Rheostat--as desired		
14.	5 min to eng start--B-52	5 min to eng start	
15.	Gage chk:		
	FUEL PRESSURE_____		
	LOX PRESSURE_____		
	H_2O_2 PRESSURE_____		
	H_e TANK NO. 1_____		
	H_e TANK NO. 2_____		
	GEAR PRESS_____		
	CABIN AIR SOURCE_____		
	OXYGEN CYLINDER PRESSURE_____		
	OXYGEN CYLINDER PRESSURE_____		
	HYD SYS NO. 1_____		
	HYD SYS NO. 2_____		
16.	RELEASE LOCK SET lt--ON		
17.	RELEASE PRESSURE LOW lt--out	Engine start	
18.	Ready to taxi	Ready to taxi	Ready to taxi
19.	RADAR ON sw--ON		
20.		taxi	
21.	Plug in Bio Med pkg		

B. CLIMB TO ALTITUDE CHECKS:

NO	X-24A PILOT STATION	B-52 PILOT STA.	LAUNCH OPER
1.		Brake Release	
2.		Takeoff	
3.		Climb Pattern	
4.	CABIN PRESSURE ALTITUDE--10,000 ft		
5.	ATT IND INV sw-ON		
6.	OXYGEN SELECT sw-B-52		
7.	OXYGEN CYLINDER PRESSURE gage: Upper--80 ± 10 psi Lower--1800 + 50, -0 psi		
8.	Close helmet visor		
9.	HELMET VISOR HEAT sw--to desired level		
10.	CANOPY FOG sw--AIR for fogging cond		
11.	CANOPY FOG sw--HEAT extreme fogging		
12.	SAS INV cb --in		
13.	FLT CONT INV cb--in		
14.	ATT DIR INV cb--in		
15.	INV AUTO TRANS sw--moment to RESET		
16.	RIGHT & LEFT MASTER CAUTION light--press to reset		
17.	Winds Aloft--NASA 1		
18.	M SENSOR DC cb--ON		
19.	M SENSOR M SVO cb-ON		
20.	MACH REPEATER sw-AUTO compare to B-52 reading_____	Check airspeed	
21.	ANGLE OF ATTACK ind--compare to B-52 reading_____		
22.	RADIO INTERPHONE sw--RADIO		
23.	Edw Srfc winds--NASA 1		
24.	Call 15 Min to launch-NASA 1		

C. PRE-LAUNCH. 15 MINUTES TO LAUNCH:

NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
1.	HYD PUMP MOT RELAY cb--in		
2.	HYDRAULIC SYSTEM PUMP SELECT sw--ON		
3.	PRE-FLT PUMP SELECT sw-- NO. 1 & 3 pos SYS NO. 1 gage_____psi LOW PRESS WARN light SYS NO. 2--on		
4.	WARN LT SYS MA cb--out		
5.	WARN LT SYS MA cb--in for reset		
6.	PITCH-ROLL YAW cb--ON		
7.	BIAS A/C BKRS--ON		
8.	RUDDER & FLAP BIAS AUTO MAN mode sw--AUTO		
9.	UPPER FLAP, RUDDER & K_{RA} BKR--in/ON		
10.	RIGHT MASTER CAUTION lt--push to reset off		
11.	PITCH, ROLL, YAW MODE sw--MAN		
12.	PITCH GAIN sw--_____(Pos 4)		
13.	ROLL GAIN sw--_____(Pos 5)		
14.	YAW GAIN sw--_____(Pos 4)		
15.	All SAS cb--ON		
16.	NOSE GR STEER cb--in		
17.	SV-5 REL PNEU V cb--in		
18.	SAS STATUS lts amber--push to reset		
19.	SMRD TEST sw--SMRD TEST		
20.	HYD ACTUATOR MODE SELECT sw-AUTO		
21.	GYROS TORQUE sw--momt to GYROS TORQUE		
22.	HYD ACTUATOR MODE checks: PITCH NO. 1 sw--OFF GYROS TORQUE sw--momt GYROS TORQUE SAS STATUS PITCH lt-amber/on PITCH NO. 2sw--OFF GYROS TORQUE sw--momt GYROS TORQUE SAS STATUS PITCH lt--red & amber on SAS STATUS PITCH lt--amber reset PITCH NO. 1 & 2 sw--MAN SAS STATUS PITCH lt-- amber reset GYROS TORQUE sw--momt GYROS TORQUE		

C. PRE-LAUNCH, 15 MINUTES TO LAUNCH: (Cont)

NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
22.	(Cont) PITCH NO. 1 & 2 sw--AUTO SAS STATUS PITCH lt--amber reset YAW NO. 1 sw--OFF GYROS TORQUE sw--momt GYROS TORQUE SAS STATUS YAW lt--on YAW NO. 2 sw--OFF GYROS TORQUE sw--momt GYROS TORQUE SAS STATUS YAW lt--amber & red lts--on SAS STATUS YAW lt--amber reset YAW NO. 1 & 2 sw--MAN GYROS TORQUE sw--momt GYROS TORQUE YAW NO. 1 & 2 sw--AUTO SAS STATUS YAW lt--amber reset ROLL NO. 1 sw--OFF GYROS TORQUE sw--momt GYROS TORQUE SAS STATUS ROLL lt--amber on ROLL NO. 2 sw--OFF GYROS TORQUE--momt GYROS TORQUE SAS STATUS ROLL lt--amber & red on SAS STATUS ROLL lt-amber reset ROLL NO. 1 & 2 sw--MAN GYROS TORQUE--momt GYROS TORQUE ROLL NO. 1 & 2 sw-AUTO SAS STATUS ROLL lt--amber reset		
23.	5 minutes to launch-	Decel to______ KIAS	

D. LAUNCH READY, 5 MINUTES TO LAUNCH:

NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
1.	SOLENOID SAF VALVE sw--AUTO		
2.	CABIN AIR SOURCE sw--SV-5 gage--______		
3.	OXYGEN SELECT sw____SV-5 gage--______		
4.	DC POWER SELECT sw--BAT		
5.	L/D ARM sw--ON		
6.	L/D THROTTLE--closed (back)		
7.	PUMP THRM PROT sw--OUT FLIGHT		
8.	CAMERA ON sw--ON		
9.	RECORDER ON sw--ON		
10.	NASA 1 verify LOX topoff	No vapor trail aft of X-24A	
11.	H_2O_2 PRESSURIZATION sw-- PRESSURIZE		
12.	H_2O_2 PRESSURE ind-- 450 ± 25 psi		
13.	FUEL & LOX PRESSURIZATION sw--PRESSURIZE		
14.	FUEL & LOX PRESSURE ind-- 45 ± 5 psi		
15.	PRPLNT SUPPLY sw--OPEN		
16.	PRPLN IGN SYS cb--in		
17.	ENGINE MASTER sw--ON		
18.	NASA 1 verify open LOX val	Vapor trail aft of X-24A	
19.	NASA 1 verify open FUEL pr val--	Vapor trail aft of X-24A	
20.	PITCH, ROLL & YAW MODE select sw--AUTO		
21.		B-52 Mach No.______	
22.	Indicator Readings: MACH REPEATER ______( ) MACH NO.______( ) Upper left RUDDER POSITION DEG______( ) Lower left RUDDER POSITION DEG______( ) Upper right RUDDER POSITION DEG______( ) Lower right RUDDER POSITION DEG______( ) UPper left FLAP POS_____( ) LWR left FLAP POS______( ) UPper right FLAP POS______( ) LWR right FLAP POS_____( )		

LAUNCH READY. 5 MINUTES TO LAUNCH			
NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
23.	Full roll right checks: Indicator Readings: Upper left RUDDER POSITION DEG_______( ) Upper right RUDDER POSITION DEG_______( ) Upper left FLAP POS _______( ) LWR left FLAP POS _______( ) Upper right FLAP POS _______( ) LWR right FLAP POS _______( )		
24.	Full roll left checks: Indicator Readings: Upper left RUDDER POSITION DEG_______( ) Upper right RUDDER POSITION DEG_______( ) Upper left FLAP POS _______( ) LWR left FLAP POS _______( ) Upper right FLAP POS _______( ) LWR right FLAP POS _______( )		
25.	UFB auto mode disengage sw--depress & hold FLAP BIAS INCR DECR sw--momt to DECR until upper flaps have lowered 5 deg. FLAP BIAS INCR DECR sw--momt to INCR until upper flaps have returned to original position UFB auto mode disengage sw--release		
26.	RUDDER BIAS AUTO MAN sw-MAN RUDDER BIAS TOE OUT TOE IN sw--momt to TOE OUT until all rudders have returned to original position RUDDER BIAS AUTO MAN sw--AUTO		

LAUNCH READY. 5MINUTES TO LAUNCH			
NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
27.	K_{RA} AUTO MAN sw--MAN K_{RA} INCR DECR sw--momt to DECR until K_{RA} ACTUATOR PERCENT Reads 5% K_{RA} INCR DECR sw--momt to INCR until K_{RA} ACTUATOR PERCENT indicator returns to original position KRA AUTO MAN sw-- AUTO		
28.	Pitch full forward stick checks; Indicator Readings Upper left FLAP POS ________( ) LWR left FLAP POS ________( ) Upper right FLAP POS ________( ) LWR right FLAP POS ________( )		
29.	Pitch full back stick checks; Indicator Readings Upper left FLAP POS ________( ) LWR left FLAP POS ________( ) Upper right FLAP POS ________( ) LWR right FLAP POS ________( )		
30.	Full yaw right rudder pedal checks; Indicator Readings Upper left RUDDER POSITION DEG________( ) Upper right RUDDER POSITION DEG________( )		
31.	Full yaw left rudder pedal checks; Indicator Readings Upper left RUDDER POSITION DEG________( ) Upper right RUDDER POSITION DEG________( )		

2-9. X-24A LAUNCH CHECKS:

NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER.
1.	RELEASE PRESSURE LOW lt--out		
2.	LAUNCH sw--on (guard raised)	Launch	Launch
3.	THRUST CHAMBER CONTROLS sw: NO. 1 & 3 simultaneously--ON NO. 1 & 3 lts--on NO. 1 & 3 CHAMBER indicators-- ________ NO. 2 & 4 simultaneously--ON NO. 2 & 4 lts--ON NO. 2 & 4 CHAMBER indicators-- ________		

2-10. X-24A BURNOUT CHECKS:

NO.	X-24A PILOT STATION	B-52 PILOT STA	LAUNCH OPER
1.	LOX PRESSURIZATION sw--VENT CLOSED		
2.	FUEL PRESSURIZATION sw--VENT CLOSED		
3.	LOX JETT sw--LOX JETT		
4.	FUEL JETT sw--FUEL JETT		

2-11. X-24A DESCEND CHECKS:

NO.	X-24A PILOT STATION	CHASE PILOT	
1.	LOX FUEL JETT--close at 15000 ft altitude		
2.	L/D THROTTLE--OPEN momt	Check streamout aft of X-24	
3.	H_e TANK NO. 1 gage--if below 1000 psi sw to NO. 2		
4.	Use L/D Rockets as required during landing approach		

2-12. X-24A POST LANDING CHECKS:

NO.	X-24A PILOT STATION		
1.	ENGINE MASTER sw--OFF		
2.	THRUST CHAMBER CONTROLS sw--OFF		
3.	H_2O_2 PRESSURIZATION sw--VENT OPEN		
4.	PRPLNT SUPPLY sw--CLOSE		
5.	L/D ARM sw--OFF		
6.	PRPLN MASTER sw--OFF		
7.	CANOPY DEFOG sw--OFF		
8.	OXYGEN SELECT val--OFF		
9.	CABIN AIR SOURCE sw--OFF		
10.	CANOPY sw-OPEN		
11.	HYDRAULIC SYSTEM PUMP SELECT sws--off		
12.	Left fuse and cb panel--all cb out		
13.	Left aft vertical panel--all cb OFF/out		

2-13. INSPECTORS CHECKLIST
X-24A PILOT ENTRY
Verify with Pilot

A. Left console panel:

1. Circuit breakers	in
XCVR NO. 1	
XCVR NO. 2	
DYNAMICS EXPMT	if expmt is scheduled
PRPLNT FD & PRESS SYS PWR	
All other circuit breakers	OFF/out
2. Switches:	
PRPLN MASTER	ON
H_E MASTER	NO. 1
LOX PRESSURIZATION	VENT OPEN
FUEL PRESSURIZATION	VENT CLOSE
H_2O_2 PRESSURIZATION	VENT OPEN
3. All other switches	OFF/normal
4. Gages:	
H_E TANK NO. 1 TANK NO. 2	4000 ± 100 psi
All other gages	0
5. All lights	off
6. L/D THROTTLE	OFF/back

B. Left fuse and circuit breaker panel:

1. Circuit breakers	in
INSTR DC PWR	
INST INV	
Circuit breakers others	all OFF/out
2. Switches	OFF

C. Left aft vertical panel:

1. All circuit breakers	OFF/out
2. All lights	off

D. Left forward vertical panel:

1. Circuit breakers:	
VALVE HTR	in
JETT SYS	in
2. Switches:	off (guard closed)
3. Alllights	off

E. Glare Shield:

1. All switches	OFF/normal
2. All lights	off
3. All gages	0

F. Pedestal Sub-panel:

1. Switches	
PUMP THRM PROT	IN PRE-FLT
All other switches	OFF or down
2. Lights:	
All lights	off
3. Indicators/gages:	
GEAR PRESS	4200 ± 100 psi
CABIN PRESSURE ALTITUDE	0

G. Instrument panel:

1. Switches	
All switches	off/normal
2. Lights:	
All lights	off
3. Indicators/gages:	
ALTmeter	2000 ft
All other indicators/gages	0
4. Controls:	
LANDING GEAR	in
CANOPY JETTISON	in

H. Right Console:

1. Circuit breakers:	in
EXT PWR RELAY	
WARN LT SY MA	
B-52 PWR RELAY	
All/1 other circuit breakers	out
2. Switches:	
DC POWER SELECT	B-52
RADIO NO. 1 RADIO NO. 2	RADIO NO. 1
UHF XCVR No. 1 ON OFF	ON
UHF XCVR CHANNEL SELECTOR	_____
RADIO INTERPHONE	INTERPHONE
All other switches	OFF/NORMAL
3. Lights:	
HYDRAULIC SYSTEM LOW PRESSURE WARN SYS NO.2	ON
All other lights	off
4. Indicators/gages:	
HYDRAULIC SYSTEM SYS NO. 1	
OXYGEN CYLINDER PRESSURE upper	80 $\pm$ 10 psi
OXYGEN CYLINDER PRESSURE lower	1800 + 50, -0 psi
CAB AIR SOURCE	3000 $\pm$ 100 psi
All indicators/gages	0

I. Right fuse panel:

1. Fuses only
2. Return to Para. 2-8 Step 3.

EMERGENCY PROCEDURES

SECTION III

NOTE

Certain actions must be performed immediately and instinctively if the emergency is not to be aggravated and injury or damage is to be avoided. These items are listed in bold-face capital letters.

The canopy should be retained (not jettisoned) during landing emergencies aborted takeoff. Under such emergency conditions, probability of survival is enhanced with canopy retention. The canopy is protection against being saturated with flaming fuel and is temporary protection against the direct effects of fire. Following an emergency in which the canopy is retained, normal opening should first be attempted with jettisoning used as an alternate method. The application of these considerations does not preclude the pilot from exercising sound judgment in jettisoning the canopy when he deems it necessary.

UNSUCCESSFUL START: (FAILURE TO IGNITE)

1. If chamber fails to ignite as indicated by no chamber pressure and/or no indicator light.

a. Place all THRUST CHAMBER CONTROLS switches OFF for 5 seconds

b. Reperform start sequence

c. If some chambers fire, but others do not, pilot must elect to fly alternate (low thrust) mission or jettison propellants and glide to an alternate landing site.

UNSUCCESSFUL START (DUE TO OVERSPEED)

1.	TURBOPUMP OVERSPEED light on glare shield	ON
2.	Place THRUST CHAMBER CONTROLS switches	OFF
3.	Place TURBOPUMP OVSP switch	Momentarily to RESET until light goes out
4.	Reperform start sequence again	

FIRE WARNING LIGHTS ON:

1. Signal automatically discharges H_e into the engine compartment. Pilot monitor H_e TANK NO. 2 gage. If pressure does not drop to zero, place FIRE EXTNG switch ON.
2. Pilot prepare to eject if subsequent events or chase pilot indicates fire not controlled.

H_2O_2 HOT LIGHT ON:

1. Pilot place JETTISON H_2O_2 switch to JETTISON position.
2. If propellants were not previously expended, place LOX JETT and FUEL JETT valve switches in LOX JETT and FUEL JETT position.

EJECTION CONSIDERATIONS

NOTE

Every emergency in which ejection is considered will have its particular set of circumstances involving such factors as airplane speed, attitude and control, altitude, and sink rates. The information presented below indicates capabilities under various combinations of these circumstances and some desirable techniques and procedures to improve the probability of a successful ejection. It must be emphasized, however, that the decision to eject must be based on the particular circumstances at hand and not just on the specification (0-0 to 450 KCAS (KIAS) limits of the system.

The zero-zero egress system is designed for ejection in a zero altitude-zero speed condition to 450 KCAS (KIAS) with certain limitations under various combinations of critical attitudes and sink rates. Pitch attitude has the most influence on the recovery capability. Ejection while the nose of the airplane is above the horizon results in a more nearly vertical trajectory of the seat, thus providing more altitude and time for seat separation and parachute deployment. With an airspeed of 180 KCAS (KIA) and wings level, the escape system will provide safe ejection under an additional 1500 feet/minute sink rate if the nose is rotated from -10° pitch to $+10^{\circ}$ pitch. Therefore, when at all possible, maintain sufficient airspeed to employ the "zoom-up" maneuver and eject with the nose above the horizon (limit $+50^{\circ}$ pitch). Any bank angle conditions other than zero or a level airplane will degrade the ejection system capability. Computer studies indicate that with a nose high airplane, the level ejection capability is degraded by 20% with a 20° bank angle and 60% with a 40° bank angle.

The zero-zero egress system provides safe escape capability under most conditions on the ground with the canopy closed, i.e., static, taxi, and ground roll prior to takeoff after landing.

WARNING

The canopy must be closed to ensure safe removal during the automatic ejection sequence.
Before a ground level ejection is attempted, consideration should be given to the possibility of manually disconnecting the parachute, personnel equipment, and lap belt and "going over the side."

The zero-zero egress system provides safe escape capability under all conditions at and immediately after takeoff within an envelope defined by a nose high airplane and upt to 40° of bank. At 150 feet altitude with a nose high airplane, safe ejection can be accomplished at up to 65° of bank. At 500 feet altitude, safe ejection can be accomplished at up to 85° of bank.

The ejection seat should be used to abandon the airplane in flight. The airplane should be slowed down as much as possible if at high airspeeds, as forces on the body and injury hazard are decreased when airspeed is reduced. In addition, the ballistically deployed parachute lends itself to better performance at lower airspeeds. The maximum speed for an inflight ejection of the zero-zero egress is 450 KCAS (KIAS). Slow the airplane to below 450 KCAS (KIAS) prior to ejection if possible. The "zooming" maneuver is encouraged at all points in the flight envelope. The zoom will exchange airspeed for altitude which will result in the desired condition of a nose high/lowest speed possible ejection. Inflight capabilities are as follows:

Conditions	Minimum Safe Ejection Altitude
Sink Rate: 0 to 10,000 feet per Minute Pitch Attitude: 0 to -12° Bank: 0 to 85° Airspeed: 0 to 450 KCAS (KIAS)	2000 feet above terrain

a. The minimum safe ejection altitude for an airplane with a relatively slow forward velocity of 180 KCAS (KIAS), -10^{o} nose down, wings level, and with a 5000 ft/min sink rate is 200 feet (terrain clearance).

b. With at least a $+10^{o}$ pitch attitude, 180 KCAS (KIAS) velocity and a wings level airplane, ejection can be accomplished at any altitude with a sink rate of 3500 ft/min or less.

WARNING

When the X-24A is in a descending attitude and cannot be leveled, ejection should not be delayed as this will reduce the possibility of success.
Do not delay ejection below 2000 feet above terrain in futile attempts to start the engine or for other reasons that may commit you to an unsafe ejection or a marginal landing.
Under spin or dive conditions or any uncontrollable maneuver, eject at least 15,000 ft above the terrain whenever possible.

The zero-zero egress system provides safe ejection capability at all points in a normal landing pattern. It is essential that proper airspeed be maintained to provide the capability to "zoom" the X-24A prior to an ejection in the landing pattern.

WARNING

Do not delay decision to eject if X-24A becomes uncontrollable at any point in the landing pattern.

The zero-zero egress system has been extensively tested and has been demonstrated to be a reliable system. The automatic system featuring the automatic opening safety belt, seat-man separator, and ballistically deployed parachute are sequenced in operation to provide the desired results more reliably than manual operation. Therefore, to assure survival from both low and high altitude ejections, the automatic features of the equipment must be used and depended upon.

BEFORE EJECTION (If Time and Conditions Permit)

1. Throttle-OFF; reduce speed.
2. Aim X-24A toward uninhabited area.
3. SIT ERECT, PLACE ELBOWS TIGHTLY AGAINST BODY WHILE GRASPING THE EJECTION SEAT HANDGRIPS. POSITION HEAD BACK FIRMLY AGAINST HEAD-REST WITH CHIN TUCKED IN.

EJECTION

1. RAISE EITHER EJECTION SEAT HANDGRIP TO THE FULL UP AND LOCKED POSITION.

NOTE

The zero-zero egress system is a reliable, completely automatic system from the time the time the pilot pulls the ejection handgrips until there is a full canopy. A failure in the automatic system after ejection can be identified by the following:

EMERGENCY GROUND EGRESS

The following procedure prescribes the fastest method of egress from a disabled X-24A on the ground. It also provides additional pilot protection from fire. After the airplane is stopped, proceed as follows:

1. DITCHING CONTROL HANDLE - PULL.

WARNING

Failure to actuate the ditching control handle may result in firing of the parachute deployment gun and resultant entanglement of the parachute with the airplane.

2. SAFETY BELT AND SHOULDER HARNESS - RELEASE.
3. SURVIVAL KIT EMERGENCY RELEASE HANDLE - PULL.

WARNING

Extreme caution must be exercised in the use of the emergency release handle because of its similarity and close proximity to the right ejection handgrip.

4. CANOPY-JETTISON
5. Depart Airplane

WARNING

If the nose gear is extended, there is approximately an eight foot drop to the ground. Exercise caution to prevent an incapacitating injury.

EMERGENCY ENTRANCE

COCKPIT ENTRANCE

BEFORE ATTEMPTING TO ENTER COCKPIT CHECK POSITION OF EJECTION SEAT HANDGRIPS FOR DOWN AND STOWED POSITION

WARNING

If the handgrips are raised, do not pull the canopy external jettison handle or the pilot and seat will be ejected.

IF EJECTION SEAT HANDGRIPS ARE DOWN.

1. Remove canopy external jettison handle access door.
2. Grasp canopy external jettison handle and pull outboard approximately 6 feet to fire canopy

NOTE

The canopy should travel up and aft sufficiently to clear the cockpit. However, it will probably strike the airplane midsection.

WARNING

Sparks from the canopy jettison charge may ignite fuel spilled in or near the airplane.

3. If canopy fails to jettison by ballistic charge, or if presence of fuel fumes makes jettison inadvisable, use procedures as given below.

IF EJECTION SEAT HANDGRIPS ARE RAISED.

1. Open external canopy control access door located just below the left windshield.
2. Grasp canopy external latch handle and pull outboard approximately 6 inches to release canopy latches.
3. Raise the canopy electrically.
   Hold the spring-loaded toggle switch in the up position until the canopy is open as far as desired.

4. If electrical power is not available for openint the canopy, it can be opened manually by depressing the button on the right side of the X-24A just aft of the canted bulkhead. This button manually disengages the electric canopy actuator clutch and allows manual opening of the canopy.

EMERGENCY BATTERY

LOSS OF OUTPUT FROM EITHER SYSTEM NO. 1 OR 2.

1. Pilot complete flight staying well inside the vehicle performance boundaries.

FLIGHT CONTROL SYSTEM FAILURE

K_{RA} INDICATOR PEGGED AT EITHER END OR NOT FOLLOWING CHANGES IN MACH NO. OR ANGLE OF ATTACK. POSSIBLE DUTCH ROLL.

1. Pilot avoid any rapid or sizeable roll inputs until corrective action has been taken.
2. Pilot switch K_{RA} to manual. Beep INCREASE-DECREASE switch to bring K_{RA} actuator to correct position. If no dutch roll is present, change indicator reading to 20% below M-0.8; and to 30% above M-0.8.

LOWER RUDDER POSITIONS NOT CORRESPONDING TO MACH NUMBER SCALE ON INDICATOR.

1. Pilot switch rudder bias switch to MANUAL. Beep in TOE-IN or TOE-OUT as required to put rudders in correct position. Rudders should not have trailing edge out below M-1.4.

LONGITUDINAL STICK FORCES CANNOT BE TRIMMED TO ZERO:

1. Pilot utilize emergency PITCH TRIM ALT switch on left console to get desired trim.
2. If step one above is ineffective, trim motor has failed. Pilot will have to hold position in manually.

RAPID CHANGE IN LONGITUDINAL TRIM:

1. Pilot depress UFB switch on stick and hold until diagnosis is complete.
2. Pilot compare MACH NO. indicator and MACH REPEATER dial:

a. Difference in these readings indicates a failure of the mach sensor, servo follower, or MACH NO. indicator.

b. If no difference between the indicator and repeater, failure of UFB servo is indicated.

3. Confirm MACH NO. indicator reading from chase plane or ground.

4. If failure of MACH NO. indicator is indicated, leave MACH REPEATER switch in AUTO.

5. If failure of Mach system is indicated, all automatic functions will be out.

a. Switch MACH REPEATER TO MANual and dial-in Mach number corresponding to MACH NO. indication. Release grip switch. Manually follow MACH NO. indicator through remainder of flight.

b. If UFB servo failure is indicated, switch FLAP BIAS AUTO MAN switch to MANual, release grip switch, and beep FLAP BIAS AUTO MAN switch to MANual, release grip switch, and beep FLAP BIAS INCR DECR switch in direction to maintain relation between upper flap position and Mach number as indicated on flap position indicators.

SAS YELLOW STATUS LIGHT(S) ON:

1. Pilot push to reset.

2. If reset not successful, terminate flight as rapidly as possible when roll or yaw lights are on.

SAS RED STATUS LIGHT(S) ON:

1. Pilot push to reset.

2. If reset not successful, do not attempt to land X-24A under these conditions.

Upper Flaps jammed at 56° - abort - cannot land.

Rudders jammed at 10° toe out - will have unknown buffeting going through trans-sonic rgion. Try to land.

Upper Flaps jammed at 30° or less - no problem, continue flight.

Rudders jammed at 0 - no problem, continue flight with approximately 10° additional up elevator.

Mach Transducer fails - PMR AUTO/MAN to MAN read MACH INDICATOR and manually set PMR.

Upper Flap Bias Auto Mode fails - UFB AUTO/MAN to MAN beep upper flaps to 30° and leave.

Rudder Bias Auto Mode fails - RB AUTO/MAN to MAN beep lower rudders to zero and leave.

KRA Auto Mode fails - DRA AUTO/MAN to MAN beep KRA actuator to 0.2 and leave.

SAS Roll Pitch or Yaw Auto Mode fails - SAS MODE to MAN SAS GAIN to 3 restrict from 3 to 10°.

B-52 PILOTS
EMERGENCY CHECKLIST
UNPOWERED FLIGHT

1. MANDATORY ABORT CONDITIONS:

    a. Loss of all voice communications both to and from X-24A or B-52.

    b. Loss of B-52 electrical power to the X-24A.

    c. Loss of indicated airspeed and altitude.

    d. X-24A overheat or fire warning lights "ON".

    e. Loss of prime telemetry.

    f. Loss of radar track.

    g. Solid overcast or poor visibility at launch or launch area.

    h. Loss of all chase aircraft.

SECTION IV

AUXILIARY EQUIPMENT

NOT APPLICABLE

SECTION V

OPERATING LIMITATIONS

5-1. GENERAL

The function of this section is to cover all important limitations that must be observed during normal operation. Special emphasis is placed on any unusual restrictions which are particularly characteristic of the X-24A.

5-2. ENGINE LIMITATIONS

The engine limitations covering such points as ignition of each chamber, thrust by chamber for separate and combined operation are shown on Figure 5-49 for maximum/minimum thrust and power of the XLR11-RM-13 engine.

5-3. OPERATING WEIGHT

The operating weight is defined as the weight of the complete aircraft ready for flight. The operating weight (gross weight) is shown on the vertical axis of Figure 5-1 and the change in center of gravity is shown along the horizontal axis of the illustration. It must be noted that all weight limits based on performance are to be used as guides only since the performance data is based on standard day conditions.

5-4. OPERATING FLIGHT STRENGTH DIAGRAM

The Operating Flight Strength Diagram, Figure 5-2, shows the acceleration limits for the combinations of airspeeds and altitudes of which the X-24A is capable. All prohibited regions of operation are identified. The IAS and IMN charts must be used as reference data.

5-5. LAUNCH

The X-24A is carried aloft on the B-52 and launched within the envelope of M-0.6 to 0.8 and altitudes of from 41,000 ft. to 45,000 ft. Launch separation characteristics as functions of pertinent variables are presented in the following figures. Figures 5-3 and 5-4 present time histories of relative vehicle separation distance, vehicle

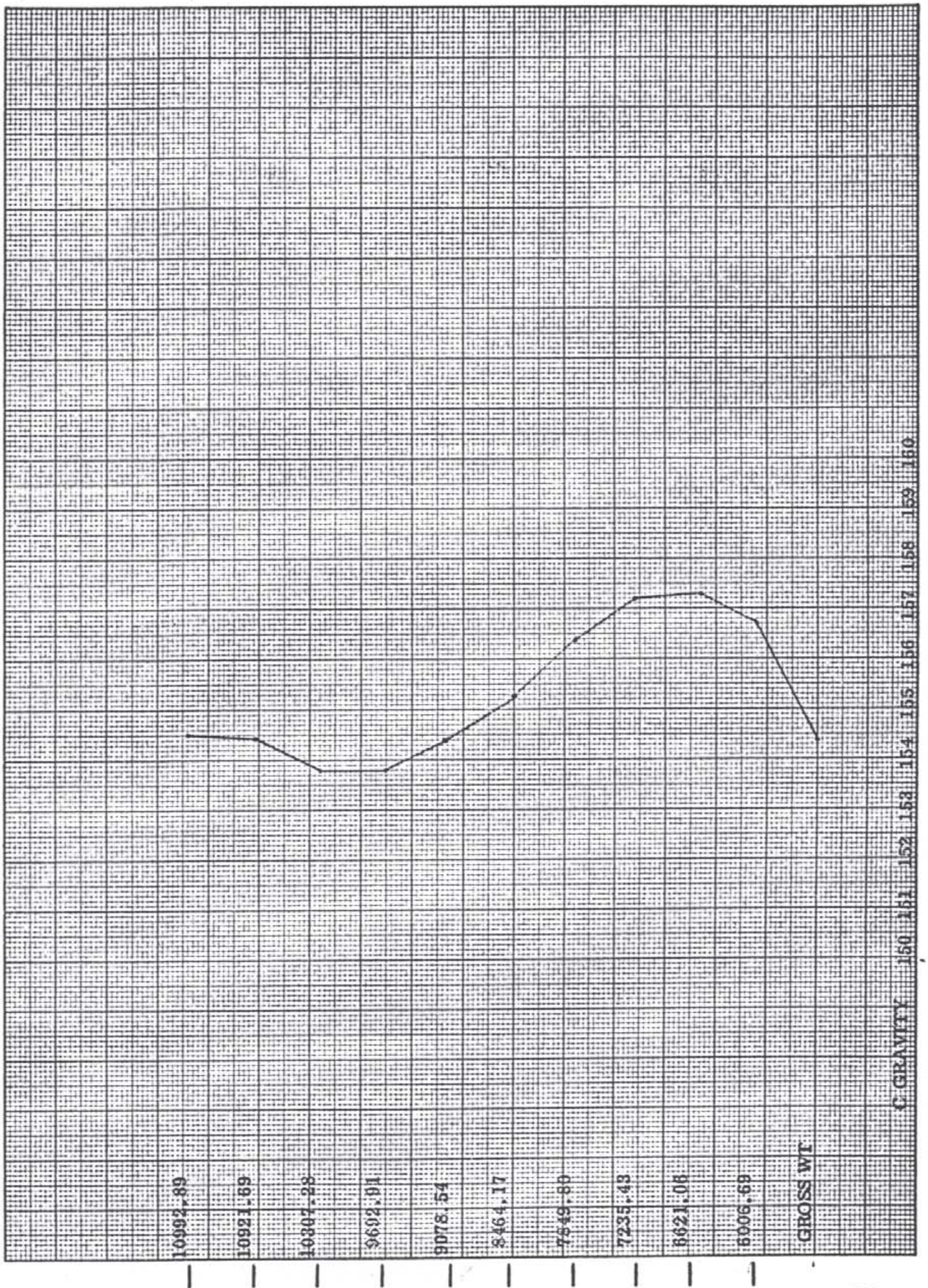


Figure 5-1. Operating Weight

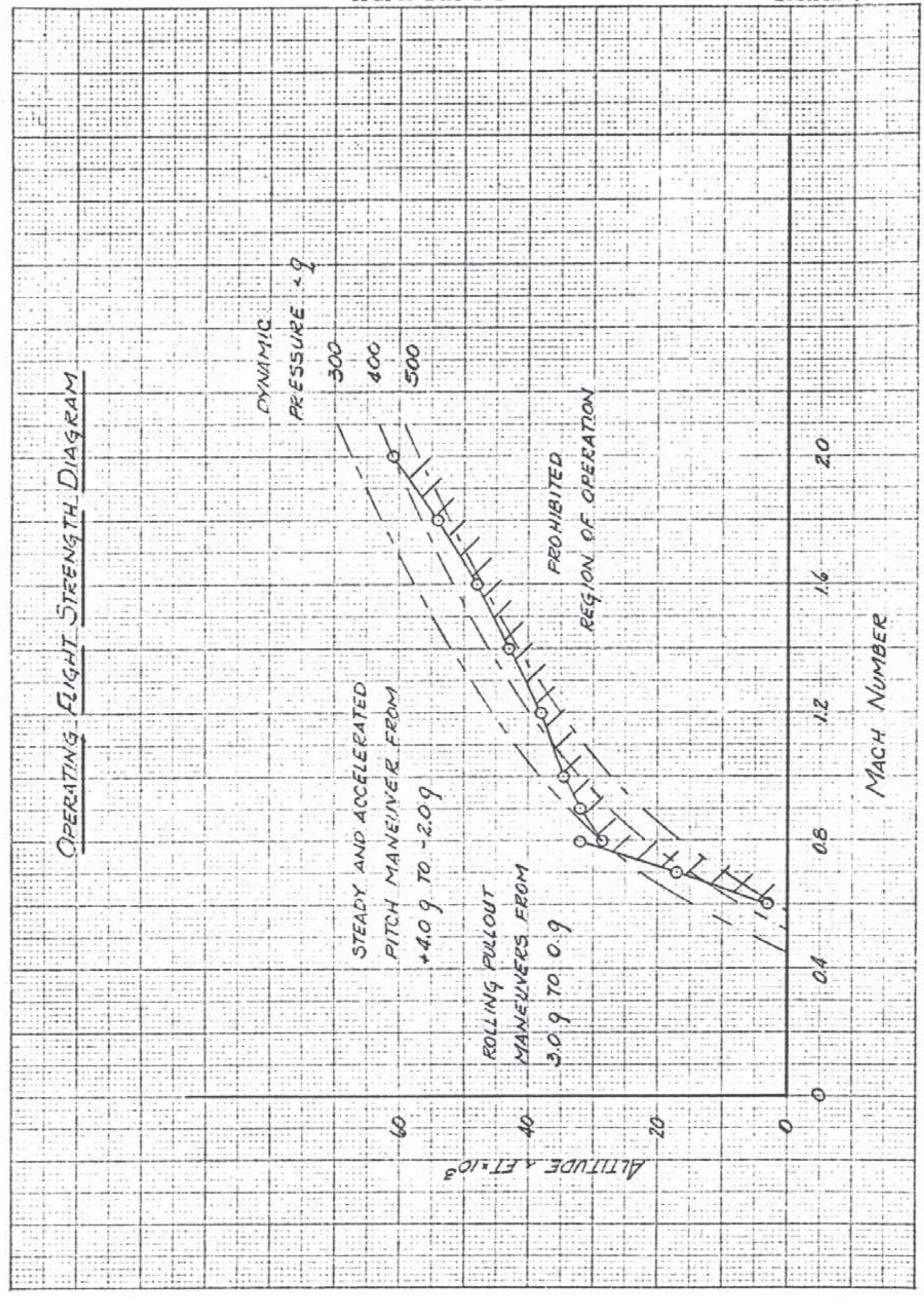


Figure 5-2. Operating Flight Strength Diagram.

attitudes, rates and accelerations showing the effects of damper loops operative and inoperative. Figure 5-5 graphically illustrates relative separation distances for the same conditions. In similar fashion, the effects of launch gross weight, carry angle relative to the B-52, X-24A preset controls, and X-24A variable control settings are shown in Figures 5-6 through 5-17.

5-6. UNPOWERED DROP

The unpowered glide descent trajectories were calculated for the following weights and center of gravity positions, utilizing a point mass three-degree-of-freedom digital program:

WEIGHT	C.G.	
5879 lbs.	57%	(Burnout weight and c.g.)
10729 lbs.	55.54%	(Boost Weight and c.g.)
10729 lbs.	57%	

The initial conditions for these descent trajectories were taken from the nominal separation from the B-52, namely Mach number = 0.8 and altitude of 45,000 feet. These initial conditions represent a 5 second delay after separation, which permits the damping of any perturbations due to the separation from the B-52.

A transition from the α at separation to that for the following conditions: for $(L/D)_{max.}$, $\alpha_{max.}$ and $\alpha_{min.}$ was incorporated into the trajectory in order to simulate the descent as closely as possible to that of the actual flight. This transition involved a 2°/sec. variation in α which is a reasonable requirement for pilot execution.

Figures 5-18, 5-19 and 5-20 demonstrate the performance characteristics of the α for $(L/D)_{max.}$ descent condition for the empty or light weight, 57% c.g. vehicle. Figure 5-18 evaluates dynamic pressure (q), altitude, velocity (fps) and Mach number as a function of time; Figure 5-19 shows the pitch angle (θ), angle-of-

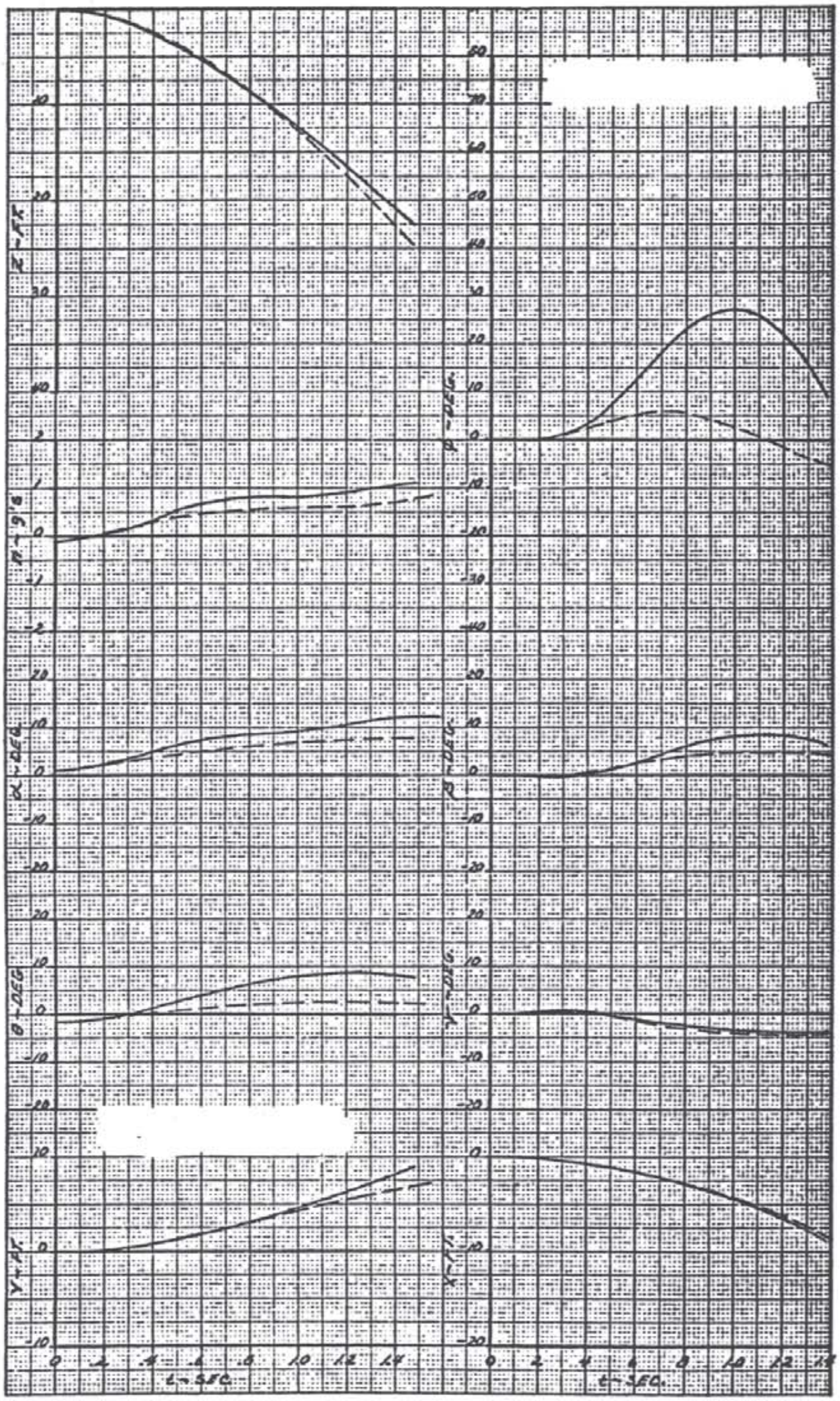


Figure 5-3. Effect of Dampers.

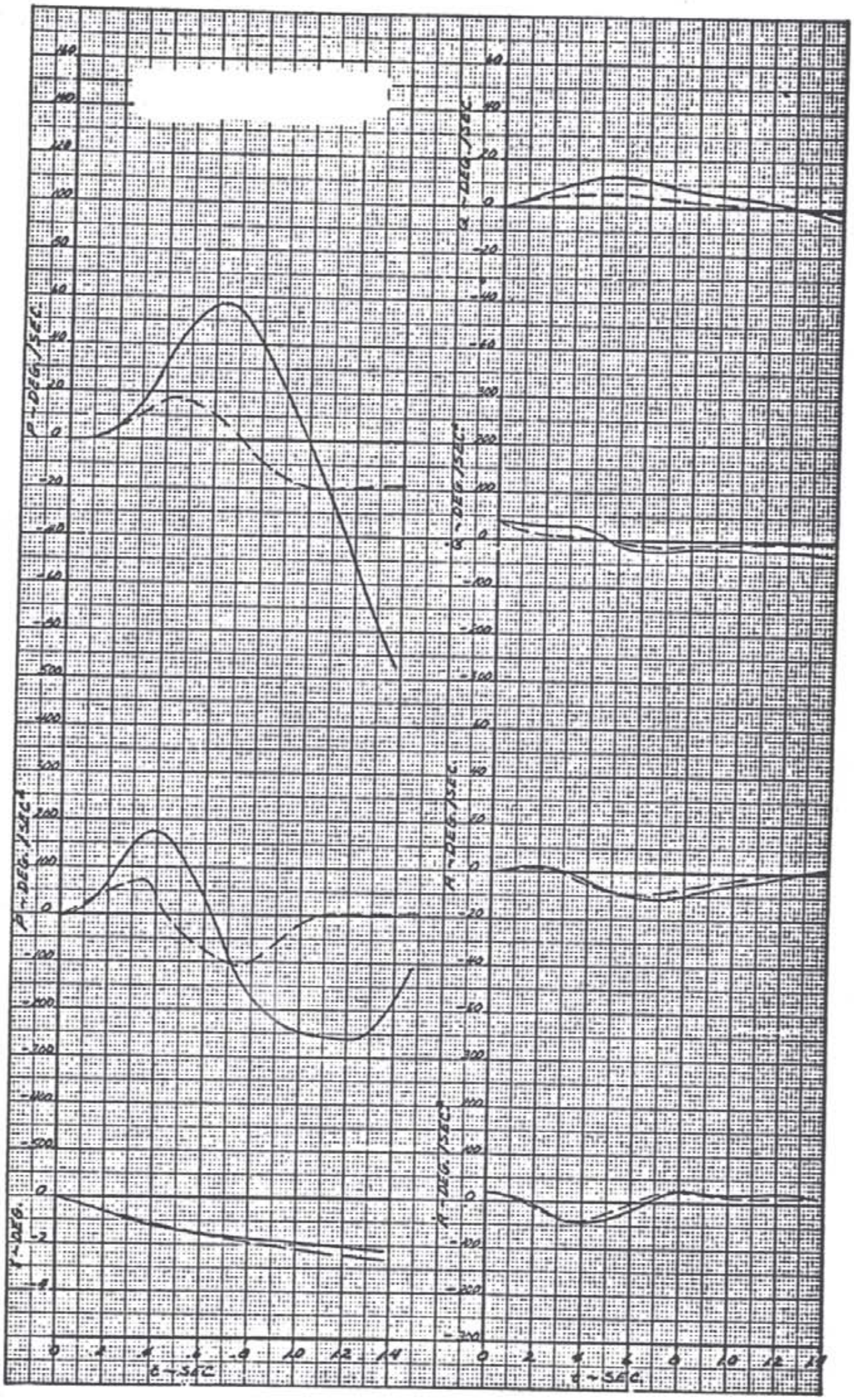


Figure 5-4. Effect of Dampers.

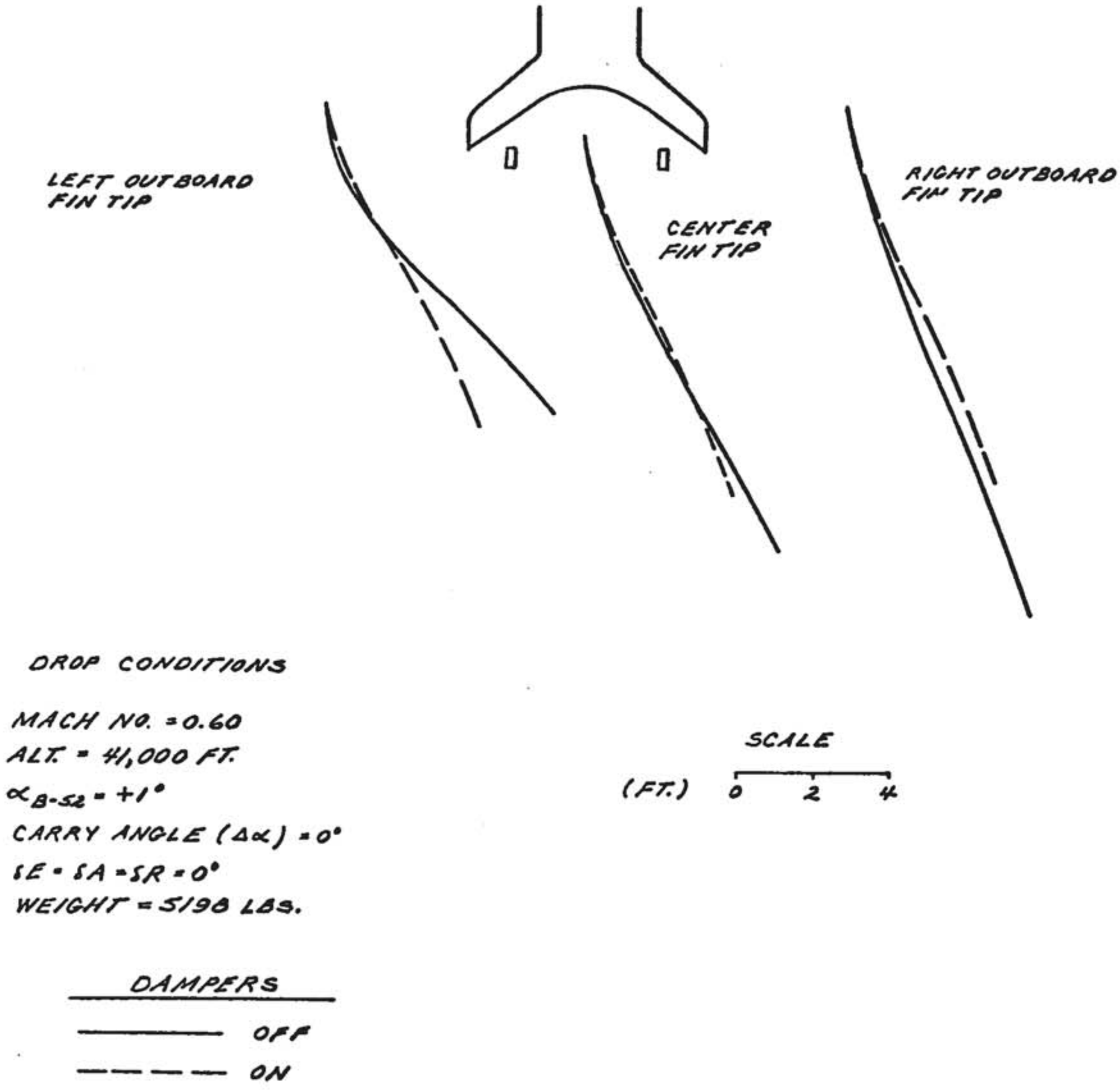


Figure 5-5. Effect of Dampers On Separation.

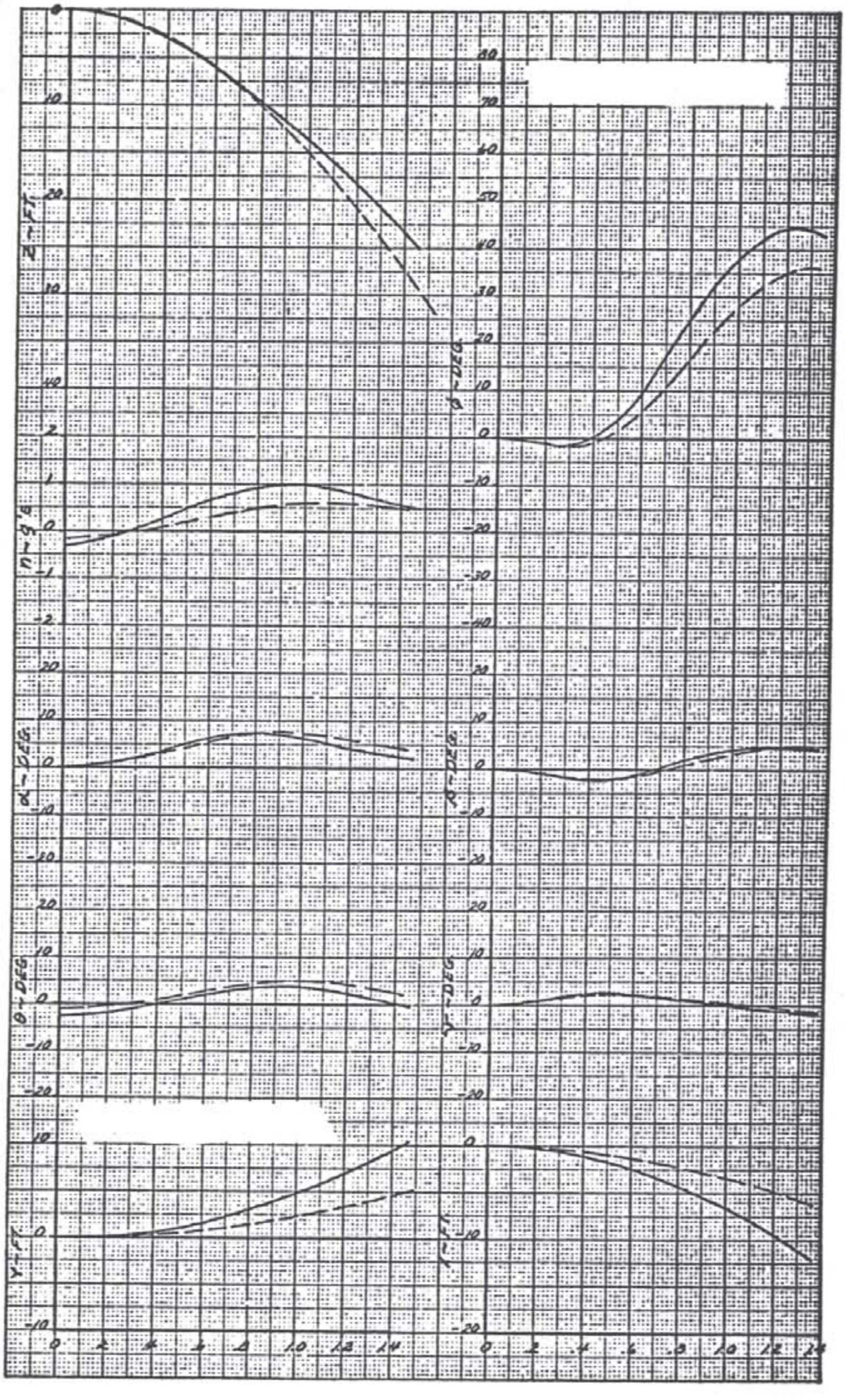


Figure 5-6. Effect Of X-24A Weight.

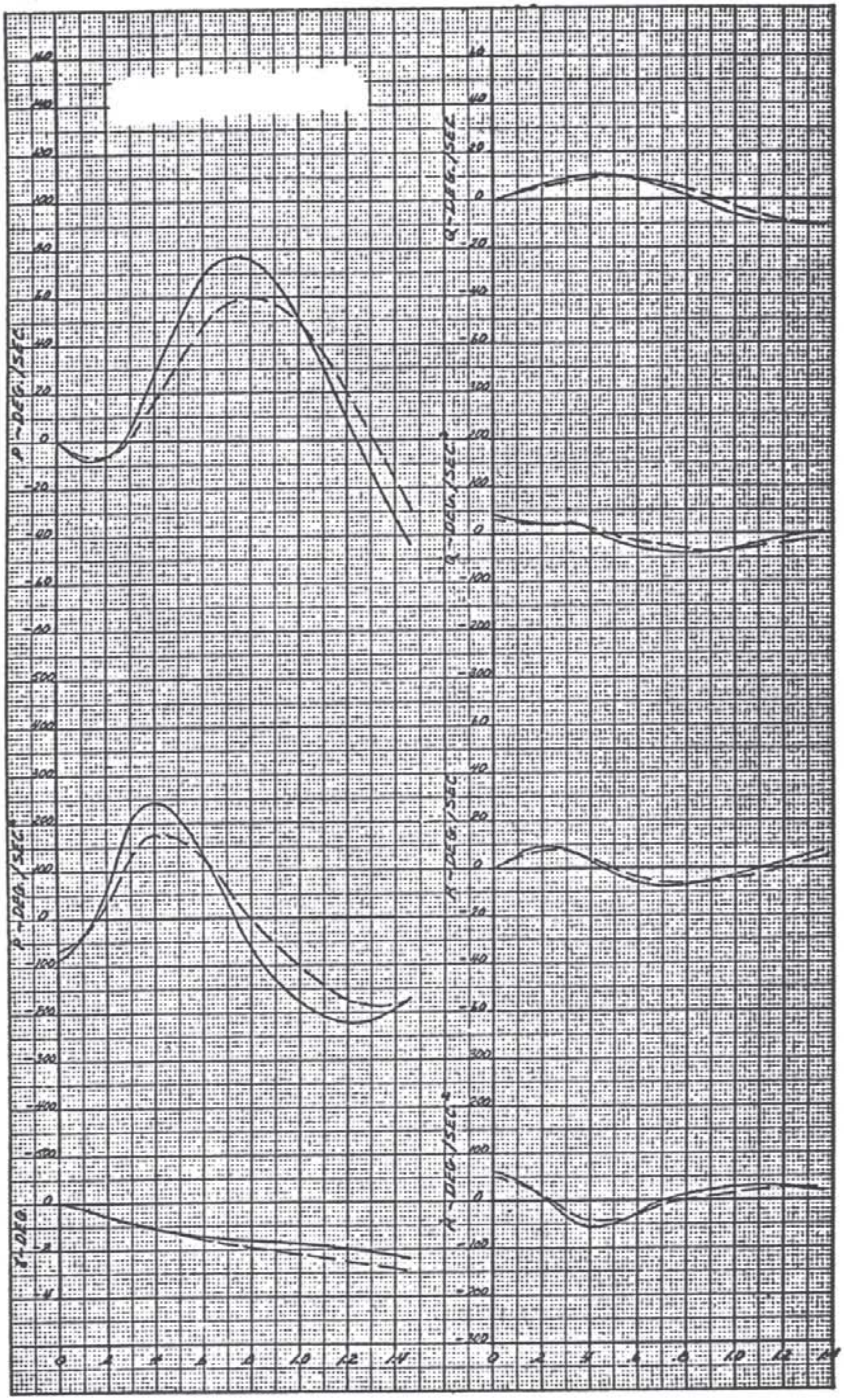
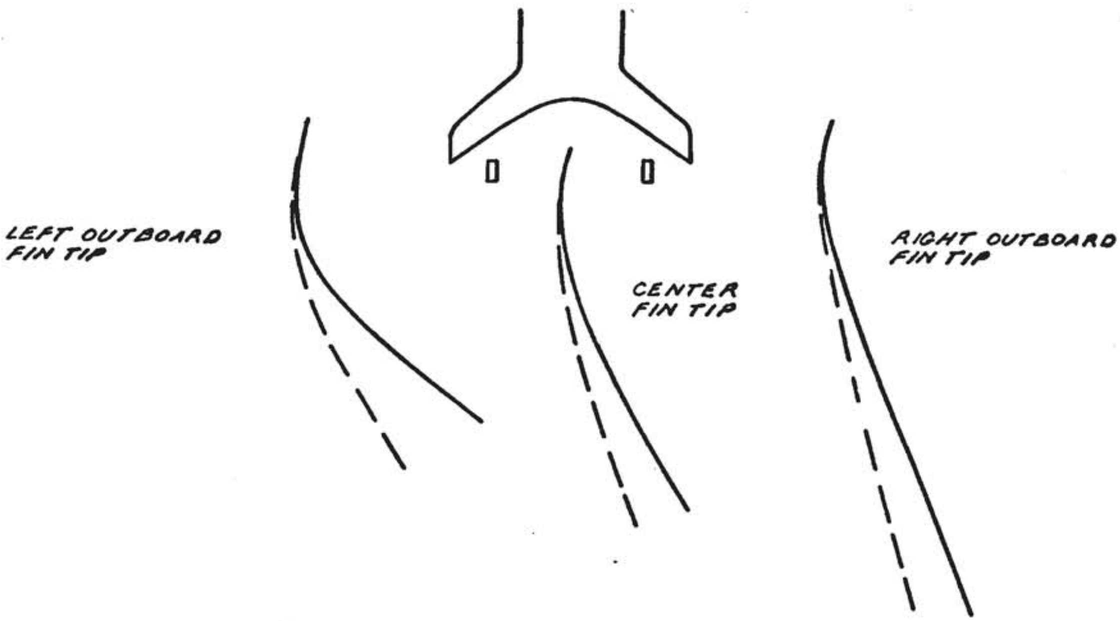


Figure 5-7. Effect Of X-24A Weight.

SECTION THROUGH X-15 PYLON AND SV-.-P PYLON ADAPTER IN VICINITY OF SV-5P FINS.
(VIEW LOOKING FORWARD)



DROP CONDITIONS

MACH NO. - 0.70
ALT. = 43,000 FT.
$\alpha_{B-52} = 0°$
SV-5P ATTACHMENT ANGLE = 0°
UPPER FLAPS = -30°
LOWER FLAPS = +20°
$\delta A = \delta R = 0°$
NO DAMPERS

SCALE
(FT.) 0 2 4

SV-5P WEIGHT

——— 5,198 LBS.
– – – 10,078 LBS.

Figure 5-8. X-24A Separation.

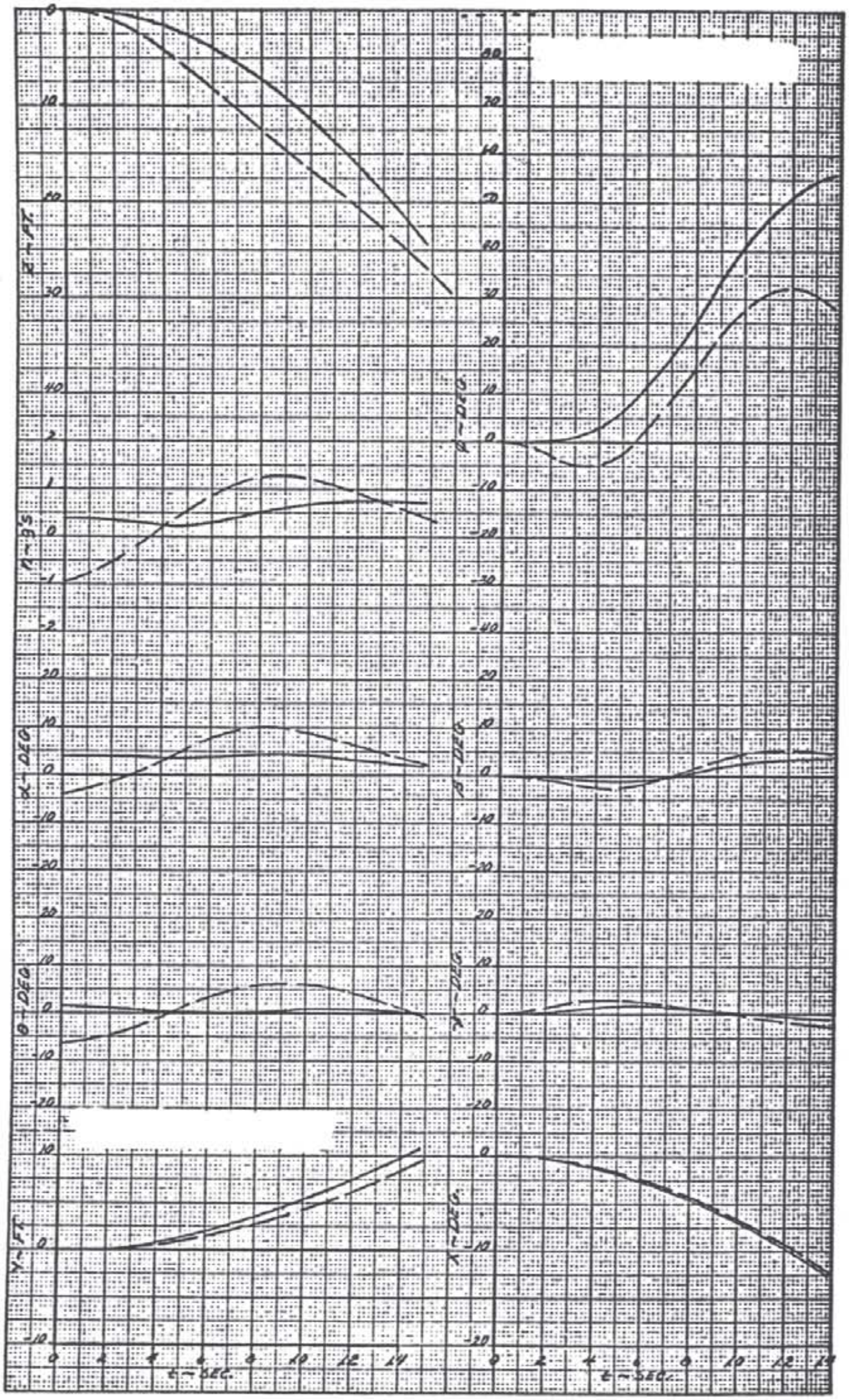


Figure 5-9. Effect Of Carry Angle.

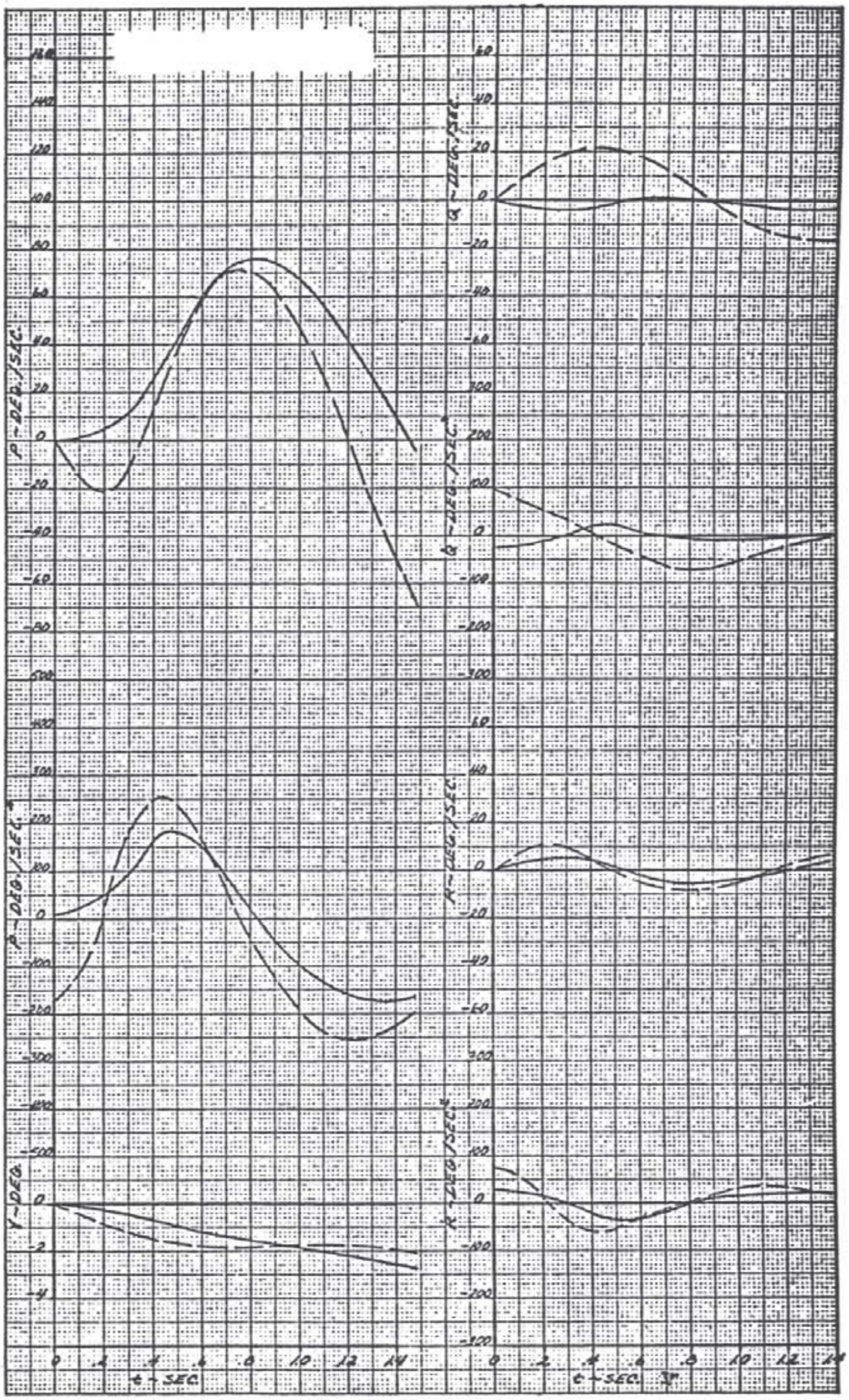


Figure 5-10. Effect Of Carry Angle.

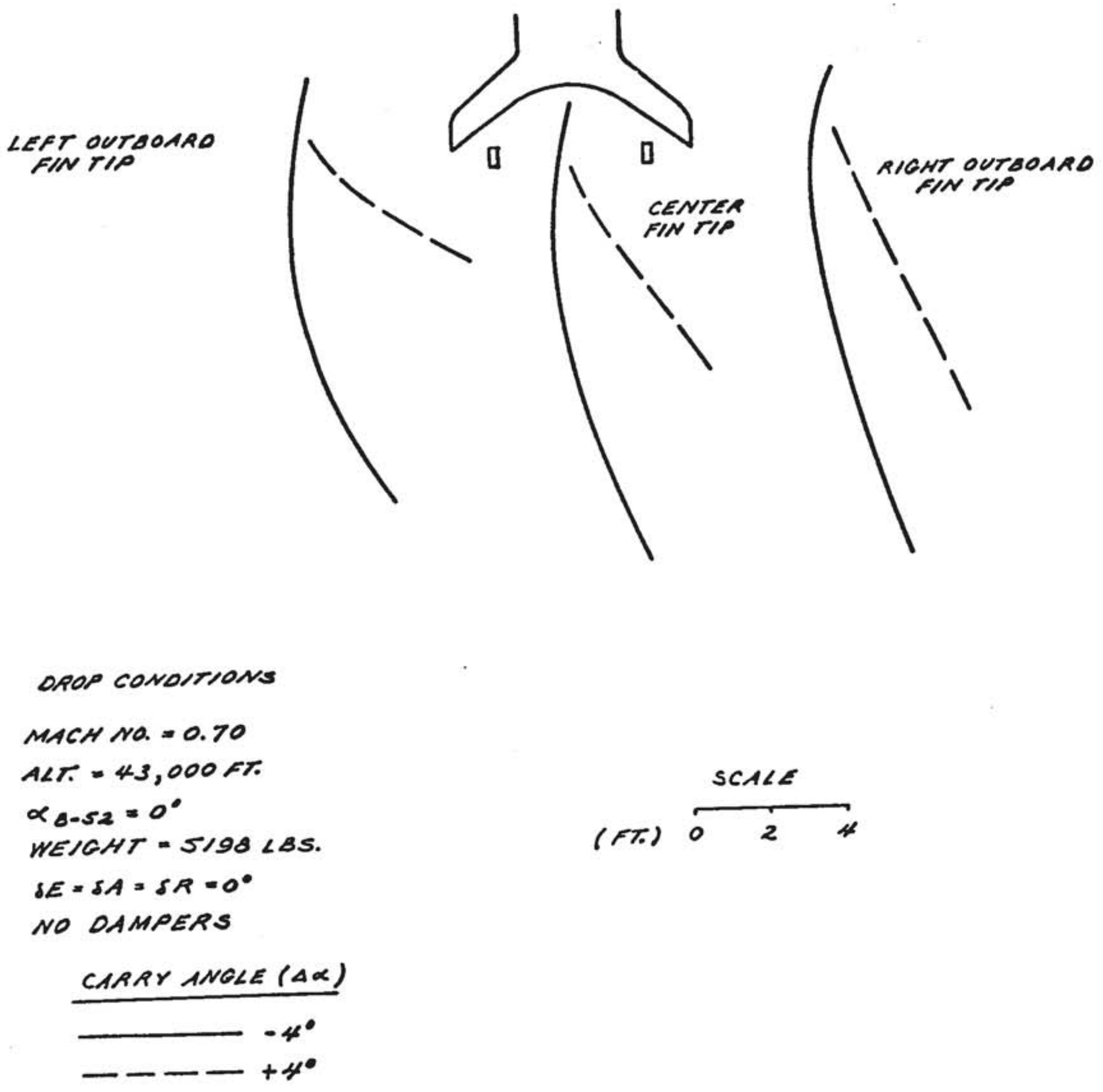


Figure 5-11. Effect of X-24A Carry Angle On Separation.

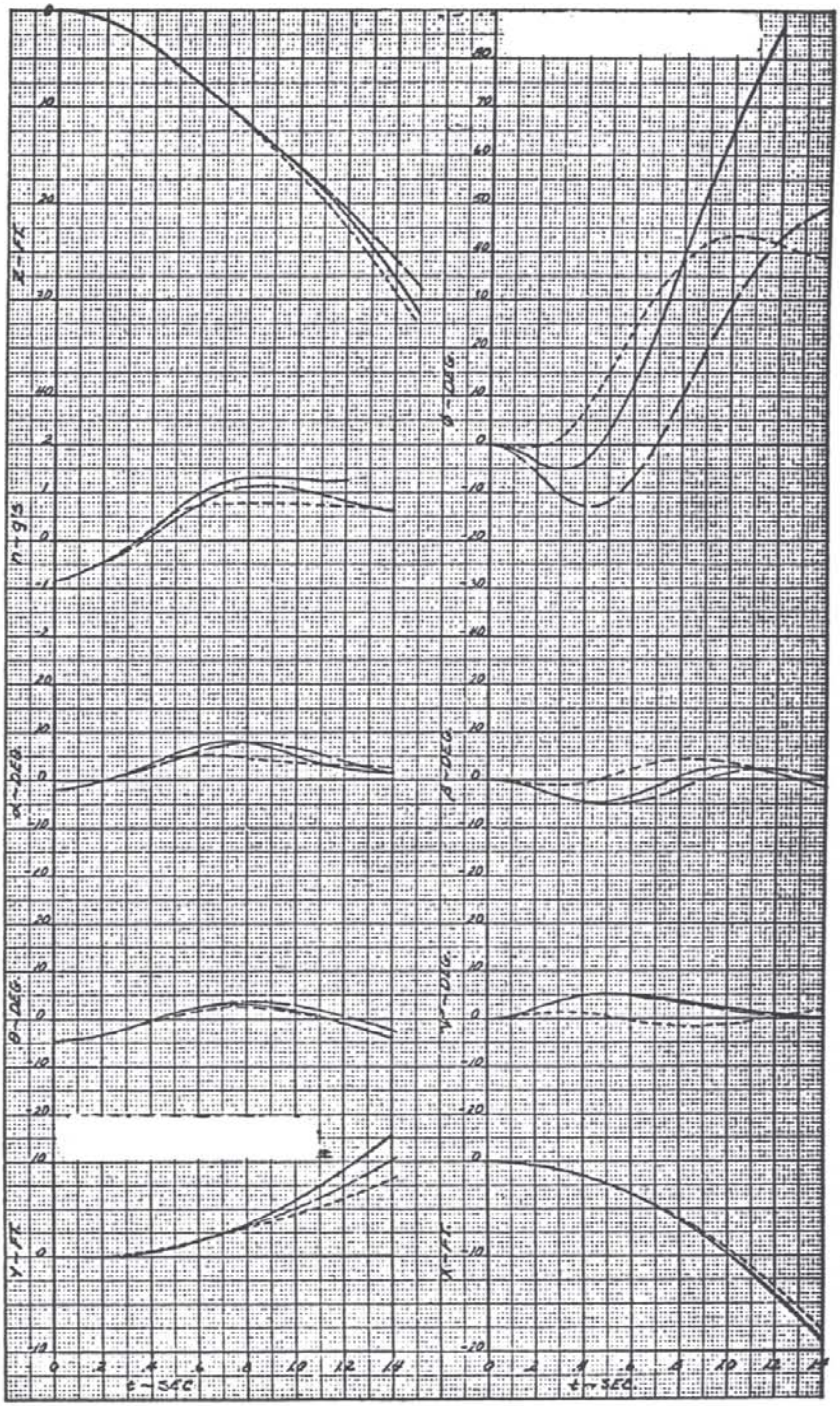


Figure 5-12. Effect Of Pre-Set Controls.

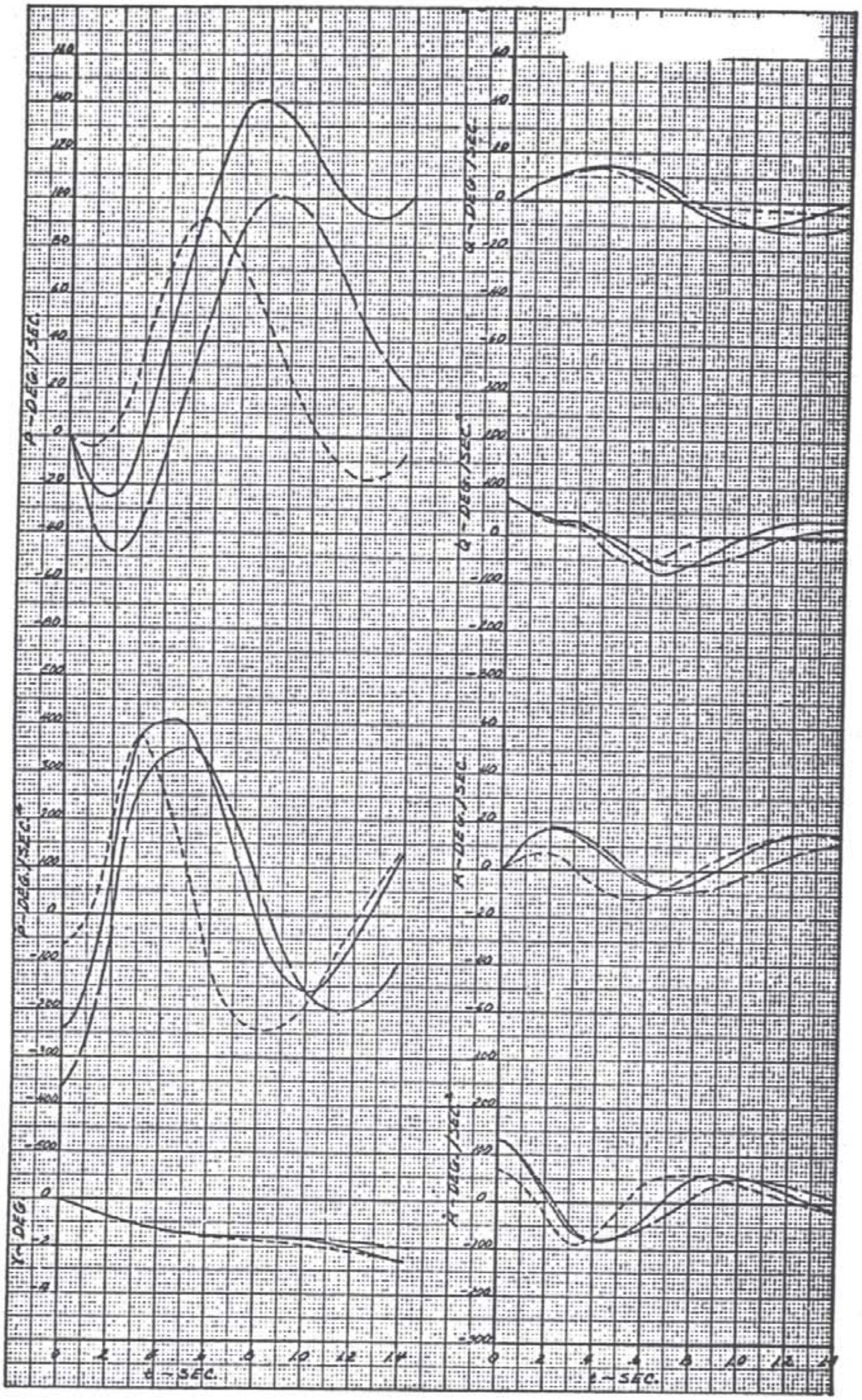


Figure 5-13. Effect Of Pre-Set Controls.

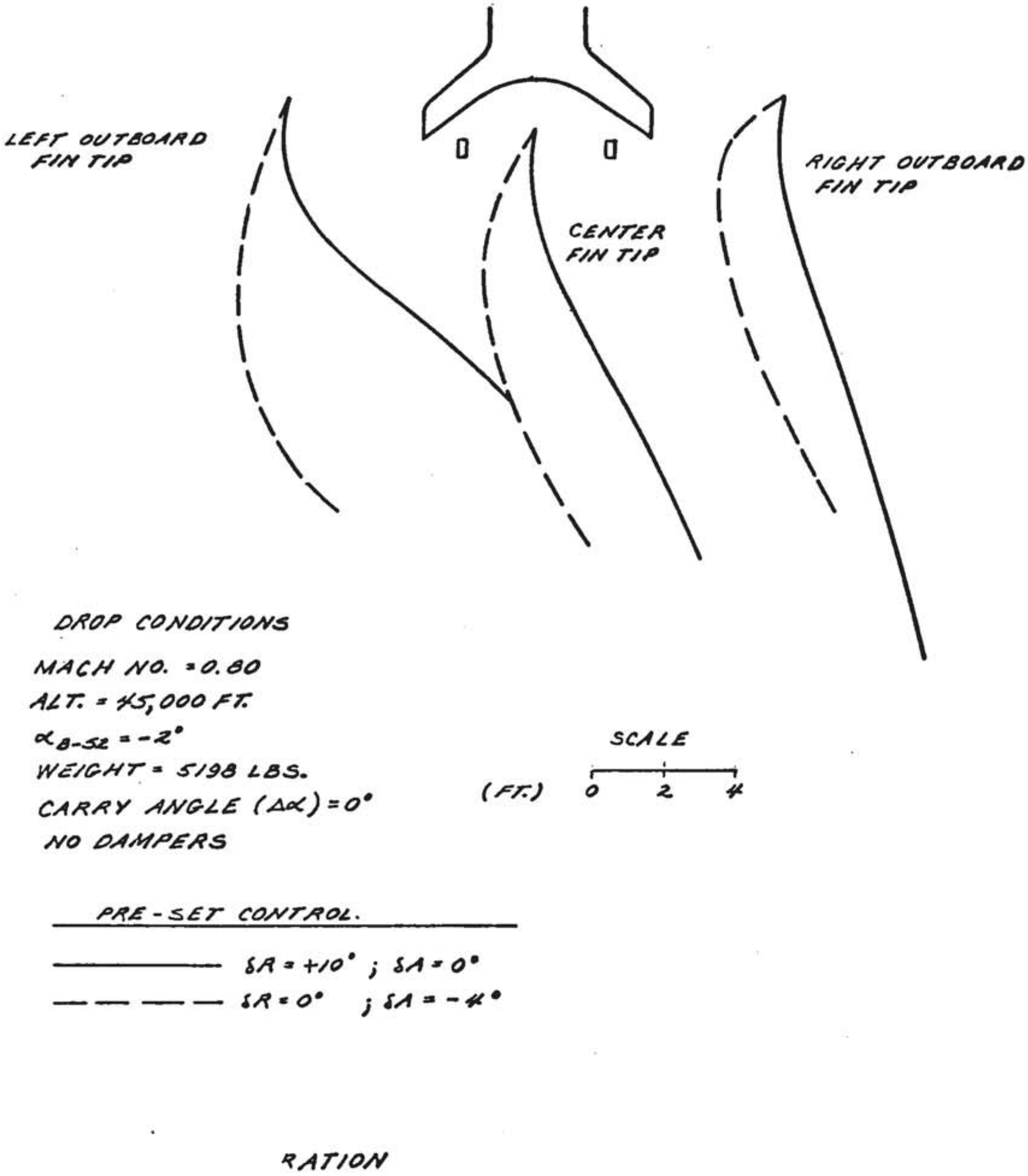


Figure 5-14. Effect Of Pre-Set Aileron and Pre-Set Rudder On Separation.

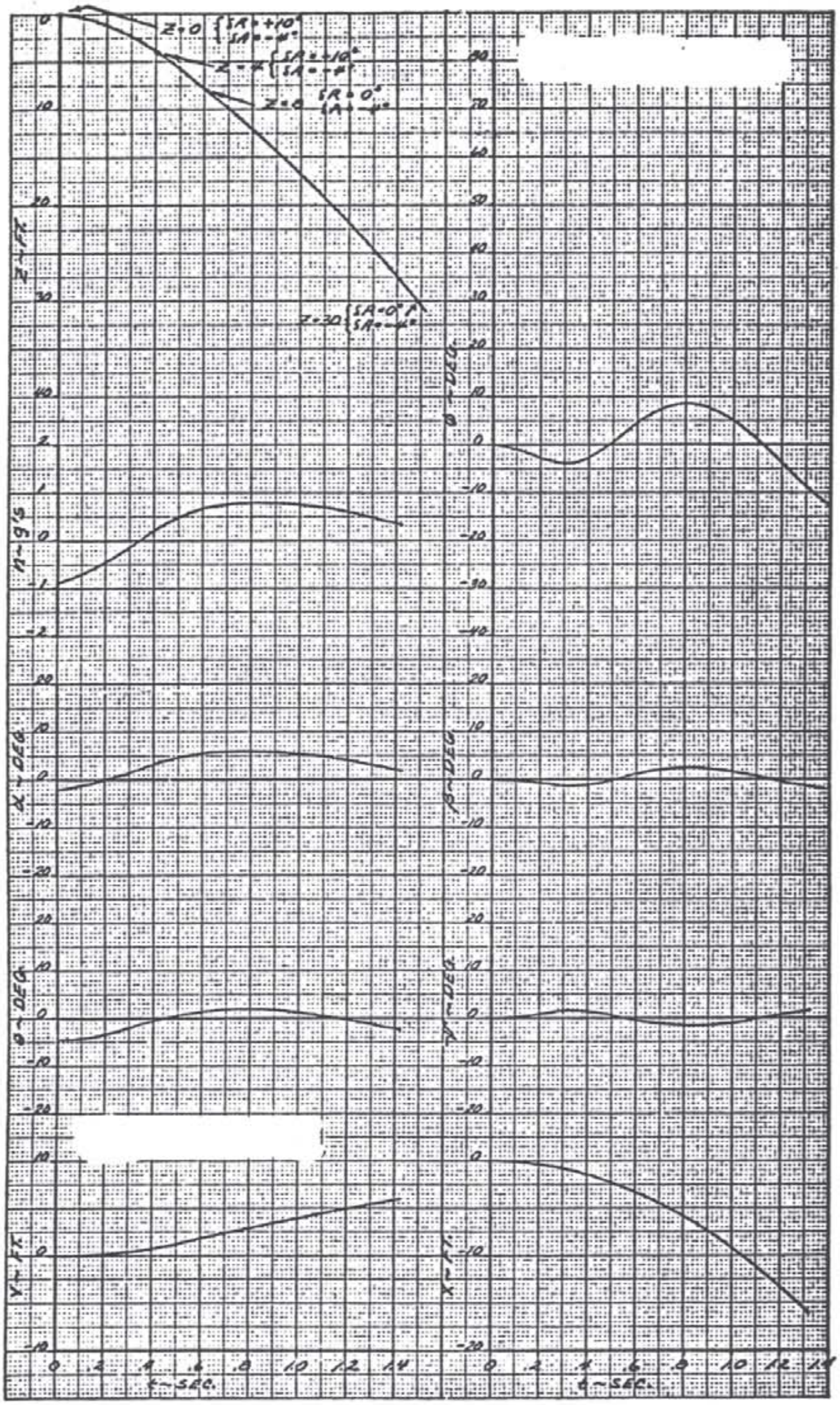


Figure 5-15. Effect Of Variable Controls.

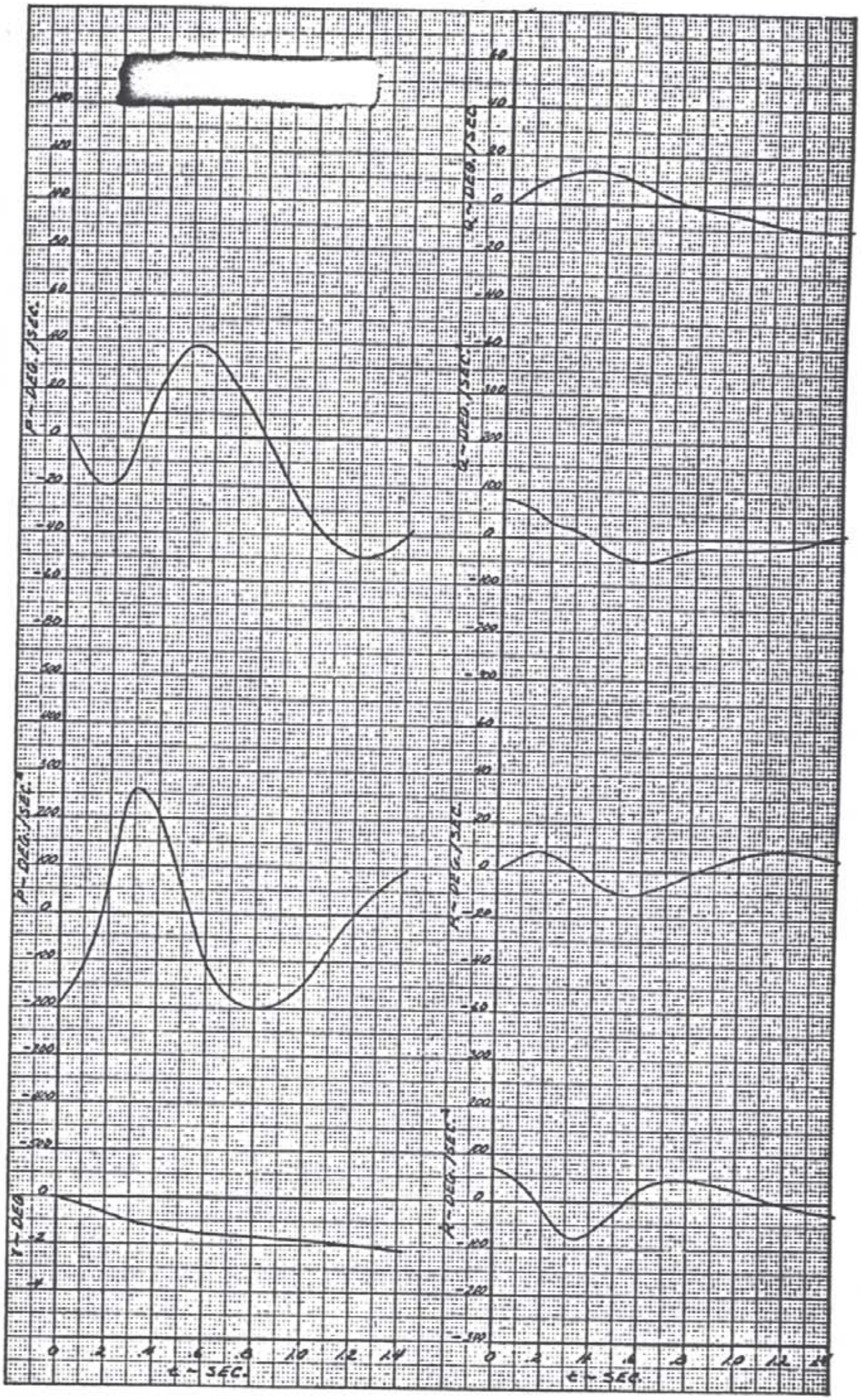
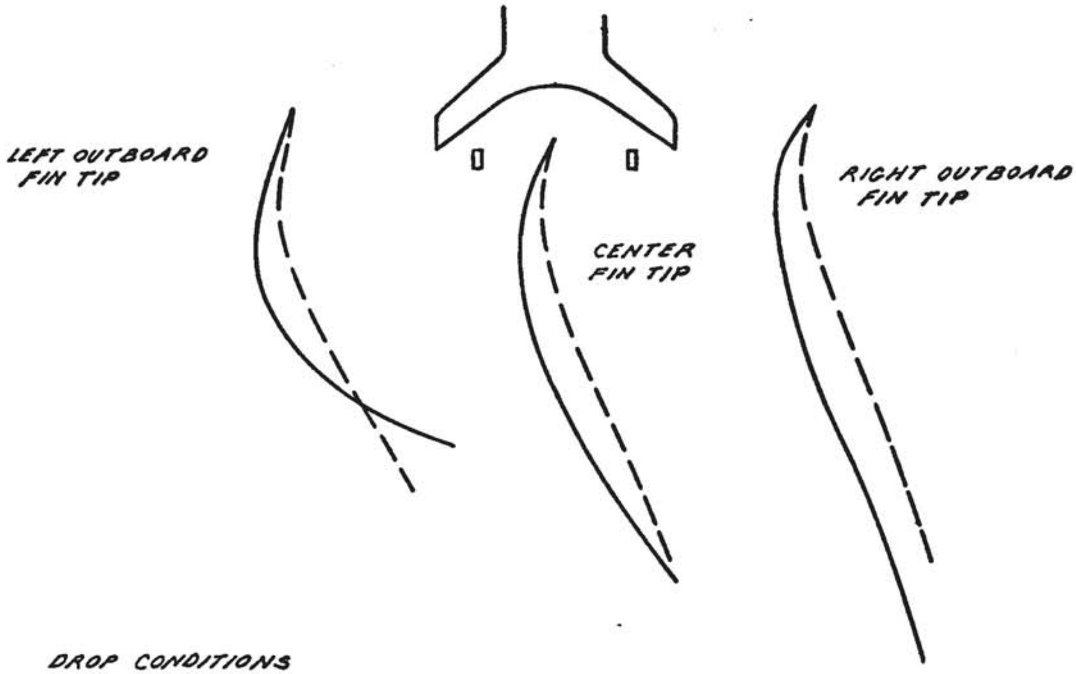


Figure 5-16. Effect of Variable Controls.



DROP CONDITIONS

MACH NO. = 0.80
ALT. = 45,000 FT.
$\alpha_{B-52} = -2^\circ$
WEIGHT = 5,198 LBS.
CARRY ANGLE ($\Delta\alpha$) = 0°
NO DAMPERS

SCALE
(FT.) 0 2 4

PRE-SET CONTROLS

———————— $\delta R = 0^\circ$; $\delta A = 0^\circ$
— — — — $\delta R = +10^\circ$; $\delta A = -4^\circ$

Figure 5-17. Effect Of Variable Controls On Separation.

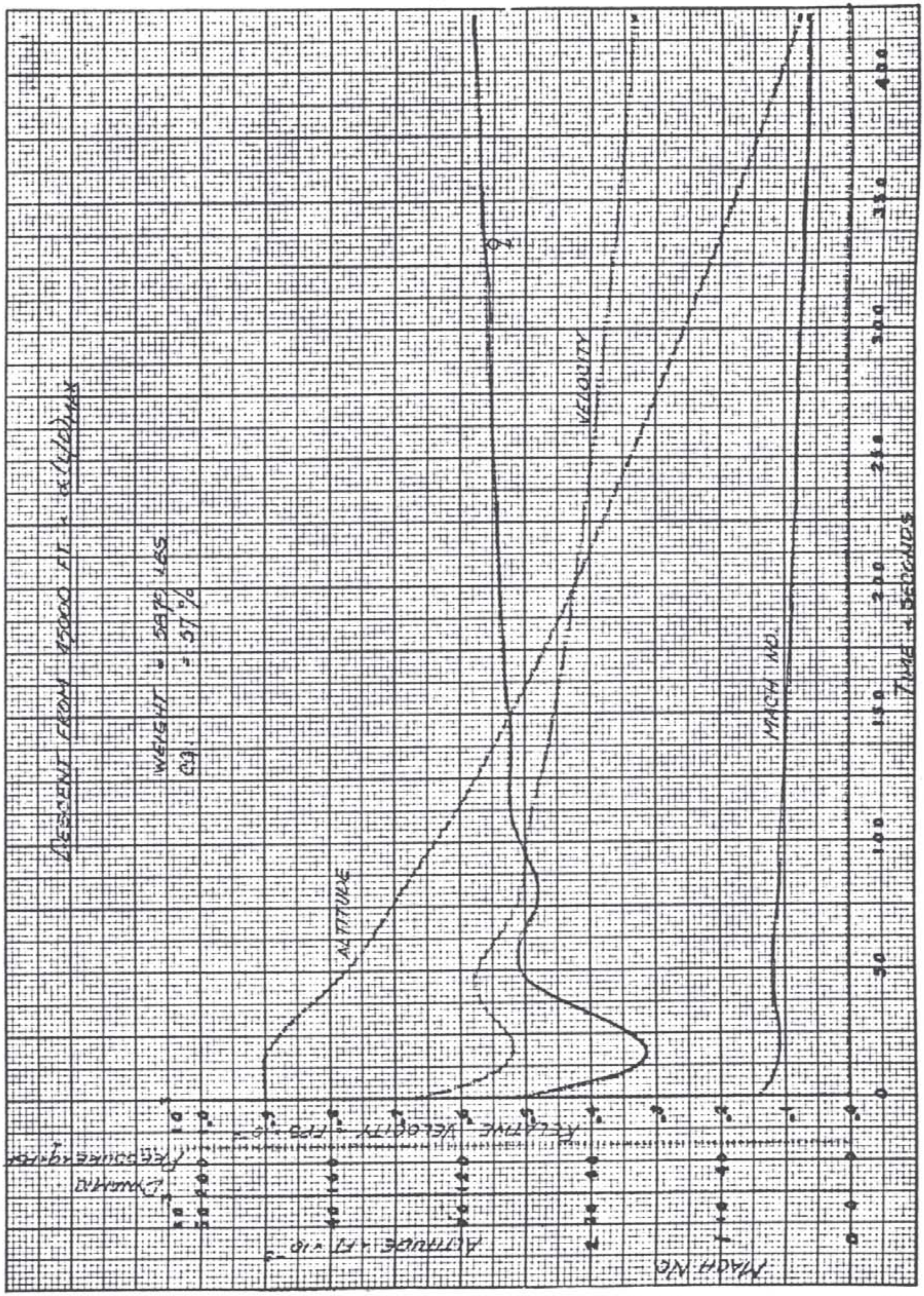


Figure 5-18. Descent From 45000 Ft. α (L/D) Max.

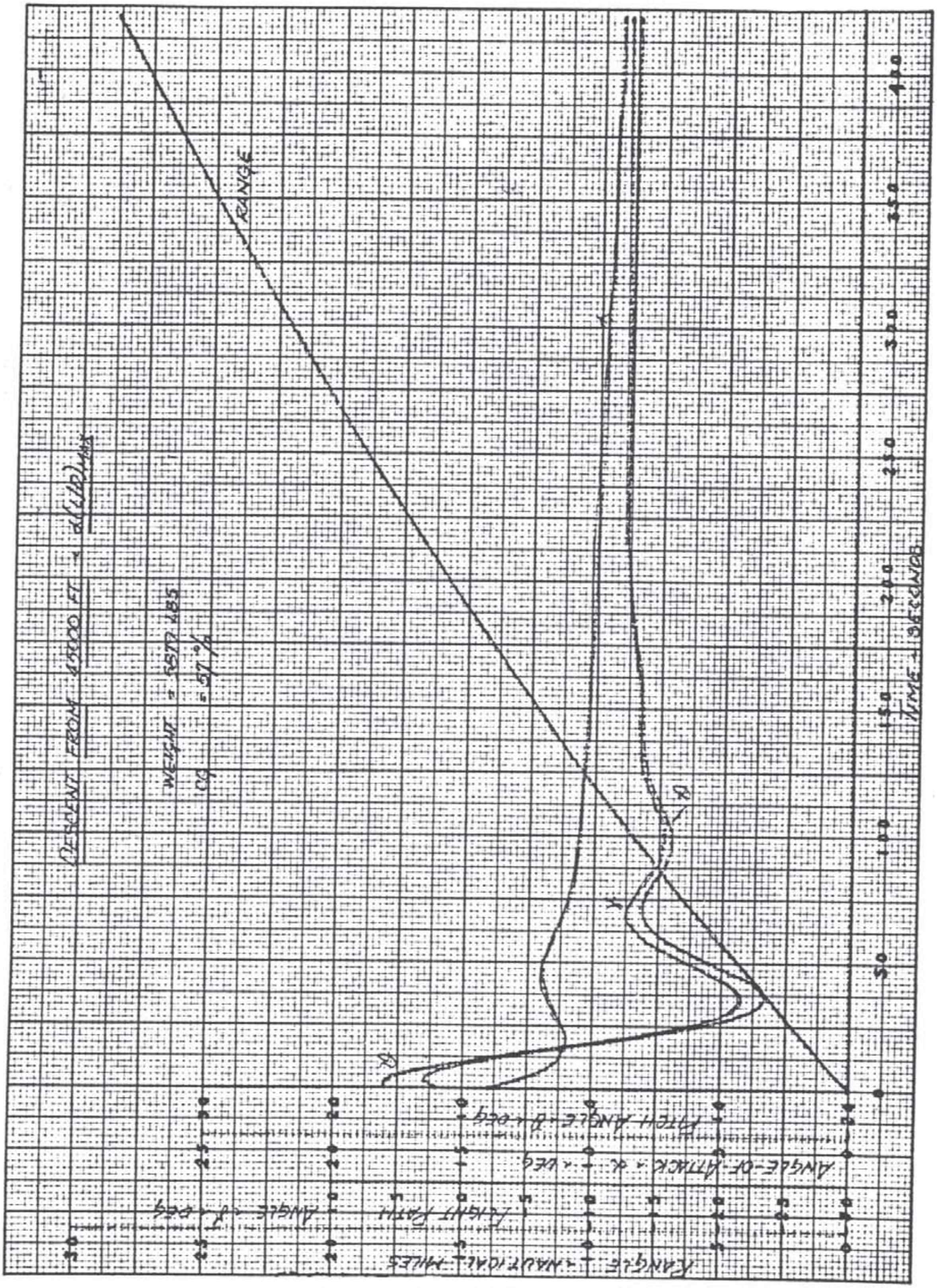


Figure 5-19. Descent From 45000 Ft. α (L/D) Max.

attack (α), flight path angle (γ) and range time histories; Figure 5-20 gives the resulting normal and axial load factors (g's) and velocity both as the indicated value and the true airspeed in knots. Figures 5-21, 5-22 and 5-23 evaluate the $\alpha_{max.}$ descent condition, and likewise Figures 5-24, 5-25 and 5-26 show the results of the $\alpha_{min.}$ condition. Figures 5-27 through 5-35 give the results of the heavy-weight (10729 lbs. at c.g. = 55.54%) descents for the three α , Mach number histories. The remaining descent flight condition, namely heavy weight (10729 lbs at c.g. = 57%) are shown in Figures 5-36 through 5-44.

In the descent analysis the aerodynamic coefficients were the trim values for the center of gravity of the vehicle as noted.

A flight mission ground trace for the heavy weight condition (10729 lbs. at c. g. = 55.54%) is shown in Figure 5-45 for the α for $(L/D)_{max.}$ condition and in Figure 5-46 for the $\alpha_{max.}$ case. These ground traces show pressure altitude check points along the path of the vehicle suitable for flying a similar mission in flight test. All roll angles executed for heading changes do not exceed 45 degrees. Similar ground traces for the light weight vehicle may be evaluated from Figures 5-47 and 5-48 showing the boost descent mission profiles.

5-7. <u>POWERED BOOST</u>

The X-24A is powered in the boost phase by the Thiokol XLR11-RM-13 turborocket engine. The engine is ignited 5 seconds after separation from the B-52, thus allowing separation perturbations to be damped-out by the pilot and the control system. At this time two barrels of the engine are ignited, followed 5 seconds later by the remaining two barrels. The thrust and specific impulse of this engine are shown in Figure 5-49.

The powered boost trajectory was optimized using angle-of-attack (α) as a control function and altitude and velocity as constraints. The α was optimized as a

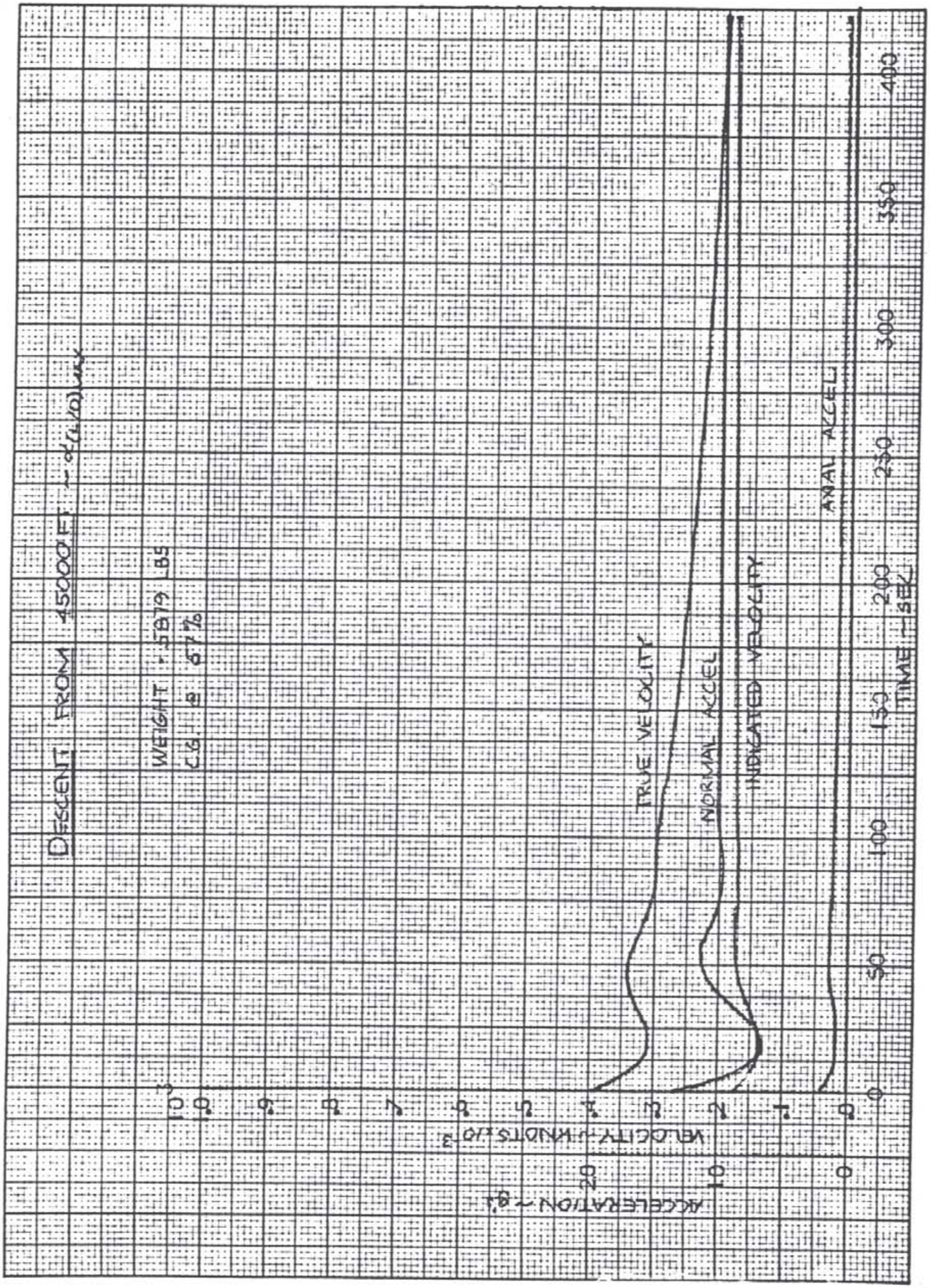


Figure 5-20. Descent From 45000 Ft. α (L/D) Max.

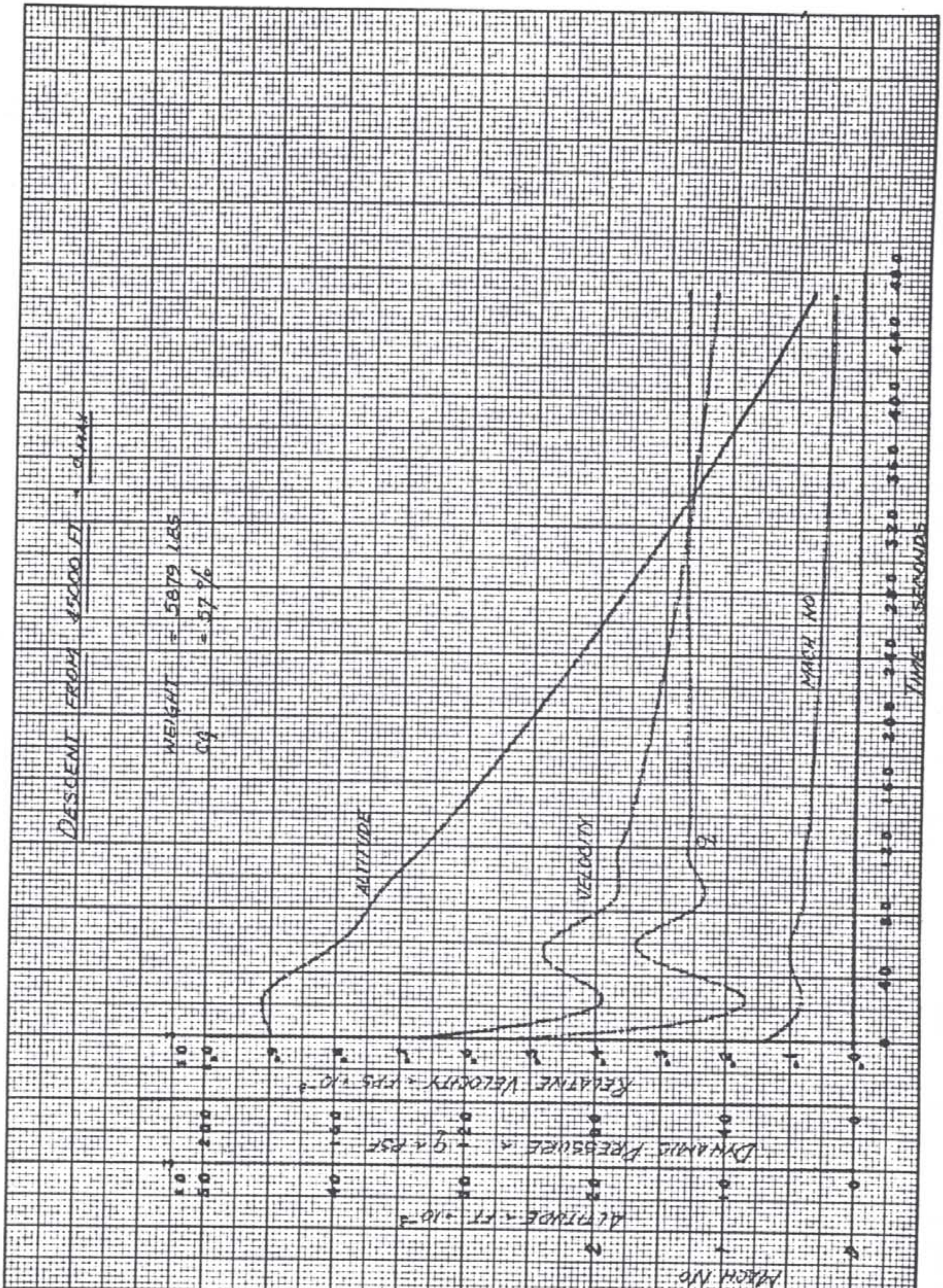


Figure 5-21. Descent From 45000 Ft. α Max.

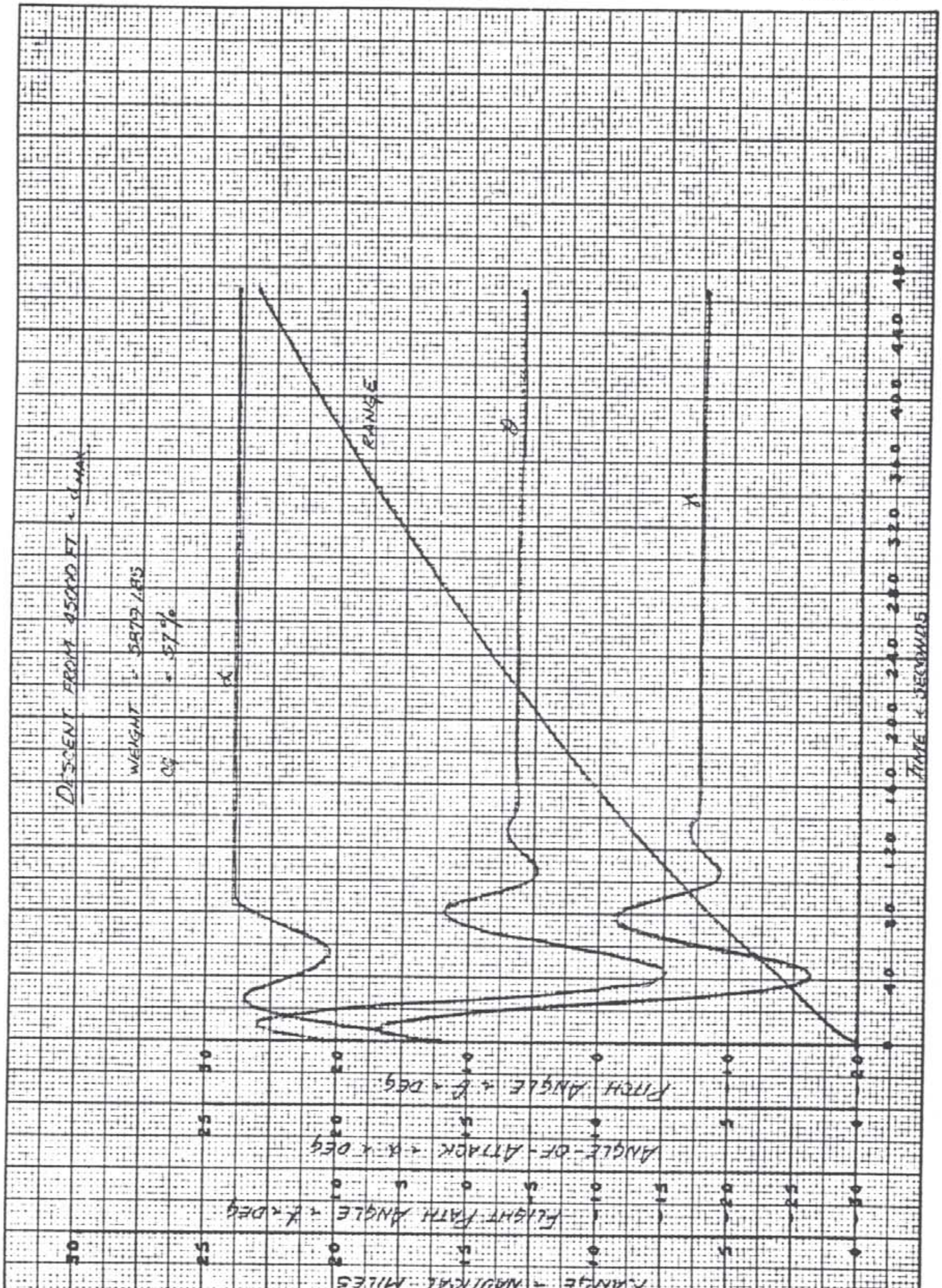


Figure 5-22. Descent From 45000 Ft. α Max.

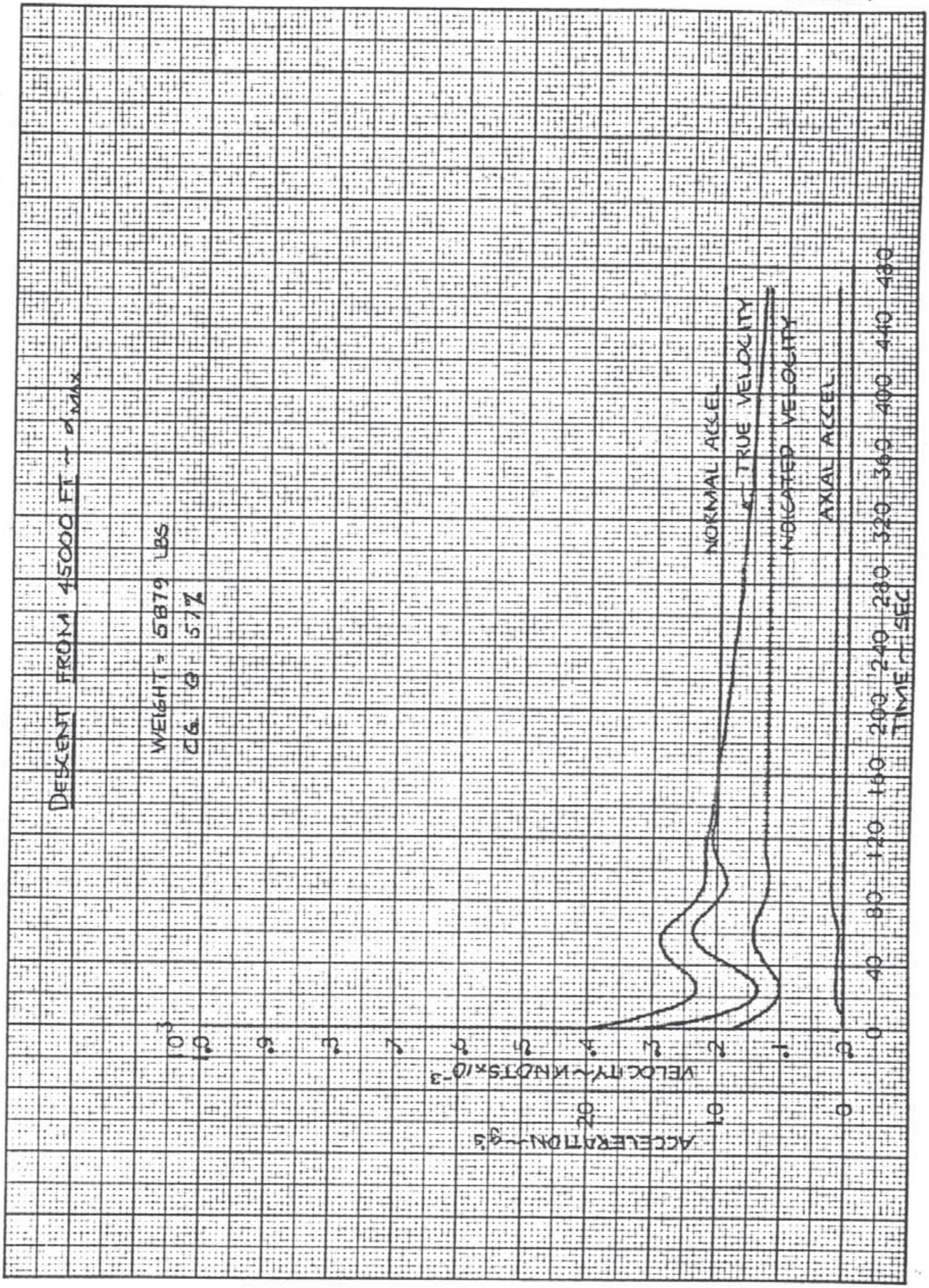


Figure 5-23. Descent From 45000 Ft. α Max.

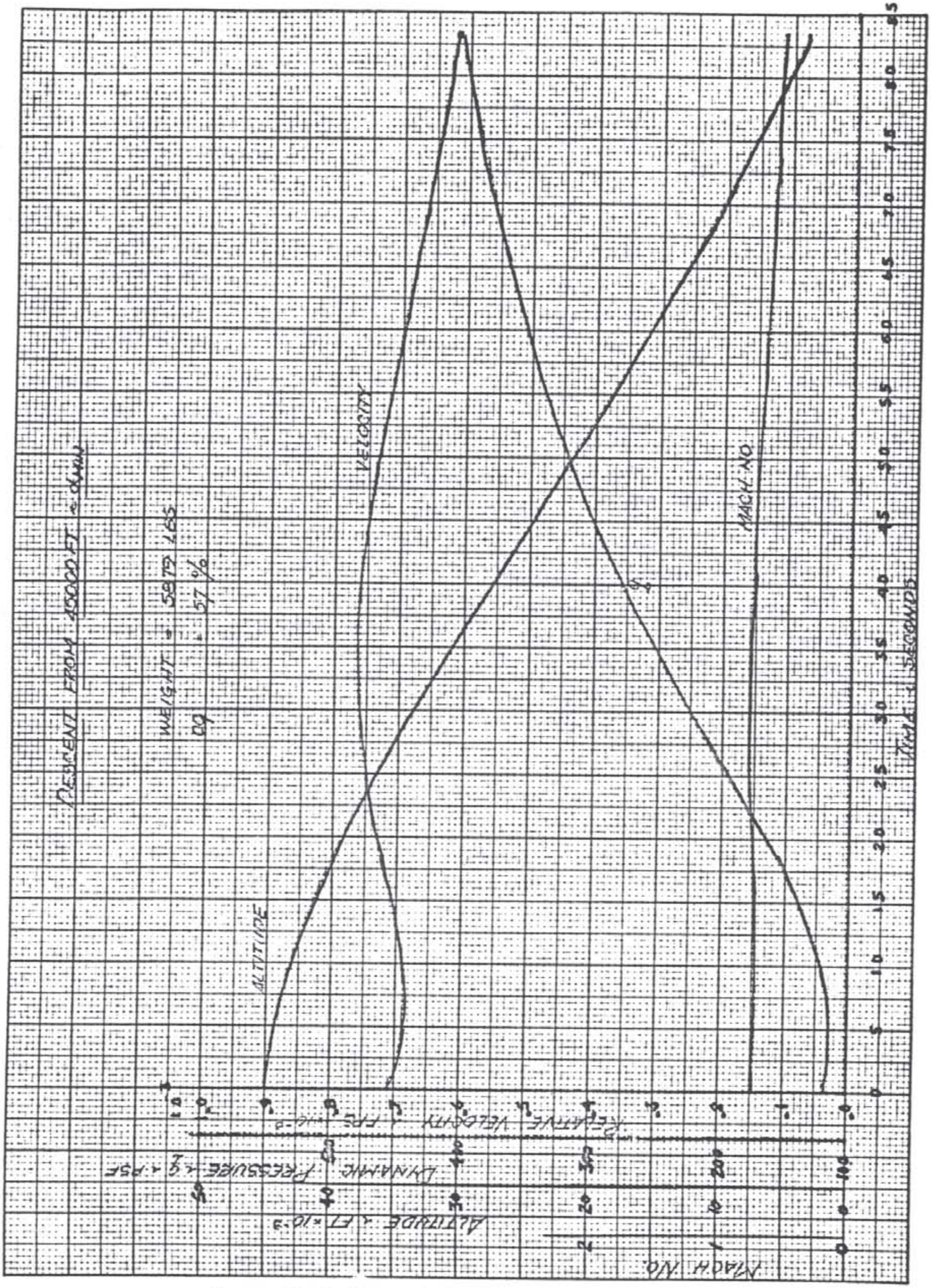


Figure 5-24. Descent From 45000 Ft. ∝ Min.

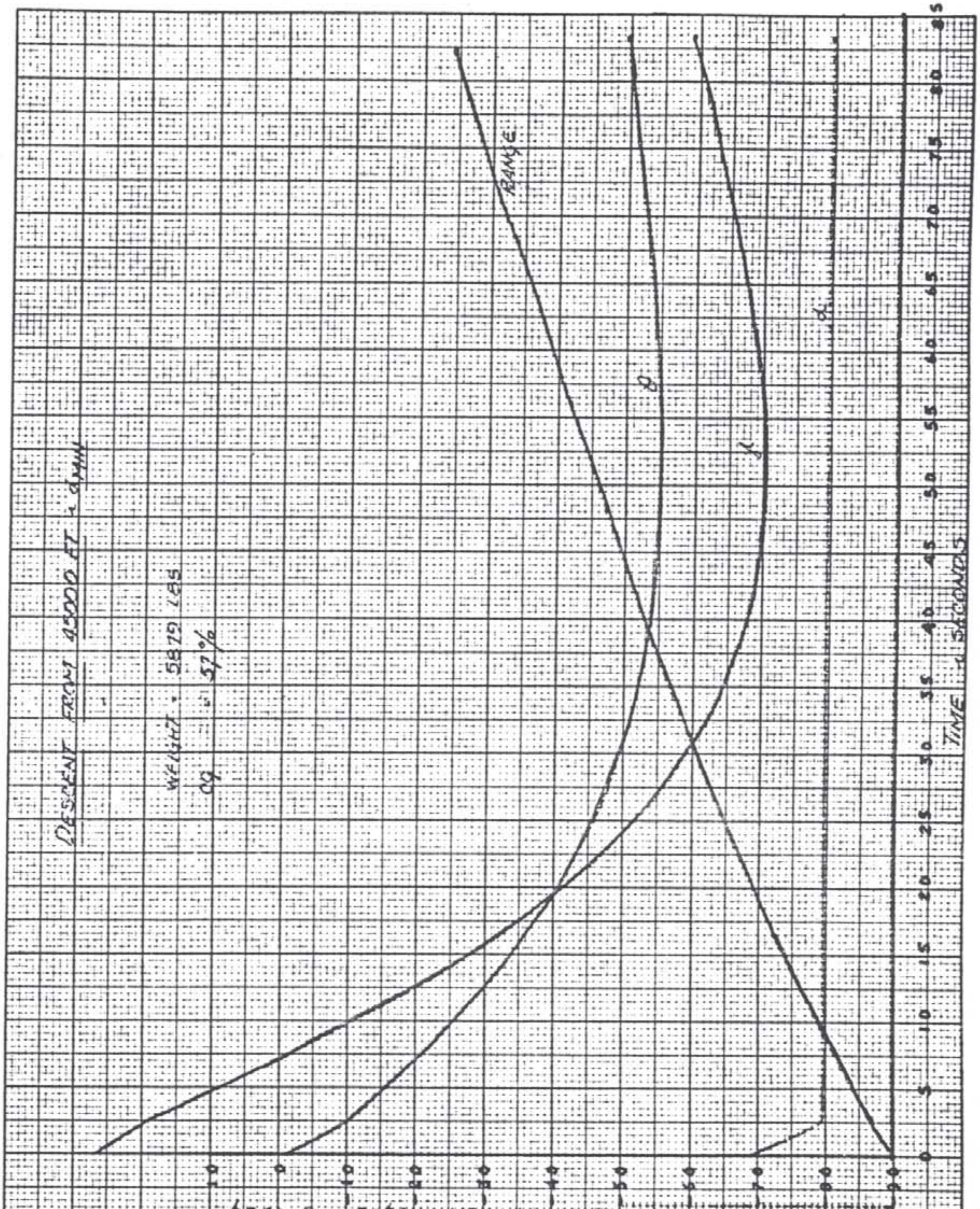


Figure 5-25. Descent From 45000 Ft. α Min.

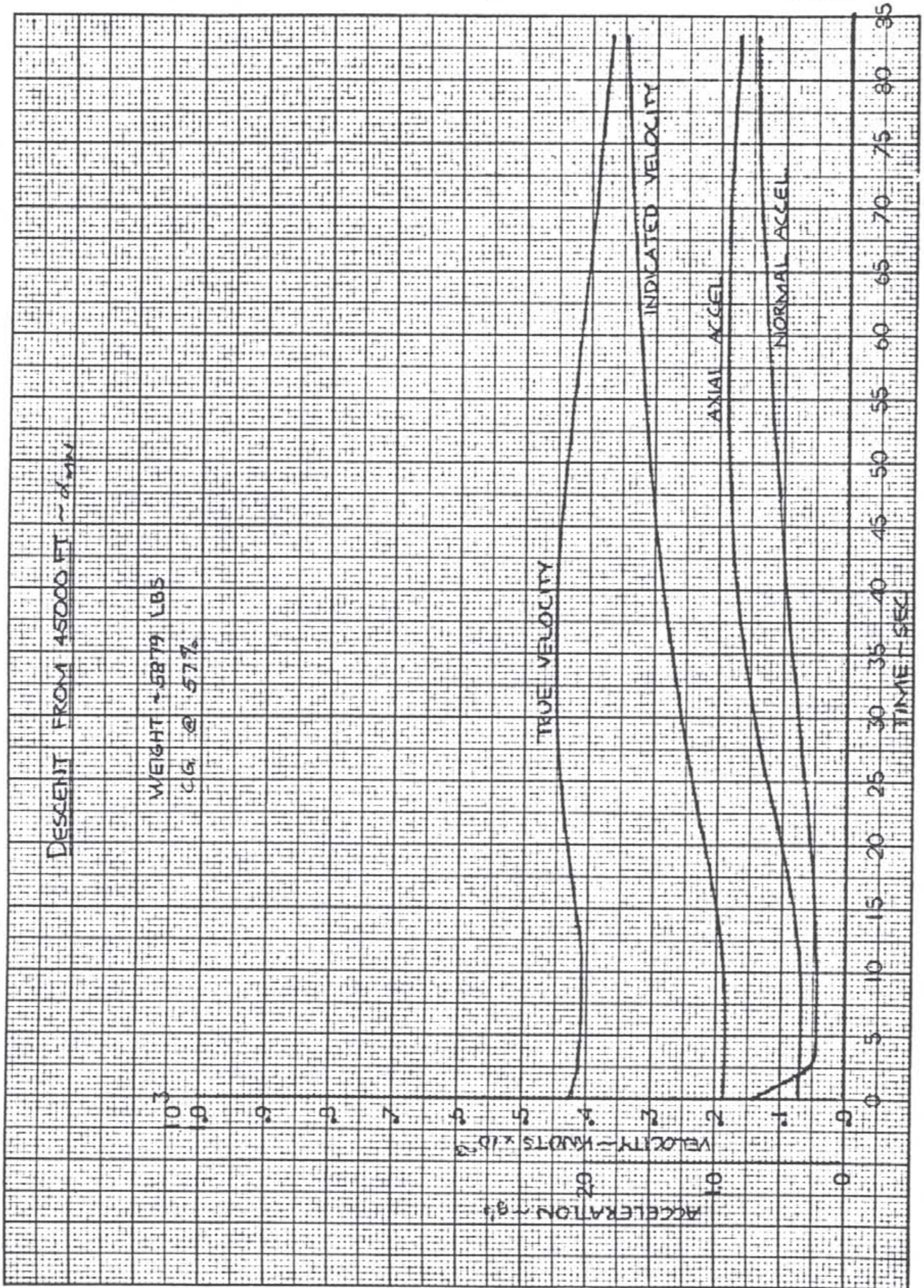


Figure 5-26. Descent From 45000 Ft. α Min.

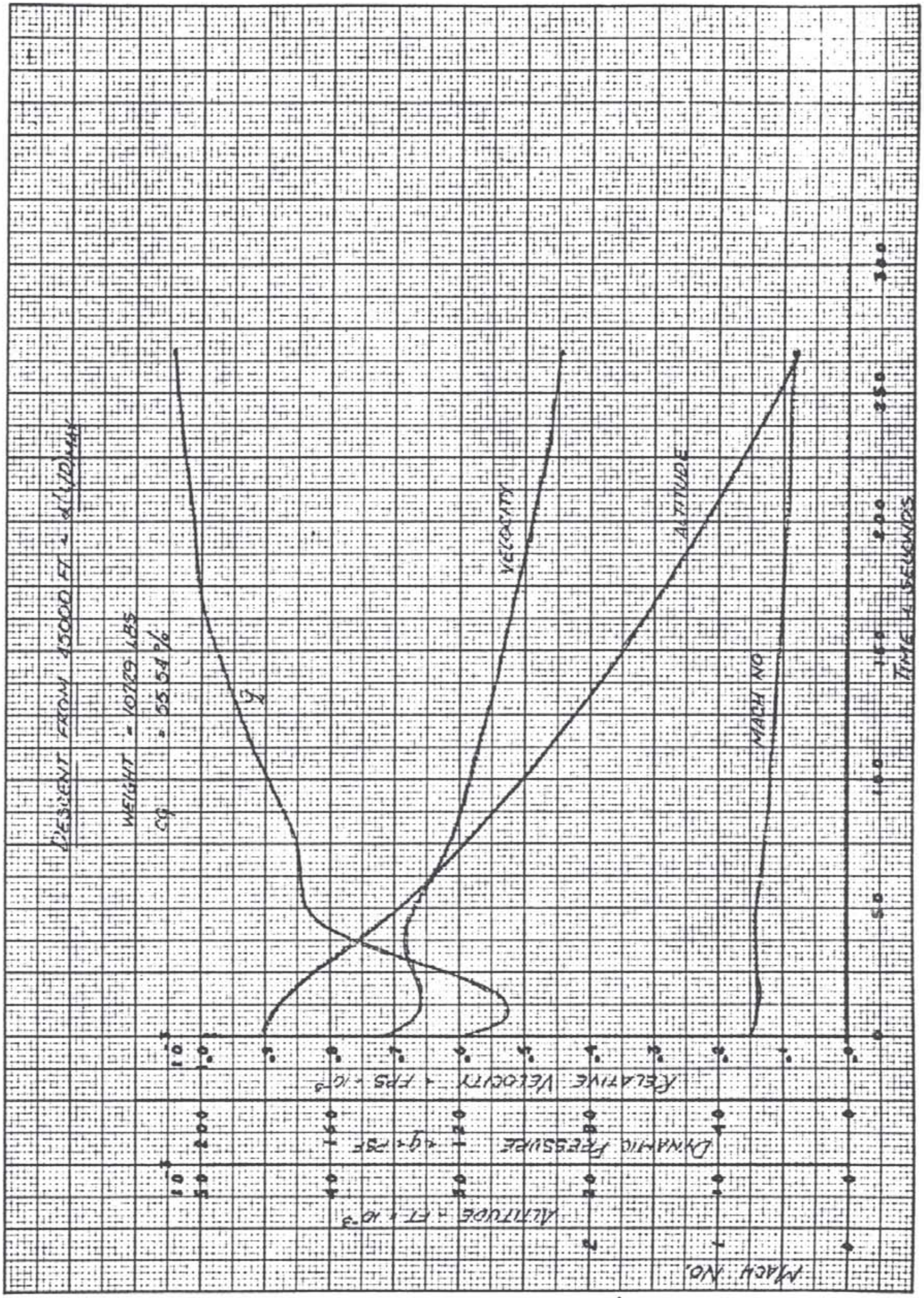


Figure 5-27. Descent From 45000 Ft. α Max.

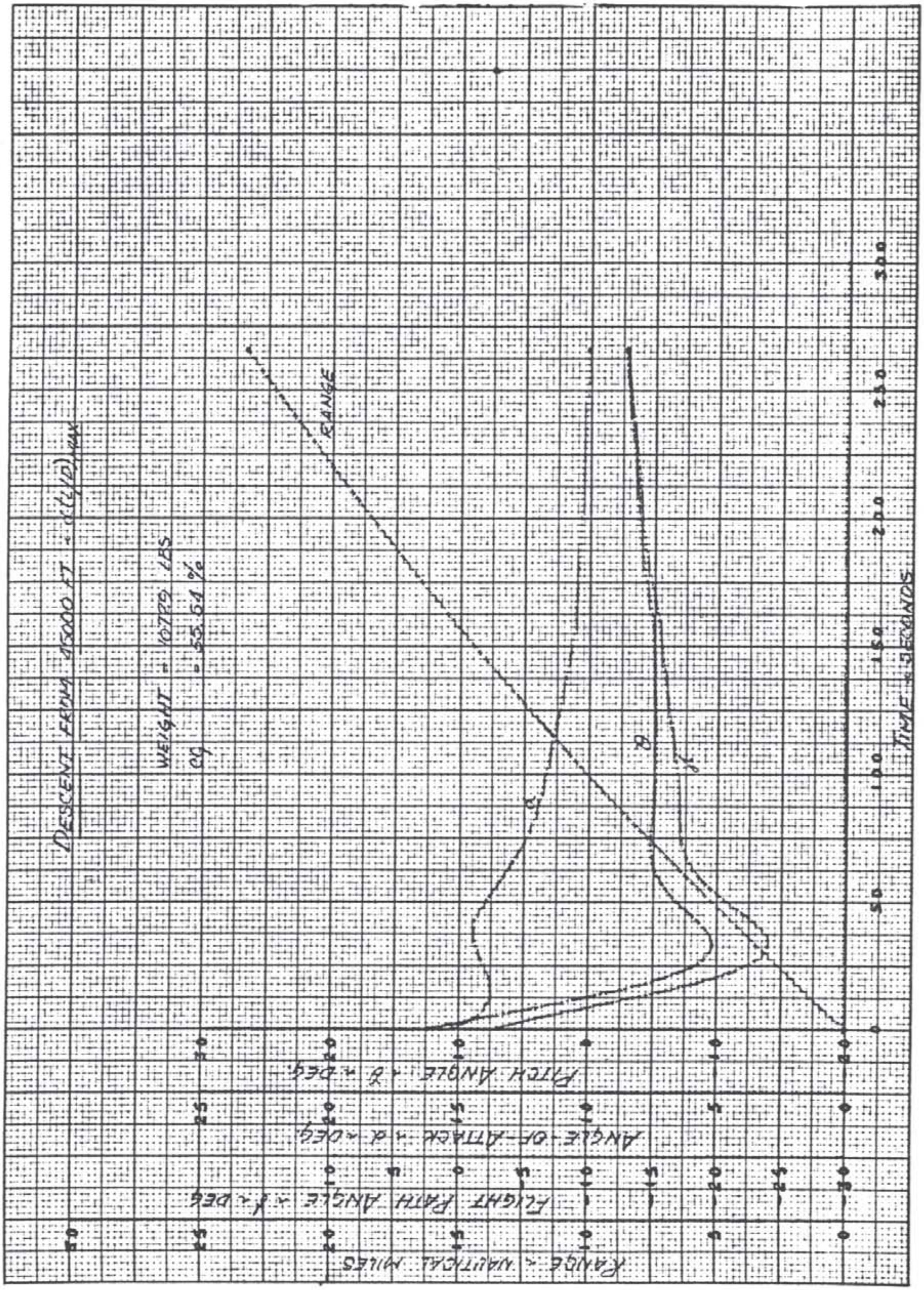


Figure 5-28. Descent From 45000 Ft. α (L/D) Max.

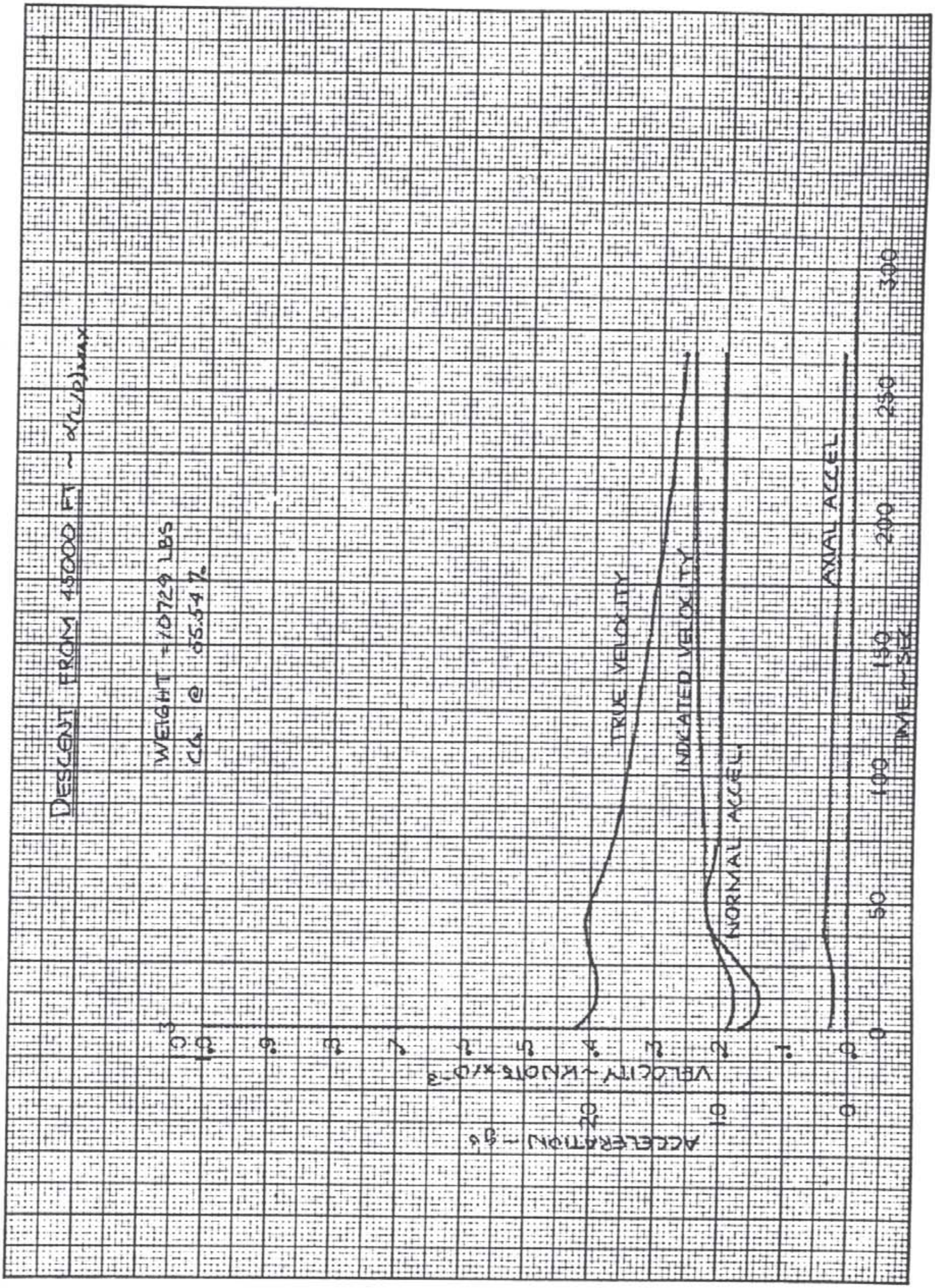


Figure 5-29. Descent From 45000 Ft. α (L/D) Max.

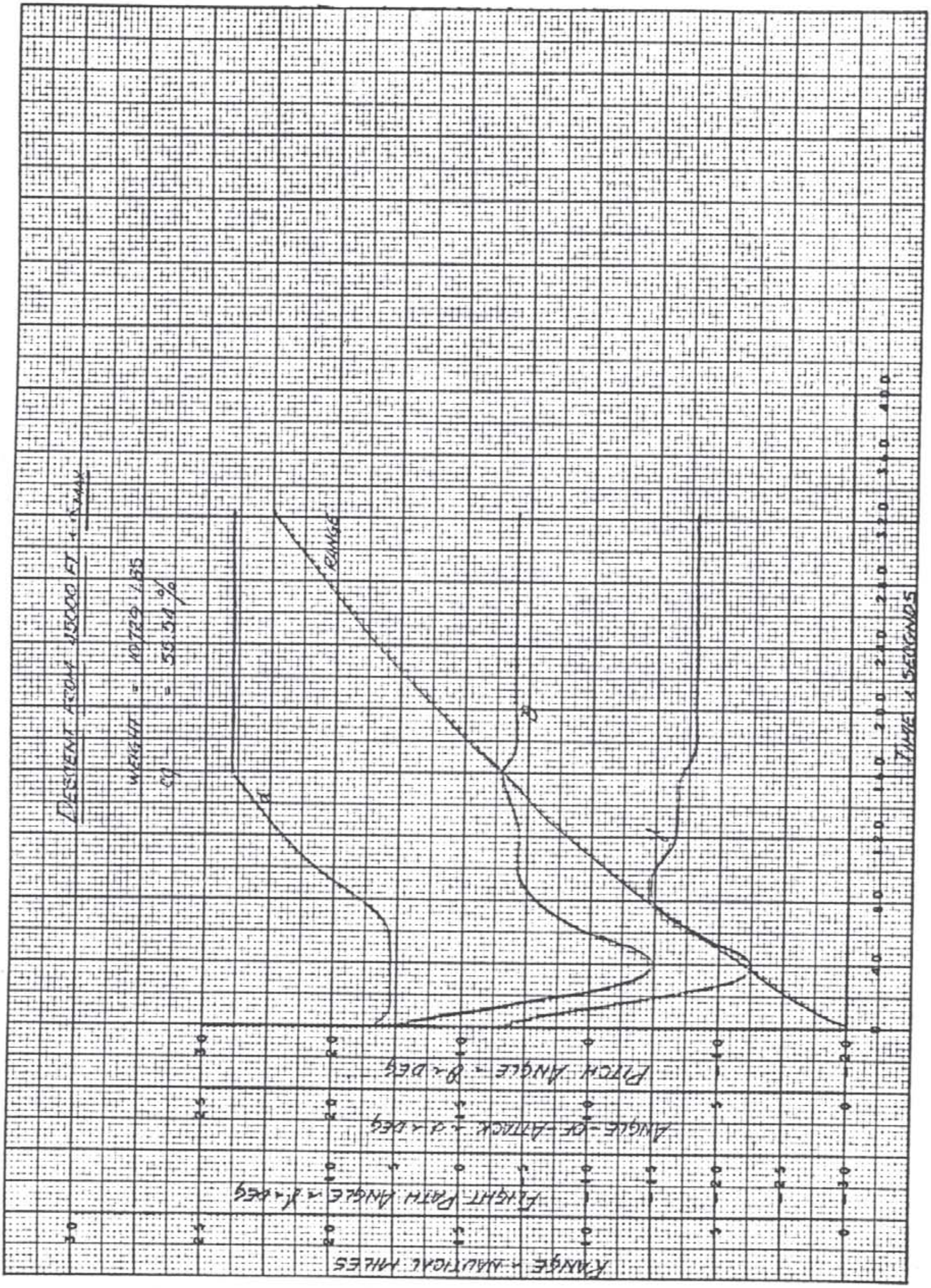


Figure 5-30. Descent From 45000 Ft. α Max.

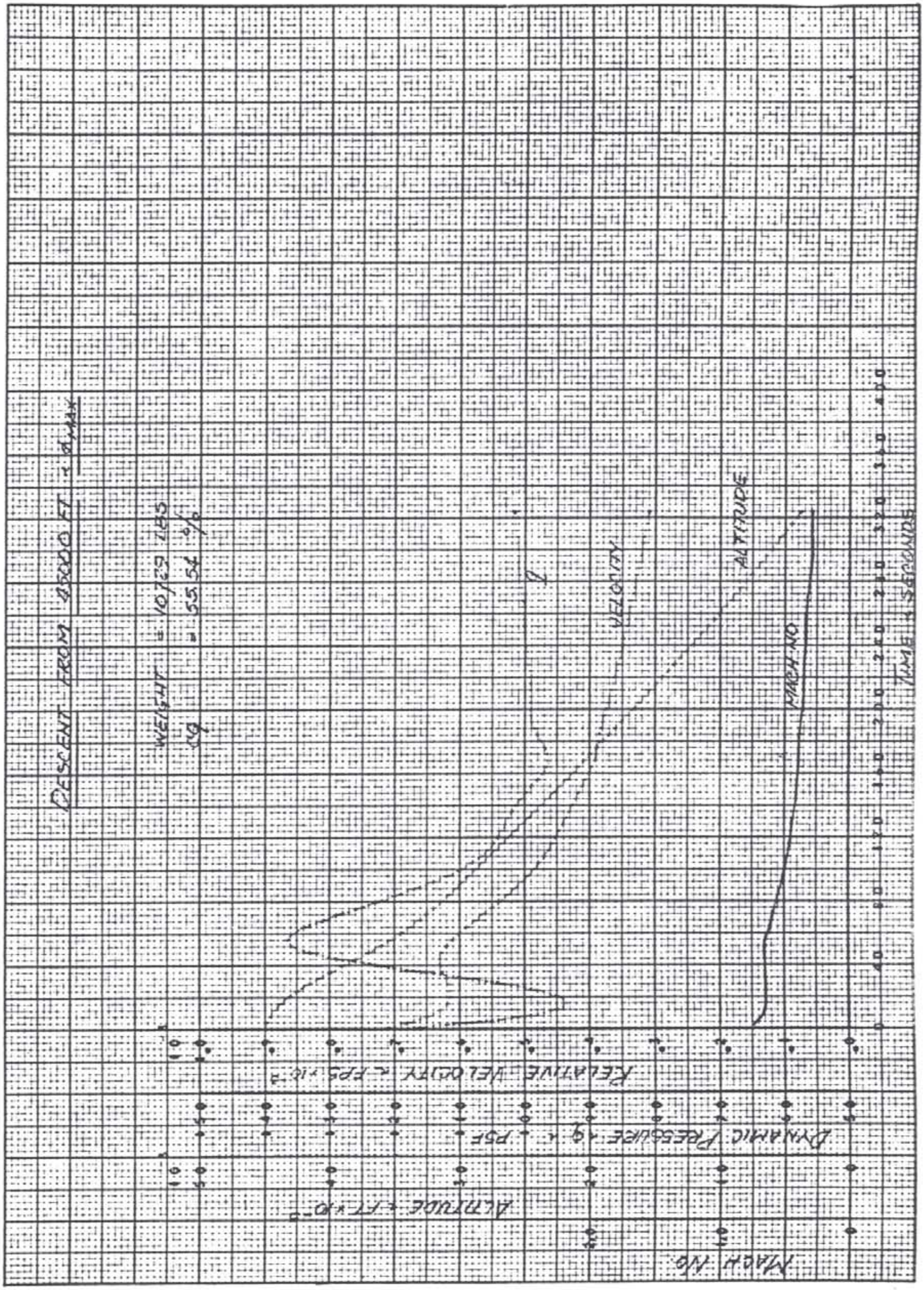


Figure 5-31. Descent From 45000 Ft. α Max.

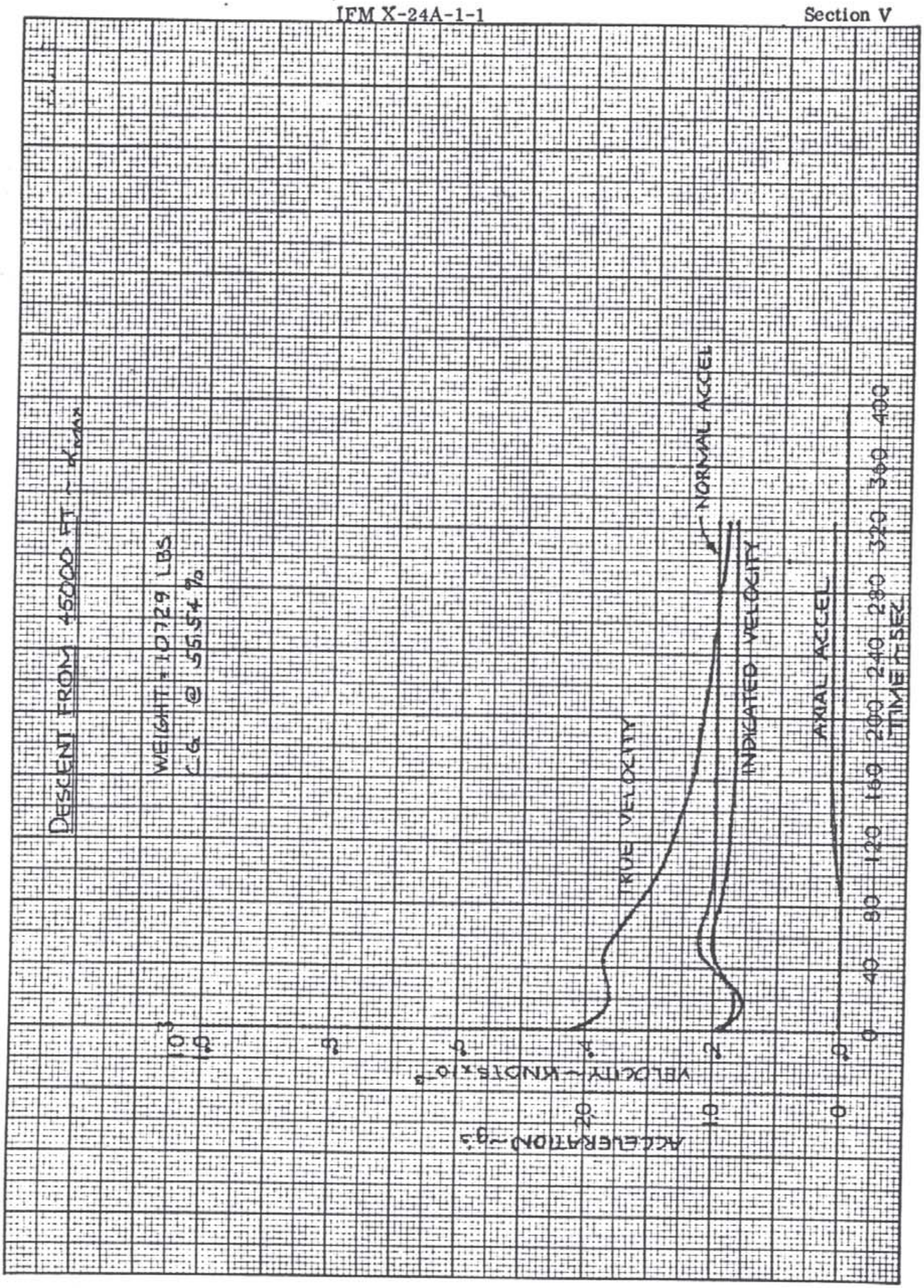


Figure 5-32. Descent from 45000 Ft. α Max.

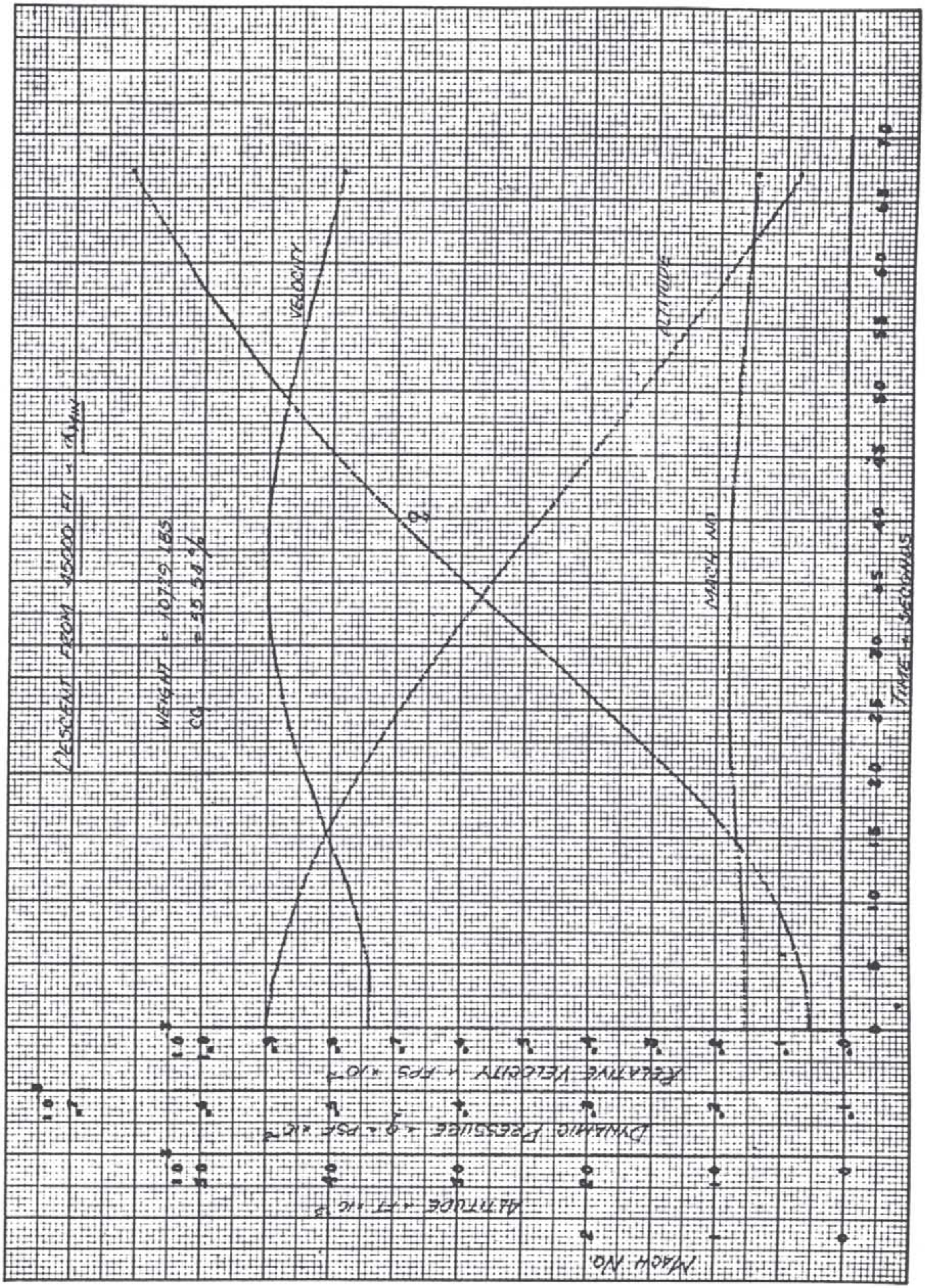


Figure 5-33. Descent From 45000 Ft. α Min.

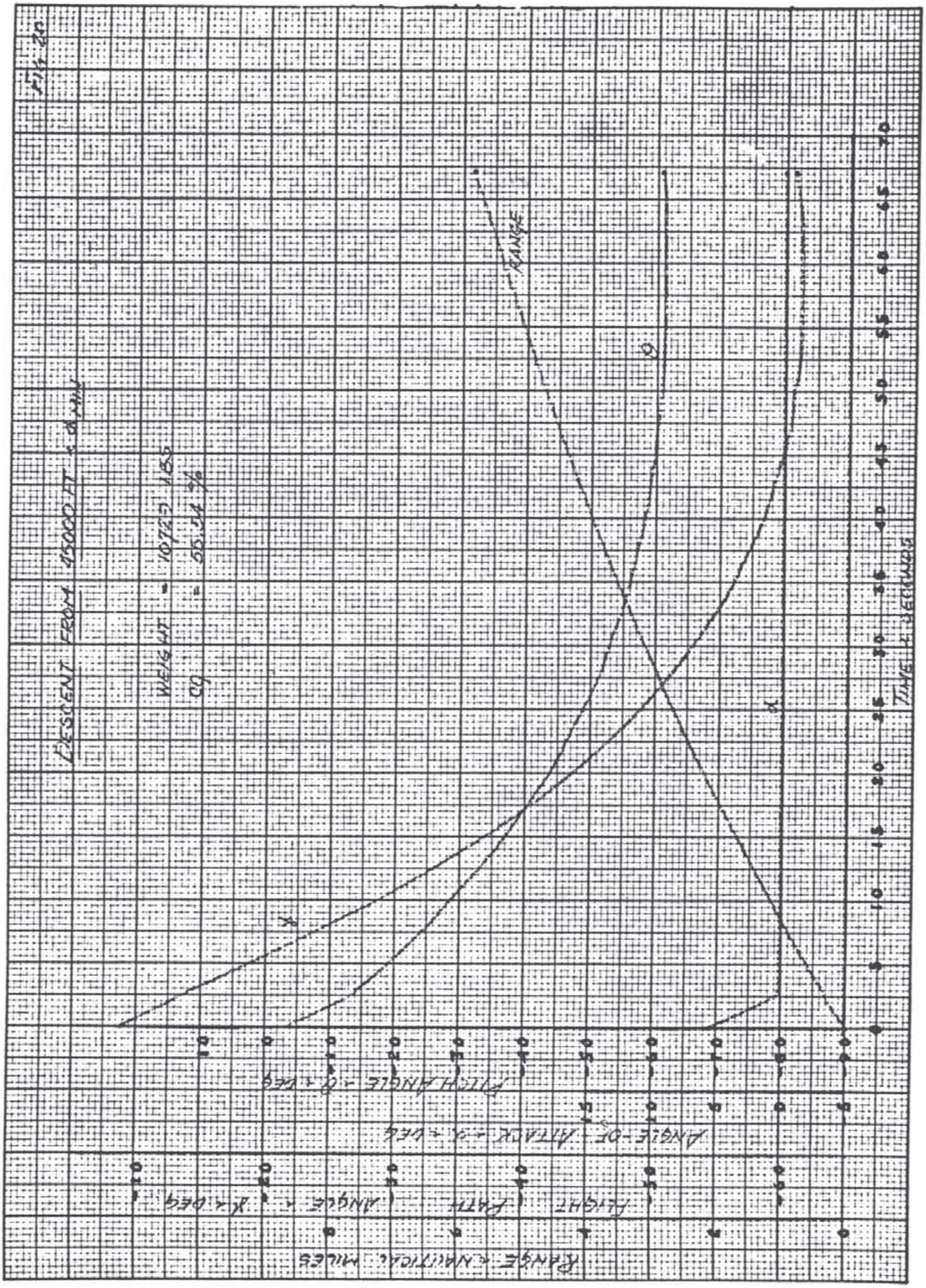


Figure 5-34. Descent From 45000 Ft. α Min

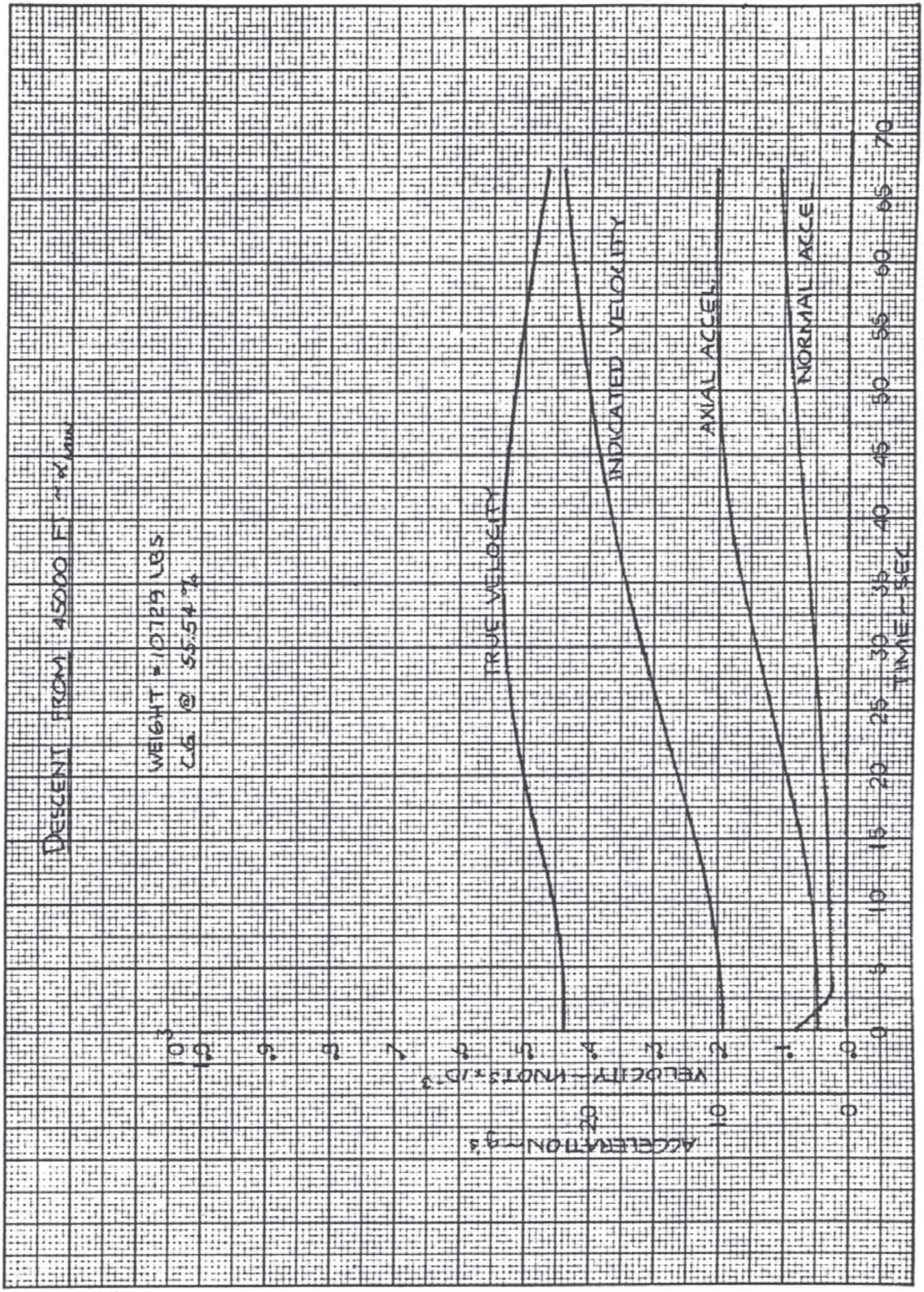


Figure 5-35. Descent From 45000 Ft. α Min.

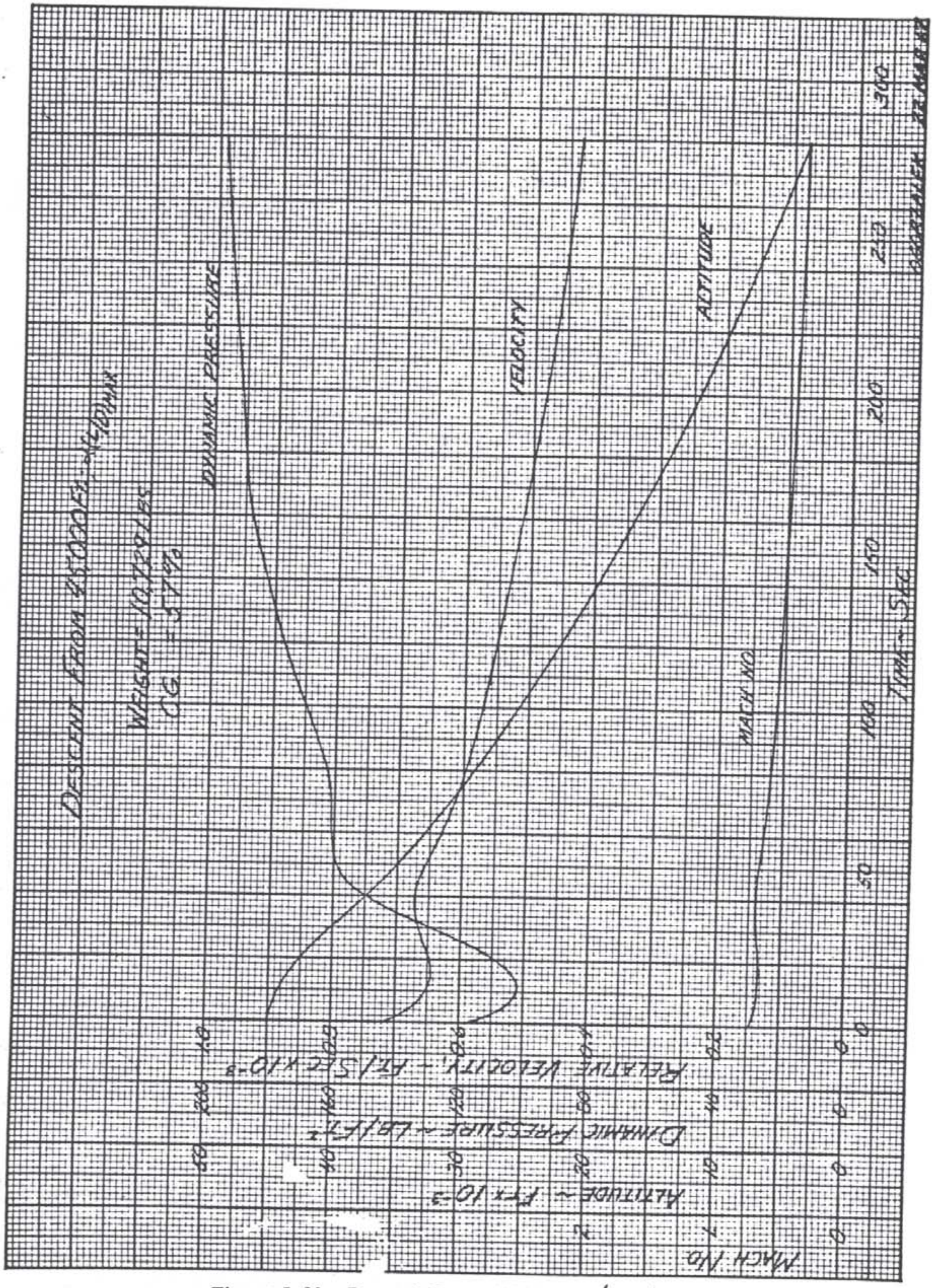


Figure 5-36. Descent From 45000 Ft. α (L/D) Max.

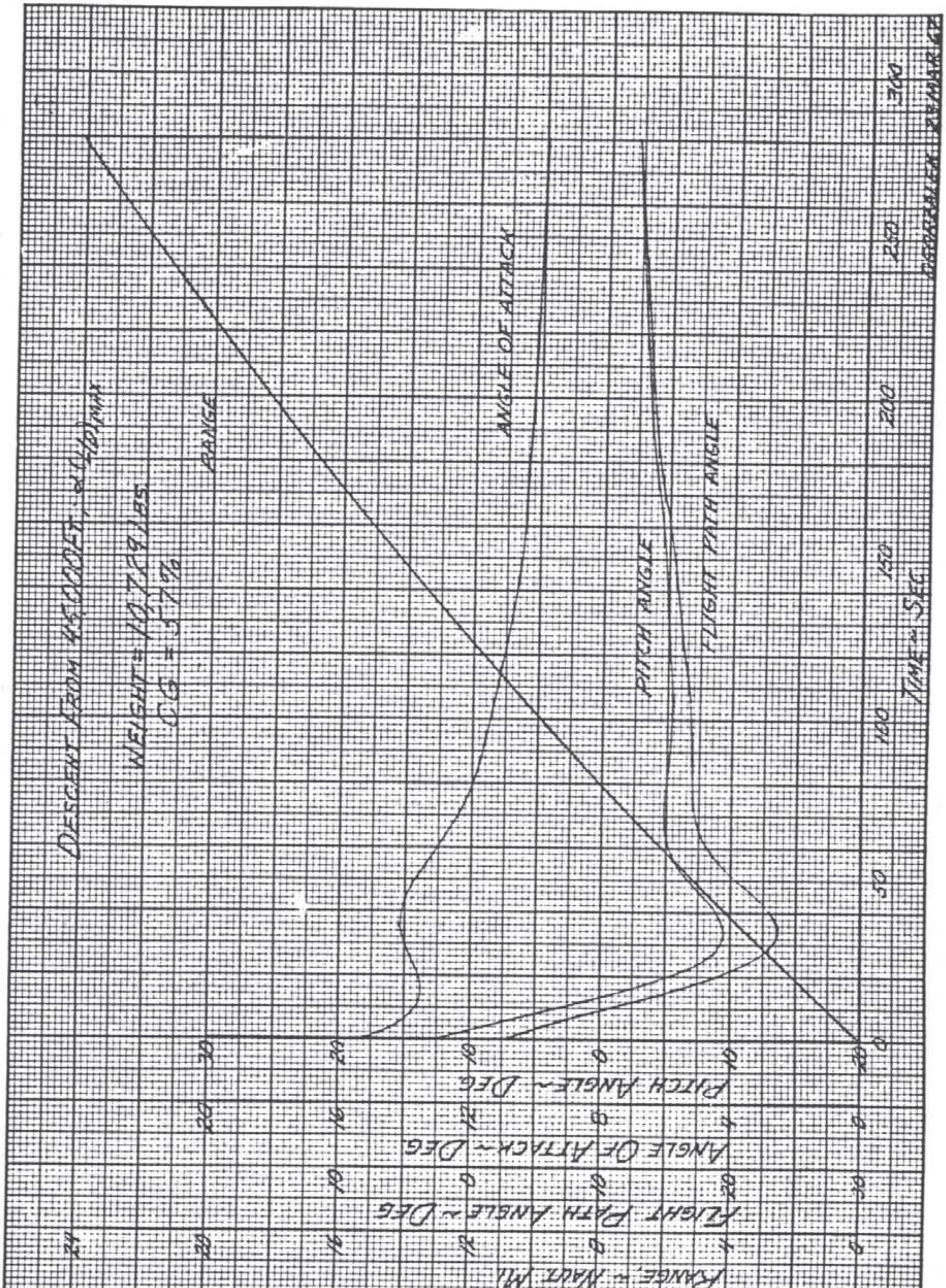


Figure 5-37. Descent From 45000 Ft. α (L/D) Max.

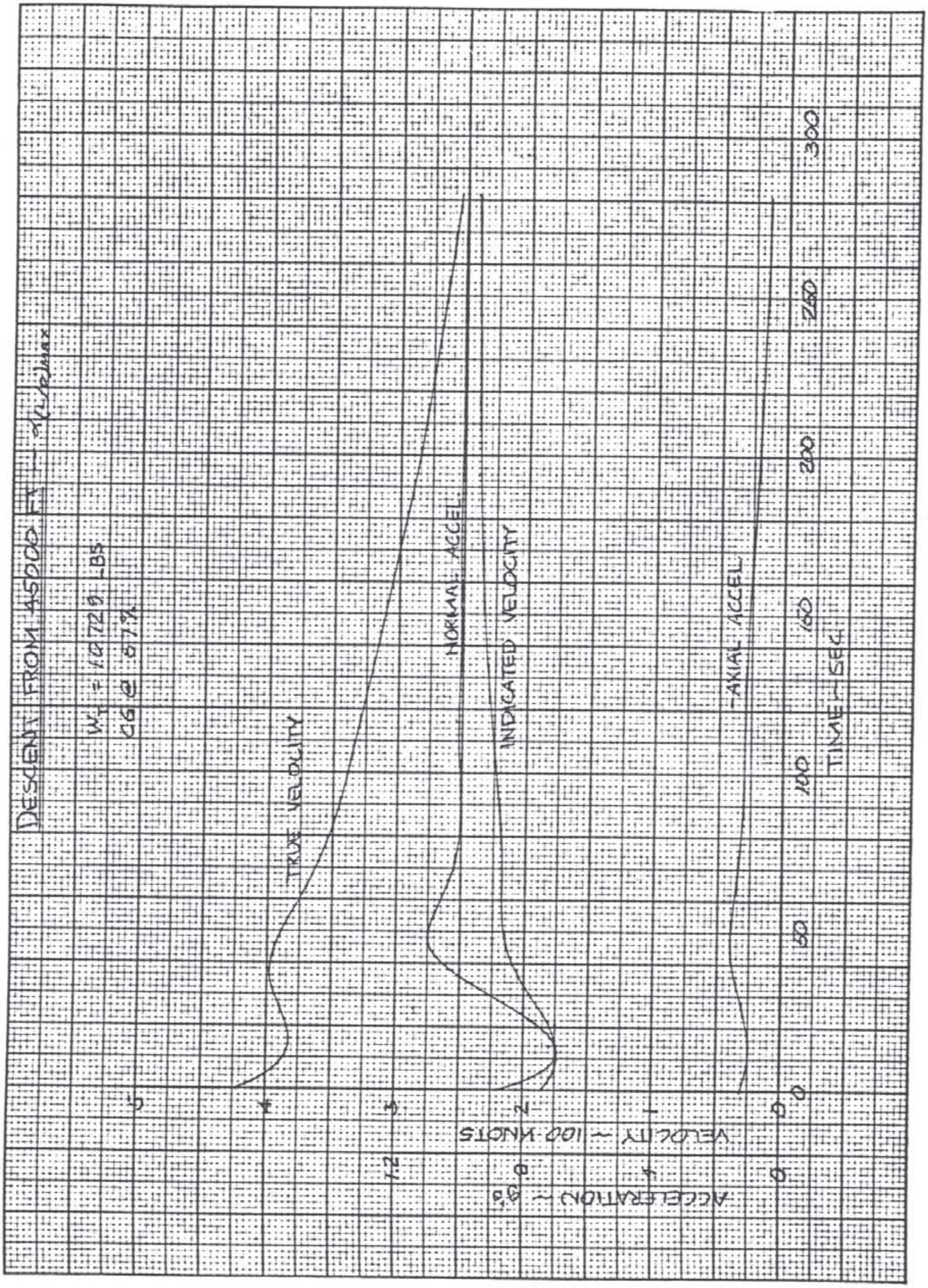


Figure 5-38. Descent From 45000 Ft. α (L/D) Max.

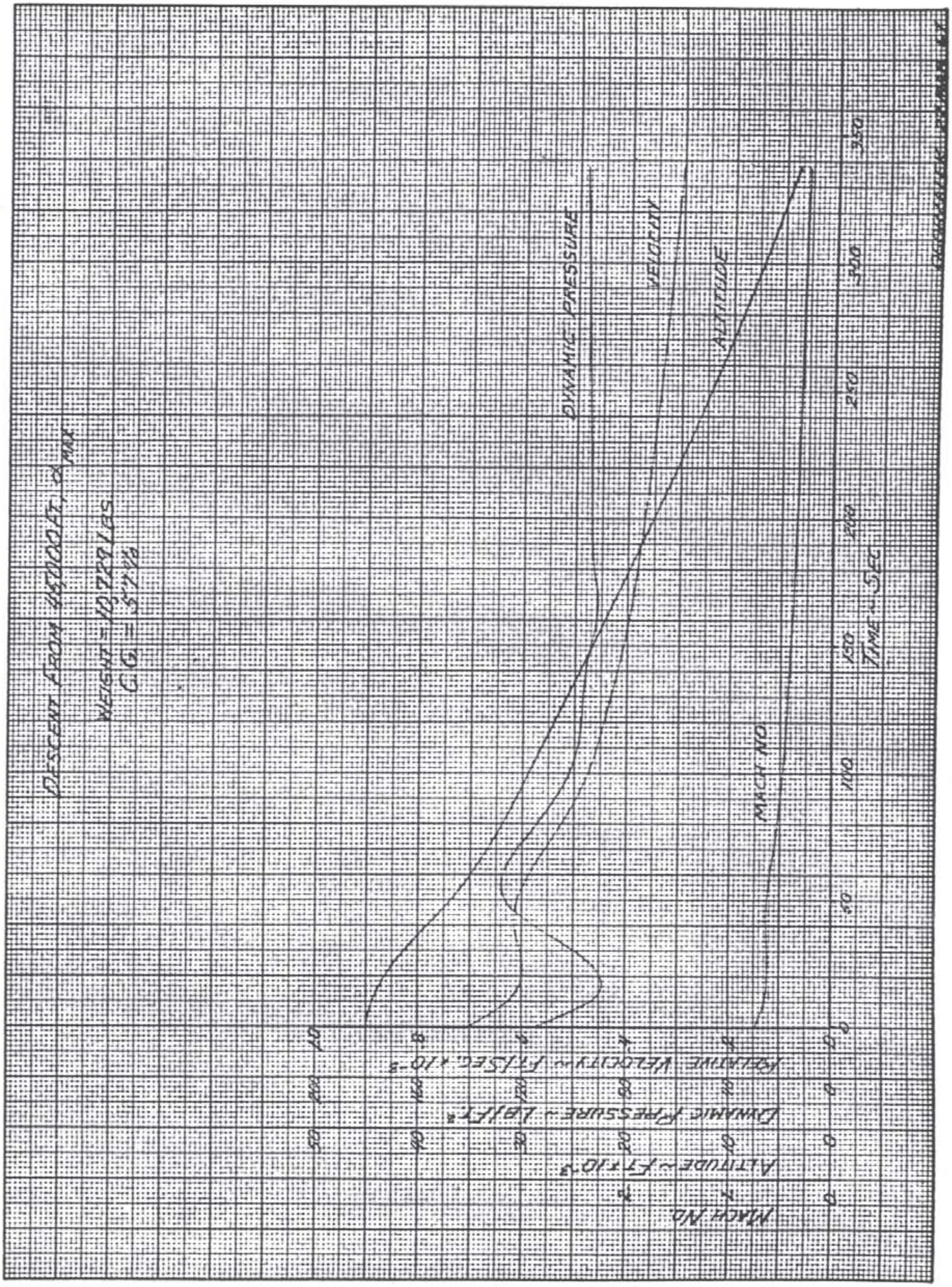


Figure 5-39. Descent From 45000 Ft. α Max.

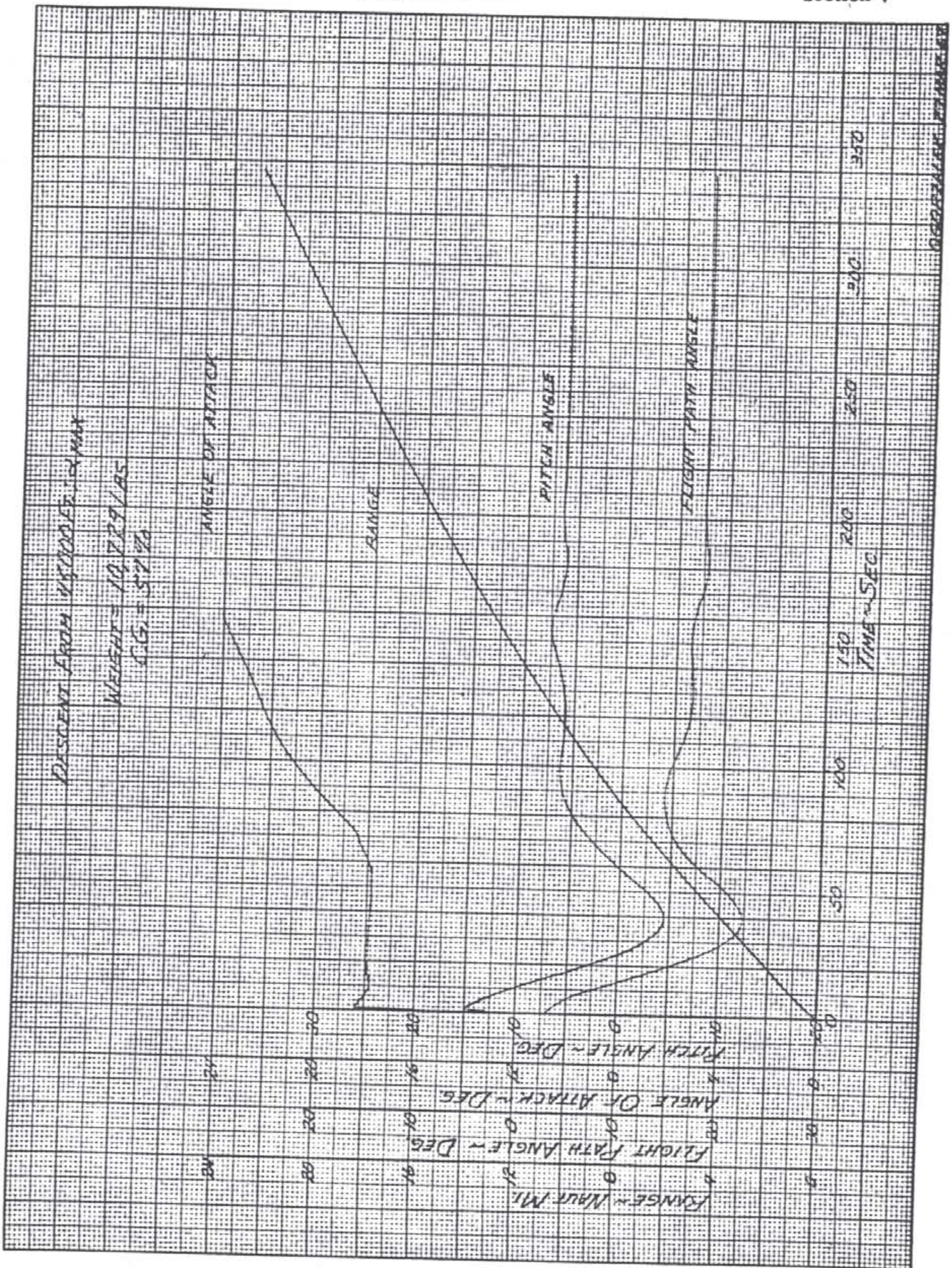


Figure 5-40. Descent From 45000 Ft. α Max.

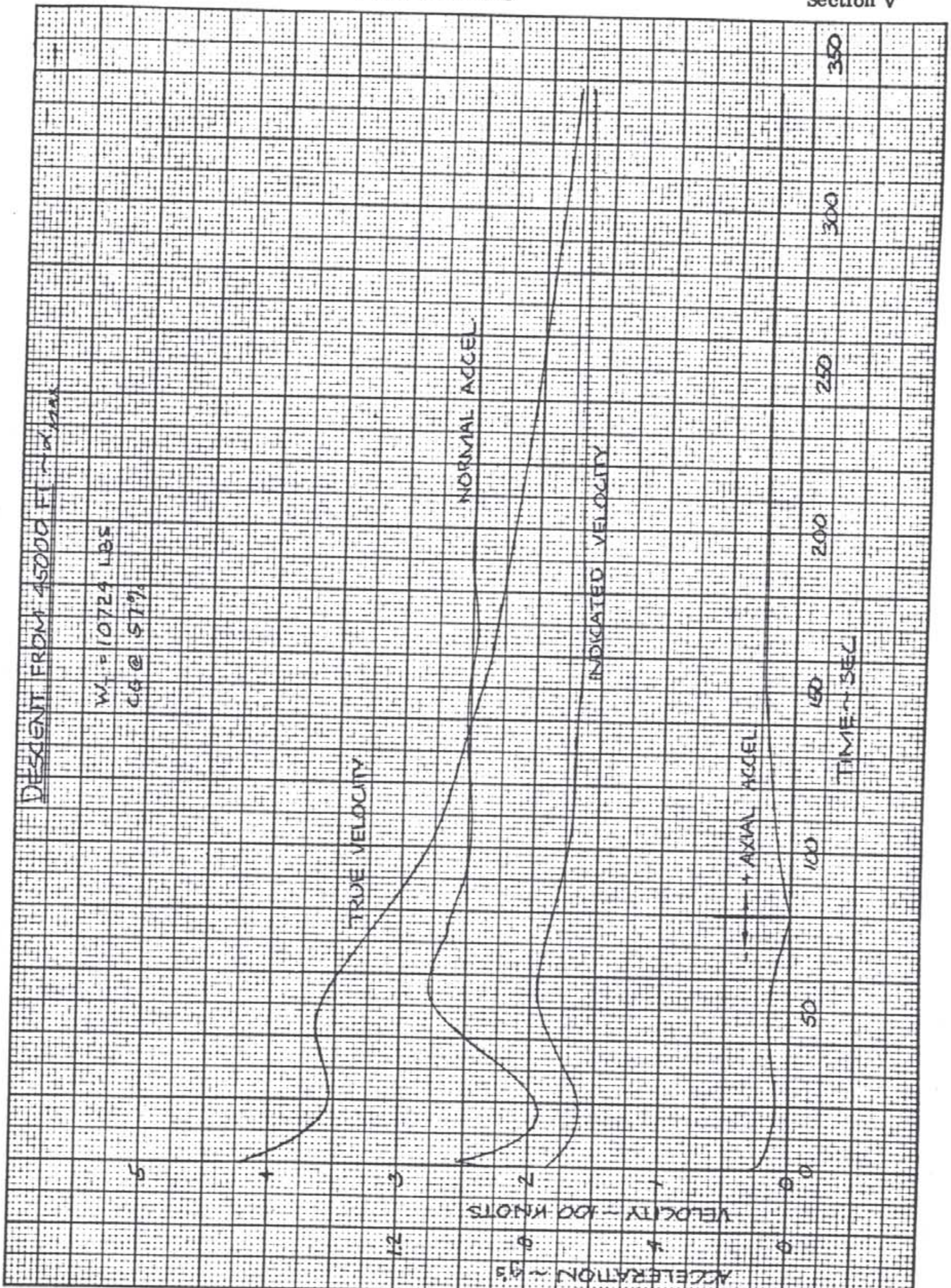


Figure 5-41. Descent From 45000 Ft. α Max.

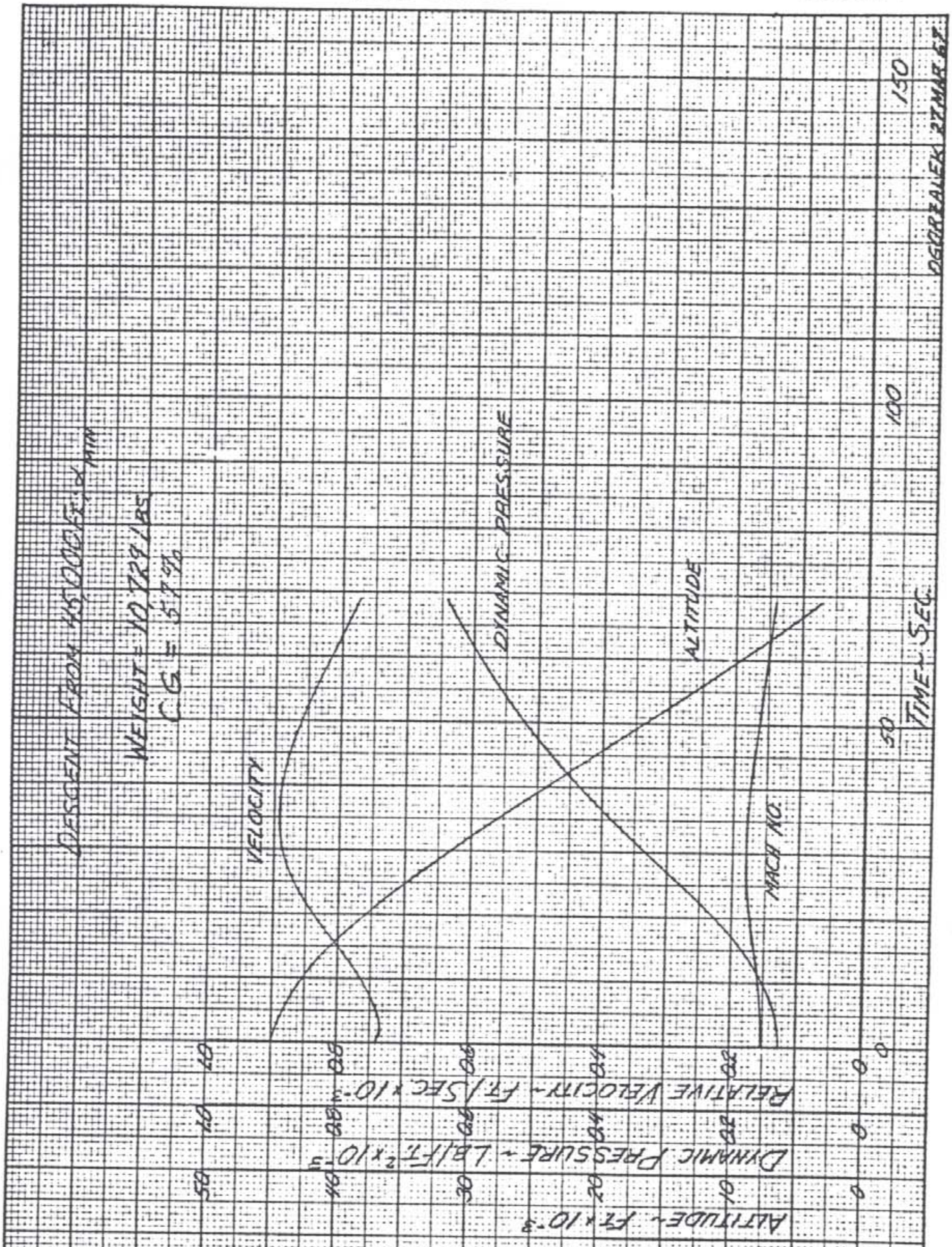


Figure 5-42. Descent From 45000 Ft. α Min.

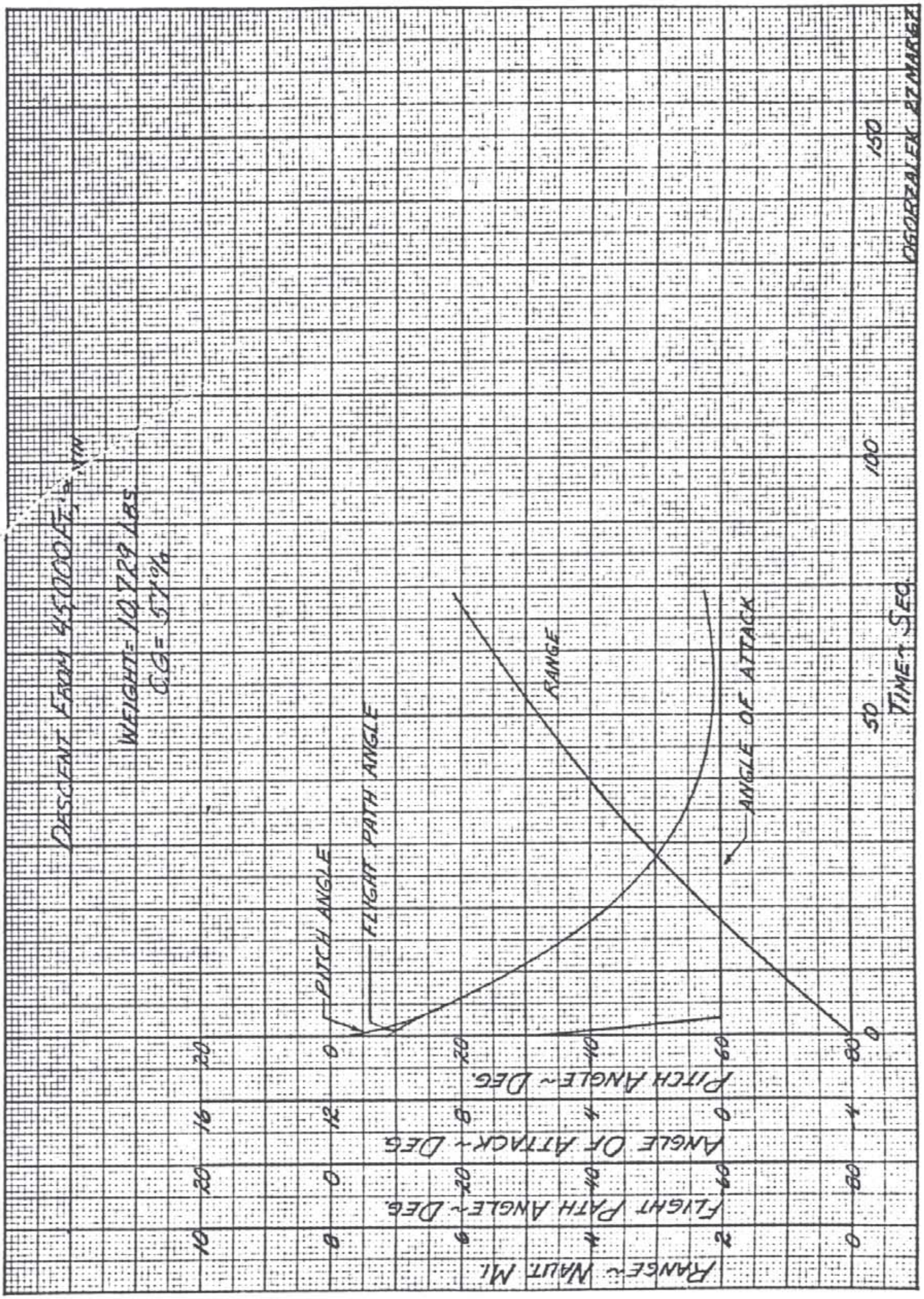


Figure 5-43. Descent From 45000 Ft. α Min.

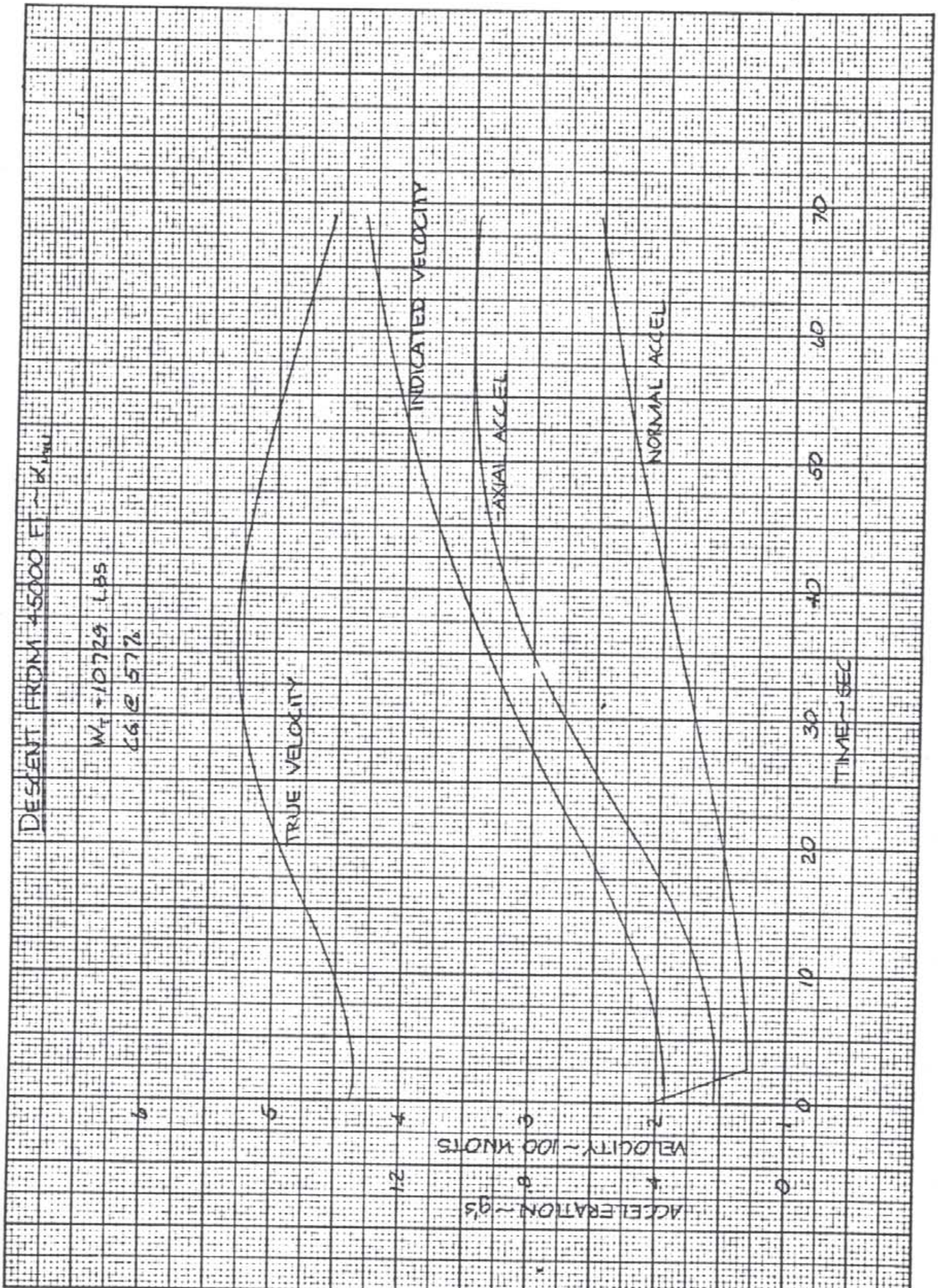


Figure 5-44. Descent From 45000 Ft. α Min.

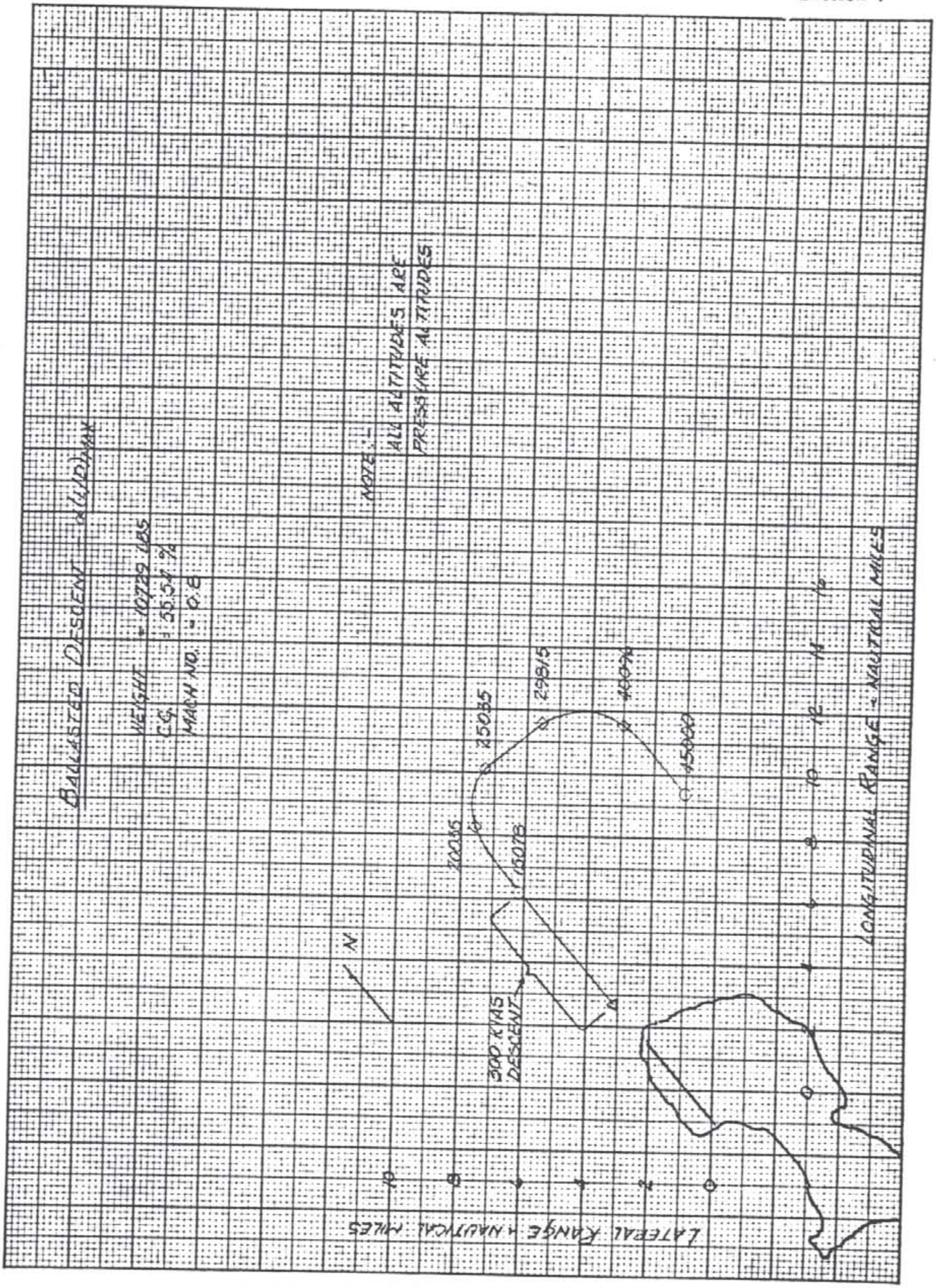


Figure 5-45. Ballasted Descent α (L/D) Max.

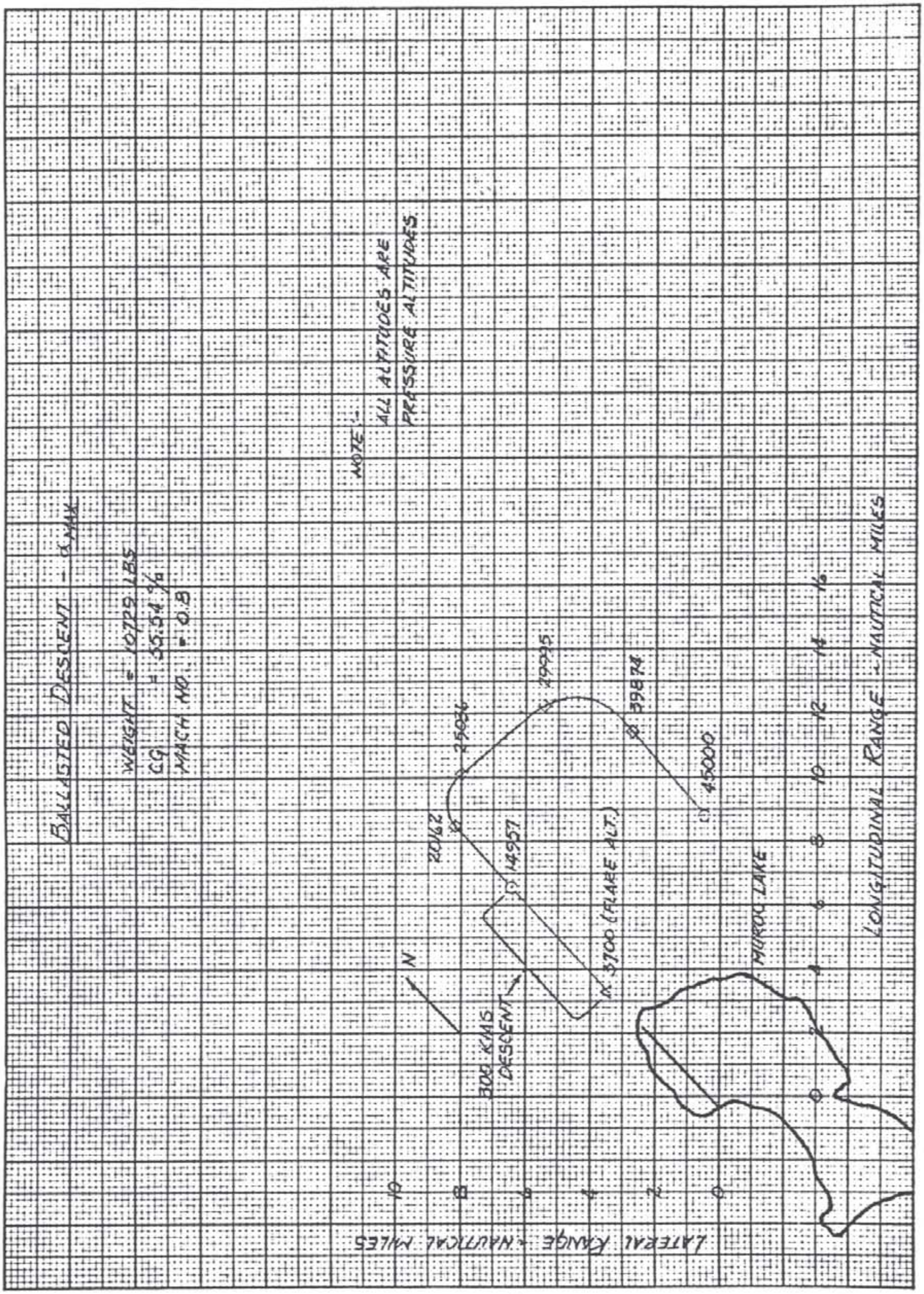


Figure 5-46. Ballasted Descent α Max.

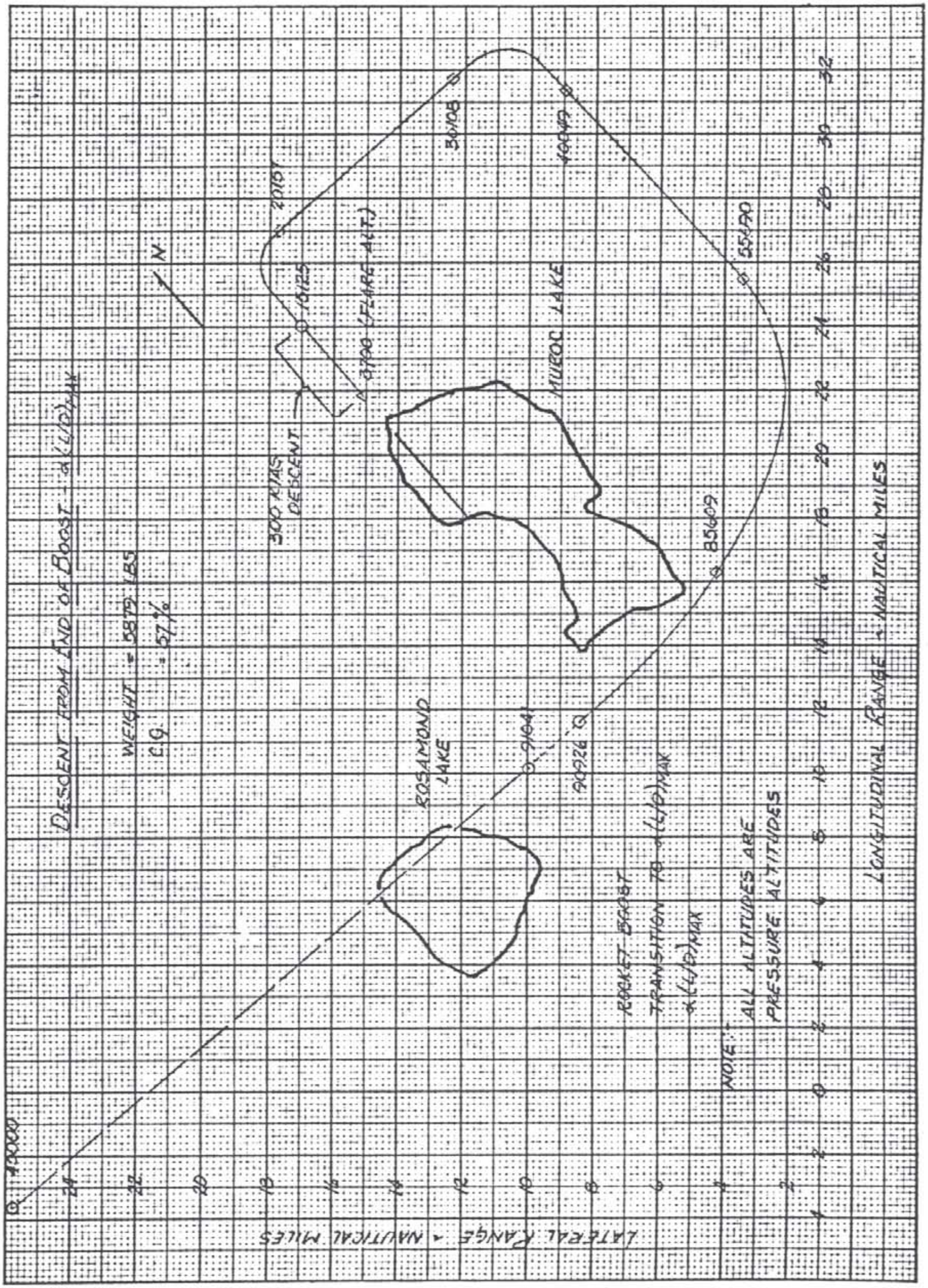


Figure 5-47. Descent From End of Boost α (L/D) Max.

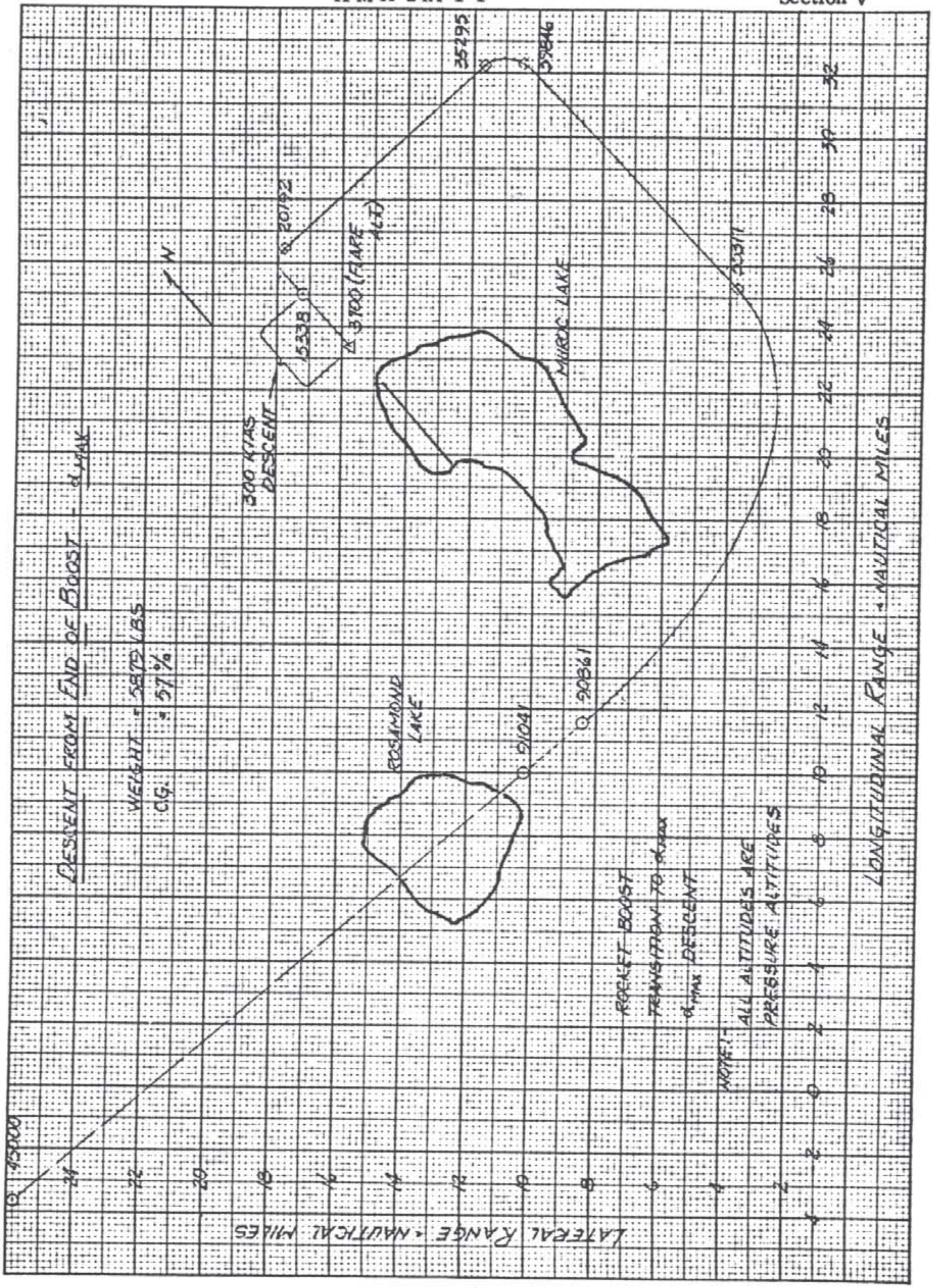


Figure 5-48. Descent From End of Boost α Max.

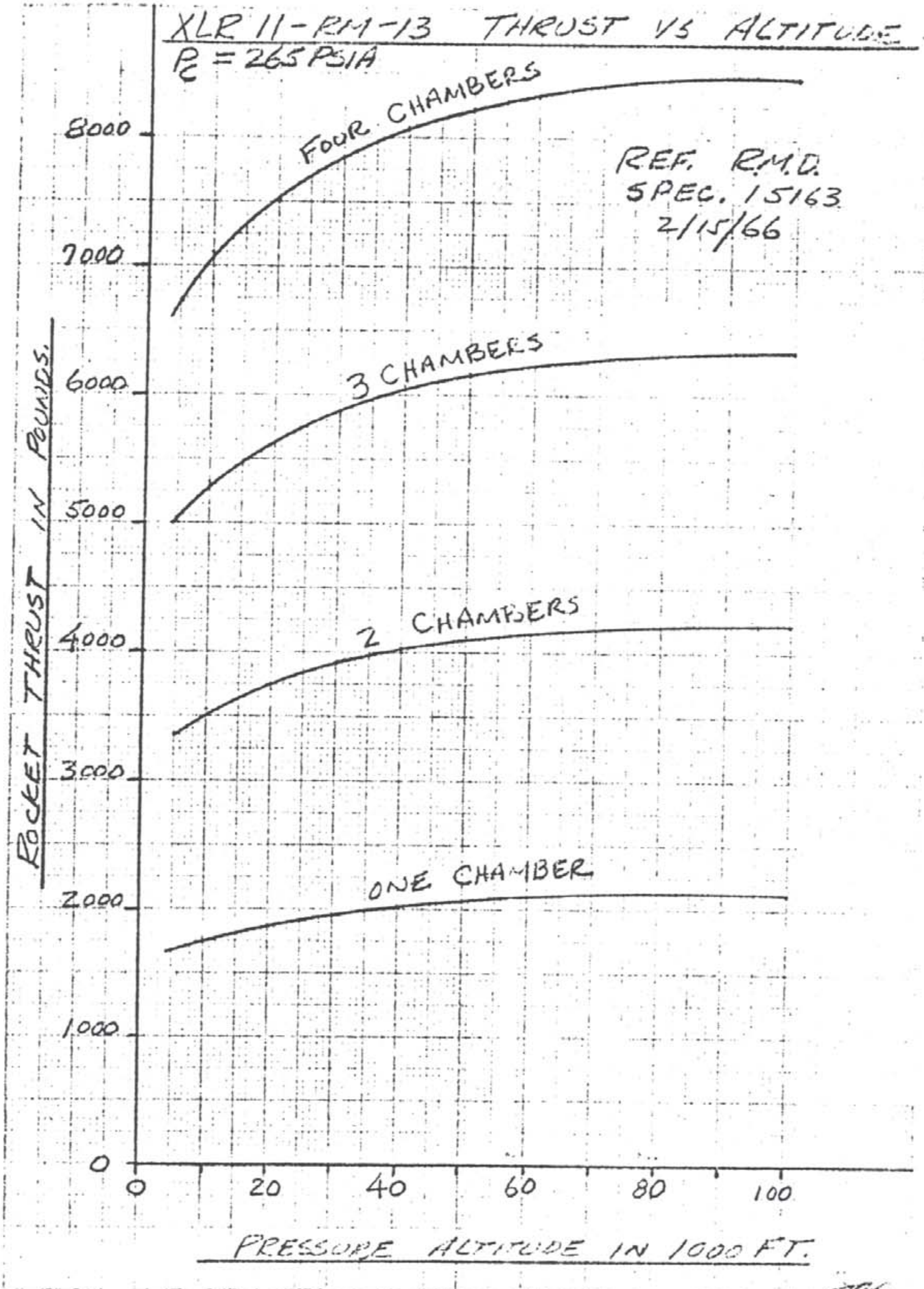


Figure 5-49. Rocket Thrust in Pounds.

function of engine burning time and was limited between values of $\alpha_{max.} = 16.0$ and $\alpha_{min.} = 6.0^{o}$. The α max. limit was dictated by a lateral stability constraint in the transonic region and the $\alpha_{min.}$ was dictated by an unfavorable Dutch Roll mode at burnout.

The initial conditions for the nominal boost trajectory are:

Altitude	=	45,000 feet
Mach	=	0.8
α	=	-3.0 degrees
Weight	=	10729 pounds

The burnout conditions resulting from optimizing the boost phase are:

Altitude	=	91,000 feet
Mach	=	1.92
α	=	1.2 degrees
Weight	=	5879 pounds

Figures 5-50, 5-51 and 5-52 evaluate this boost phase and provide the following information: Figure 5-50 shows the dynamic pressure (q), altitude, velocity, and Mach number; Figure 5-51 gives the boost time histories of pitch angle (θ), angle-of-attack (α), flight path angle (γ), and range; Figure 5-52 shows the time histories of normal and axial accelerations (g's) and indicated and true velocities in knots

Figures 5-53, 5-54, and 5-55 give the results of the boost trajectory beginning at a Mach number of 0.6 and an altitude of 45,000 feet. The α time history was not optimized, and therefore uses the same α variation as was prescribed for the nominal boost trajectory.

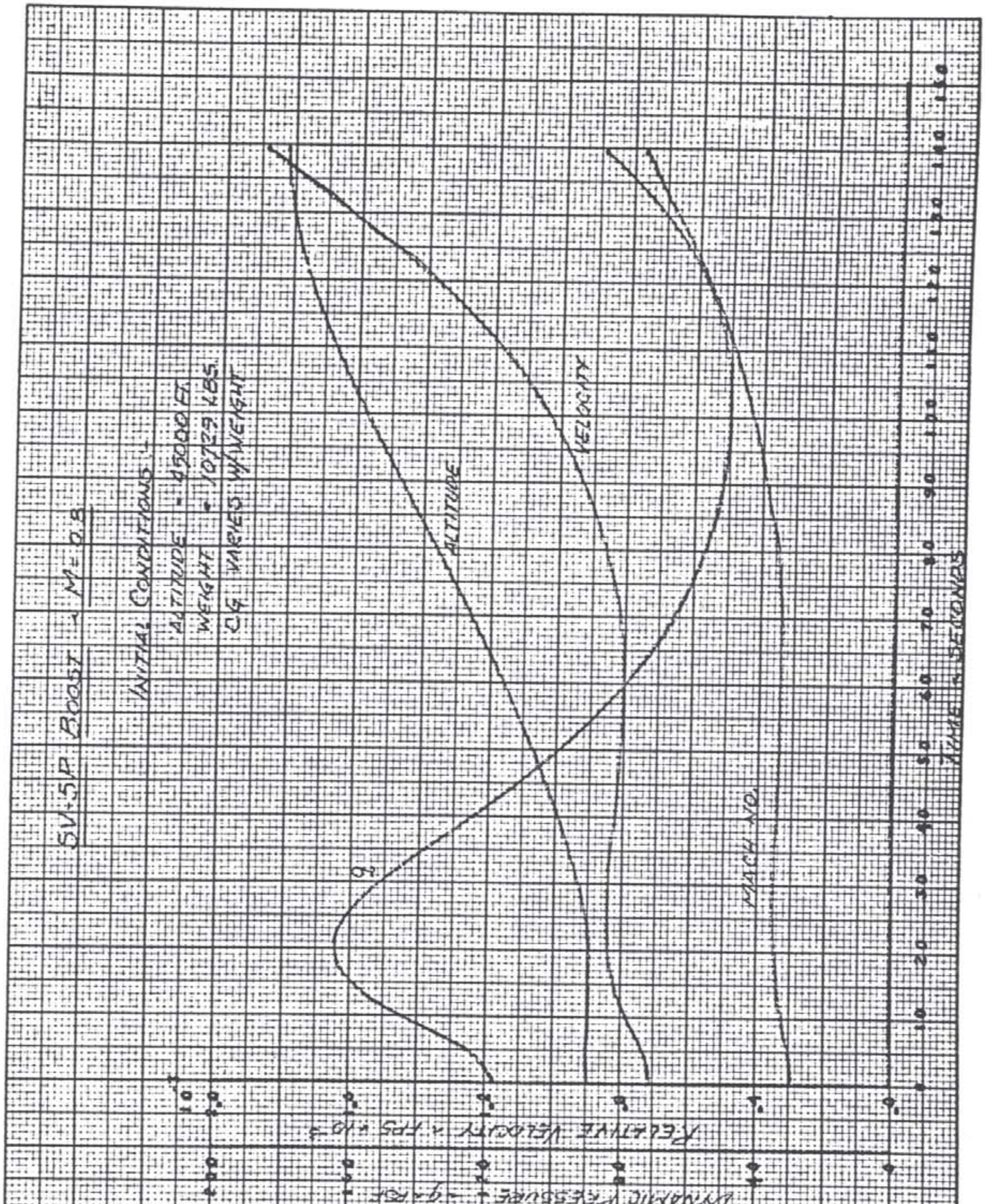


Figure 5-50. X-24A Boost ~ M=0.8.

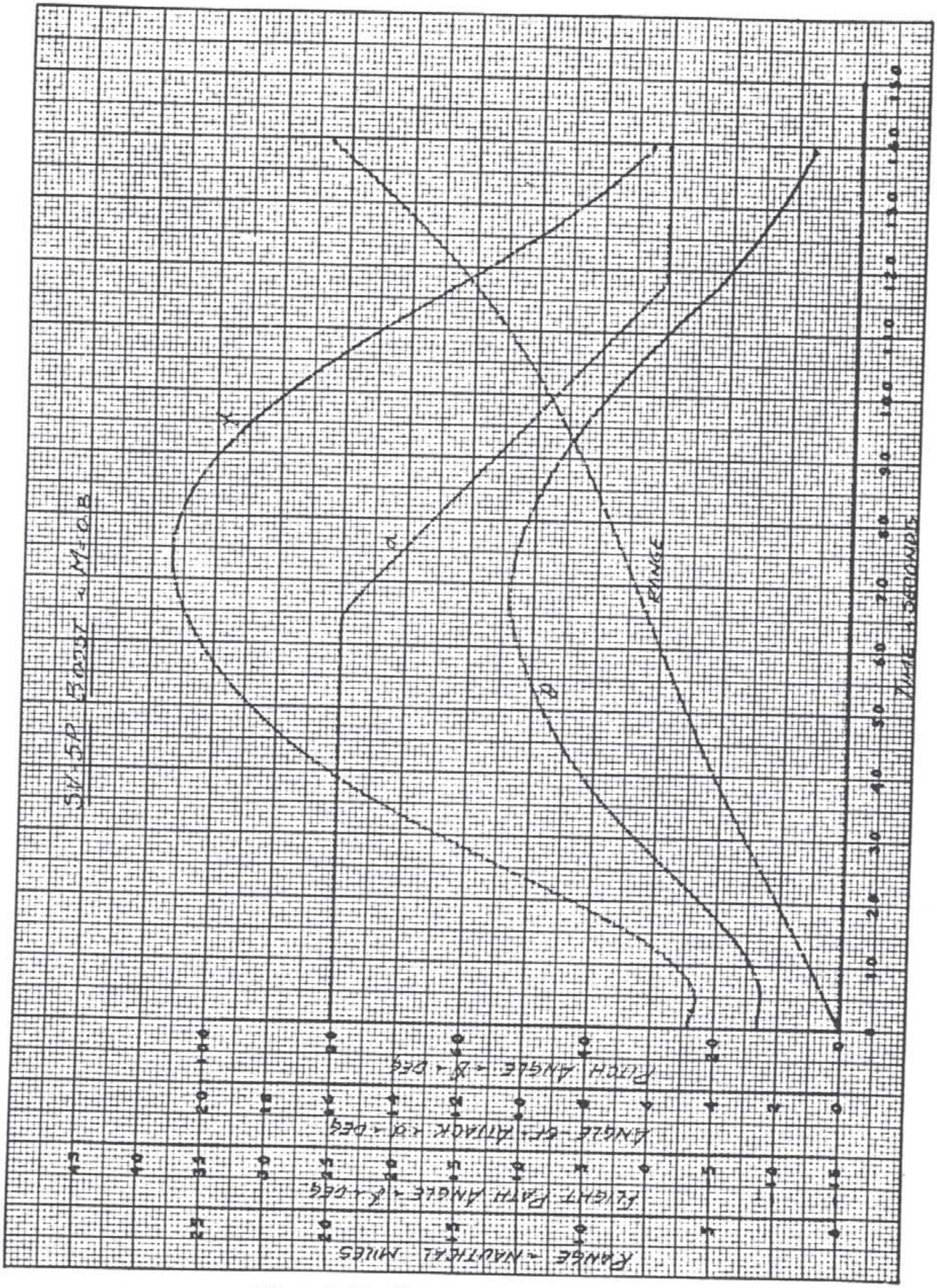


Figure 5-51. X-24A Boost ∠ M=0.8.

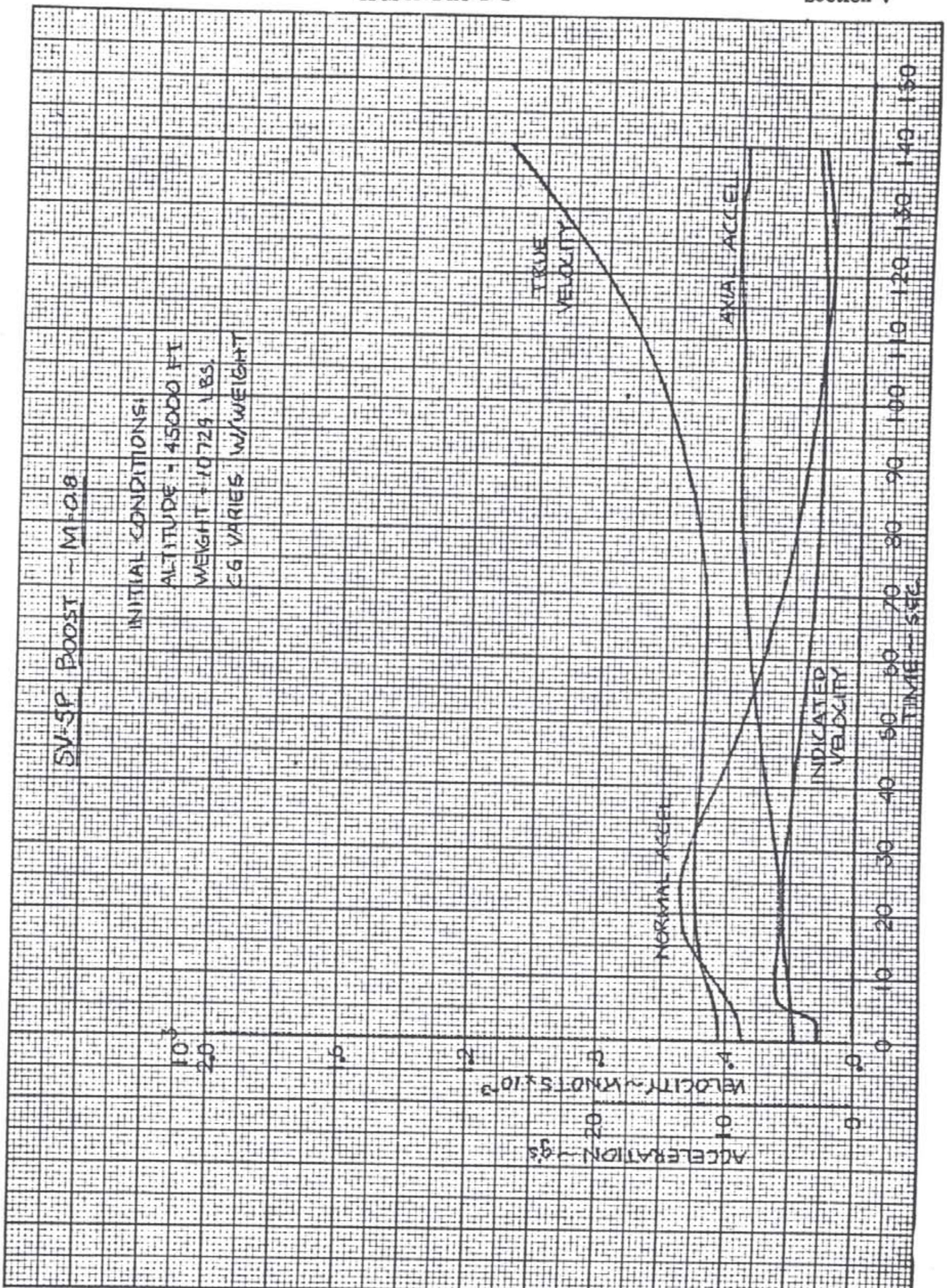


Figure 5-52. X-24 A Boost λ M=0.8.

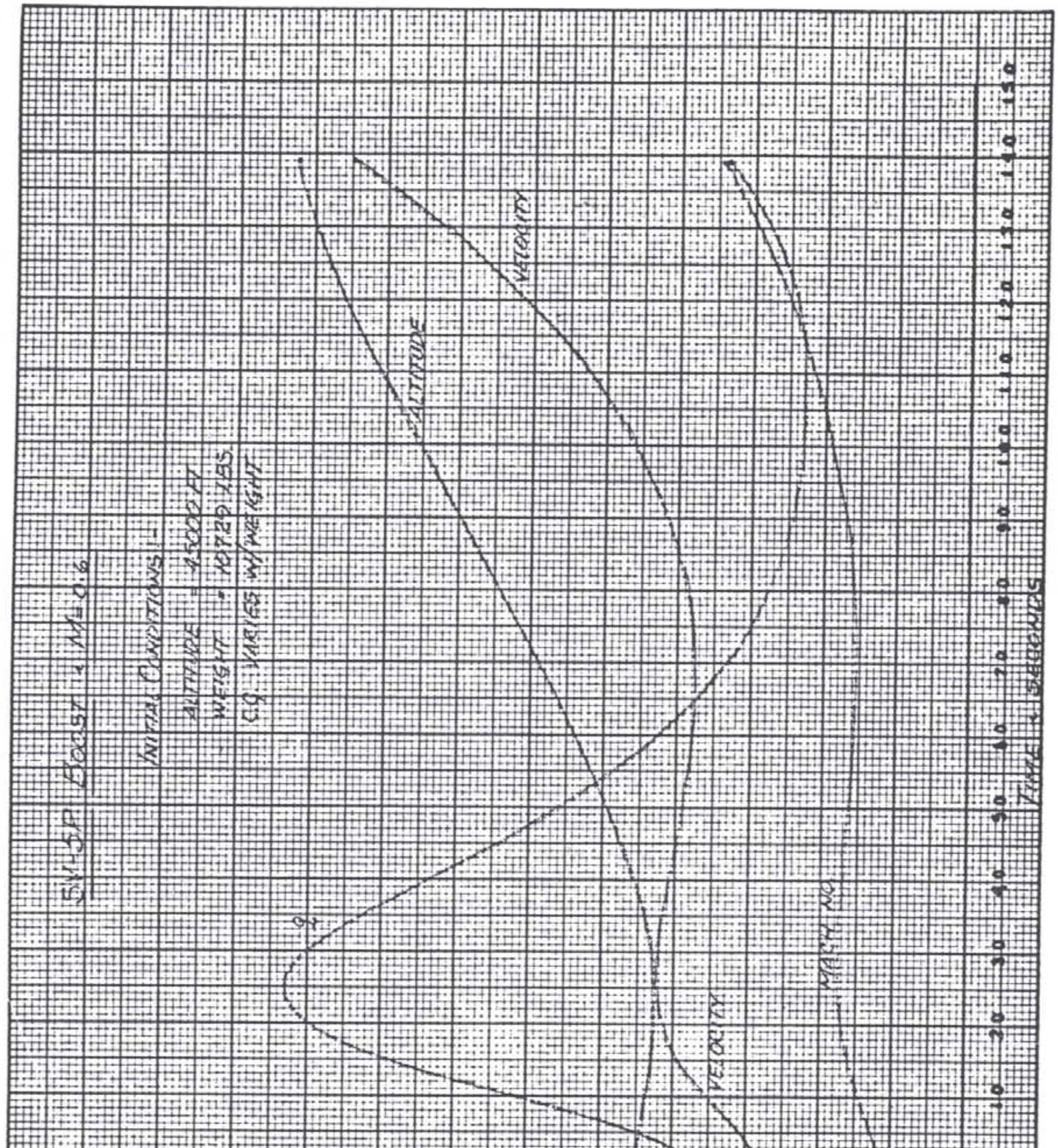


Figure 5-53. X-24A Boost ∠ M=0.6.

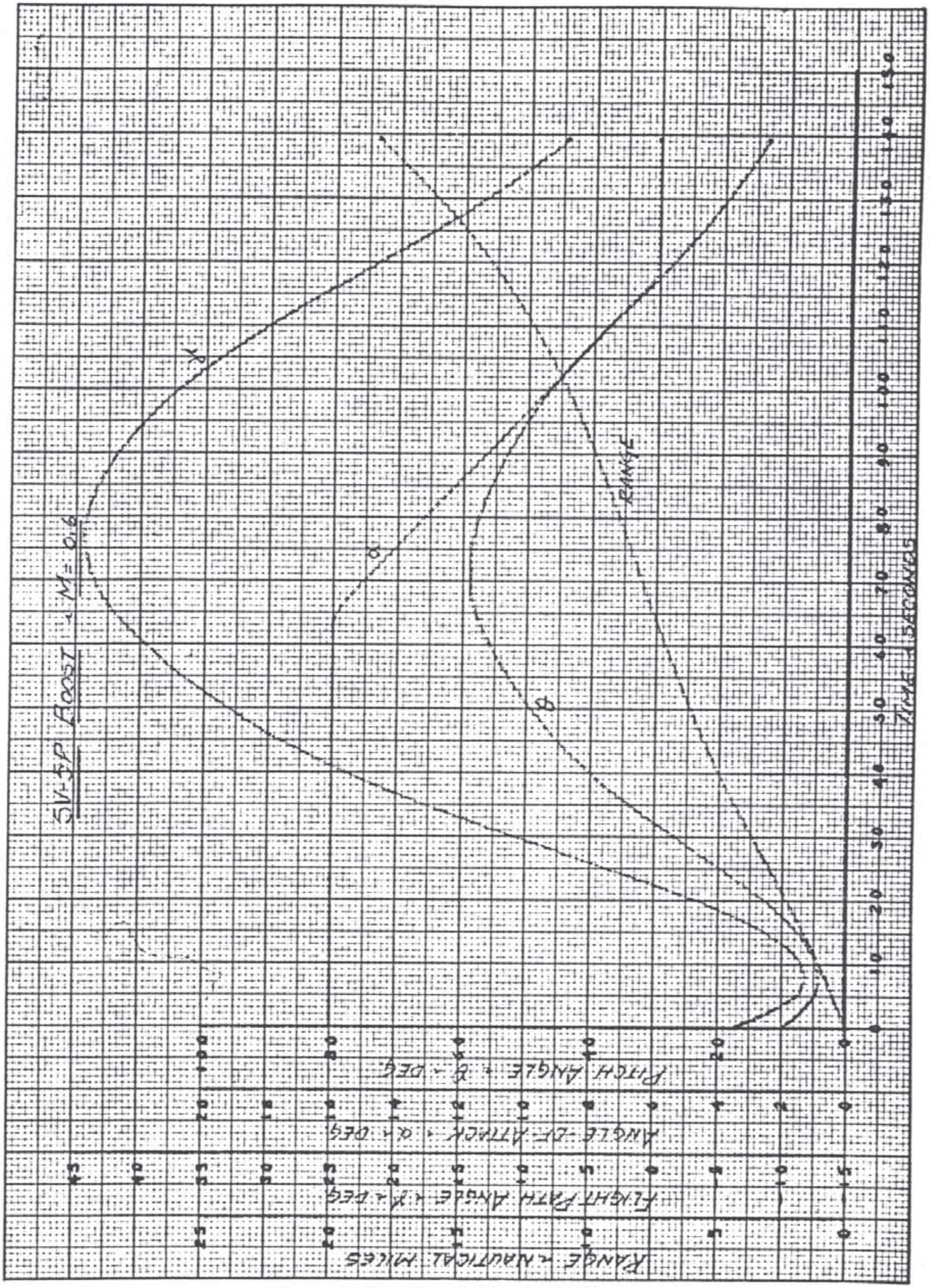


Figure 5-54. X-24A Boost ~ M= 0.6.

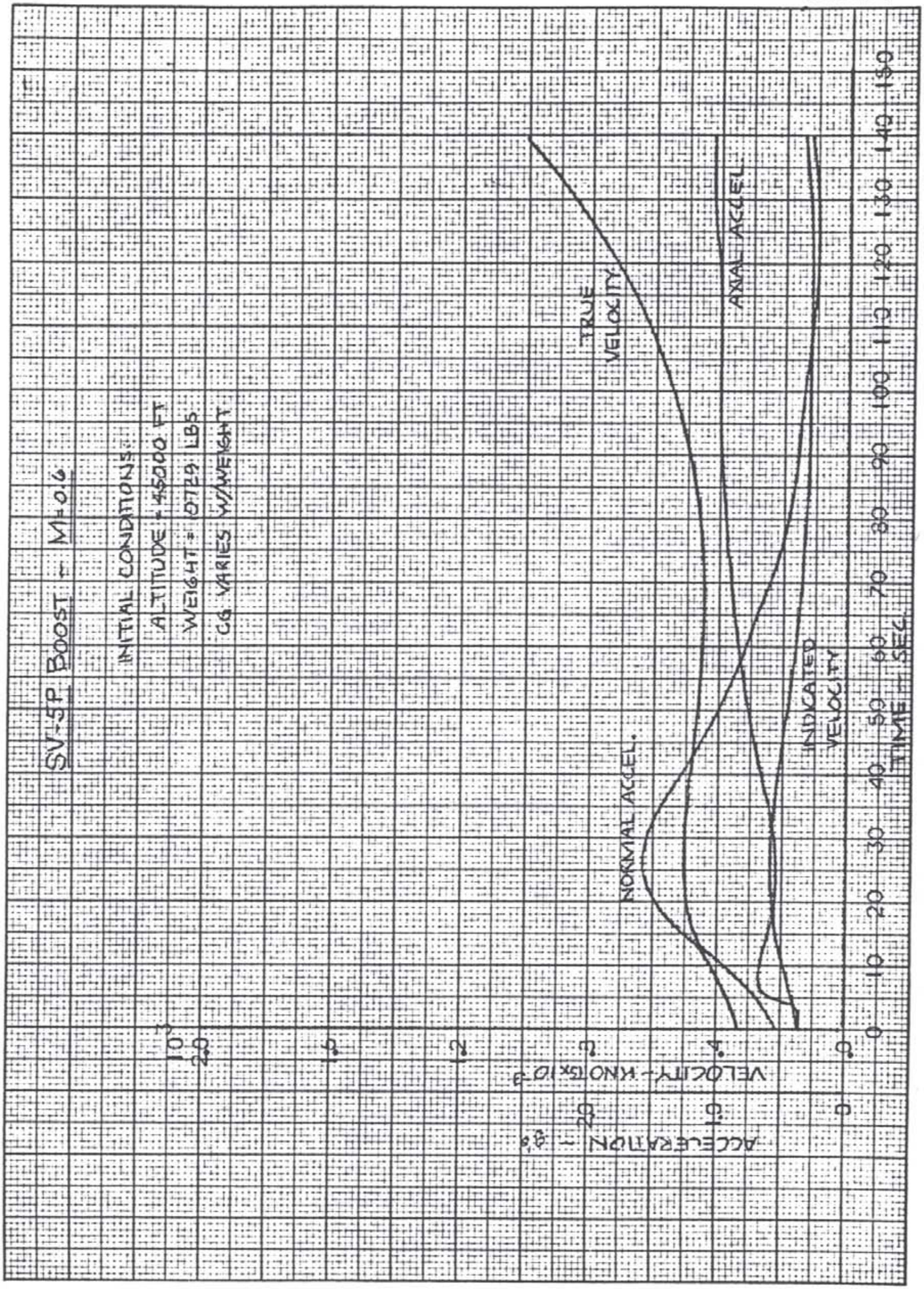


Figure 5-55. X-24A Boost - M=0.6.

In both boost conditions analyzed, the change in the aerodynamic coefficients due to center of gravity change resulting from burning fuel was taken into account.

5-8. DESCENT FROM BURNOUT

The descent trajectories from the end of the powered boost phase involve three variations in angle-of-attack (α), Mach number histories. They are (1) the α for maximum lift/drag ratio constrained only during the transonic flight regime because of dynamic stability, (2) the maximum α, Mach number history, likewise constrained in the transonic region, and (3) the minimum α, which is α = 0 degrees.

At the end of the boost phase the $\alpha = 6.0$ degrees and the Mach number is 1.92. Therefore, in order to acquire the above three variations, a transition must occur after burnout. This change in α was accomplished by ramping the α at a rate of 2 deg./sec. until it was on the prescribed α, M profile. The α for $(L/D)_{max.}$ and $\alpha_{max.}$ transitions required a +2 deg./sec. change, and the $\alpha_{min.}$ condition required a -2 deg./sec. change in α. This rate is not excessive and does not hamper the stability of the vehicle or capabilities of the pilot. During the transition and the descent there is no roll maneuver ($\phi = 0^{o}$).

Figures 5-56, 5-57 and 5-58 give the results for the α for $(L/D)_{max.}$ descent and provide the same parameter time histories as for the boost trajectories. Likewise, Figures 5-59, 5-60, 5-61 and 5-62, 5-63, 5-64 give the results for $\alpha_{max.}$ and $\alpha_{min.}$ descents, respectively.

All descent trajectories were terminated at an altitude of 3700 feet, the nominal altitude for initiating the landing flare.

Two typical mission profiles are also included in the X-24A performance analysis. These are boost, transition, and descents to flare altitude at Edwards Air Force

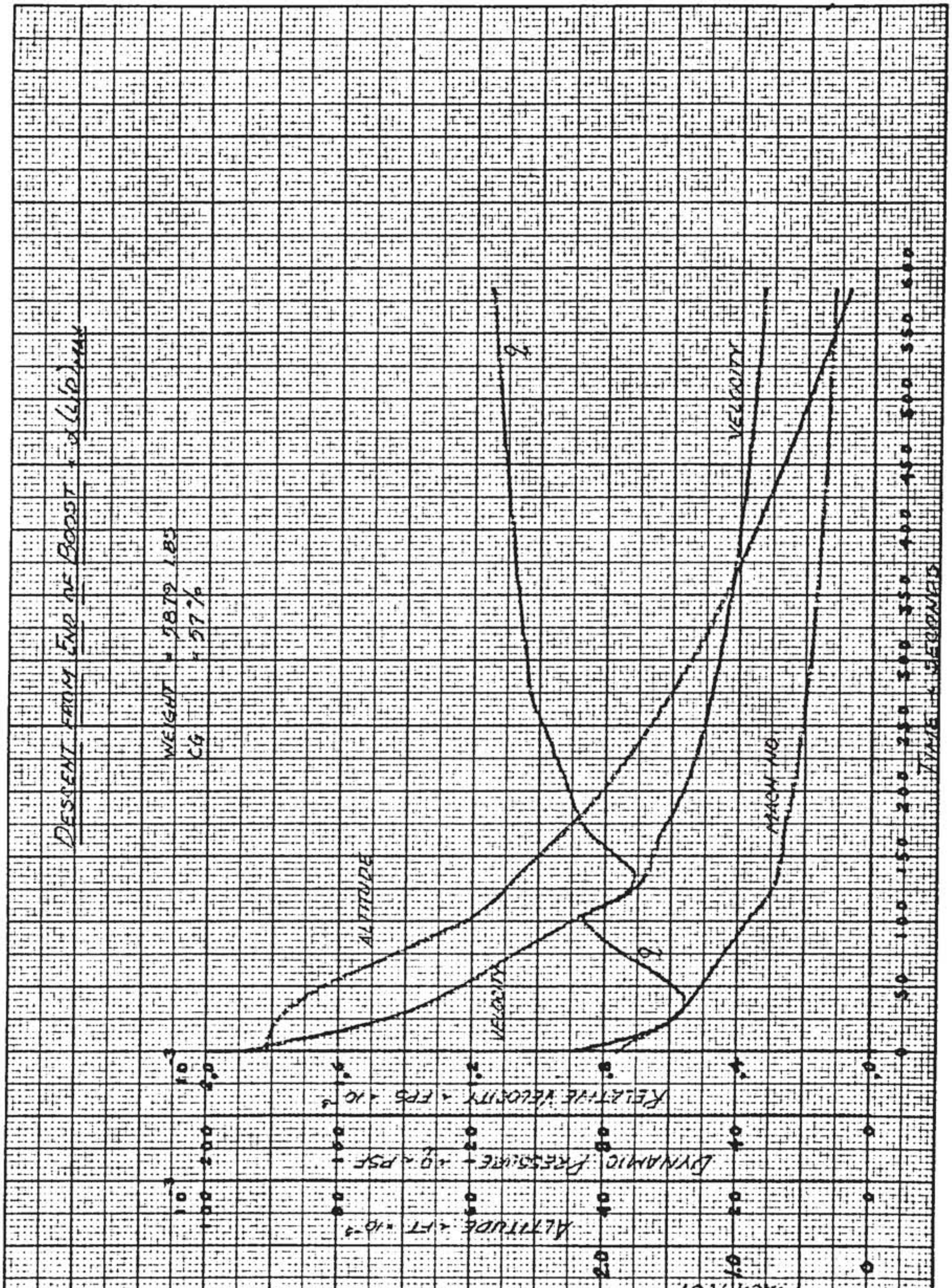


Figure 5-56. Descent From End of Boost α (L/D) Max.

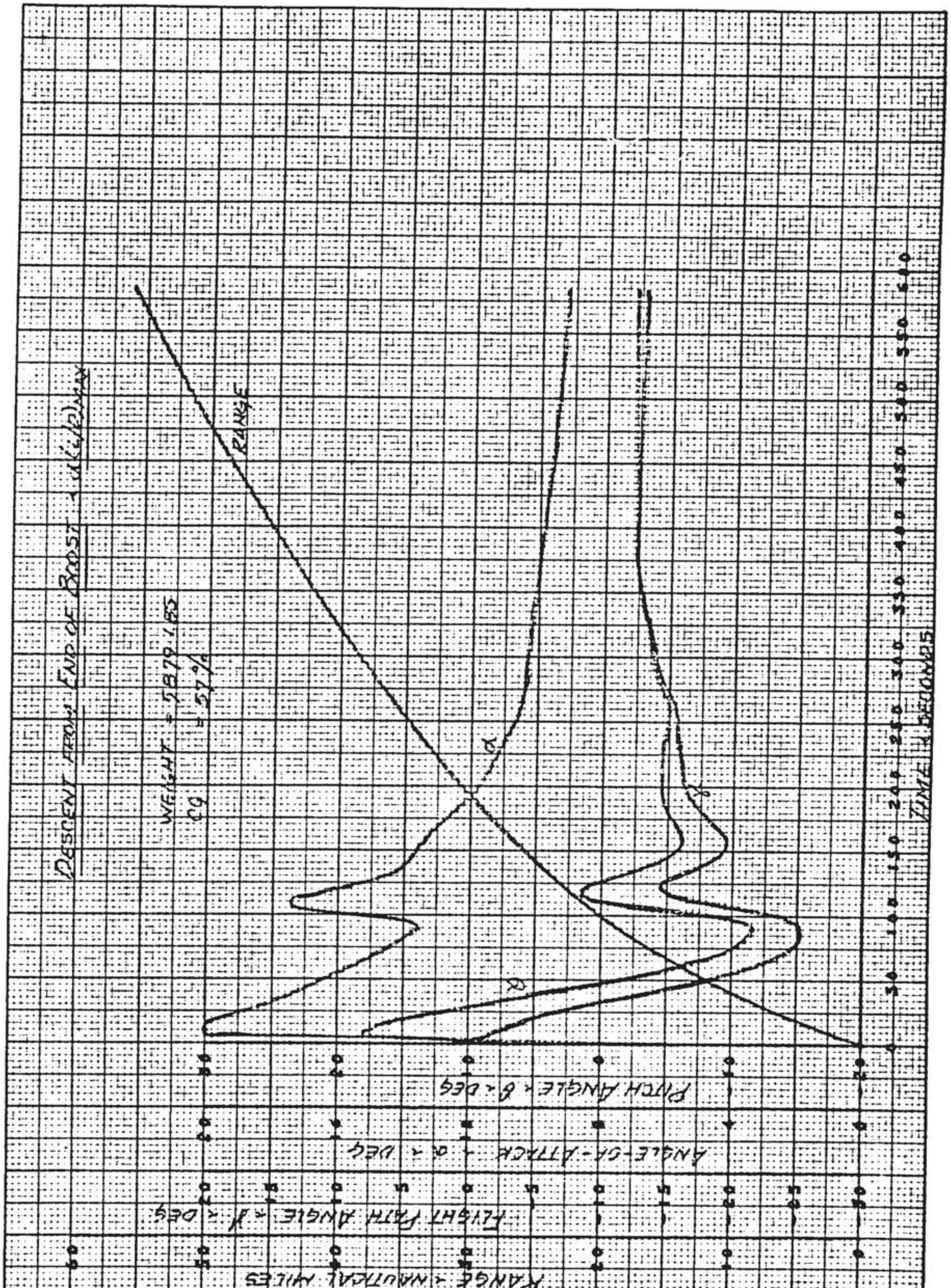


Figure 5-57. Descent From End of Boost α (L/D) Max.

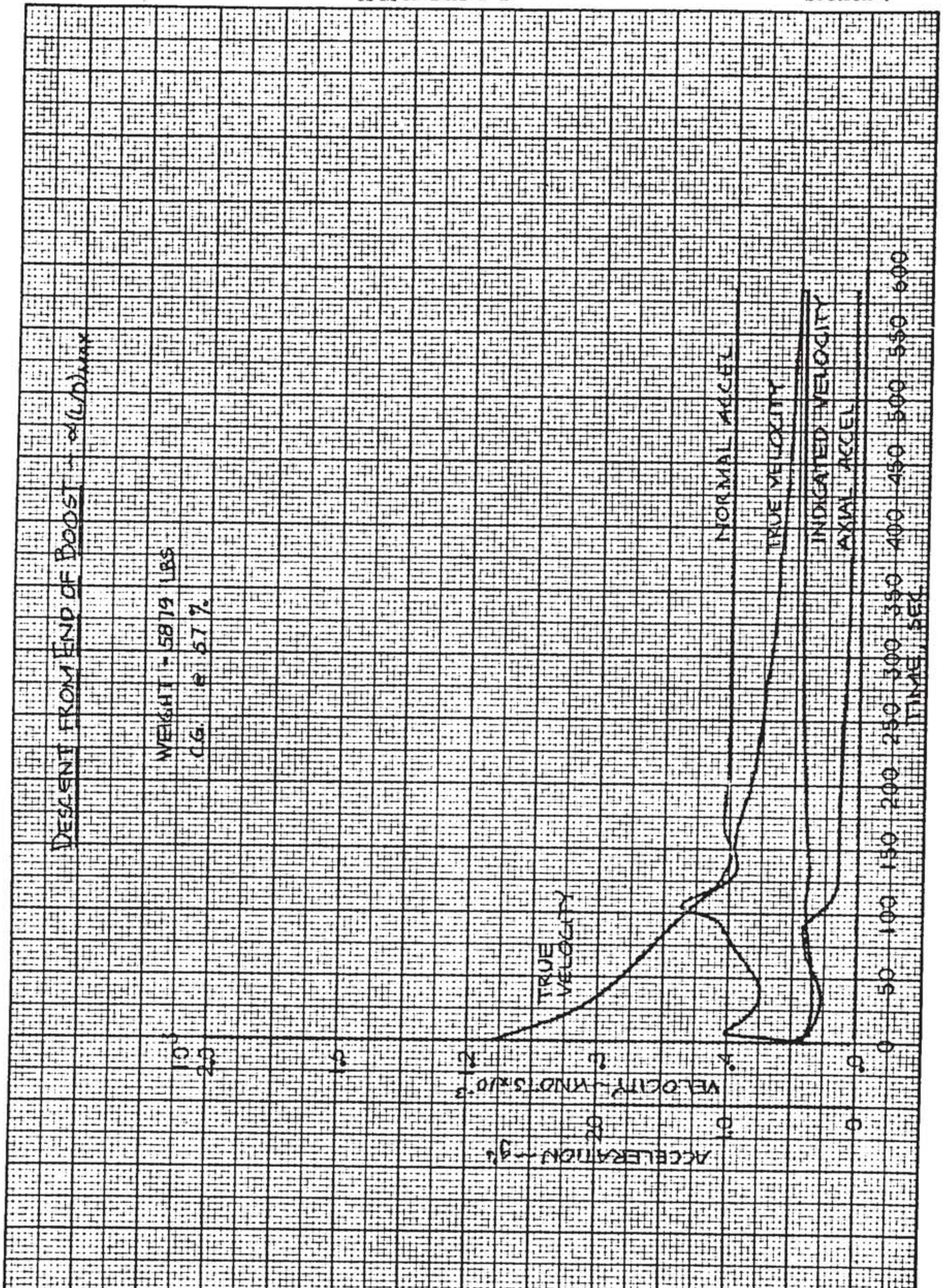


Figure 5-58. Descent From End of Boost α (L/D) Max.

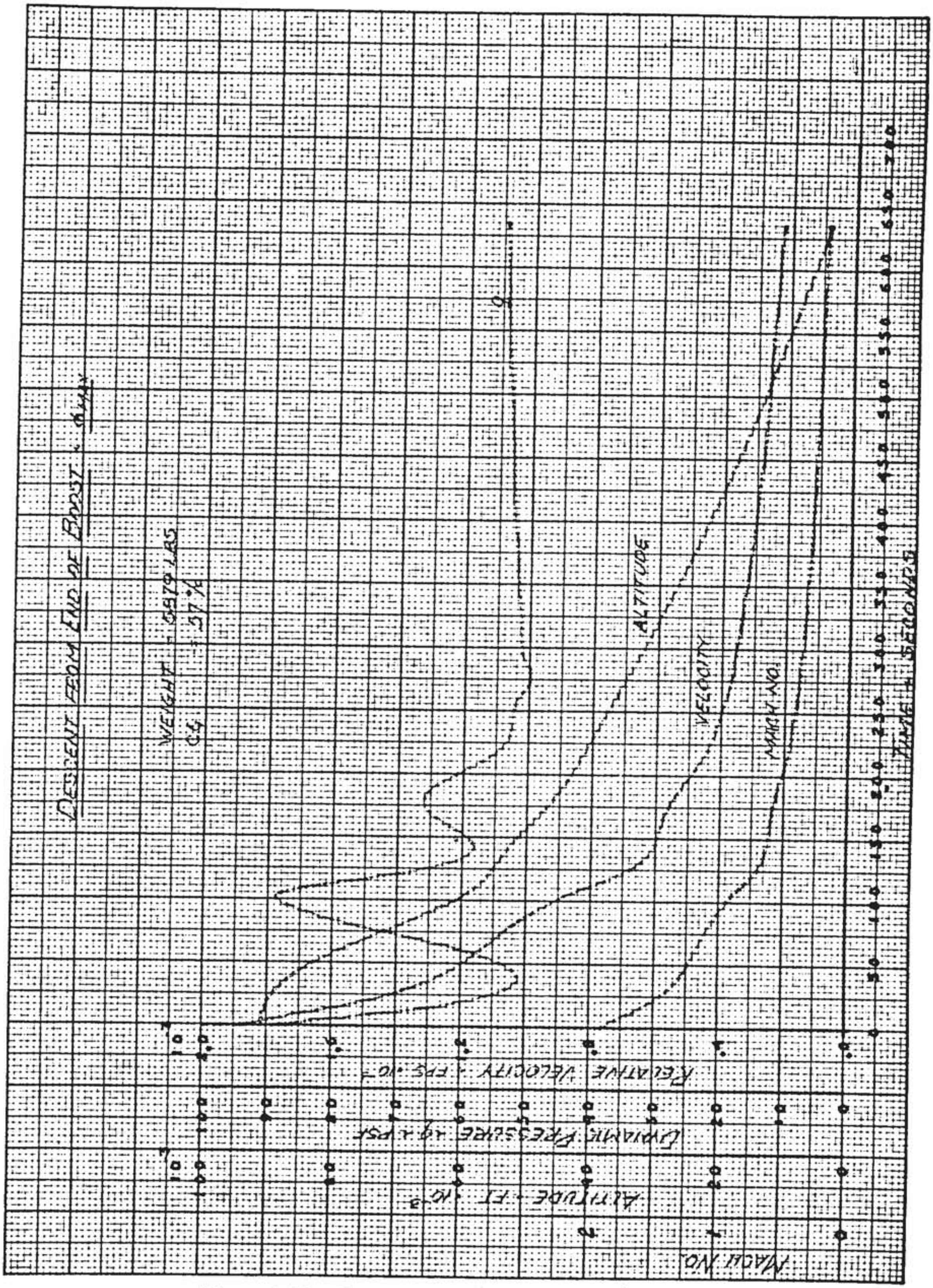


Figure 5-59. Descent From End of Boost α Max.

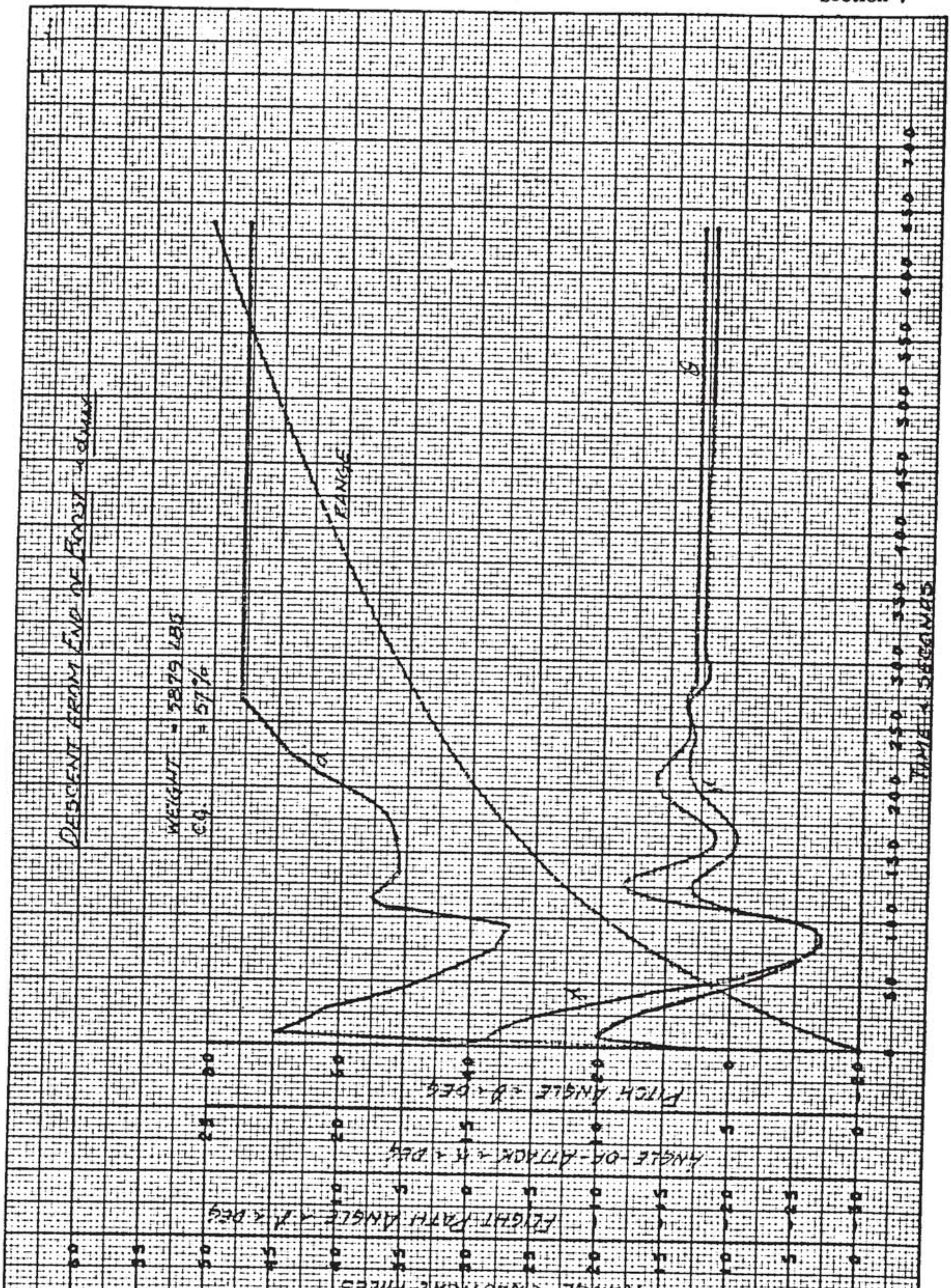


Figure 5-60. Descent From End of Boost α Max.

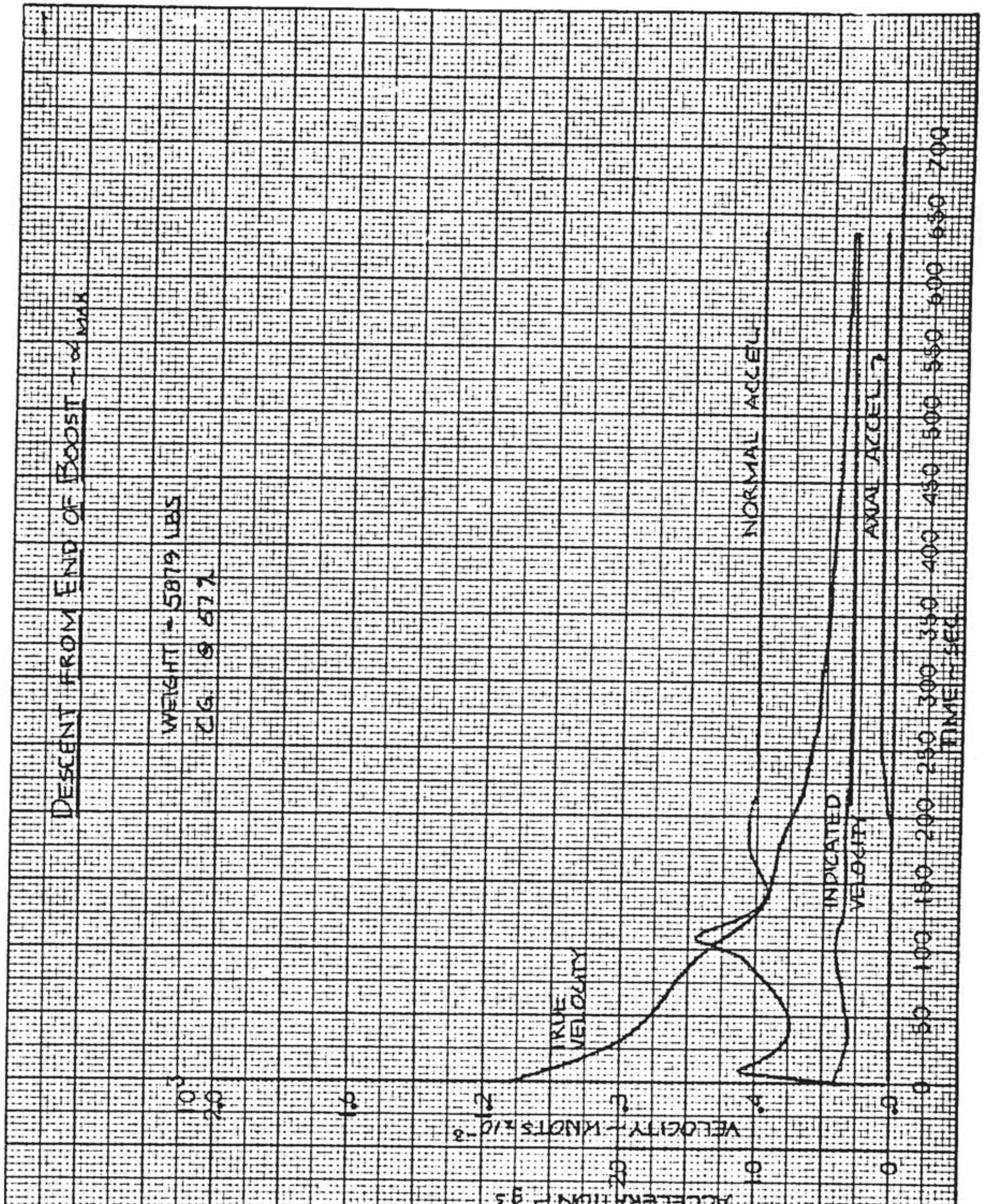


Figure 5-61. Descent From End of Boost α Max.

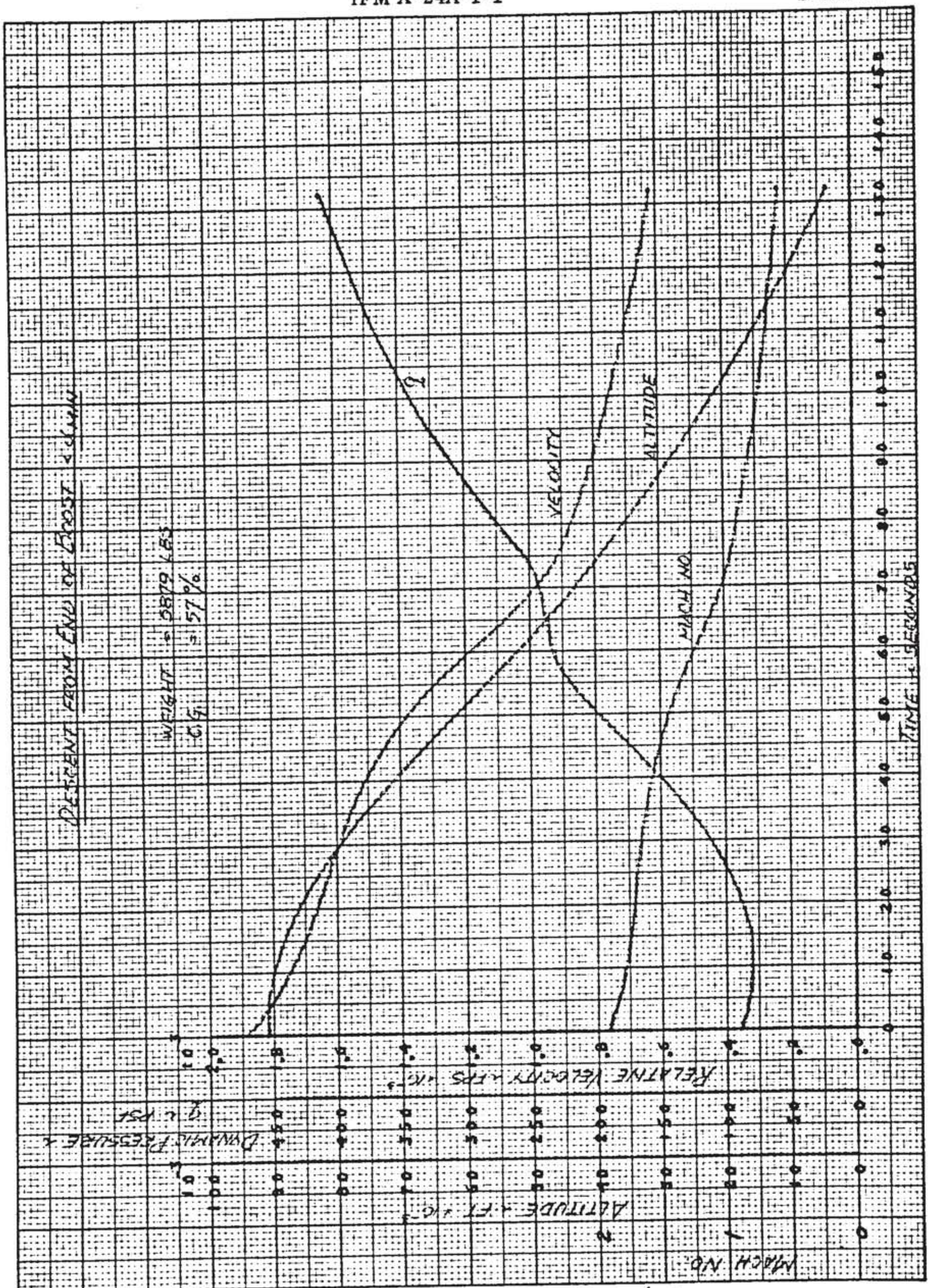


Figure 5-62. Descent From End of Boost ∝ Min.

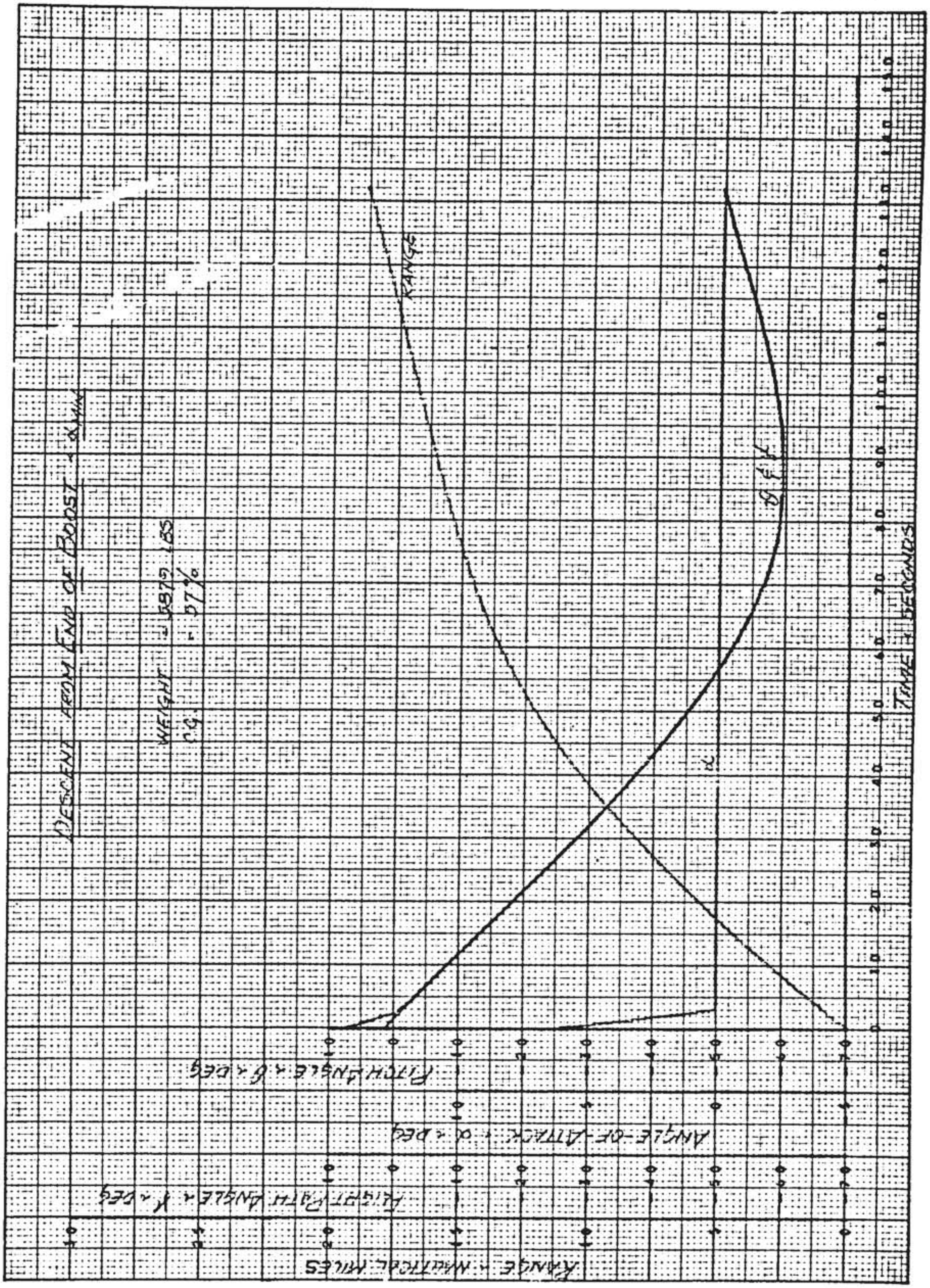


Figure 5-63. Descent From End of Boost α Min.

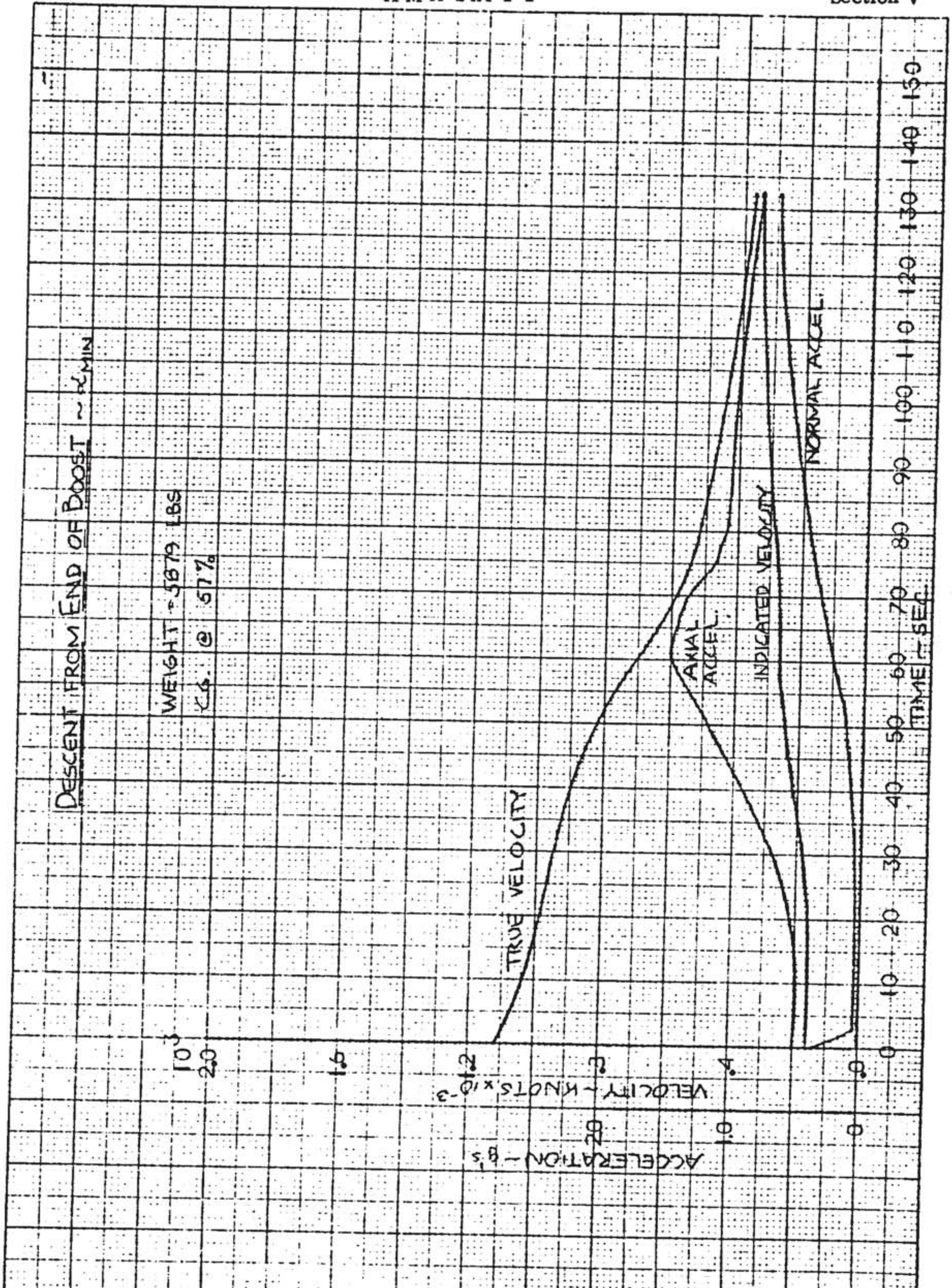


Figure 5-64. Descent From End of Boost α Min.

Base, at α for $(L/D)_{max.}$ and $\alpha_{max.}$ Figures 5-47 and 5-48 show these ground traces, with discrete altitude check points imposed on them suitable for monitoring a pilot during the mission. All heading changes are made at roll angles of 45 degrees or less. At an altitude of approximately 15,000 feet a push-over to an indicated airspeed of 300 knots is executed and held constant in order to have an excess of kinetic energy at the flare altitude (3700 feet).

5-9. LANDING

The landing performance and handling qualities of the X-24A lifting body were evaluated using a pilot-in-the-loop fixed base simulator. This simulation utilized a strong out-the-window cue and a 6 degree-of-freedom analog computer to give the pilots a true perspective of the flight characteristics of the X-24A.

Fifteen flight conditions were investigated in the study and appear to adequately cover the effects of the study variables listed below:

(1) Vehicle Wing Loading, W/S (psf)

(2) Initial Velocity, V_o (fps)

(3) Vertical Gust Amplitude, σ_{gv} (fps)

(4) Side Wind Velocity, V_w (fps)

(5) Side Gust Amplitude, σ_{gs} (fps)

(6) Initial Cross Range Error (Offset), Y_o (ft.)

Four pilots participated in the study. All pilots were graduates of and instructors at the USAF Aerospace Research Pilots School (ARPS) at Edwards Air Force Base, California. All pilots had flight experience in the landing of "dirty" F-104's at Edwards. (F-104's have (L/D) ratios comparable to the X-24A vehicle.)

The landing technique initially used in the study was the "Ames Technique" and is composed of three separate and distinct phases. The initial phase of the approach is an equilibrium glide at essentially a constant glide path to an aim point short of the runway. The second phase is a constant g pull up from a relatively steep equilibrium glide path to a rather shallow final glide path. The third phase is a float out to touch down during which the vehicle decelerates to touch down velocity. This type of approach exceeded the desired sink rates at touch down, namely 5 ft/sec., and was thus modified to include a fourth phase. The fourth phase was a second flare and the pilots were instructed to perform this flare to modulate their sink rate. The altitude at which this flare was initiated was left to the pilot's discretion and was normally begun at an altitude of approximately 50 feet. This resulting fourth phase maneuver allowed the pilots more flexibility in modulating speed and thus provided sink rates in the order of 4 or 5 ft/sec. at touch down.

Conclusions derived from the study are listed below and provide a basis for evaluating the handling and performance characteristics of the X-24A.

(1) Pitch angle at touch down is inversely dependent upon velocity at touch down (low velocity, high θ).

(2) Cross range error at altitude did not degrade landing.

(3) Realistic vertical gust amplitudes have a negligible effect on landing, unless a large gust is encountered close to touch down.

(4) Side gusts have a considerable effect upon lateral-directional handling qualities, but little effect on sink rate performance at touch down.

(5) Side wind utilized was not large enough to clearly demonstrate this effect. However, kinetic energy was reduced and an increase in heading error at touch down was noted.

(6) High wing loading required higher touch down velocities to provide reasonable sink rates.

(7) Handling qualities of vehicle were rated acceptable.

(8) Landing gear had sufficient trim effect.

(9) SAS failures, the roll rate feed back loop is most critical. Pilots felt it was possible to land the vehicle with both pitch and yaw loops inoperative.

This analysis is evaluated in detail in the following report, "Pilot Lifting Body Landing Simulation", by Joseph A. Mandour, Milton A. Grodsky, and Dale E. Campbell, RR-78, January 1967.

Figures 5-65 and 5-66 show the time variation of vehicle velocity after touch down for light and heavy gross weights, respectively. When the vehicle decelerates below rotation velocity, the upper flaps are extended to 33° at a rate of 20 deg/sec in order to increase deceleration. Following this, brakes are applied and held until velocity is zero. Figure 5-67 shows the variation of landing distance from touch down with vehicle landing weight, using the same landing technique.

5-10. INADVERTENT ENGINE SHUTDOWN

During the powered boost phase of the X-24A there is an infinite number of flight conditions where an engine failure could cause a serious problem. The condition evaluated and deemed the worst was a most forward center of gravity position. This condition was brought about by the deceleration of the vehicle at engine shutdown resulting in the remaining fuel and oxidizer moving forward in their respective tanks. This condition is characterized by the following initial conditions:

Altitude	=	65,500 feet
Mach Number	=	0.86 at a q = 60 psf
Weight	=	8160 pounds at a c.g. = 54.32%
	α =	14.1 degrees
	γ =	38.4 degrees
	θ =	52.5 degrees

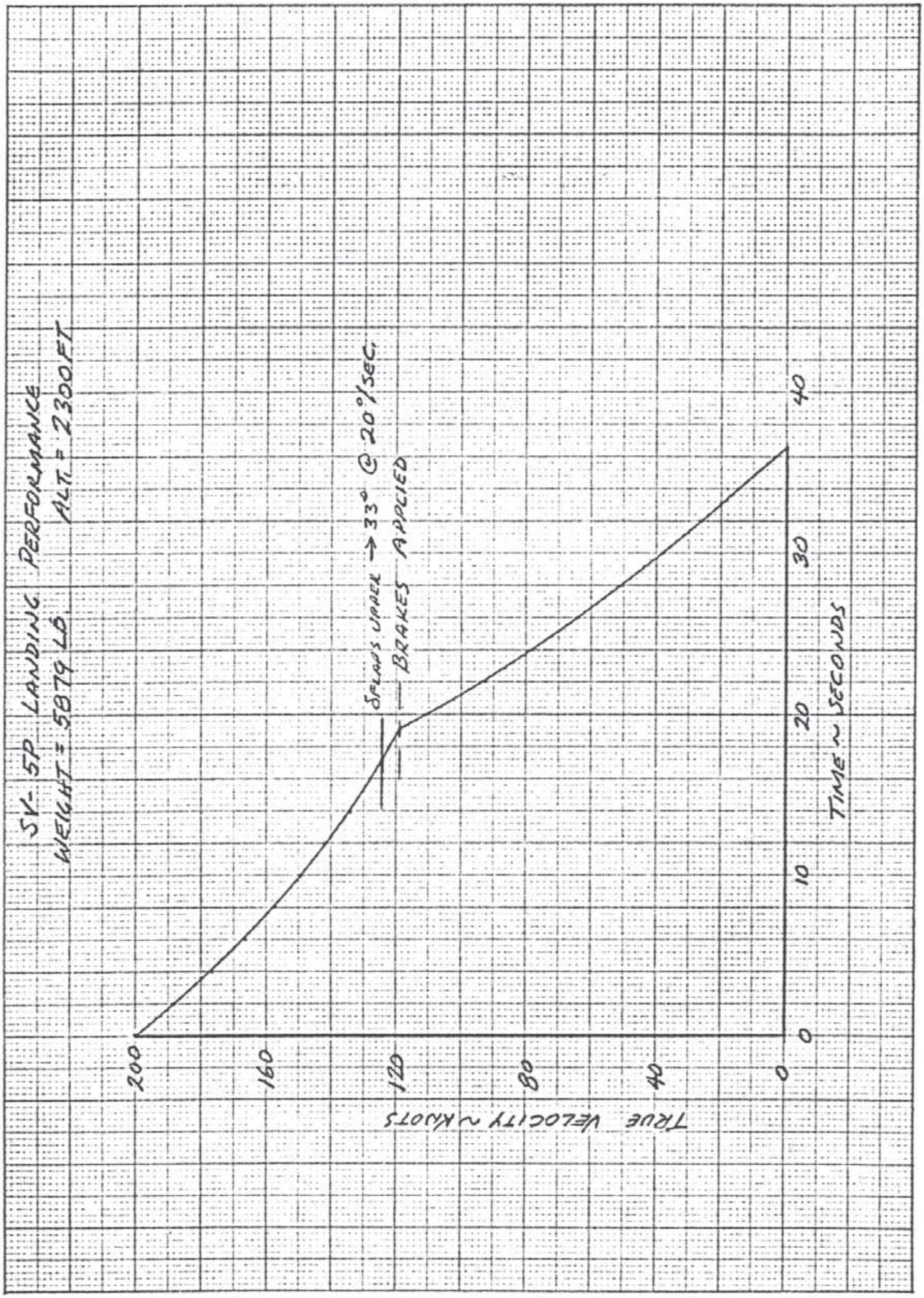


Figure 5-65. X-24A Landing Performance.

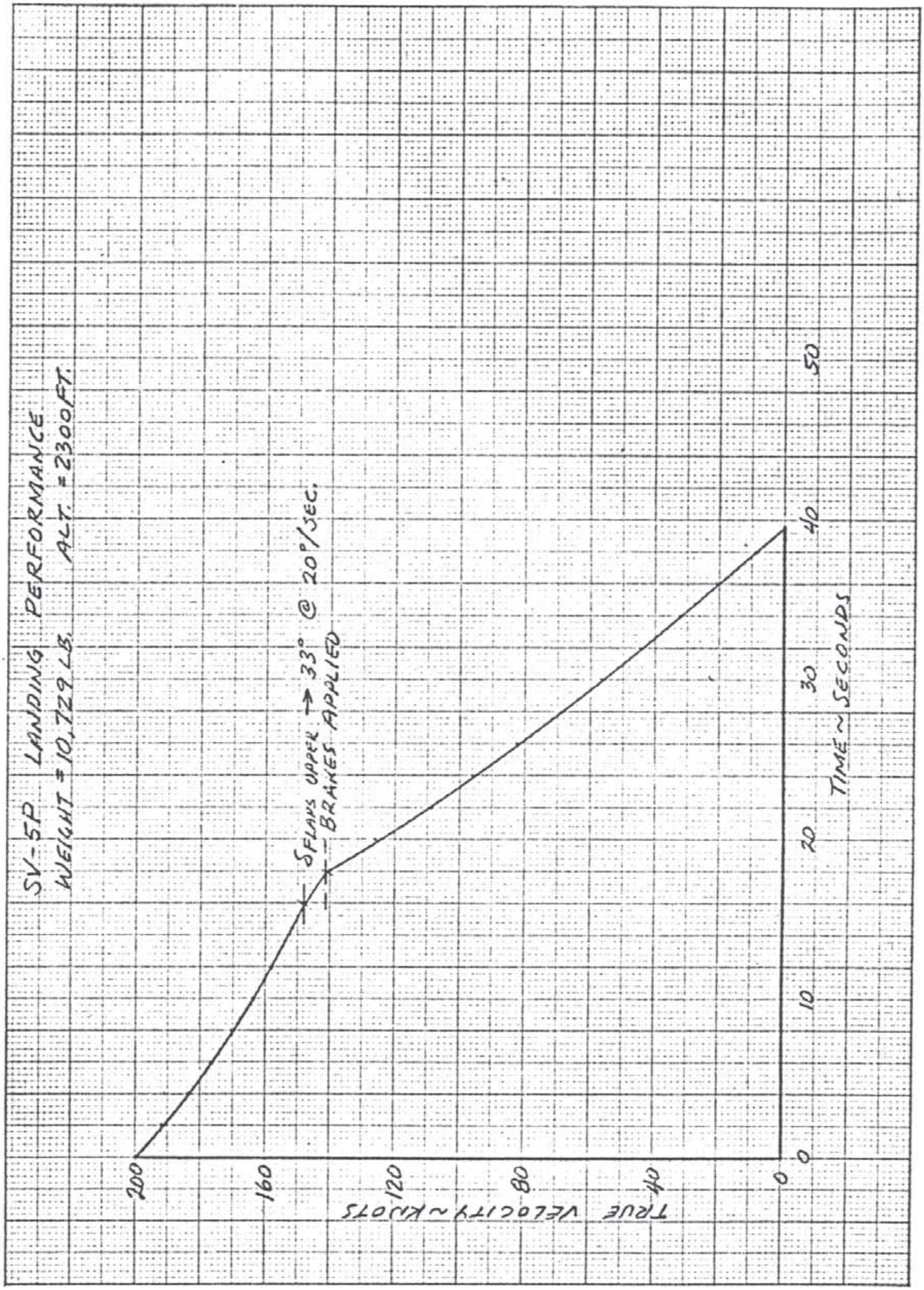


Figure 5-66. X-24A Landing Performance.

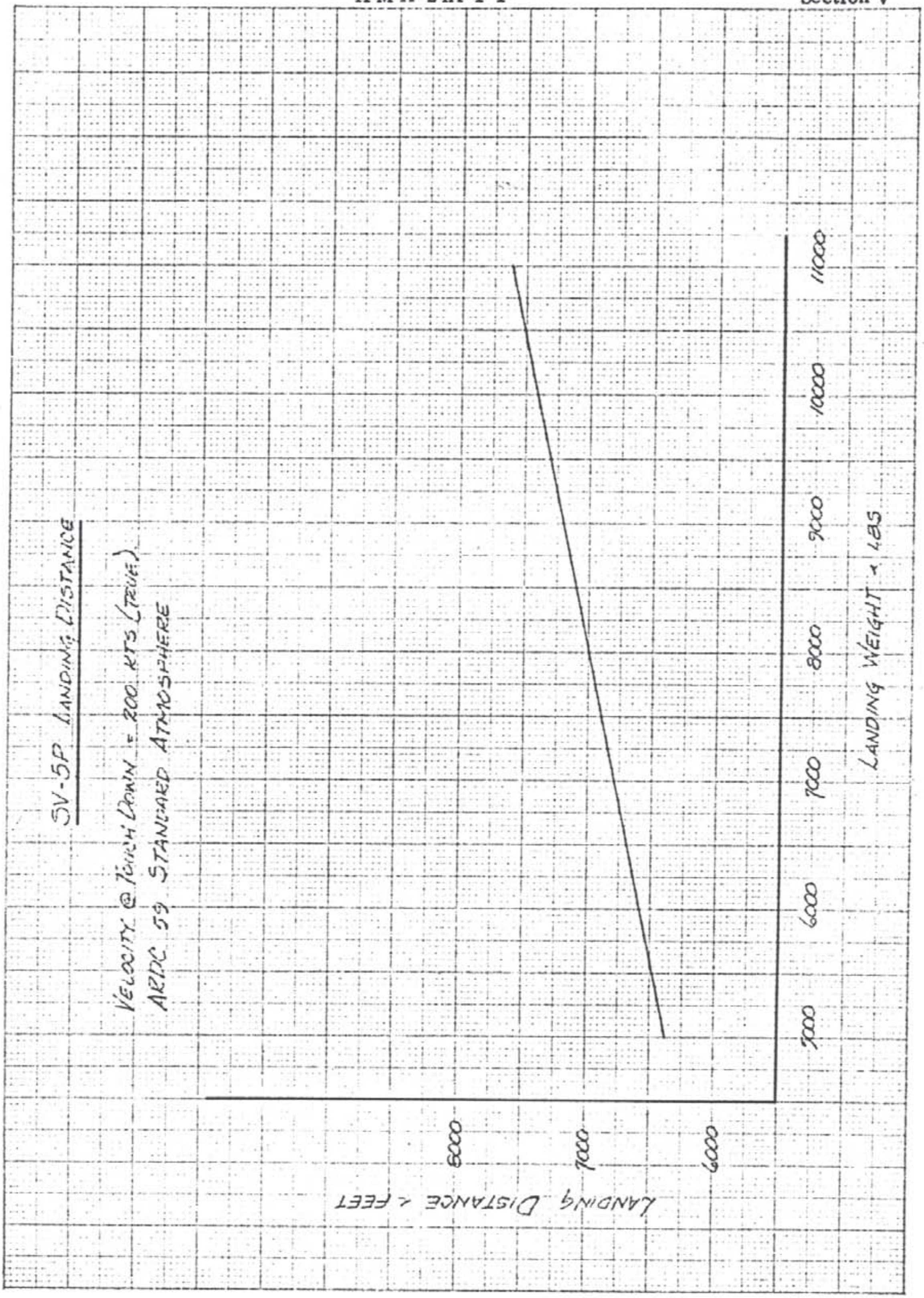


Figure 5-67. X-24A Landing Distance.

Three problems associated with this condition are, (1) the further the center of gravity moves forward the more difficult it is to trim the vehicle at high angles-of-attack, (2) the Mach number noted above is in the high transonic region of the flight regime thus bordering on the $C_{n_\beta} = ($ area, and (3) the resulting dynamic pressure (q = 60 psf), although not critically low, is of a magnitude for reduced damping for the SAS.

This condition was analyzed in a point mass three-degree-of-freedom digital trajectory program. The three conditions evaluated for the other flight descents were also analyzed for this condition, namely α for $(L/D)_{max.}$, $\alpha_{max.}$, and $\alpha_{min.}$ descent profiles. Figures 5-68 through 5-76 show the results of this analysis and provide the same variables as the descents discussed in Paragraphs 5-6 and 5-7.

To finalize the analysis, a ground trace as shown in Figure 5-77 was flown on the computer in order to determine if sufficient energy and altitude were available to land the vehicle safely. The flight descent condition for $(L/D)_{max.}$ was chosen, since this gives the pilot the largest amount of excess energy. The excess energy provided by this type of descent proved to be more than necessary, therefore, a series of dog-leg maneuvers were incorporated into the flight in order to reduce this energy and thus the altitude. The resulting safe landing on runway 018 did not require excessive roll maneuvers, as all roll angles were of 45 degrees in magnitude or less.

5-11 <u>UPPER-LOWER FLAP SETTINGS</u>

Figure 5-78 presents the upper and lower flap settings as a function of launch Mach number. These values are trim deflections with the control stick in the neutral position. Values shown are independent of launch gross weights and center of gravity positions.

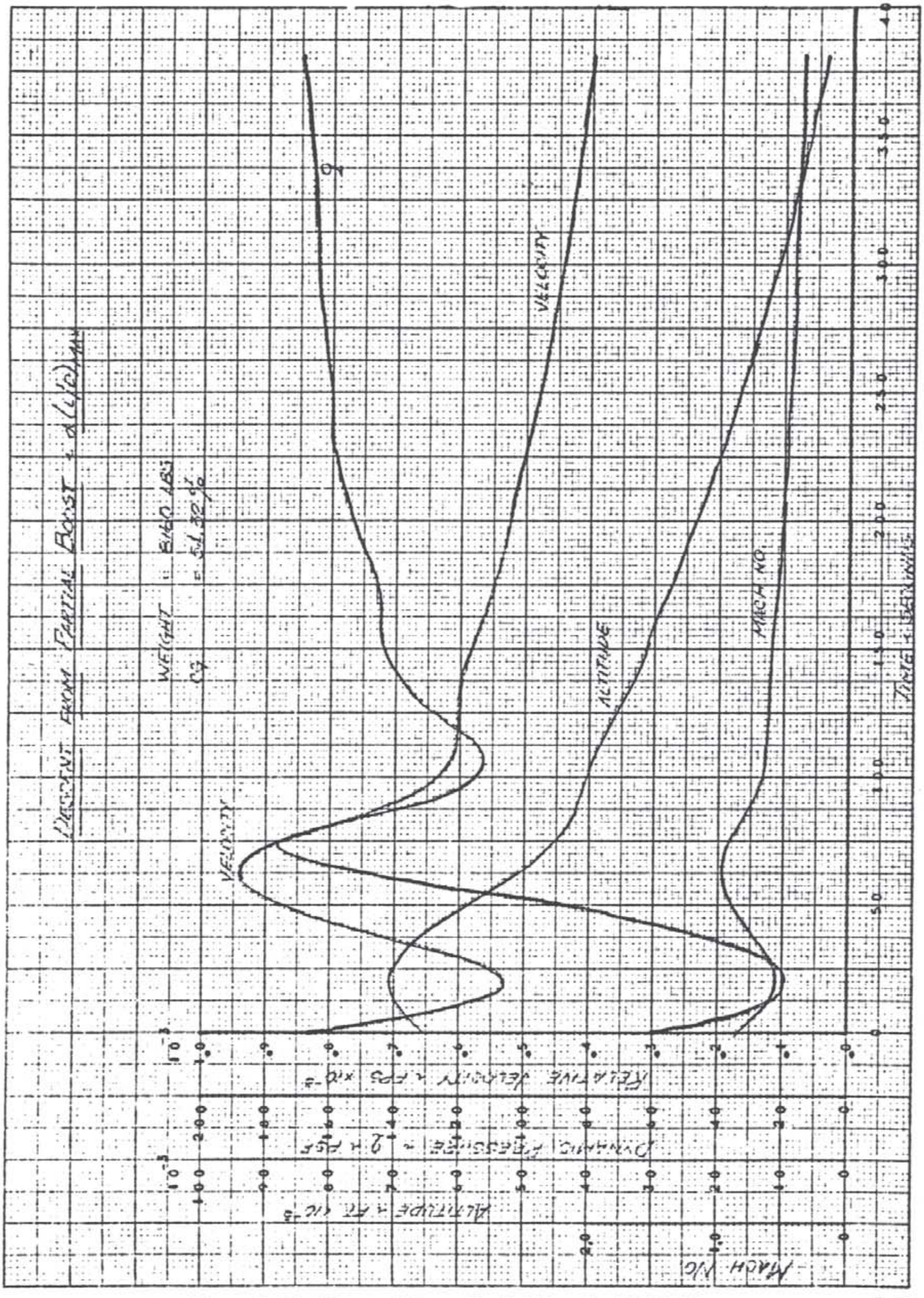


Figure 5-68. Descent From Partial Boost α(L/D) Max.

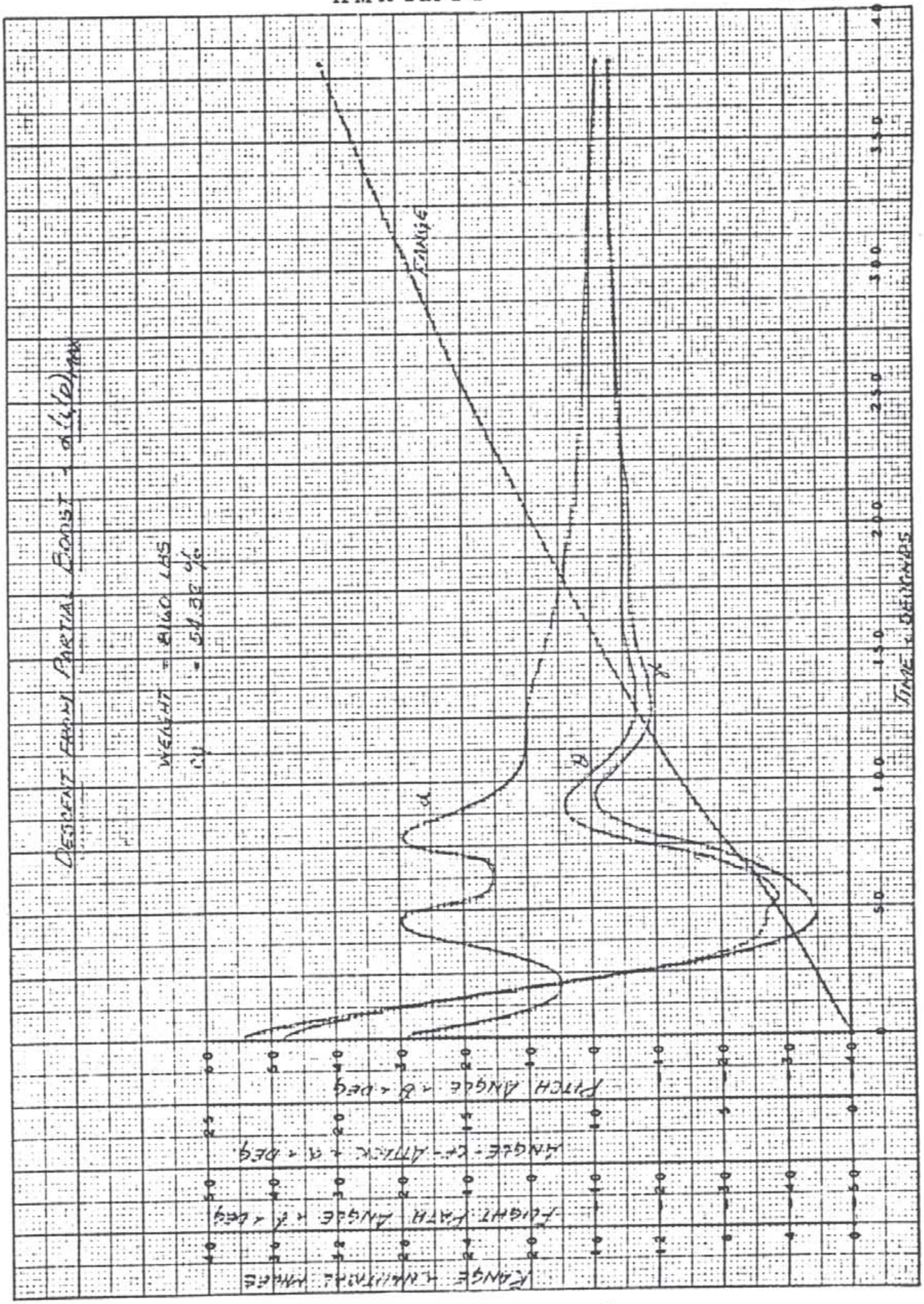


Figure 5-69. Descent From Partial Boost α (L/D) Max.

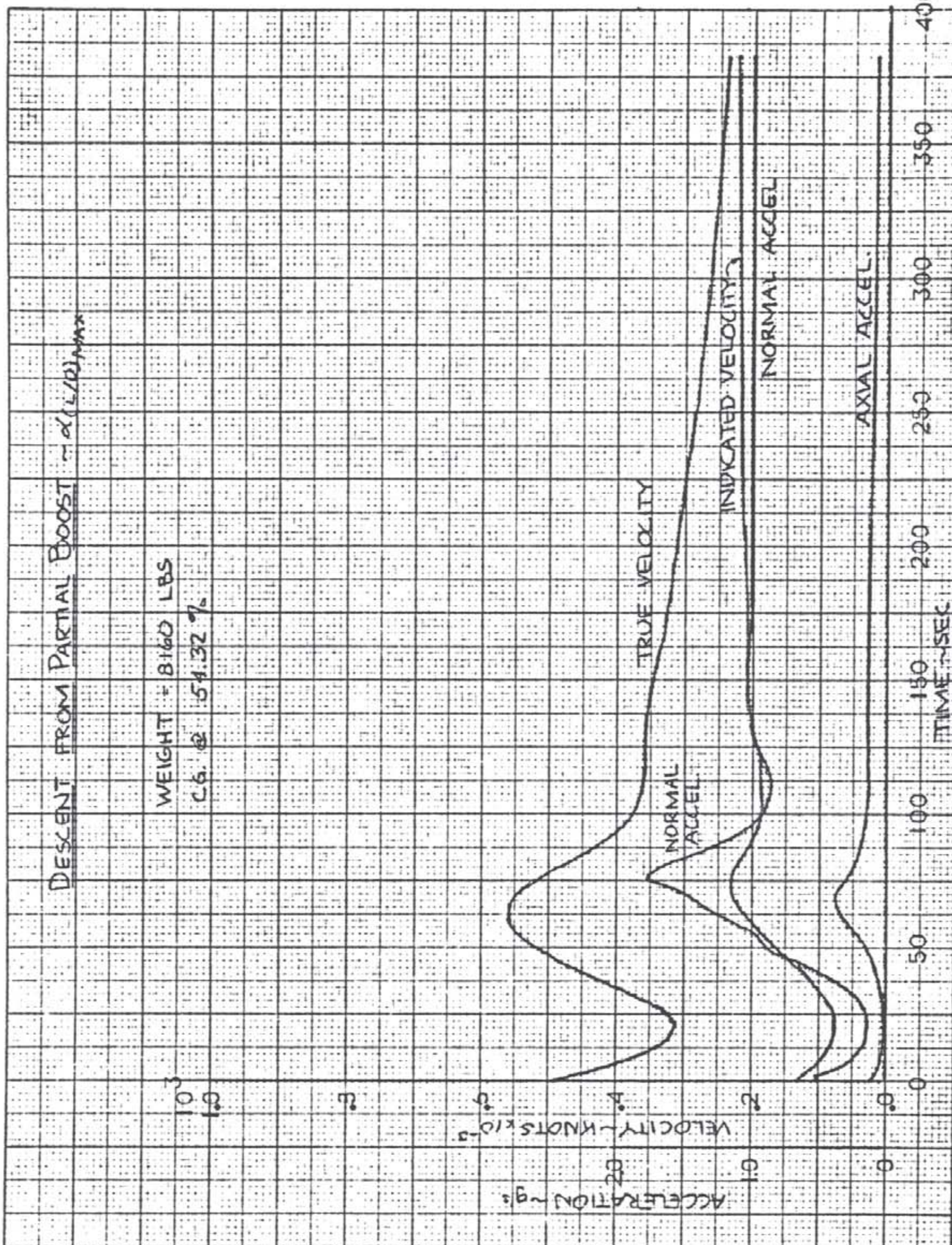
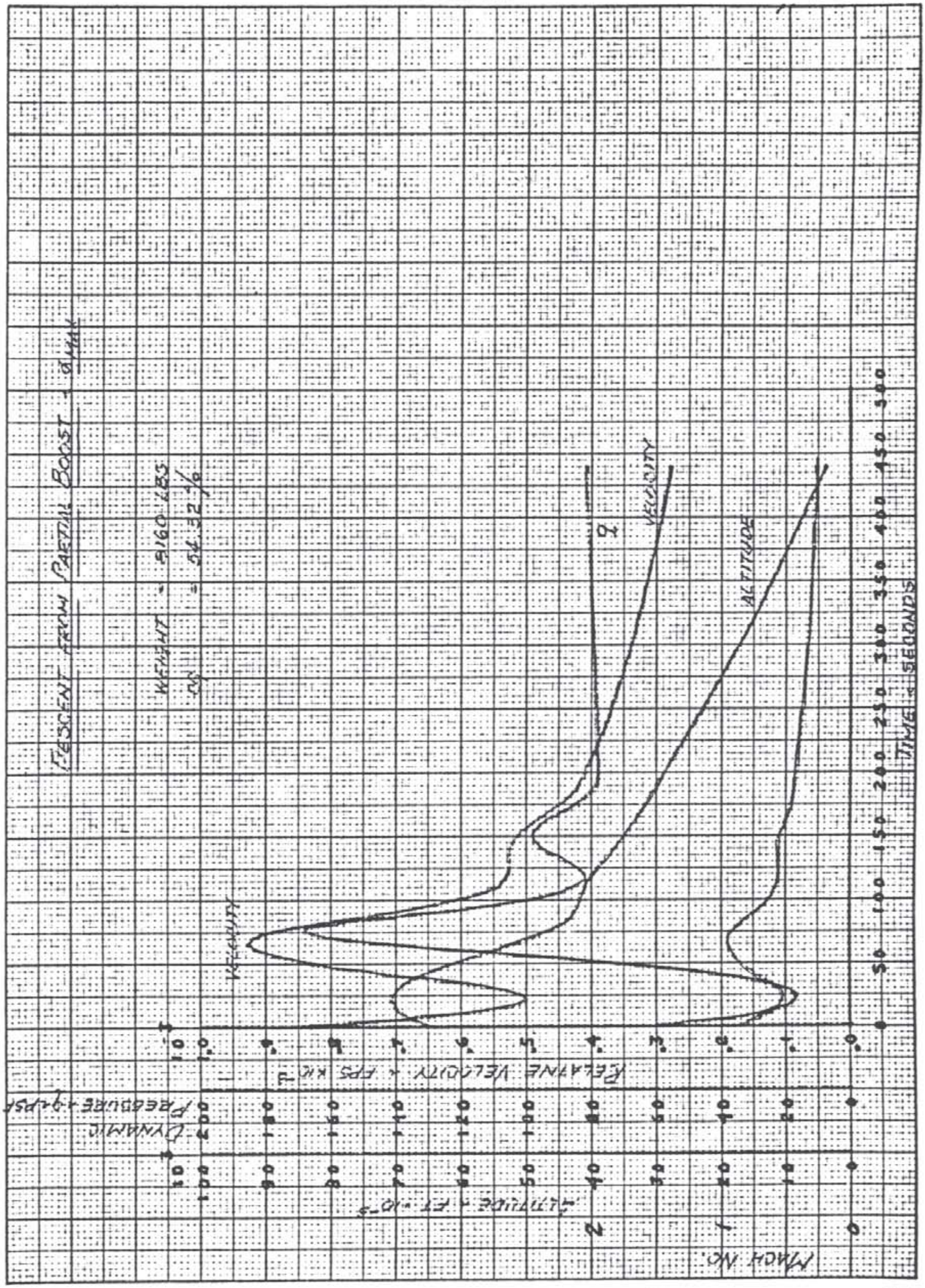


Figure 5-70. Descent From Partial Boost α (L/D) Max.



Figures 5-71. Descent From Partial Boost α Max.

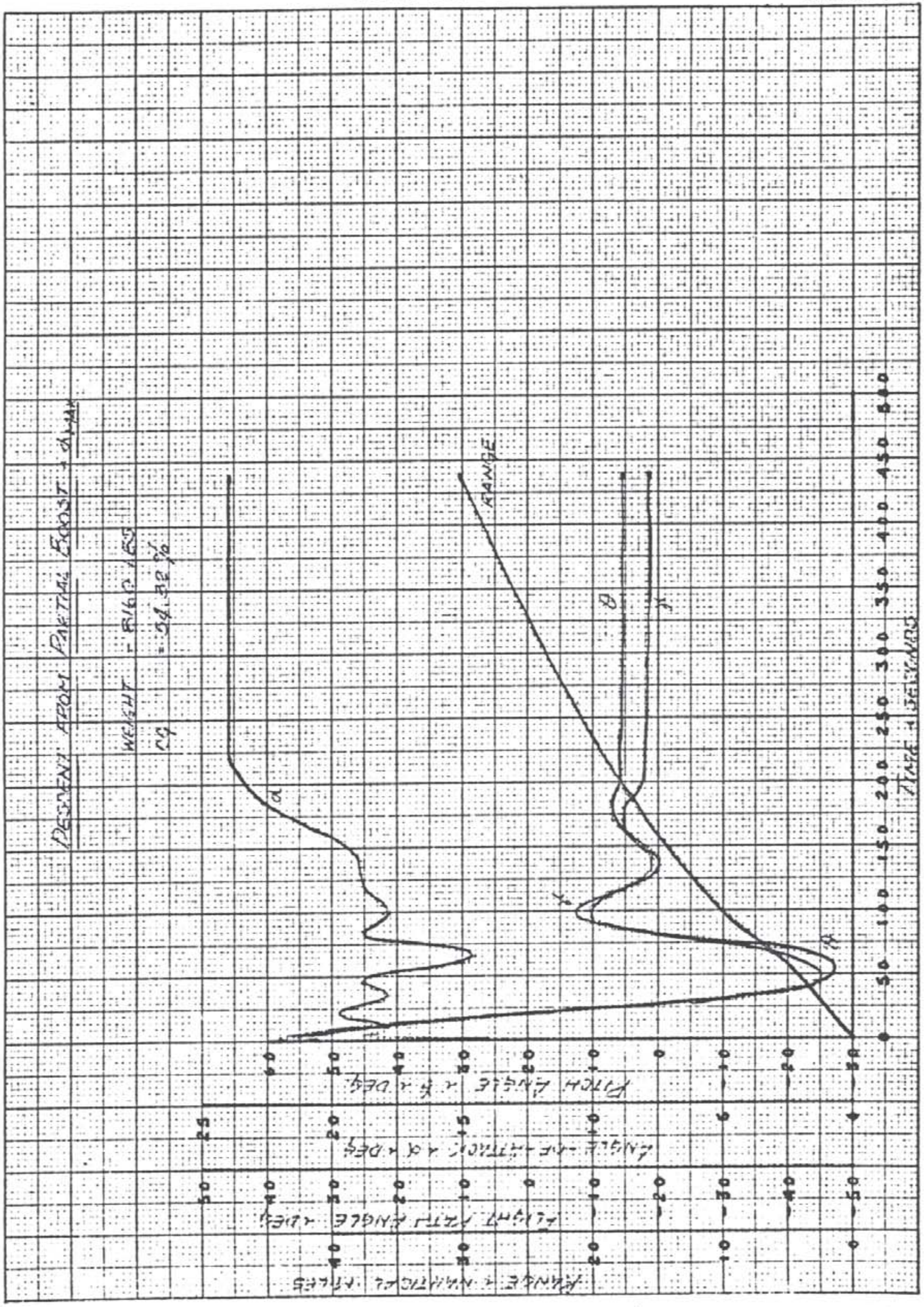


Figure 5-72. Descent From Partial Boost α Max.

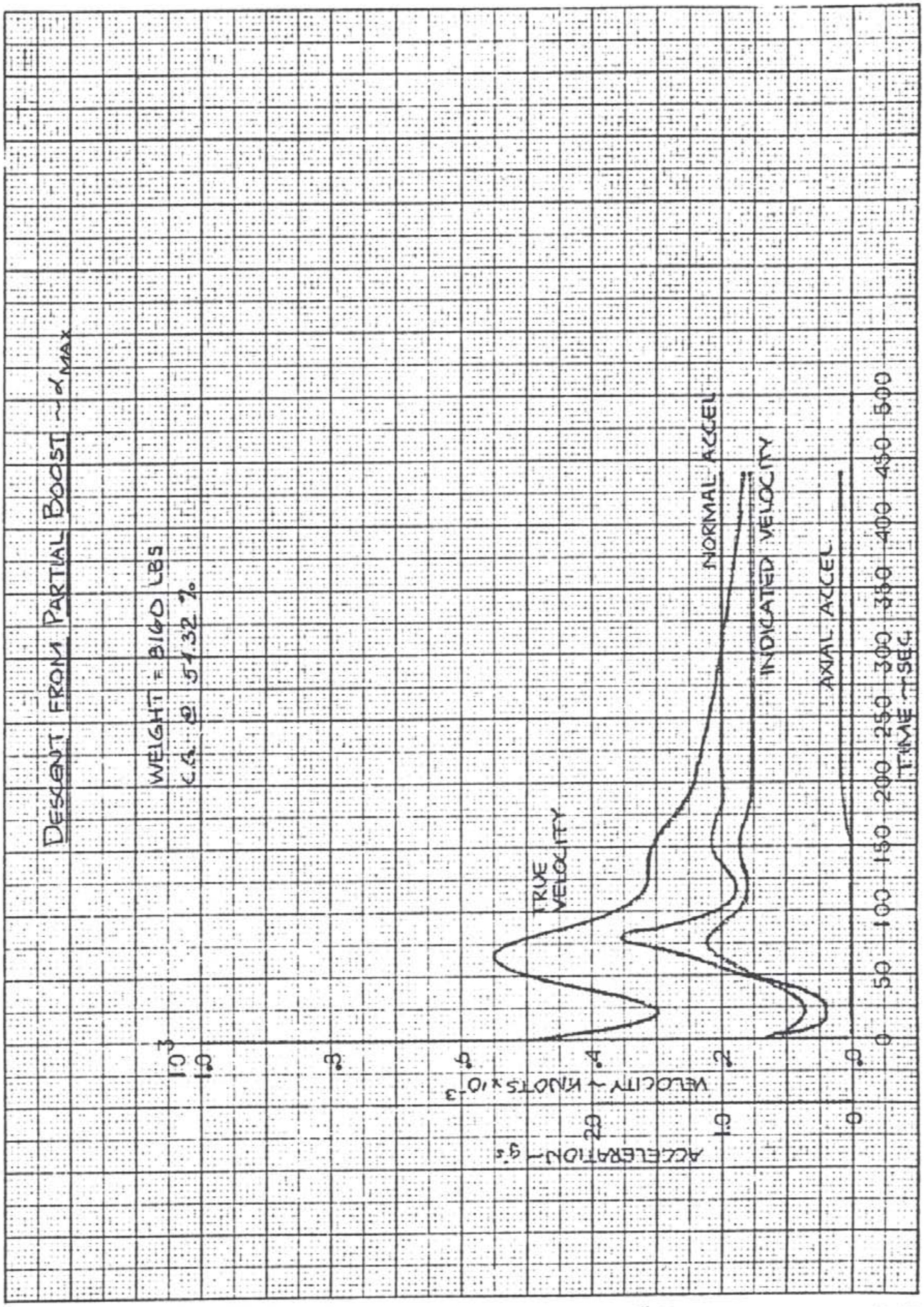


Figure 5-73. Descent From Partial Boost α Max.

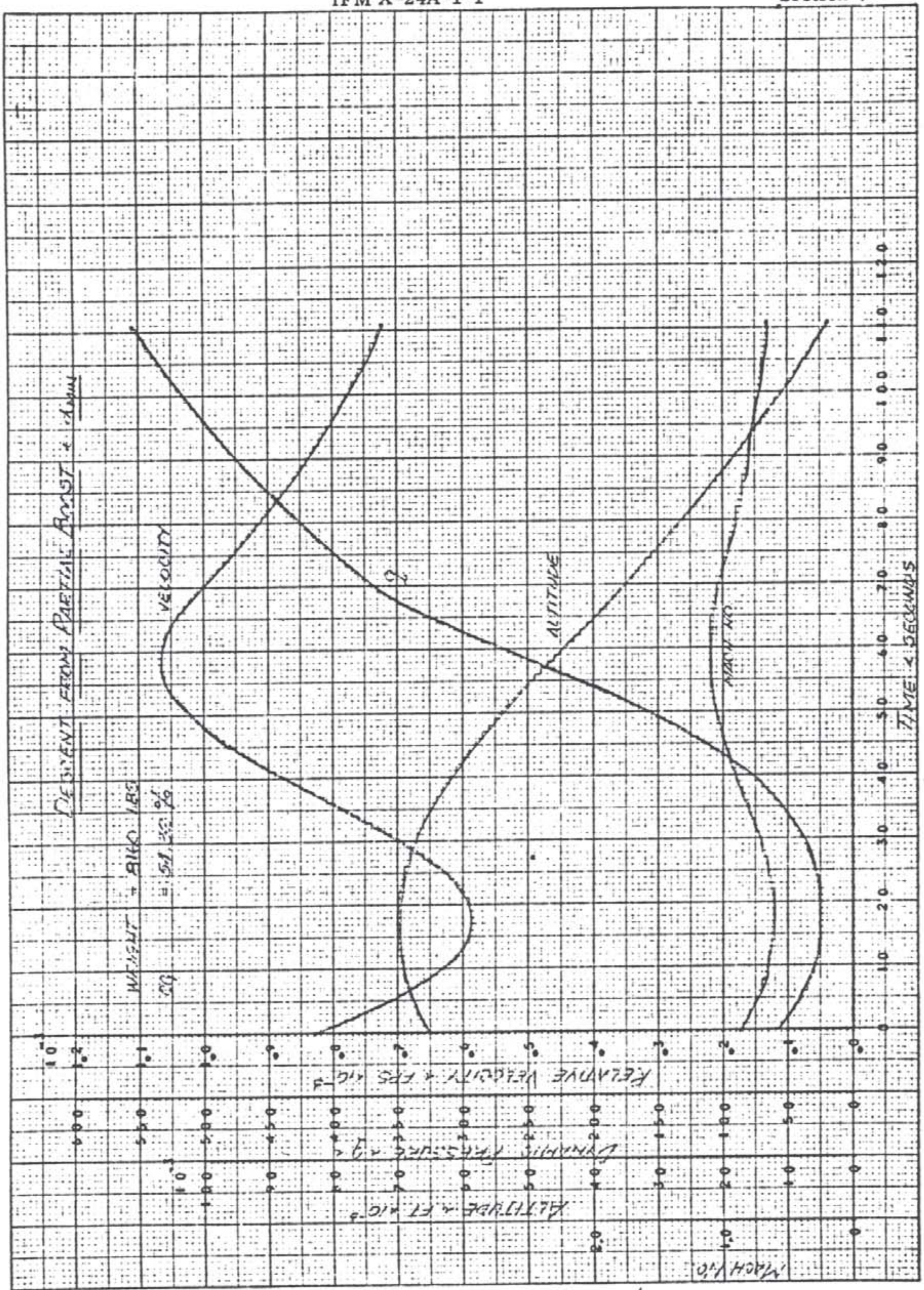


Figure 5-74. Descent From Partial Boost α Min.

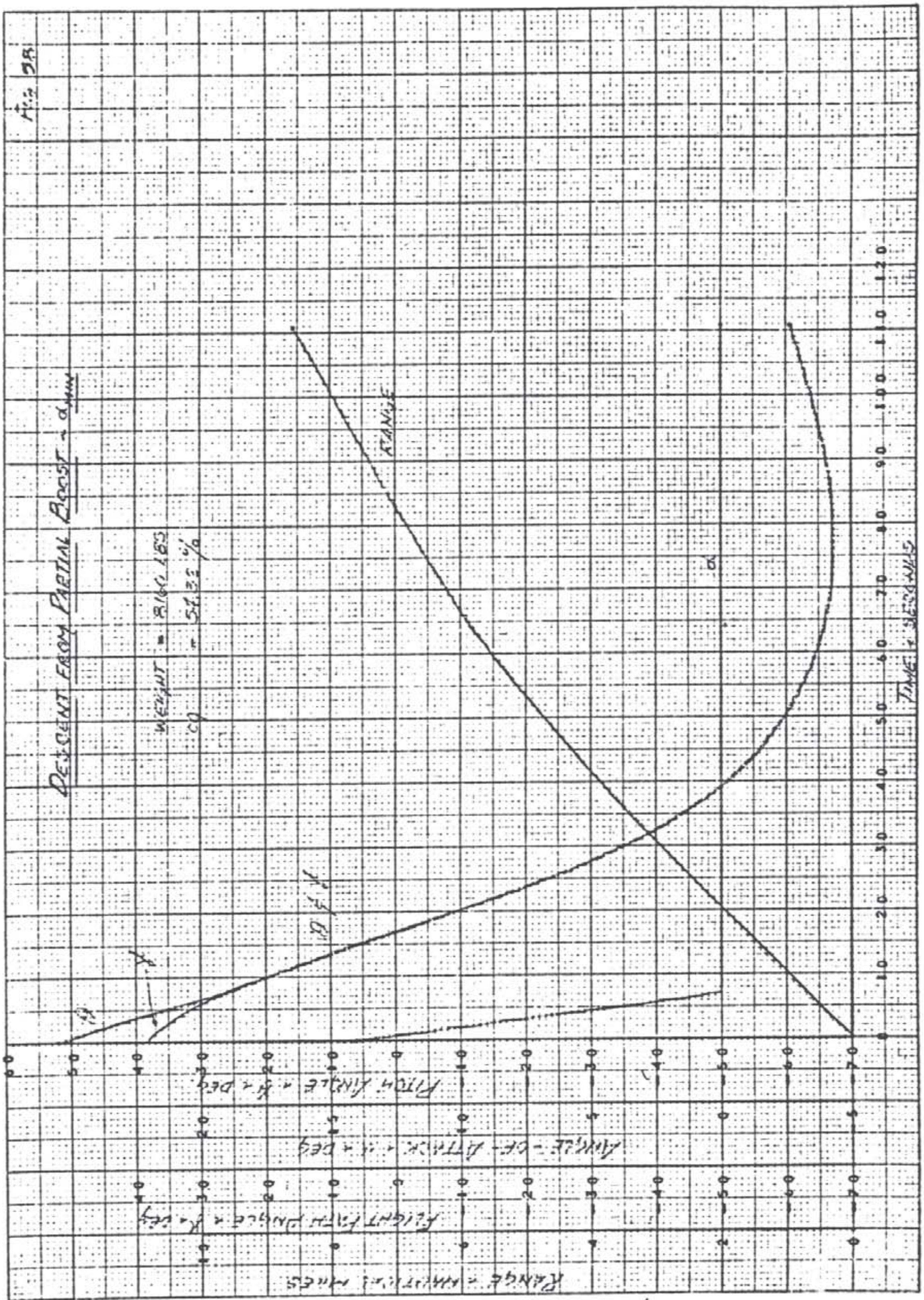


Figure 5-75. Descent From Partial Boost α Min.

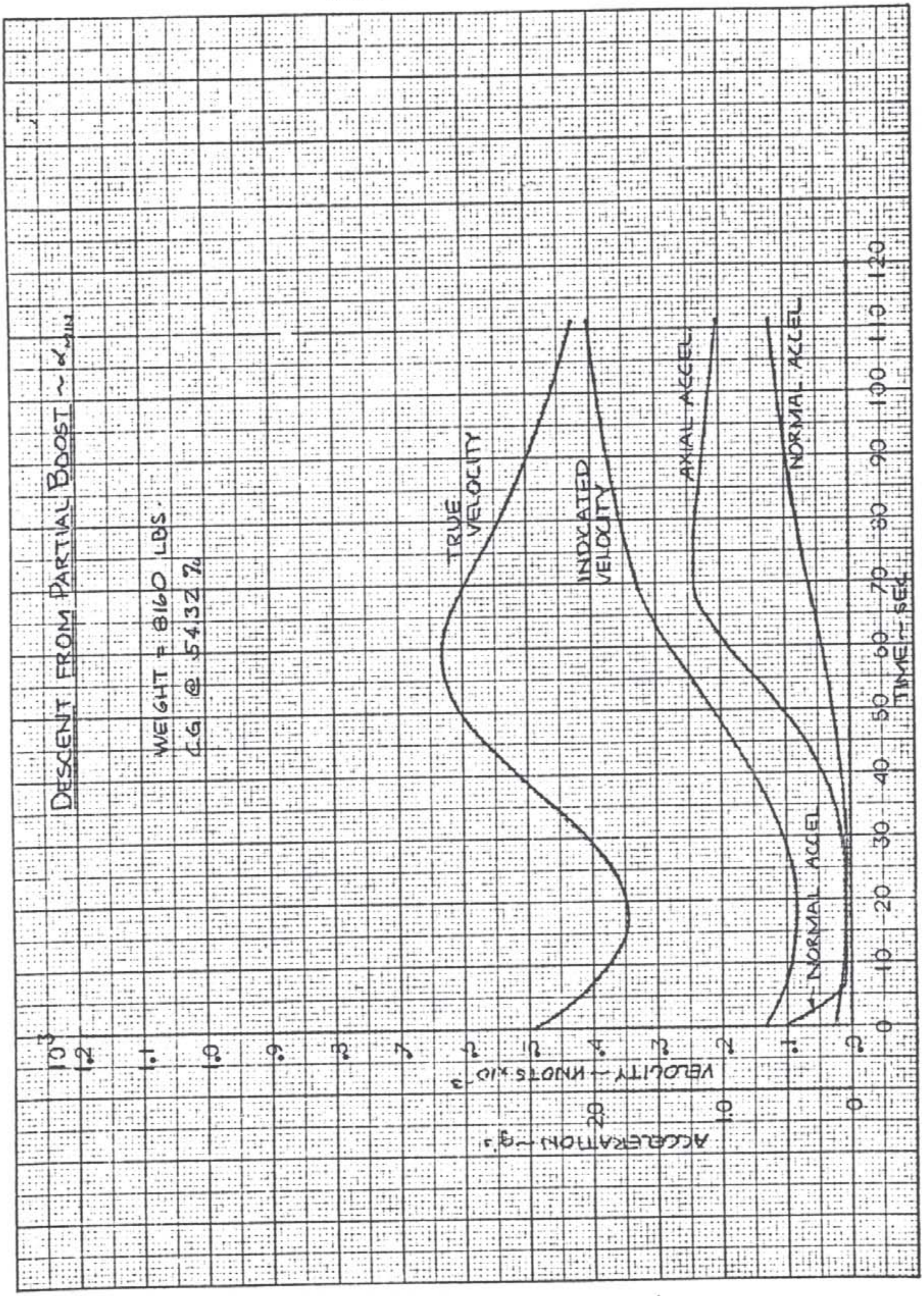


Figure 5-76. Descent From Partial Boost α Min.

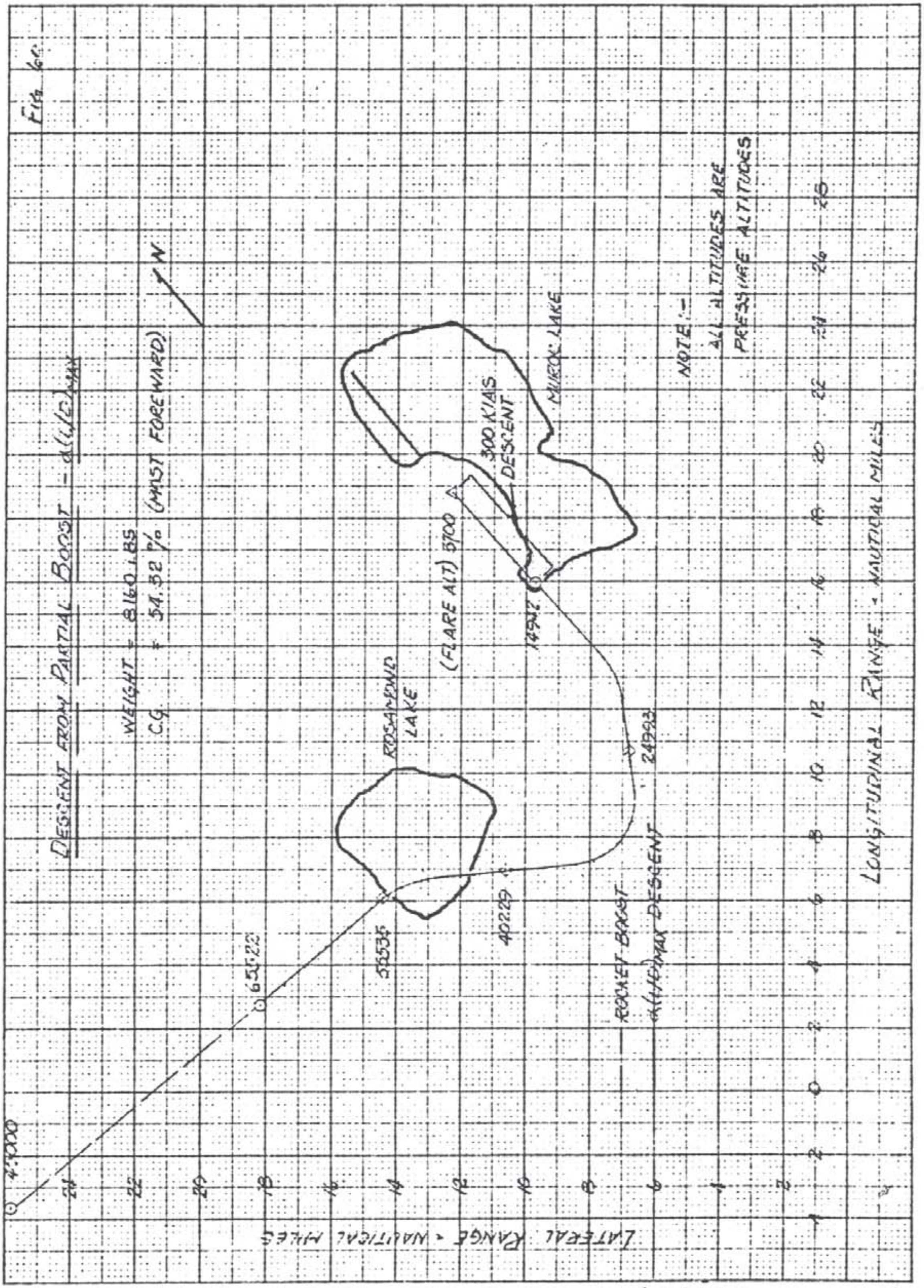


Figure 5-77. Descent From Partial Boost α (L/D) Max.

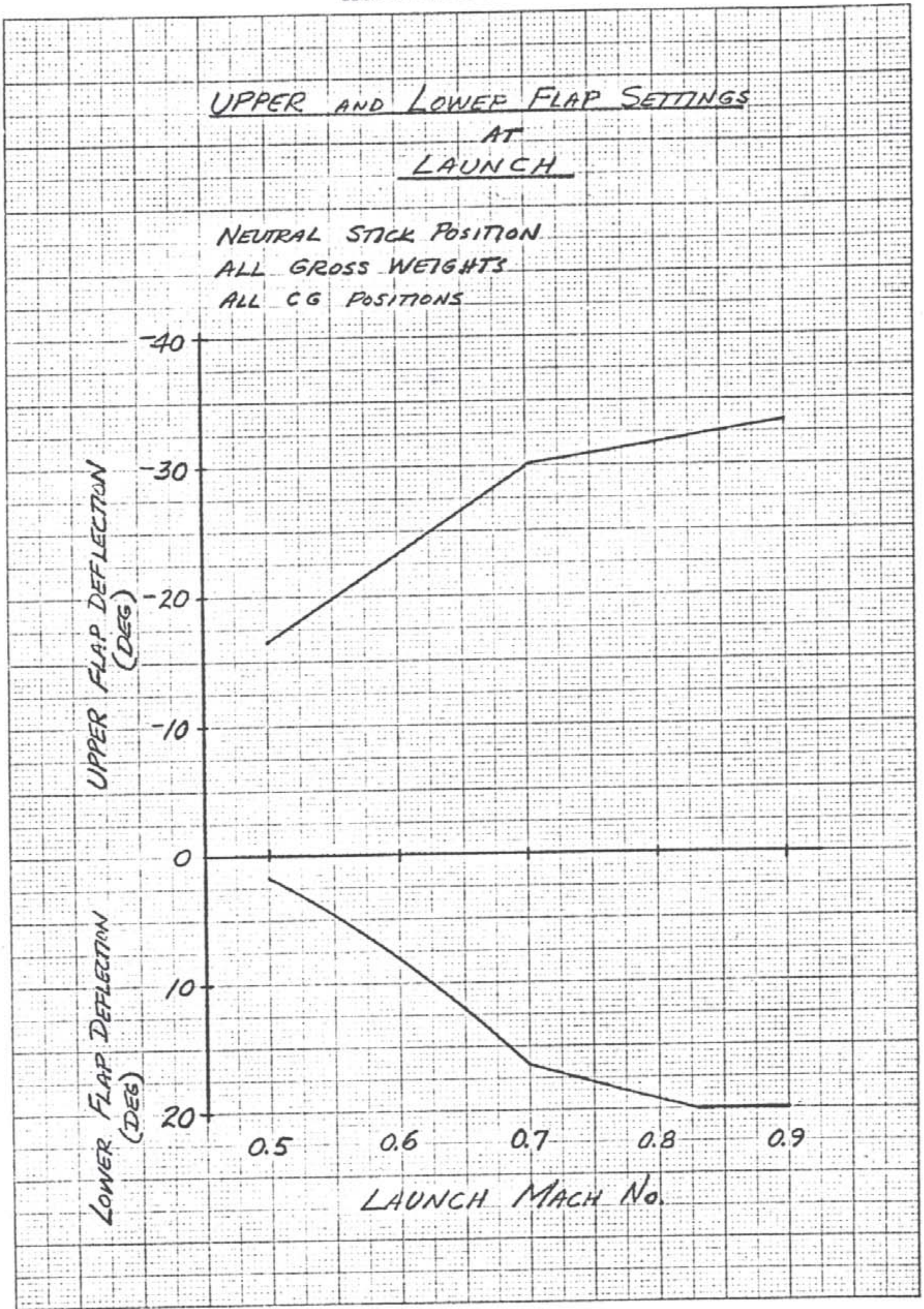


Figure 5-78. Upper and Lower Flap Settings at Launch.

5-12 STALL CHARACTERISTICS

The X-24A vehicle does not encounter stall conditions at the maximum angle of attack for practical and safe flight. For speeds greater than M = 0.6, the angle of attack limit is commensurate with neutral static stability. Below M=0.6, the angle of attack has been set corresponding to 85% of the maximum attainable ~~left~~ coefficient. The $C_{L\,max}$ value of 0.8 was obtained from the M=-.2 wind tunnel test data and corresponded to an angle of attack of 37 degrees. The 85% $C_{L\,max}$ value of 0.68 is obtained at an angle of attack of 27^{o} and 24^{o} at M=0.2 and 0.4 respectively.

Figures 5-79 gives the velocity corresponding to 85% $C_{L\,max}$ as functions of vehicle gross weight and bank angle for both clean and dirty configurations.

5-13. MISCELLANEOUS CHARTS

The performance data and charts to supplement those described previously are described below:

5-14. OAT GAGE VS OAT TRUE

This curve is a plot of gage outside air temperature versus true outside air temperature with parameters of Mach number Figure 5-80. This chart shall be for inflight use only.

5-15. TEMPERATURE CONVERSION CHART

This curve is a plot of degrees centigrade versus degrees fahrenheit (Figure 5-81).

5-16. MACH NUMBER - TRUE AIRSPEED

This type of conversion chart shall be in two parts (see Figures 5-82 and 5-83). Mission planning chart is a curve of true airspeed versus Mach number with parameters of pressure altitude, while the inflight planning chart is a curve of true airspeed versus Mach number with parameters of gage outside air temperature reading.

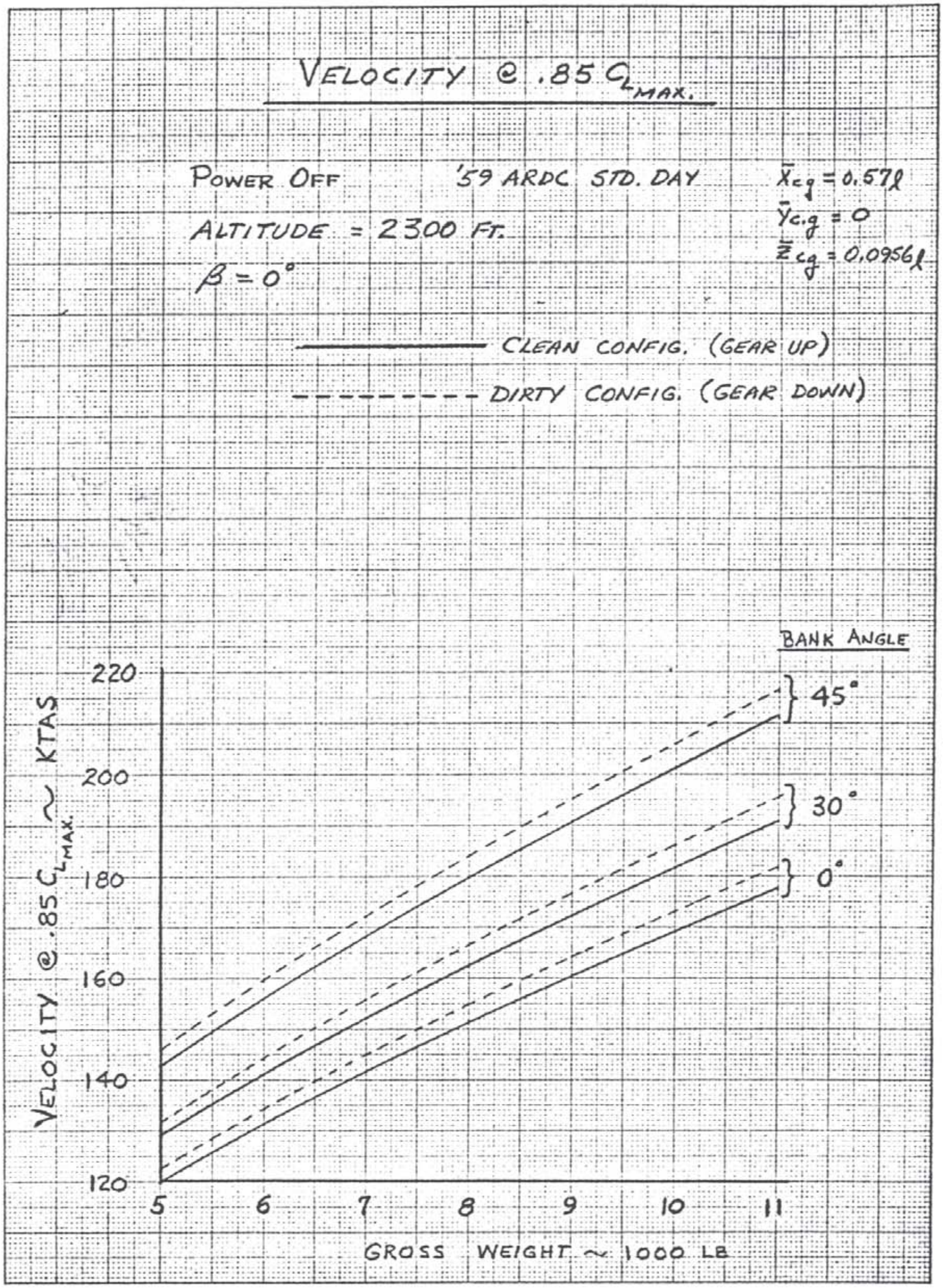


Figure 5-79. Velocity at .85 C_L Max.

OAT GAUGE VS OAT TRUE

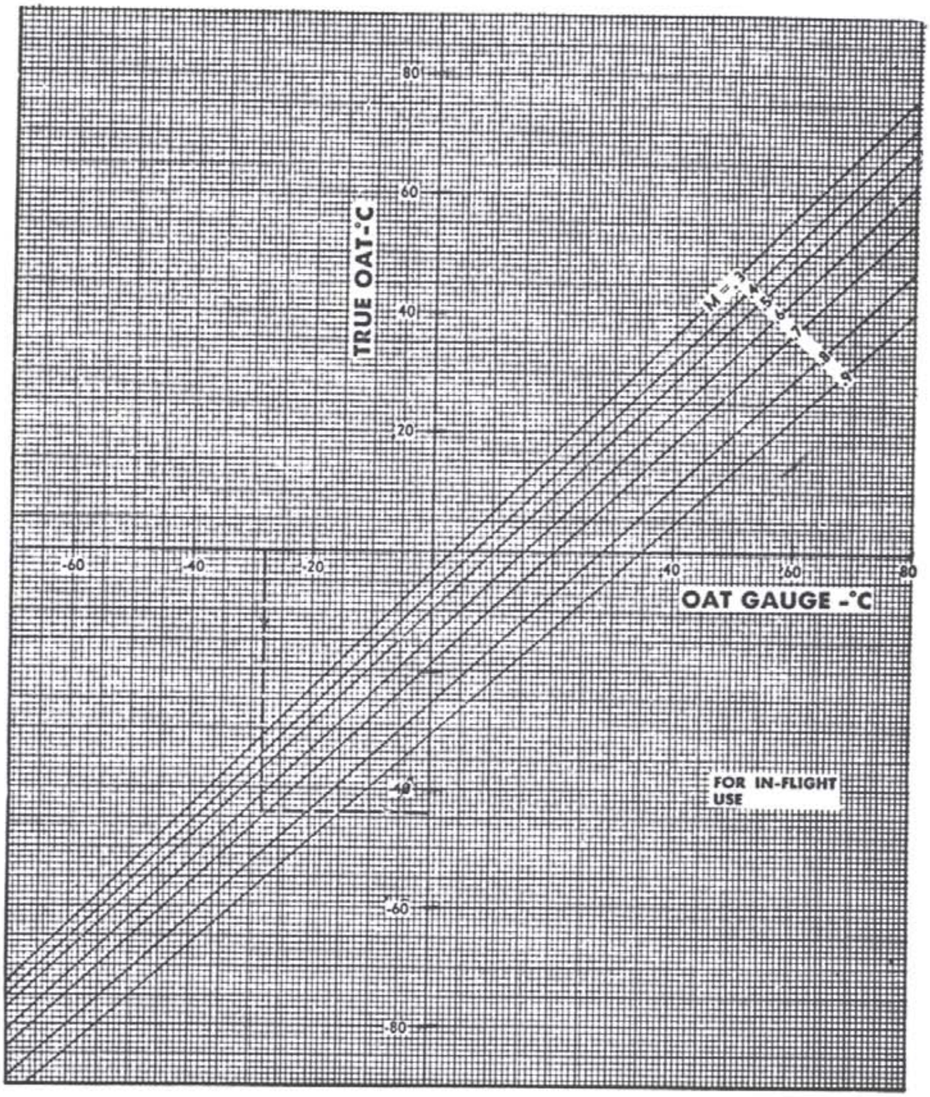


Figure 5-80. Oat Gauge Vs Oat True.

TEMPERATURE CONVERSION CHART

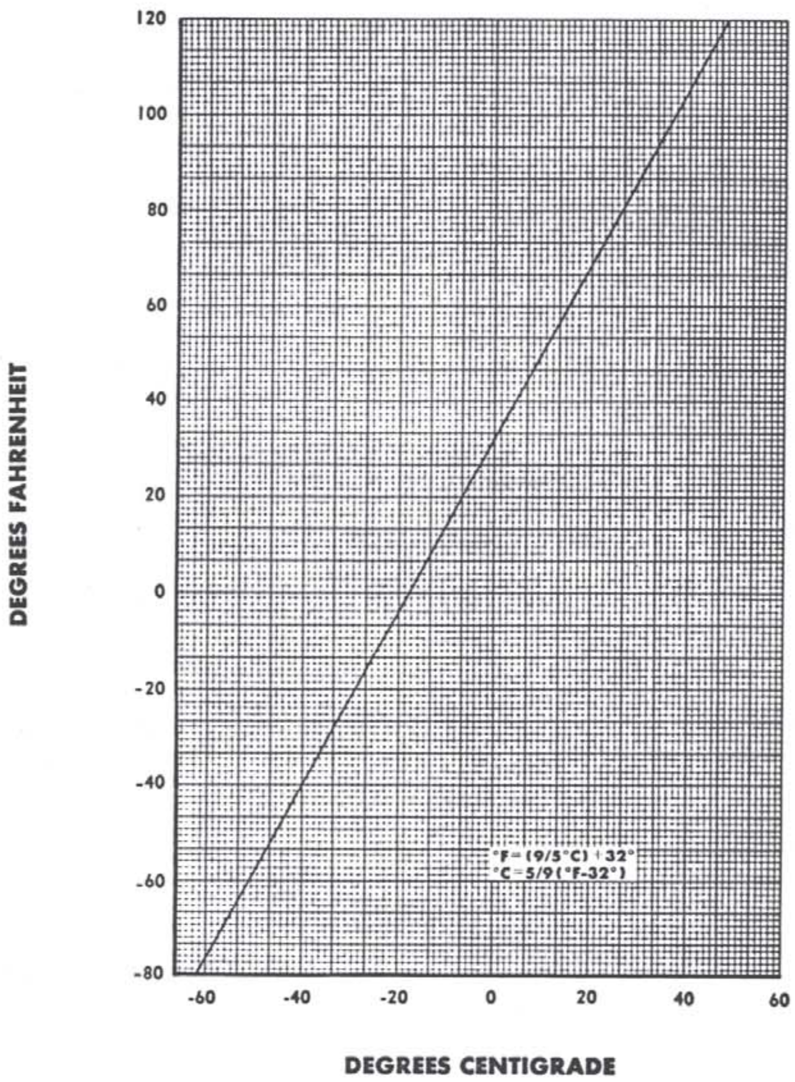


Figure 5-81. Temperature Conversion Chart.

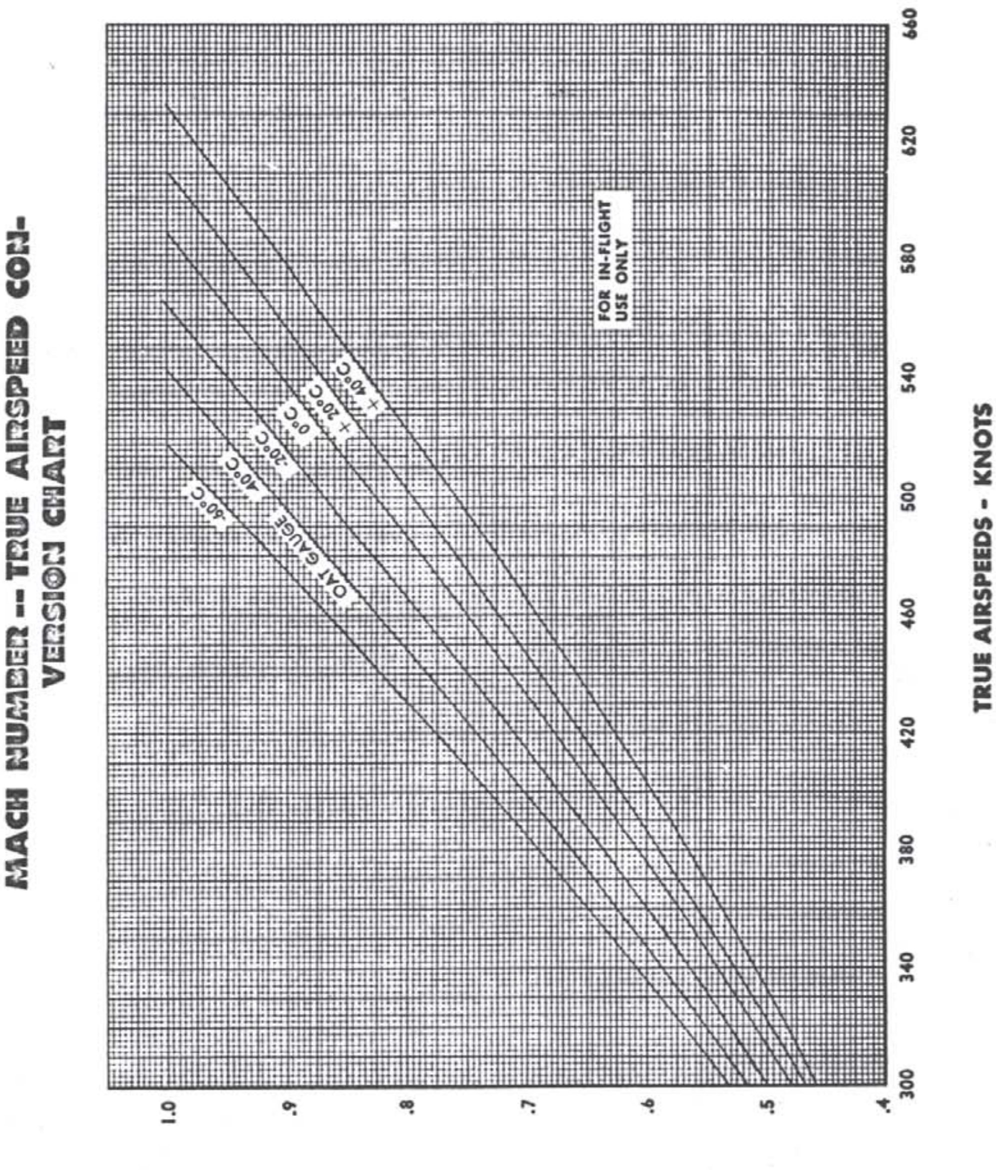


Figure 5-82. Mach Number--True Airspeed Conversion Chart.

MACH NUMBER — TRUE AIRSPEED CONVERSION CHART

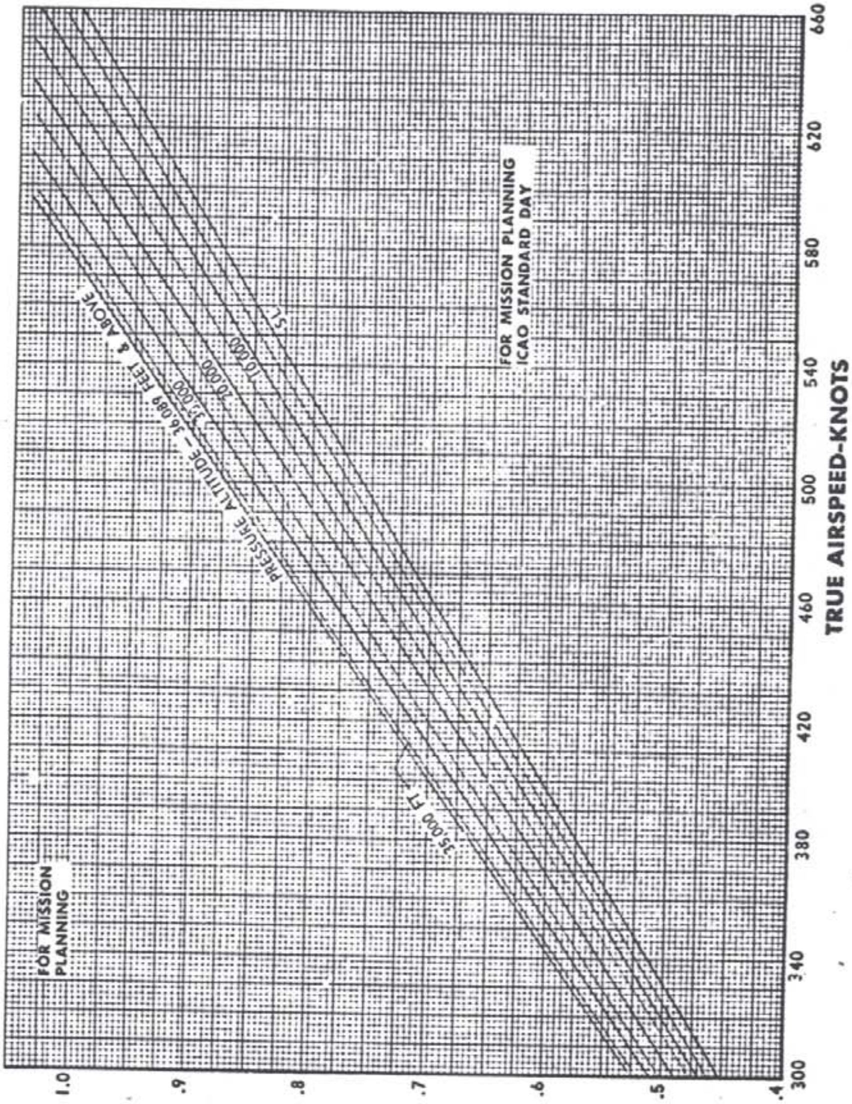


Figure 5-83. Mach Number--True Airspeed Conversion Chart.

5-17. INDICATED MACH NUMBER VS AIRSPEED (IAS)

This curve is a plot of indicated airspeed in knots versus indicated Mach number with parameters of pressure altitude (Figure 5-84).

5-18. STANDARD CHARTS

Figure 5-85, Temperature Correction for Compressibility

Figure 5-86, Density Altitude Chart

Figure 5-87, Standard Atmosphere Table

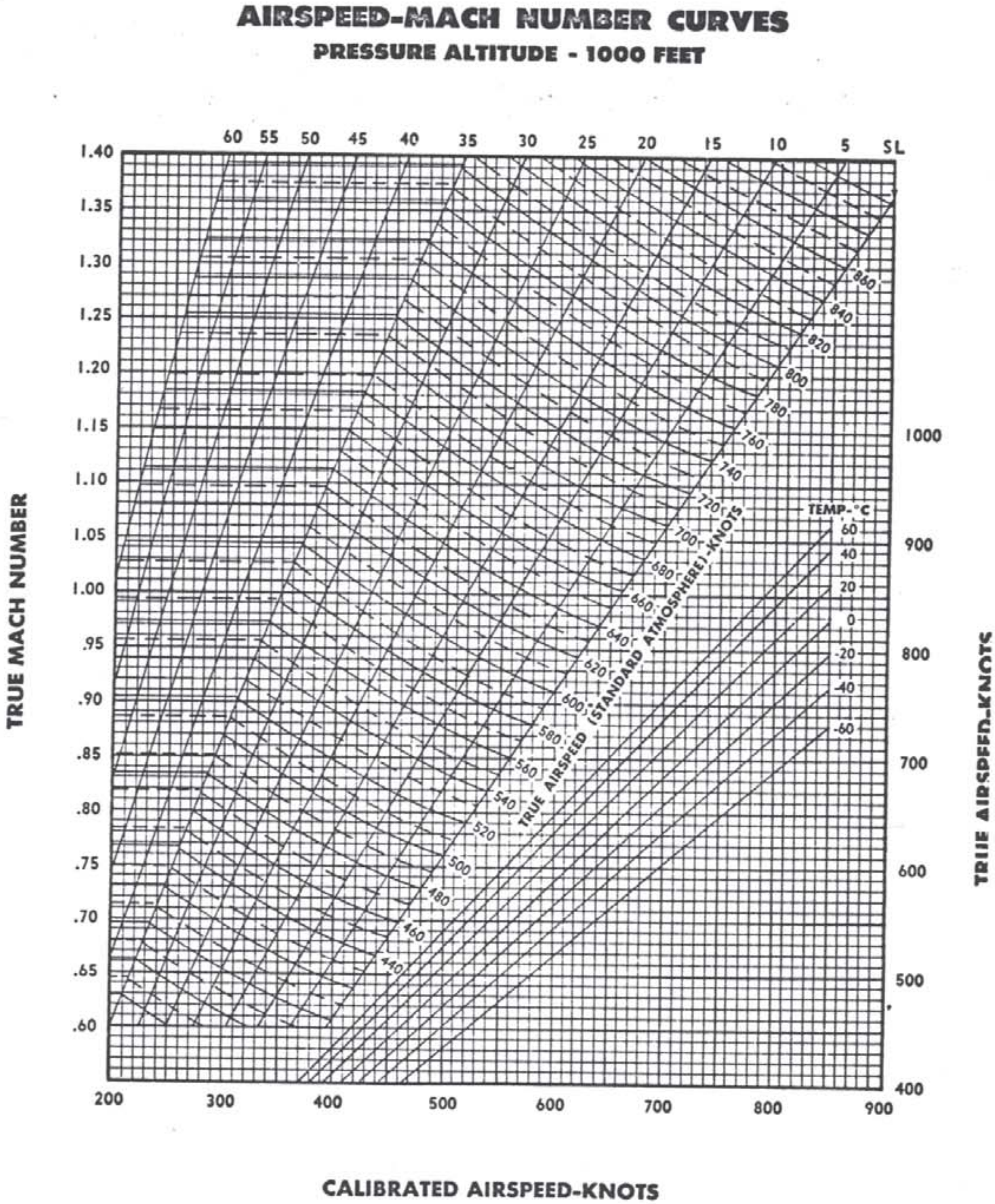


Figure 5-84. Air Speed-Mach Number Curves
Pressure Altitude - 1000 Feet
(Sheet 1 of 2)

AIRSPEED-MACH NUMBER CURVES

PRESSURE ALTITUDE - 1000 FEET

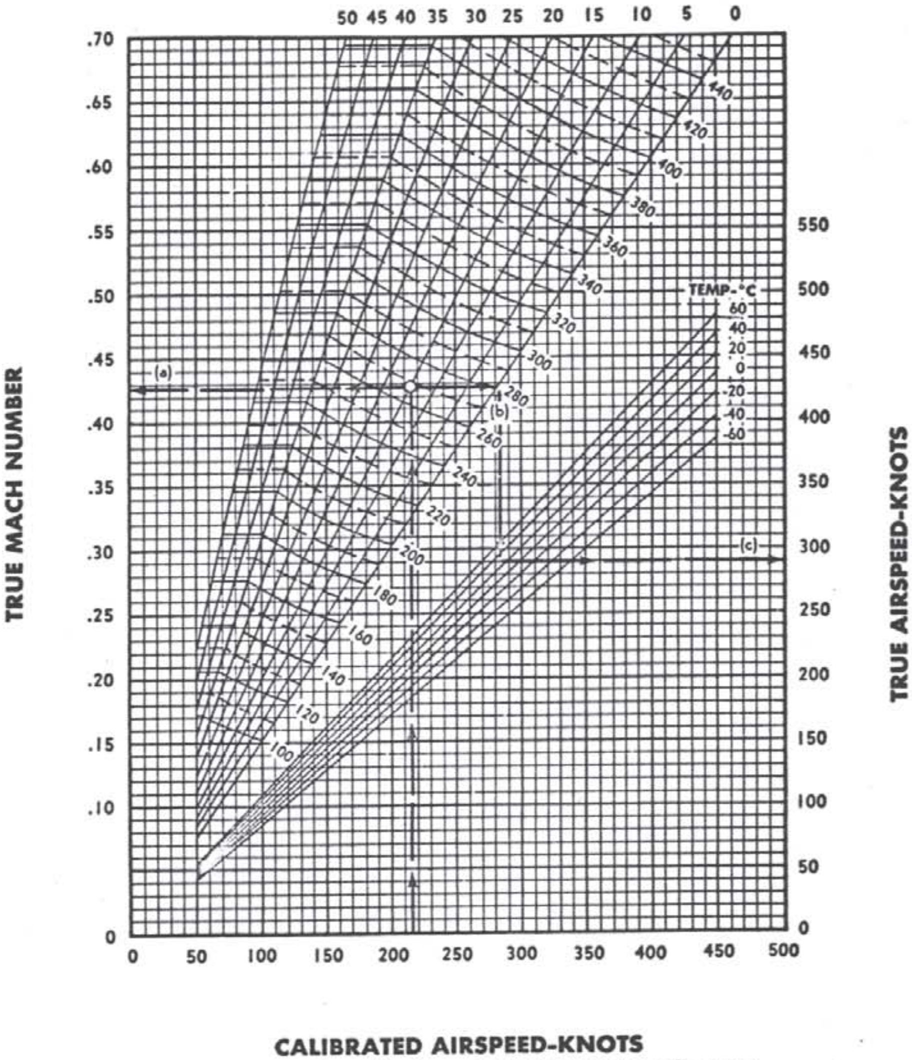


Figure 5-84. Air Speed-Mach Number Curves
Pressure Altitude - 1000 Feet
(Sheet 2 of 2)

EXAMPLE: CAS = 215 Knots
Alt = 15,000 Feet
(a) TMN = .428
(b) TAS = 267 Knots at Standard Temp (-14.7°C)
(c) TAS = 290 Knots at temp of 30°C

TEMPERATURE CORRECTION FOR COMPRESSIBILITY

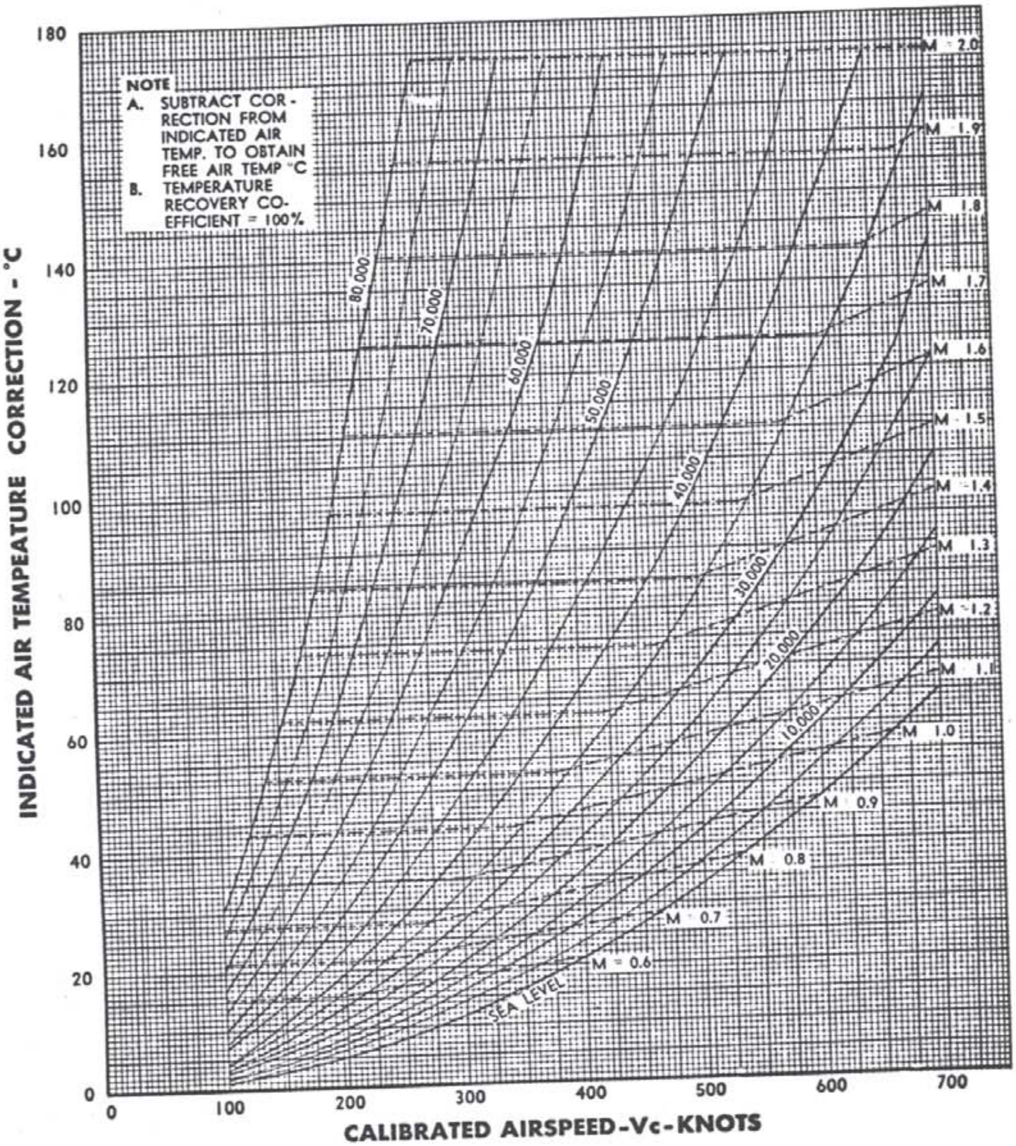


Figure 5-85. Temperature Correction For Compressibility.

DENSITY ALTITUDE CHART
ICAO

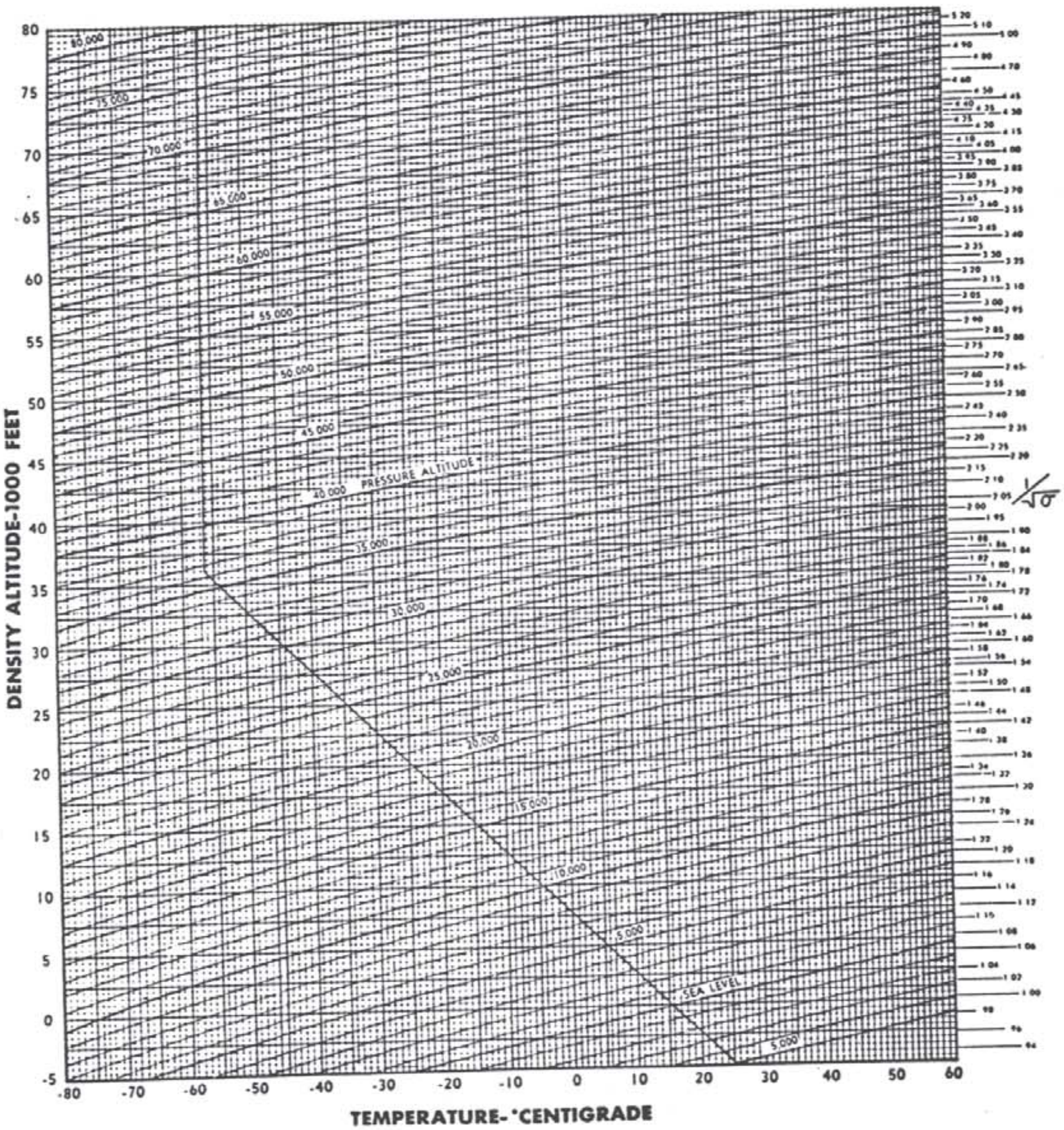


Figure 5-86. Density Altitude Chart.

STANDARD ATMOSPHERE TABLE

STANDARD S L CONDITIONS:	CONVERSION FACTORS:
TEMPERATURE 15°C (59°F)	1 IN. Hg 70.727 LB/SQ FT
PRESSURE 29.921 IN. Hg 2116.216 LB/SQ FT	1 IN. Hg 0.49116 LB/SQ IN.
DENSITY .0023769 SLUGS/CU FT	1 KNOT 1.151 M.P.H.
SPEED OF SOUND 1116.89 FT/SEC 661.7 KNOTS	1 KNOT 1.688 FT/SEC

ALTITUDE FEET	DENSITY RATIO σ	$\sigma^{-1/2}$ $\frac{1}{\sqrt{\sigma}}$	TEMPERATURE °C	°F	SPEED OF SOUND KNOTS	PRESSURE IN. Hg	PRESSURE RATIO δ
0	1.000	1.0000	15.000	59.000	661.7	29.921	1.0000
1000	.9711	1.0148	13.019	55.434	659.5	28.856	.9644
2000	.9428	1.0299	11.038	51.868	657.2	27.821	.9298
3000	.9151	1.0454	9.056	48.302	654.9	26.817	.8962
4000	.8881	1.0611	7.076	44.735	652.6	25.842	.8637
5000	.8617	1.0773	5.094	41.169	650.3	24.896	.8320
6000	.8359	1.0938	3.113	37.603	648.7	23.978	.8014
7000	.8106	1.1107	1.132	34.037	645.6	23.088	.7716
8000	.7860	1.1279	-0.850	30.471	643.3	22.225	.7428
9000	.7620	1.1456	-2.831	26.905	640.9	21.388	.7148
10,000	.7385	1.1637	-4.812	23.338	638.6	20.577	.6877
11,000	.7155	1.1822	-6.793	19.772	636.2	19.791	.6614
12,000	.6932	1.2011	-8.774	16.206	633.9	19.029	.6360
13,000	.6713	1.2205	-10.756	12.640	631.5	18.292	.6113
14,000	.6500	1.2403	-12.737	9.074	629.0	17.577	.5875
15,000	.6292	1.2606	-14.718	5.508	626.6	16.886	.5643
16,000	.6090	1.2815	-16.699	1.941	624.2	16.216	.5420
17,000	.5892	1.3028	-18.680	-1.625	621.8	15.569	.5203
18,000	.5699	1.3246	-20.662	-5.191	619.4	14.942	.4994
19,000	.5511	1.3470	-22.643	-8.757	617.0	14.336	.4791
20,000	.5328	1.3700	-24.624	-12.323	614.6	13.750	.4595
21,000	.5150	1.3935	-26.605	-15.889	612.1	13.184	.4406
22,000	.4976	1.4176	-28.587	-19.456	609.6	12.636	.4223
23,000	.4806	1.4424	-30.568	-23.022	607.1	12.107	.4046
24,000	.4642	1.4678	-22.549	-26.588	604.6	11.597	.3876
25,000	.4481	1.4938	-34.530	-30.154	602.1	11.103	.3711
26,000	.4325	1.5206	-36.511	-33.720	599.6	10.627	.3552
27,000	.4173	1.5480	-38.492	-37.286	597.1	10.168	.3398
28,000	.4025	1.5762	-40.474	-40.852	594.6	9.725	.3250
29,000	.3881	1.6052	-42.455	-44.419	592.1	9.297	.3107
30,000	.3741	1.6349	-44.436	-47.985	589.5	8.885	.2970
31,000	.3605	1.6654	-46.417	-51.551	586.9	8.488	.2837
32,000	.3473	1.6968	-48.398	-55.117	584.4	8.106	.2709
33,000	.3345	1.7291	-50.379	-58.683	581.8	7.737	.2586
34,000	.3220	1.7623	-52.361	-62.249	579.2	7.382	.2467
35,000	.3099	1.7964	-54.342	-65.816	576.6	7.041	.2353
36,000	.2981	1.8315	-56.323	-69.382	574.0	6.712	.2243
36,089	.2971	1.8347	-56.500	-69.700	573.7	6.683	.2234
37,000	.2843	1.8753				6.397	.2138
38,000	.2710	1.9209				6.097	.2038
39,000	.2583	1.9677				5.811	.1942
40,000	.2462	2.0155				5.538	.1851

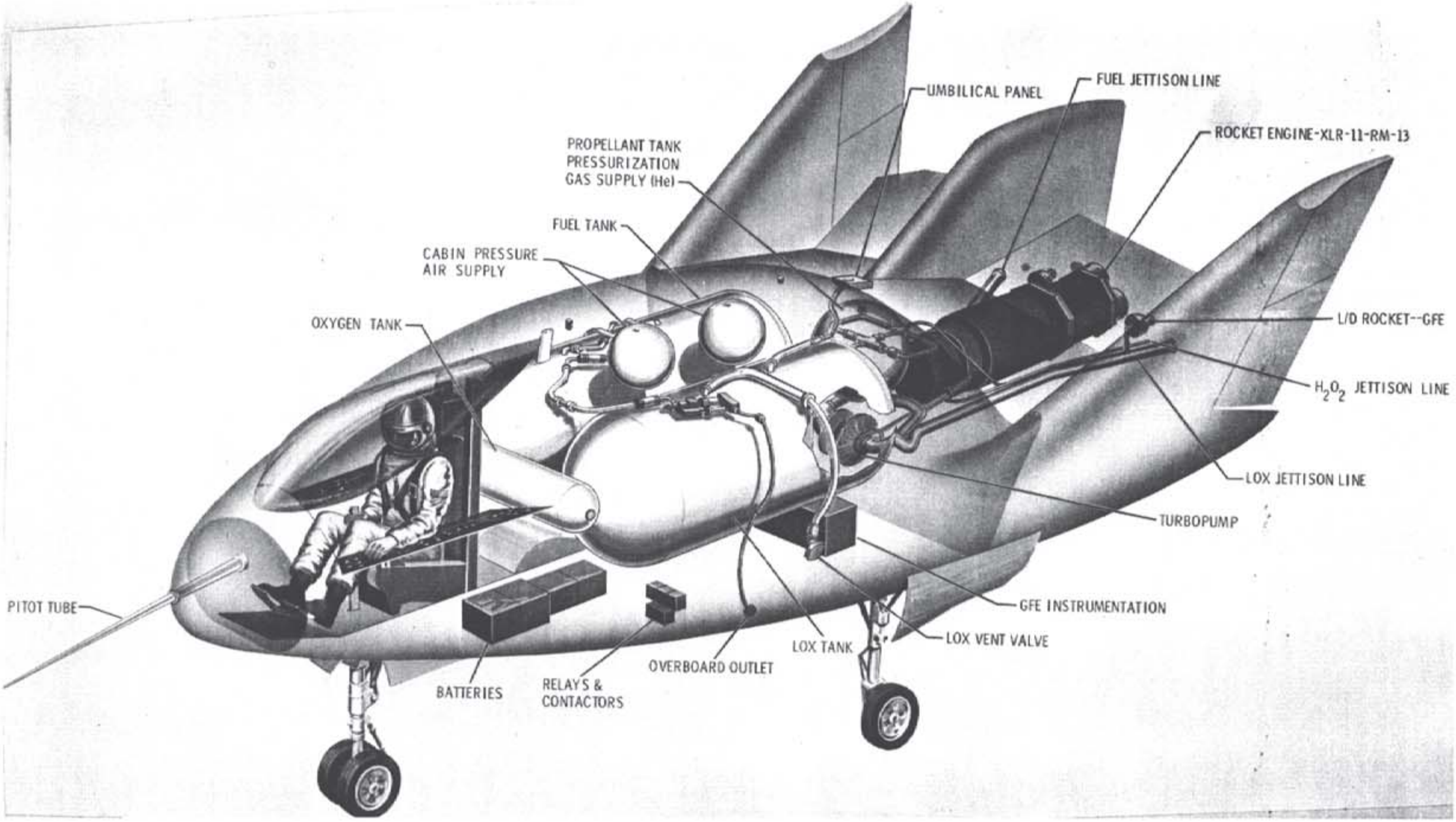
Figure 5-87. Standard Atmosphere Table.
(Sheet 1 of 2)

STANDARD ATMOSPHERE TABLE

STANDARD S L CONDITIONS:	CONVERSION FACTORS:
TEMPERATURE 15°C(59°F)	1 IN. Hg 70.727 LB/SQ FT
PRESSURE 29.921 IN. Hg 2116.216 LB/SQ FT	1 IN. Hg 0.49116 LB/SQ IN.
DENSITY .0023769 SLUGS/CU FT	1 KNOT 1.151 M.P.H.
SPEED OF SOUND 1116.89 FT/SEC 661.7 KNOTS	1 KNOT 1.688 FT/SEC

ALTITUDE FEET	DENSITY RATIO σ	$\sigma^{-1/2}$ $\frac{1}{\sqrt{\sigma}}$	TEMPERATURE °C	TEMPERATURE °F	SPEED OF SOUND KNOTS	PRESSURE IN. Hg	PRESSURE RATIO δ
41,000	.2346	2.0645	-56.500	-69.700	573.7	5.278	.1764
42,000	.2236	2.1148				5.030	.1681
43,000	.2131	2.1662				4.794	.1602
44,000	.2031	2.2189				4.569	.1527
45,000	.1935	2.2728				4.355	.1455
46,000	.1845	2.3281				4.151	.1387
47,000	.1758	2.3848				3.956	.1322
48,000	.1676	2.4428				3.770	.1260
49,000	.1597	2.5022				3.593	.1201
50,000	.1522	2.5630				3.425	.1145
51,000	.1451	2.6254				3.264	.1091
52,000	.1383	2.6892				3.111	.1040
53,000	.1318	2.7546				2.965	.09909
54,000	.1256	2.8216				2.826	.09444
55,000	.1197	2.8903				2.693	.09001
56,000	.1141	2.9606				2.567	.08578
57,000	.1087	3.0326				2.446	.08176
58,000	.1036	3.1063				2.331	.07792
59,000	.09877	3.1819				2.222	.07426
60,000	.09414	3.2593				2.118	.07078
61,000	.08972	3.3386	-56.500	-69.700	573.7	2.018	.06746
62,000	.08551	3.4198				1.924	.06429
63,000	.08150	3.5029				1.833	.06127
64,000	.07767	3.5881				1.747	.05840
65,000	.07403	3.6754				1.665	.05566
66,000	.07055	3.7649				1.587	.05305
67,000	.06724	3.8564				1.513	.05056
68,000	.06409	3.9502				1.442	.04819
69,000	.06108	4.0463				1.374	.04592
70,000	.05821	4.1447				1.310	.04377
71,000	.05548	4.2456				1.248	.04171
72,000	.05288	4.3488				1.190	.03976
73,000	.05040	4.4545				1.134	.03789
74,000	.04803	4.5633				1.081	.03611
75,000	.04578	4.6738				1.030	.03442
76,000	.04363	4.7874				0.982	.03280
77,000	.04158	4.9039				0.935	.03126
78,000	.03963	5.0231				0.892	.02980
79,000	.03777	5.1454				0.850	.02840
80,000	.03600	5.2706				0.810	.02707

Figure 5-87. Standard Atmosphere Table.
(Sheet 2 of 2)



IFM X-24A-1-1

Figure 1-1. X-24A.

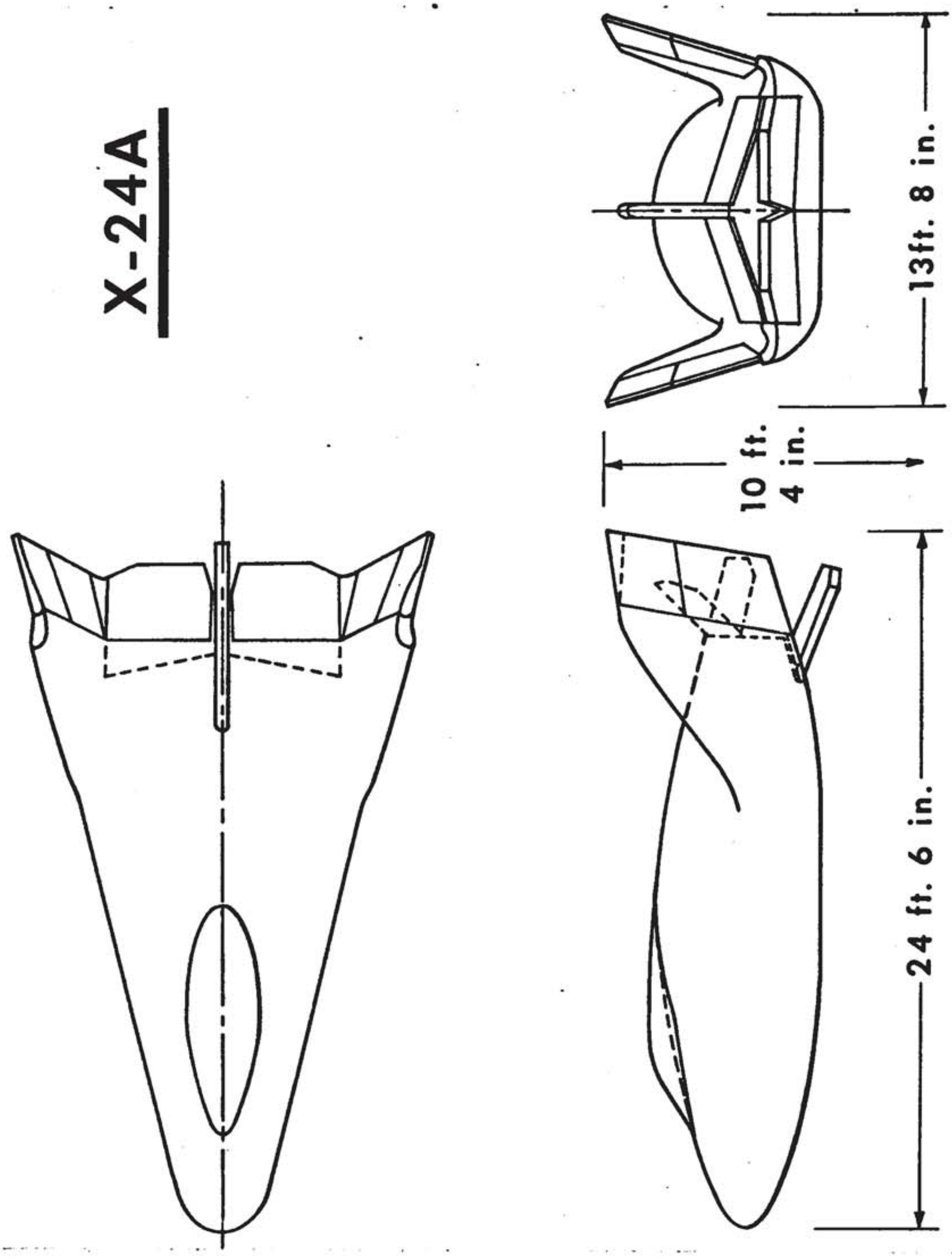


Figure 1-2. Overall Dimensions.

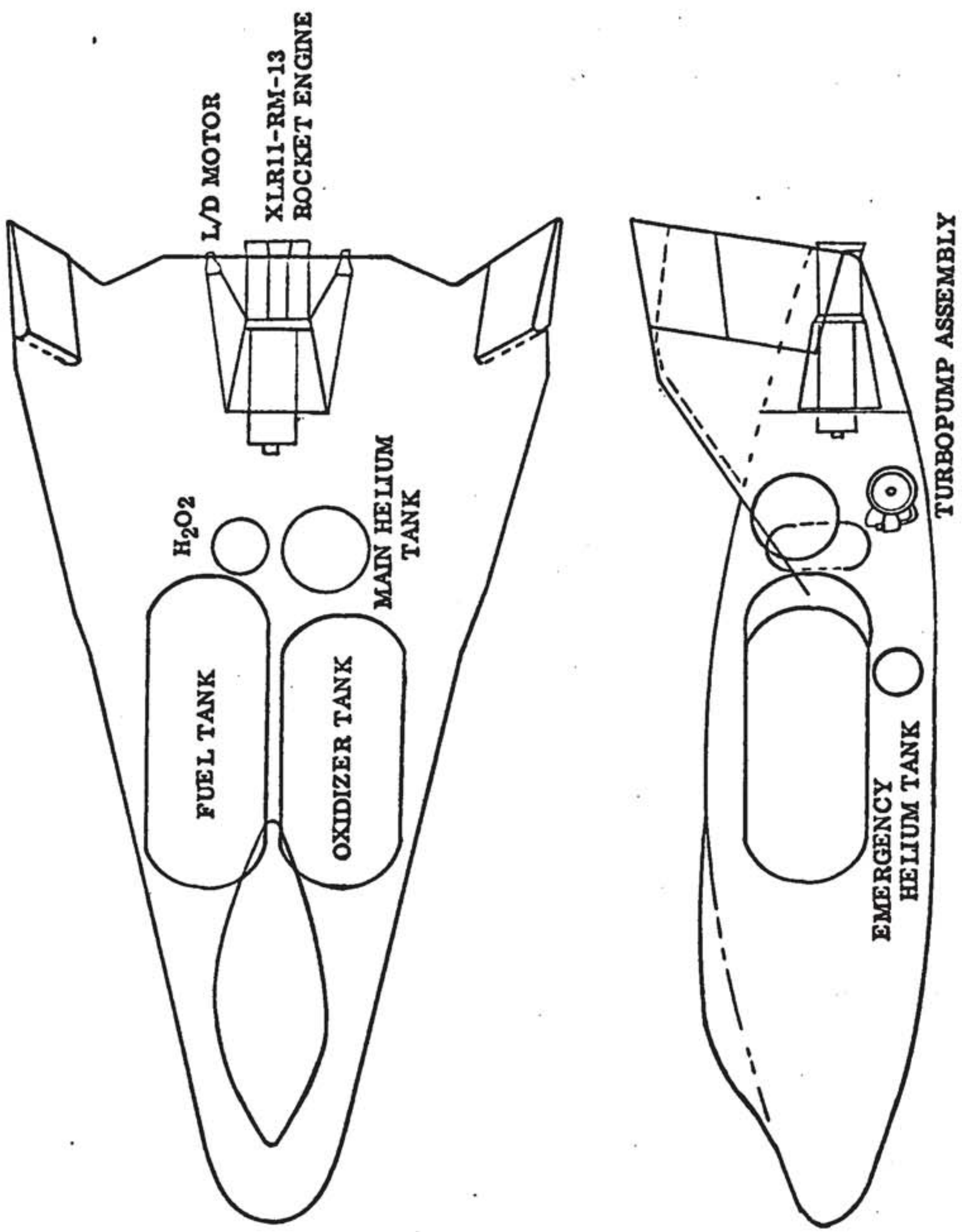


Figure 1-3. Propulsion System.

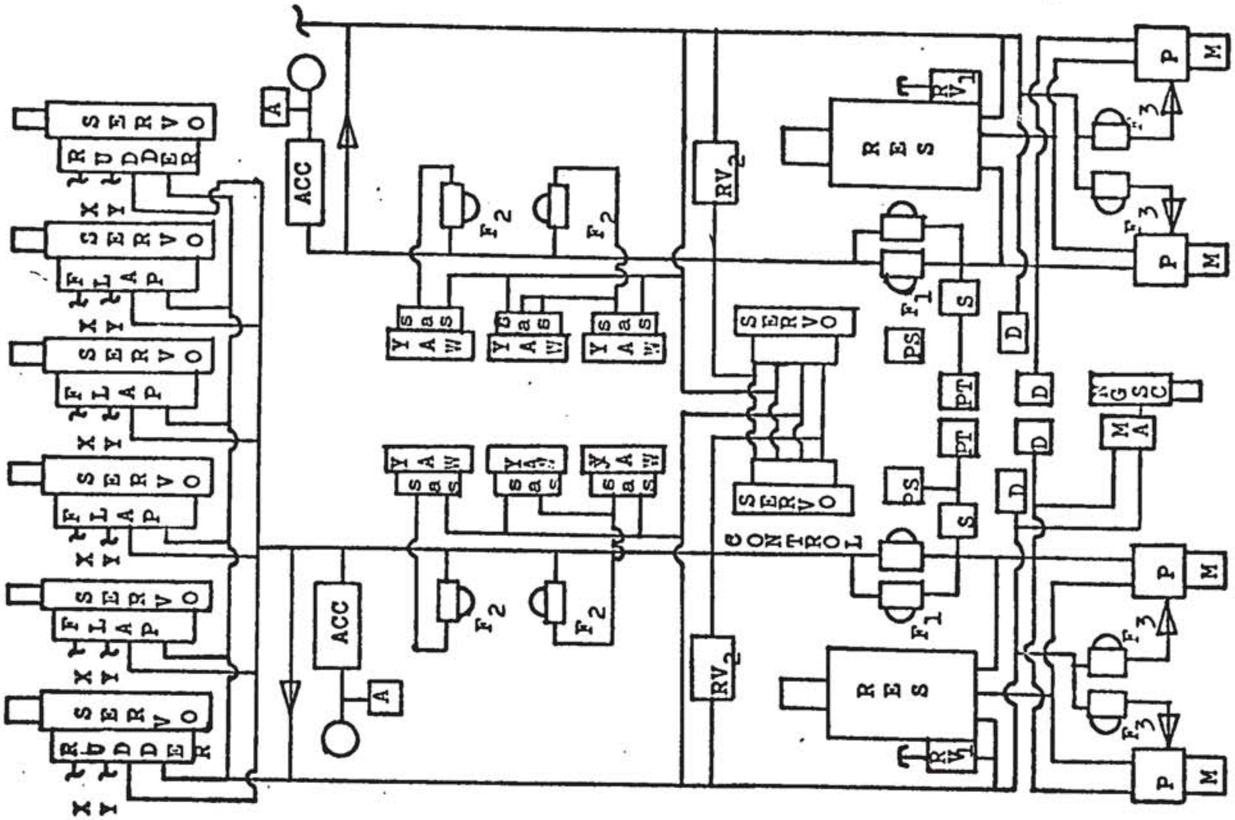


Figure 1-5. Hydraulic System.

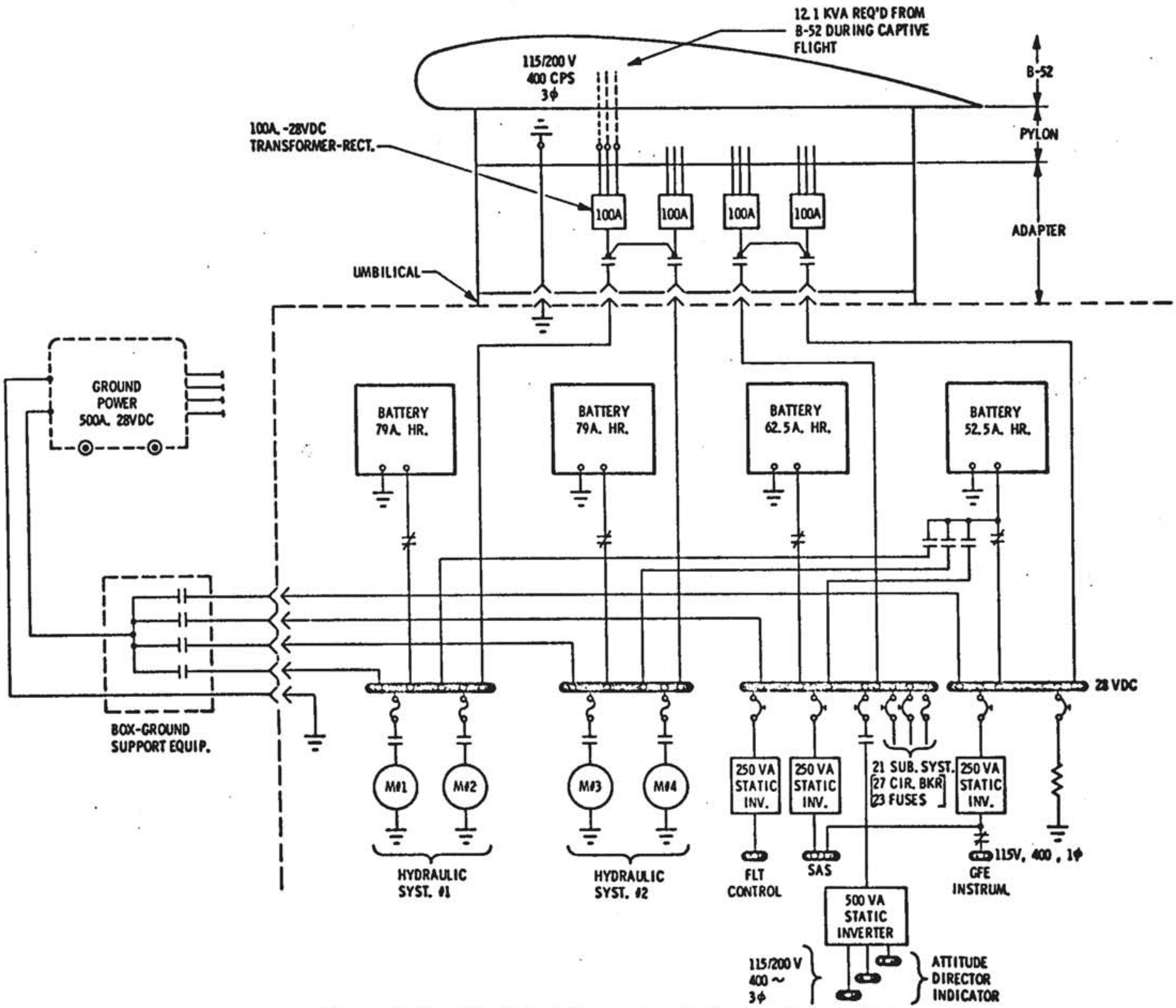


Figure 1-6. Electrical Power Supply System Schematics.

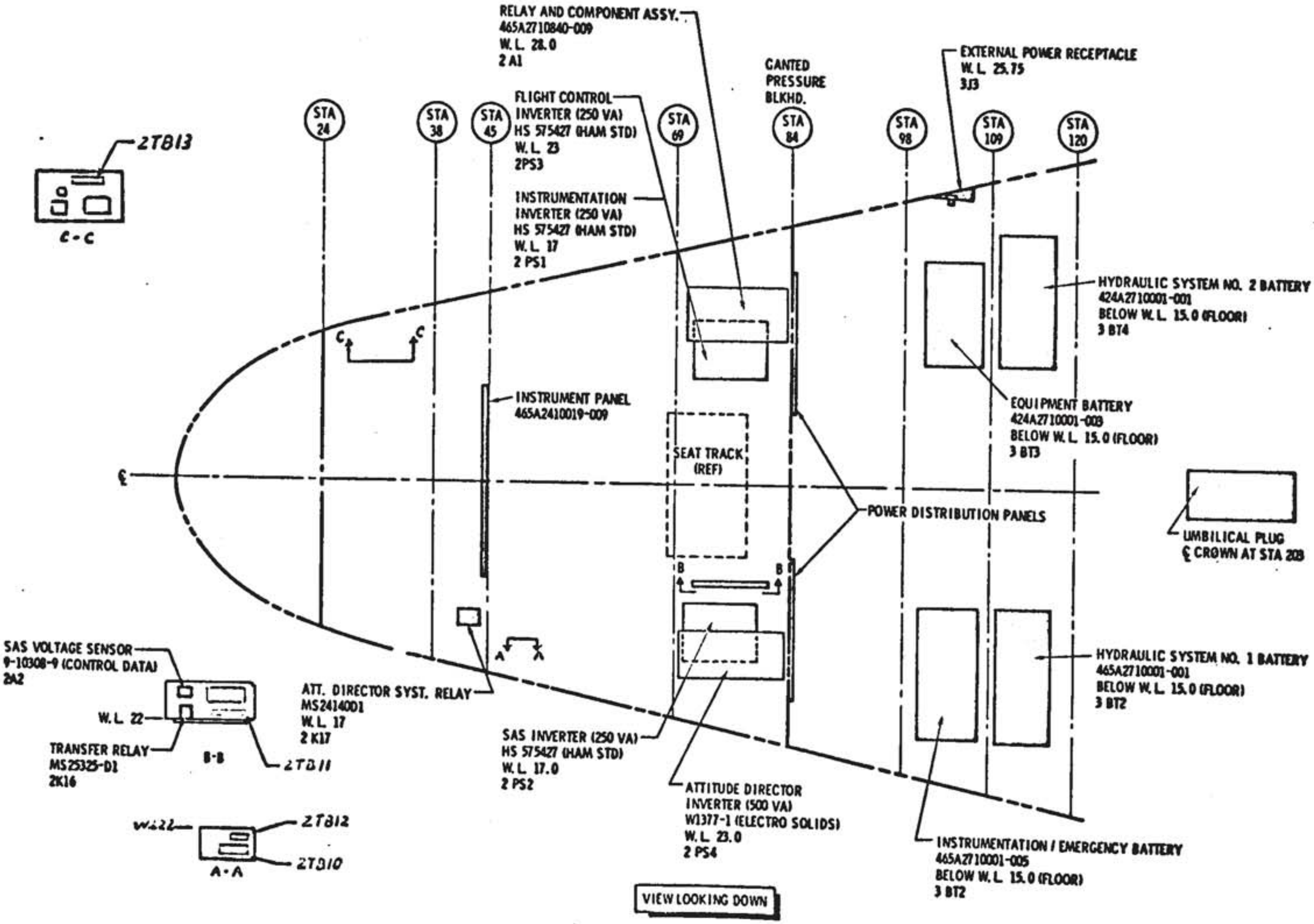


Figure 1-7. Location of Electrical Supply System Components.

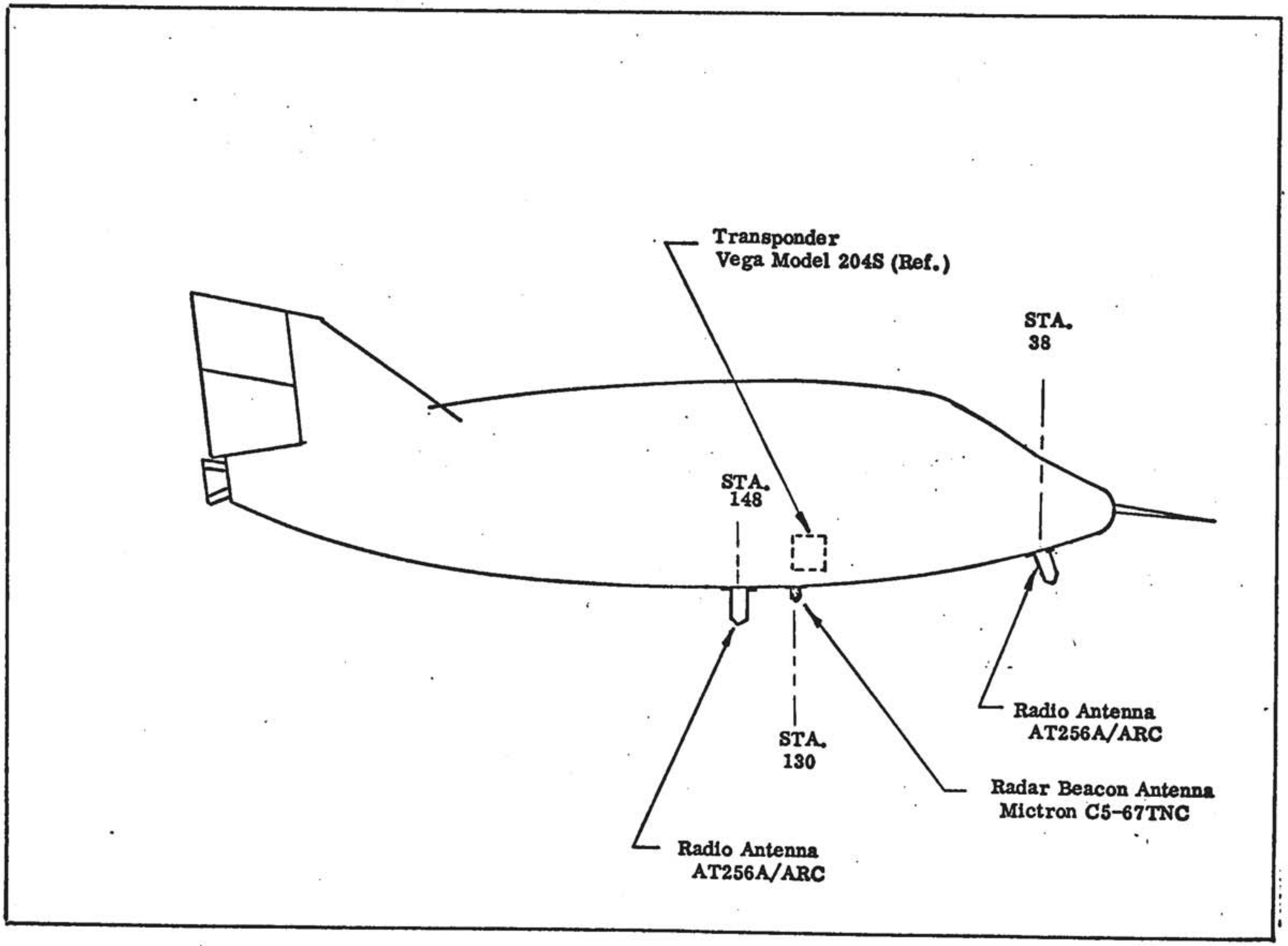


Figure 1-8. Antenna Installation-Radar Beacon and Radio.

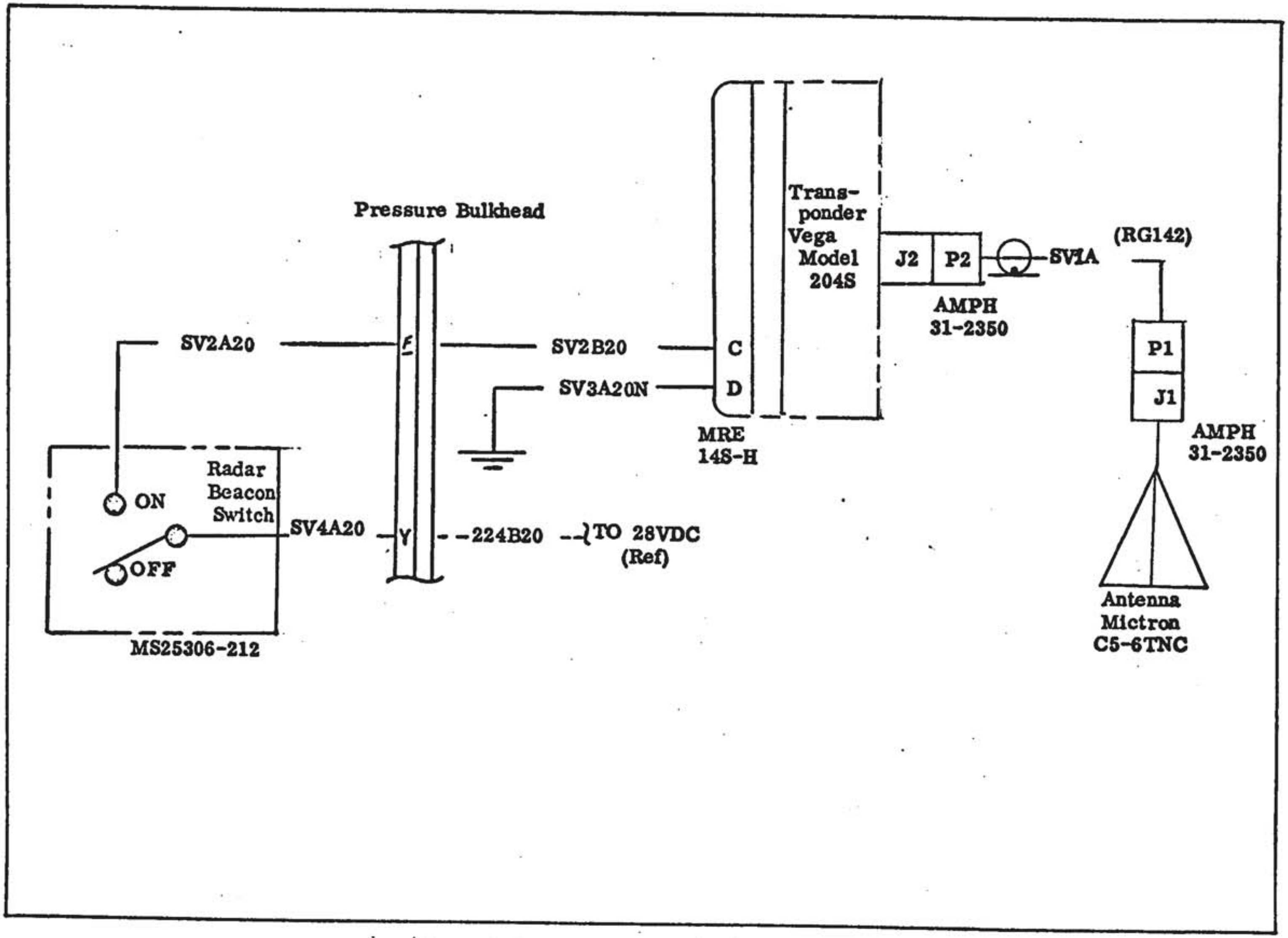


Figure 1-9. Radar Beacon System-Schematic.

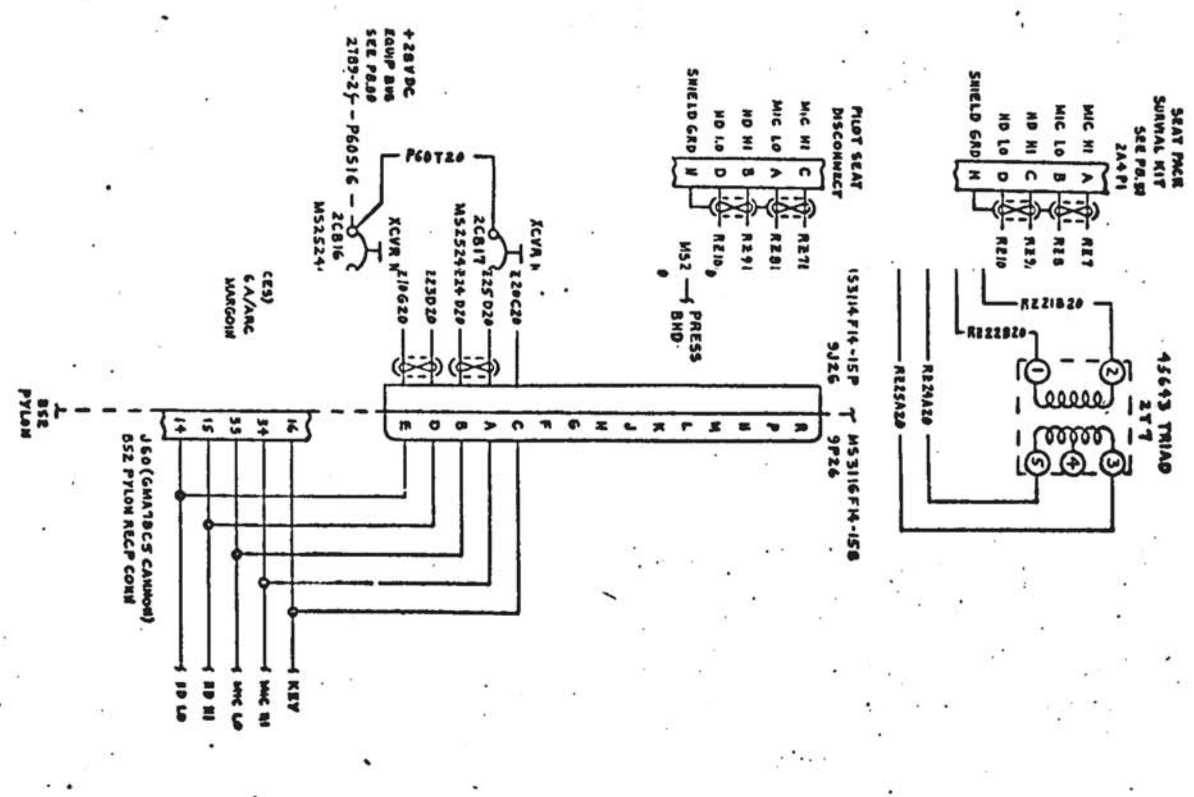


Figure 1-10. Wiring Diagram - Pilot's Intercom and Radio Systems.

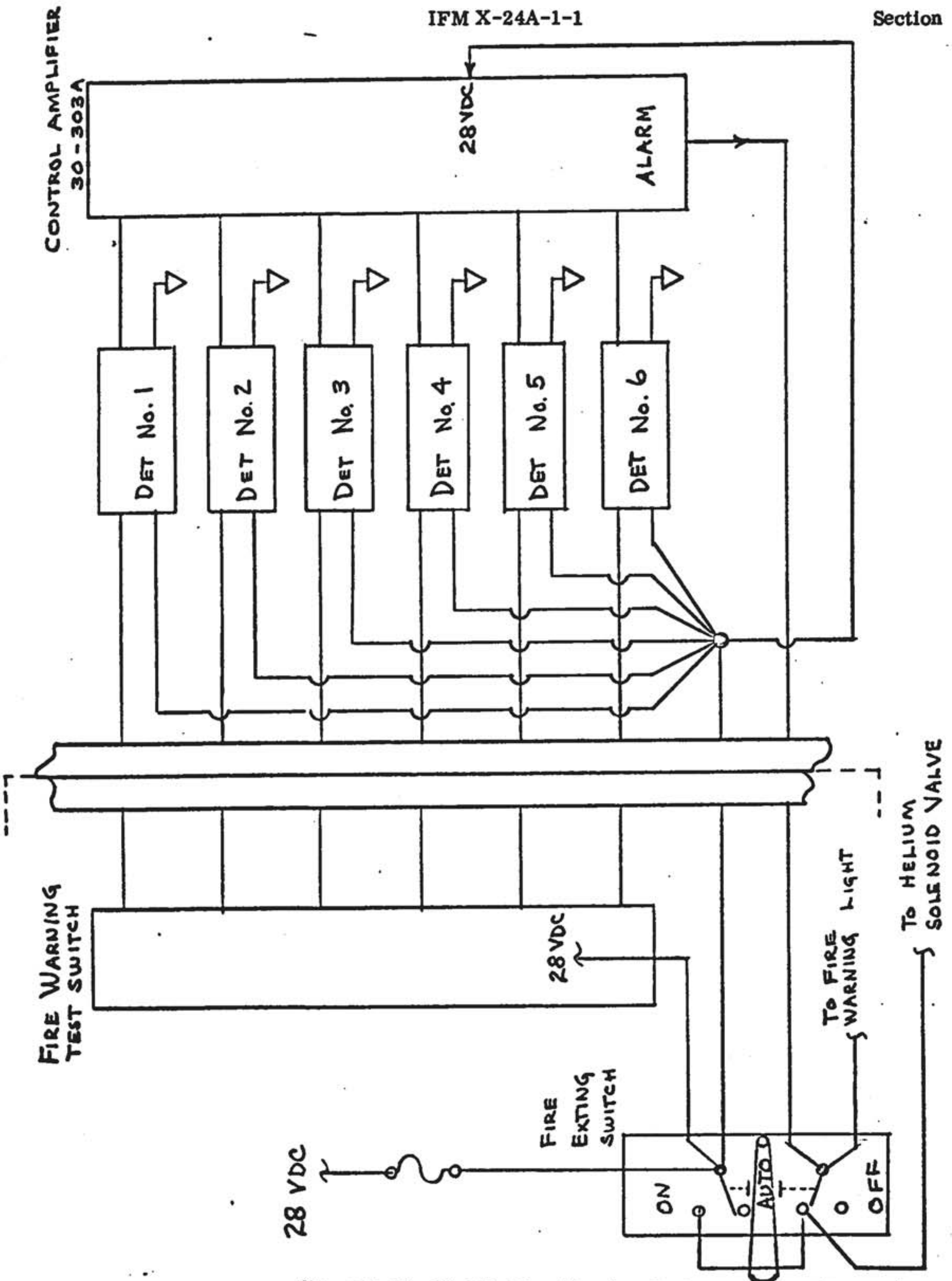


Figure 1-11. X-24A Fire Warning System.

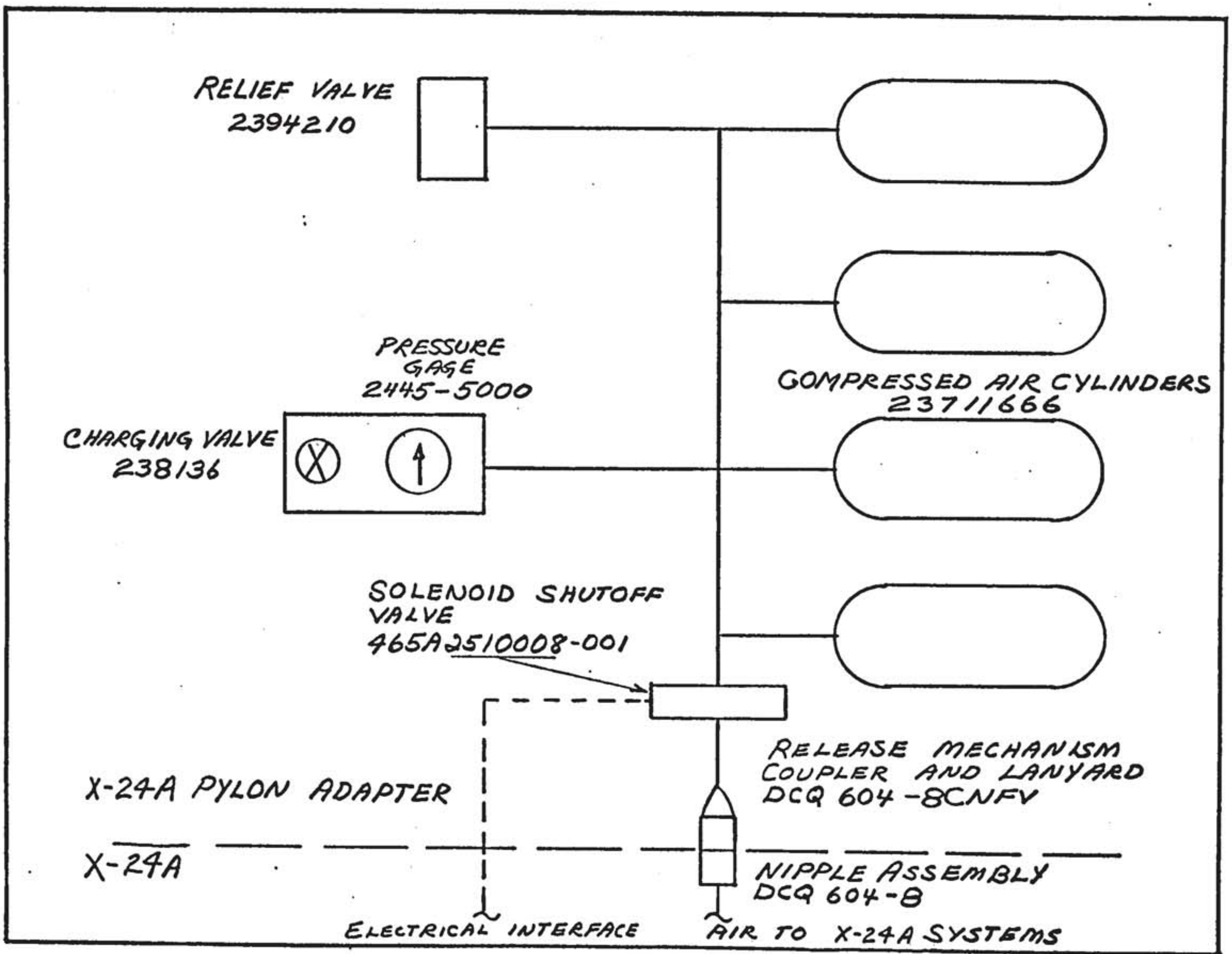


Figure 1-12. X-24A Pylon Adapter Air Supply.

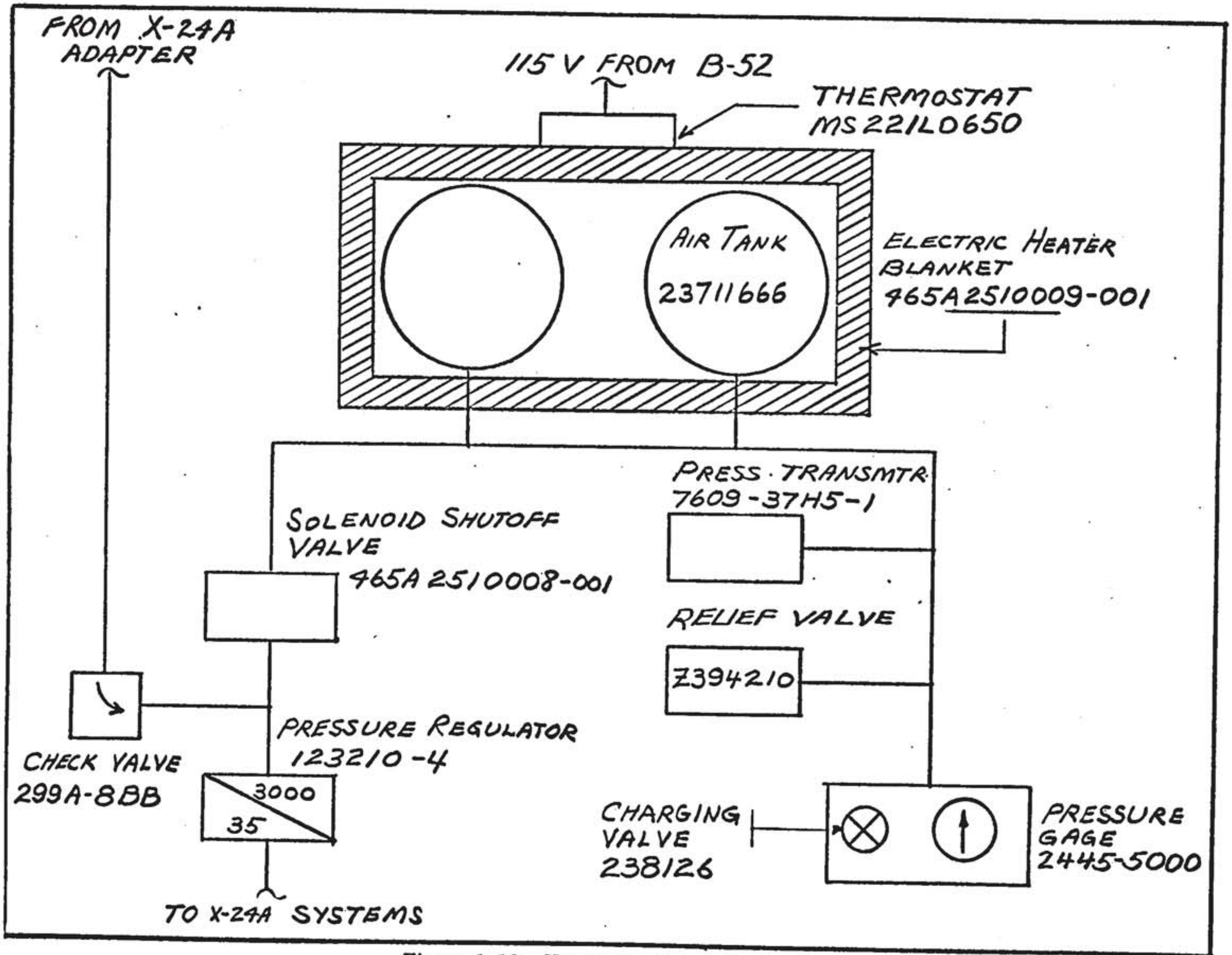


Figure 1-13. X-24A On-Board Air Supply.

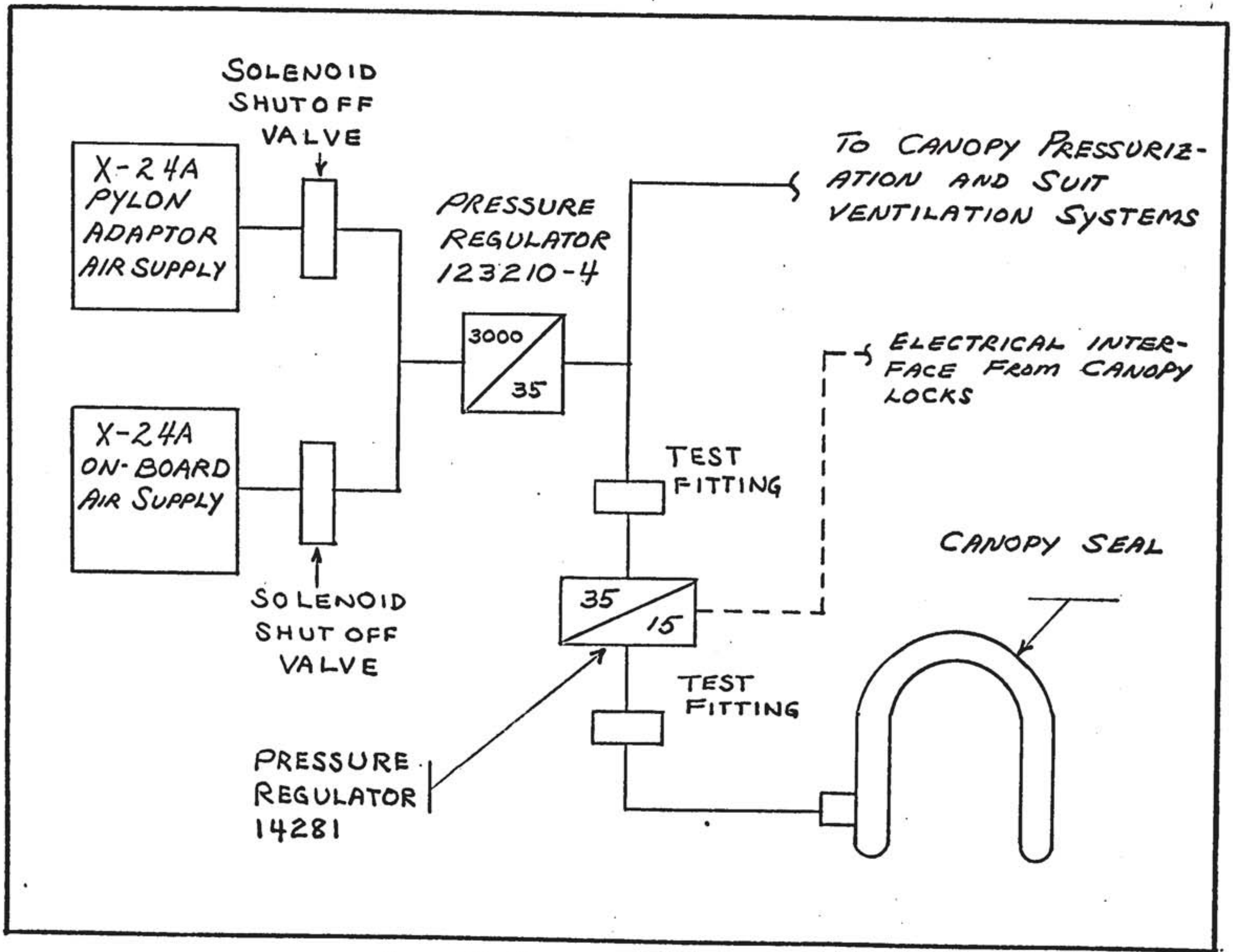
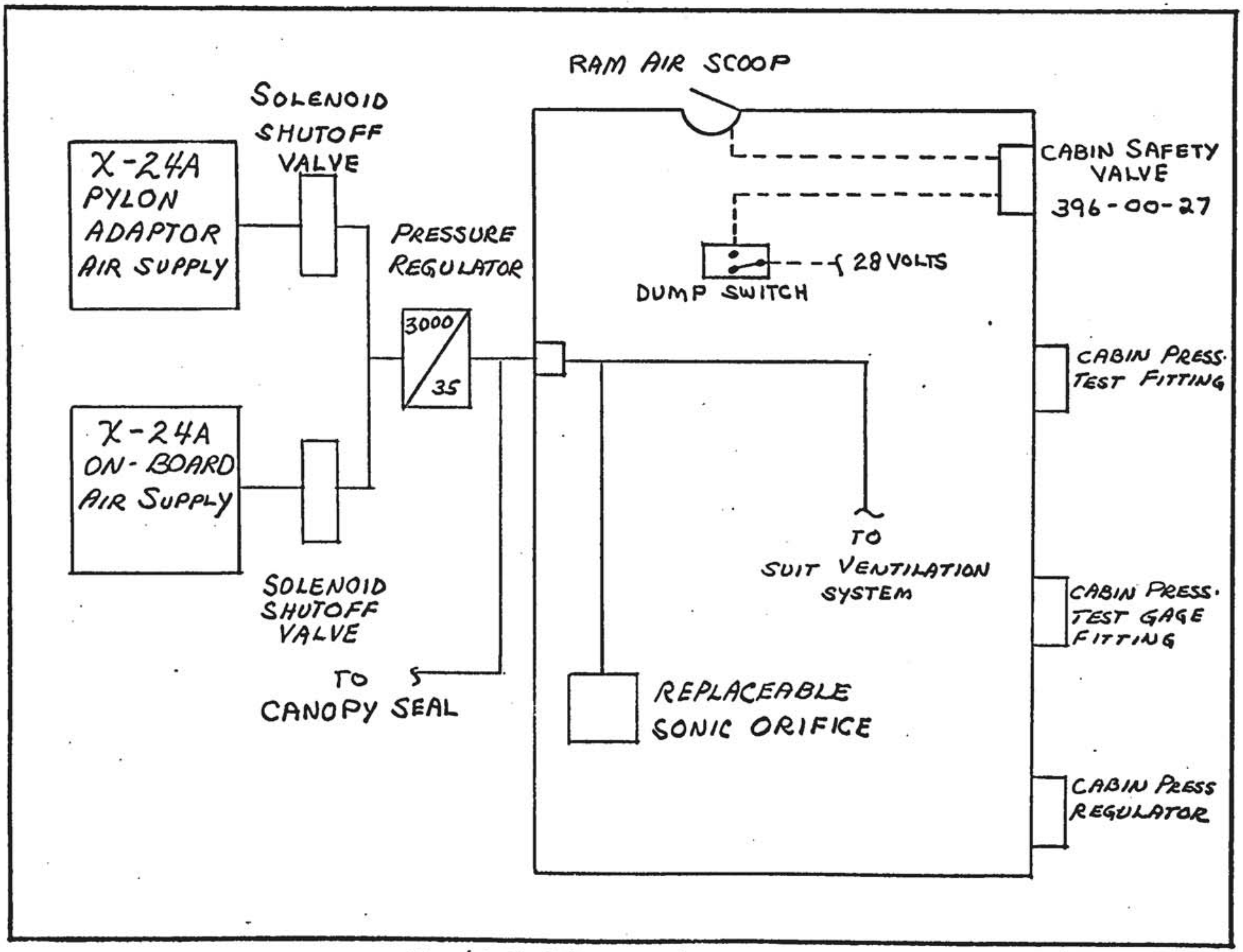


Figure 1-14. X-24A Canopy Seal Pressurization.



Figuré 1-15. Cabin Pressurization System.

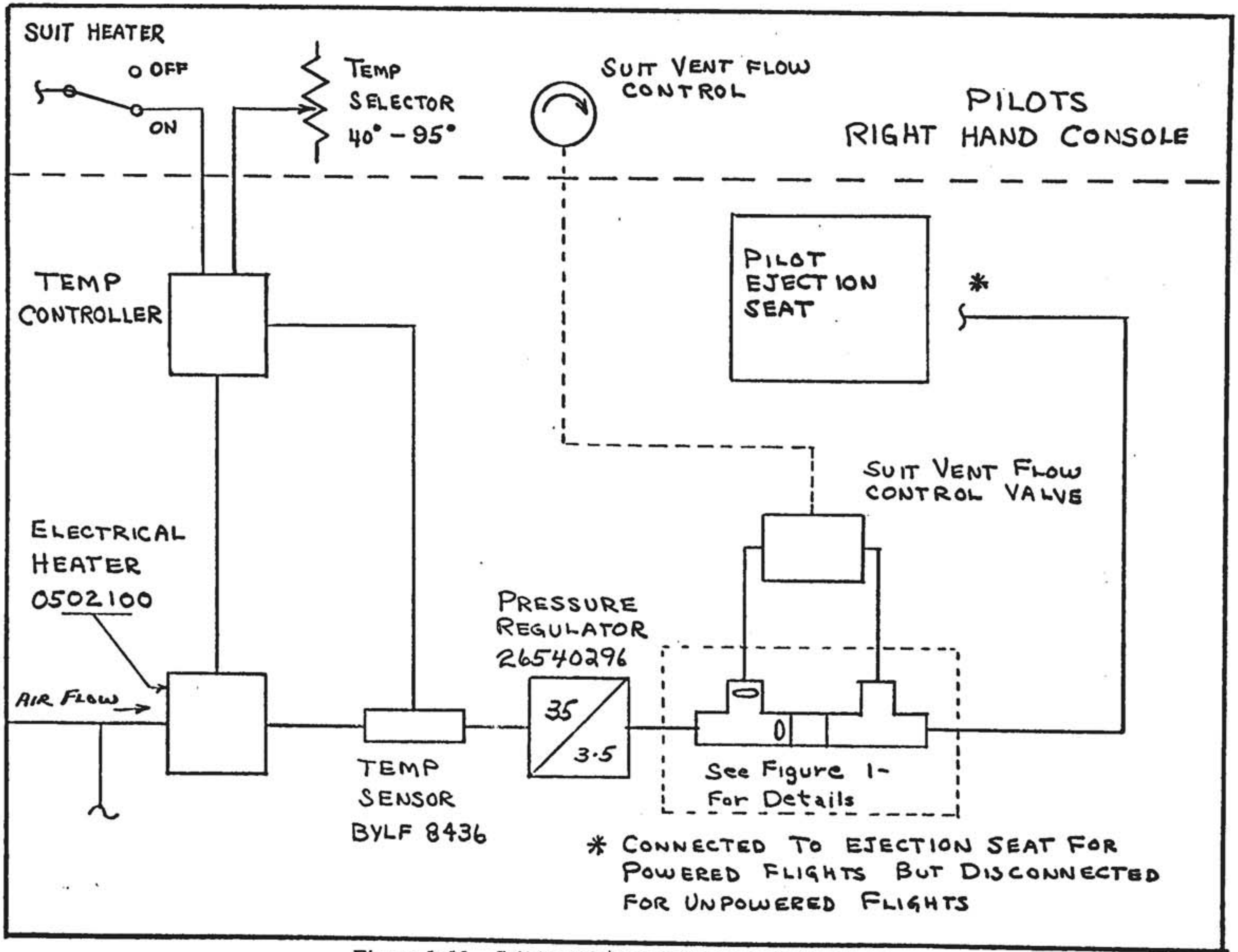


Figure 1-16. Suit Ventilation and Pressurization System.

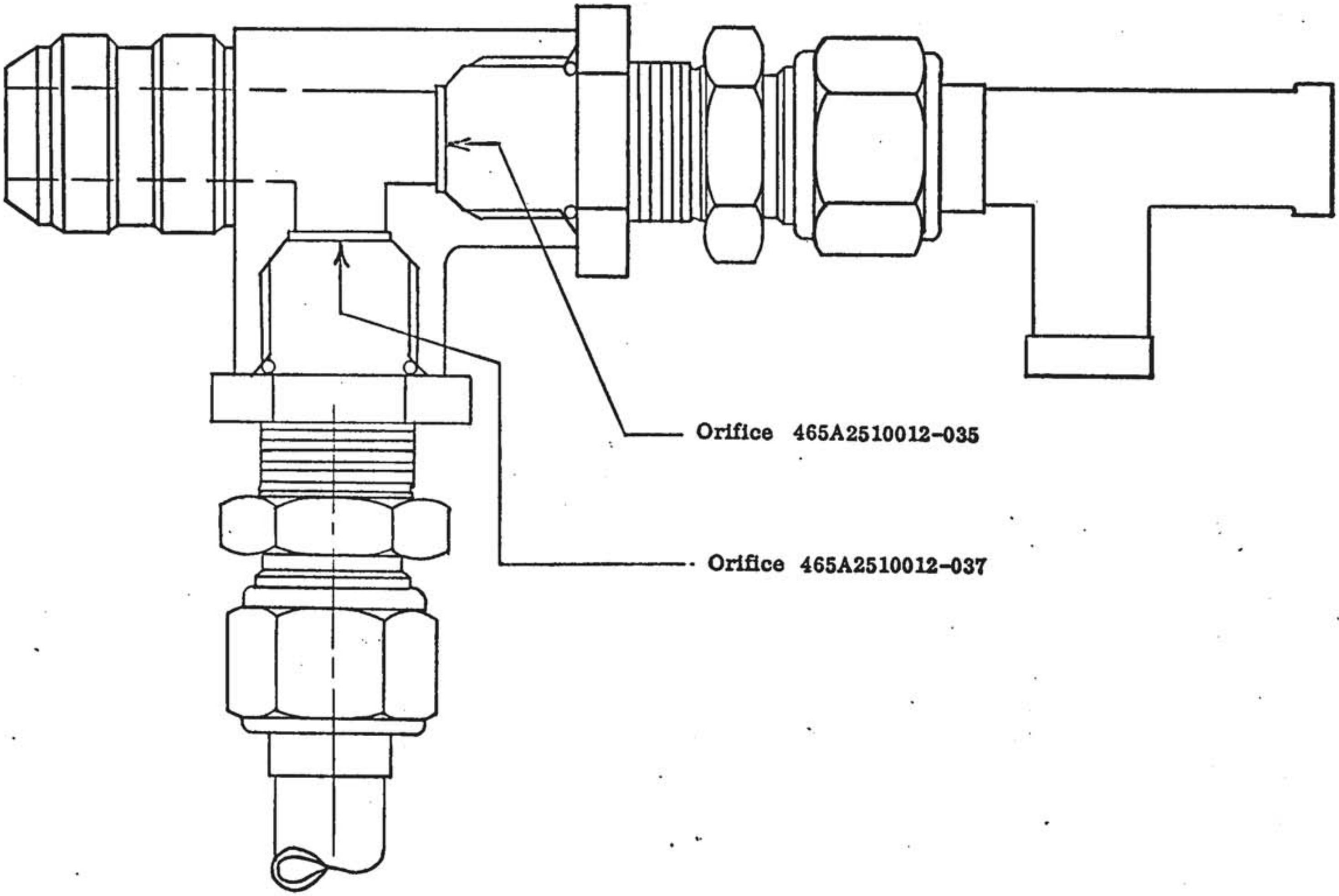


Figure 1-17. Suit Vent Orifice Assembly.

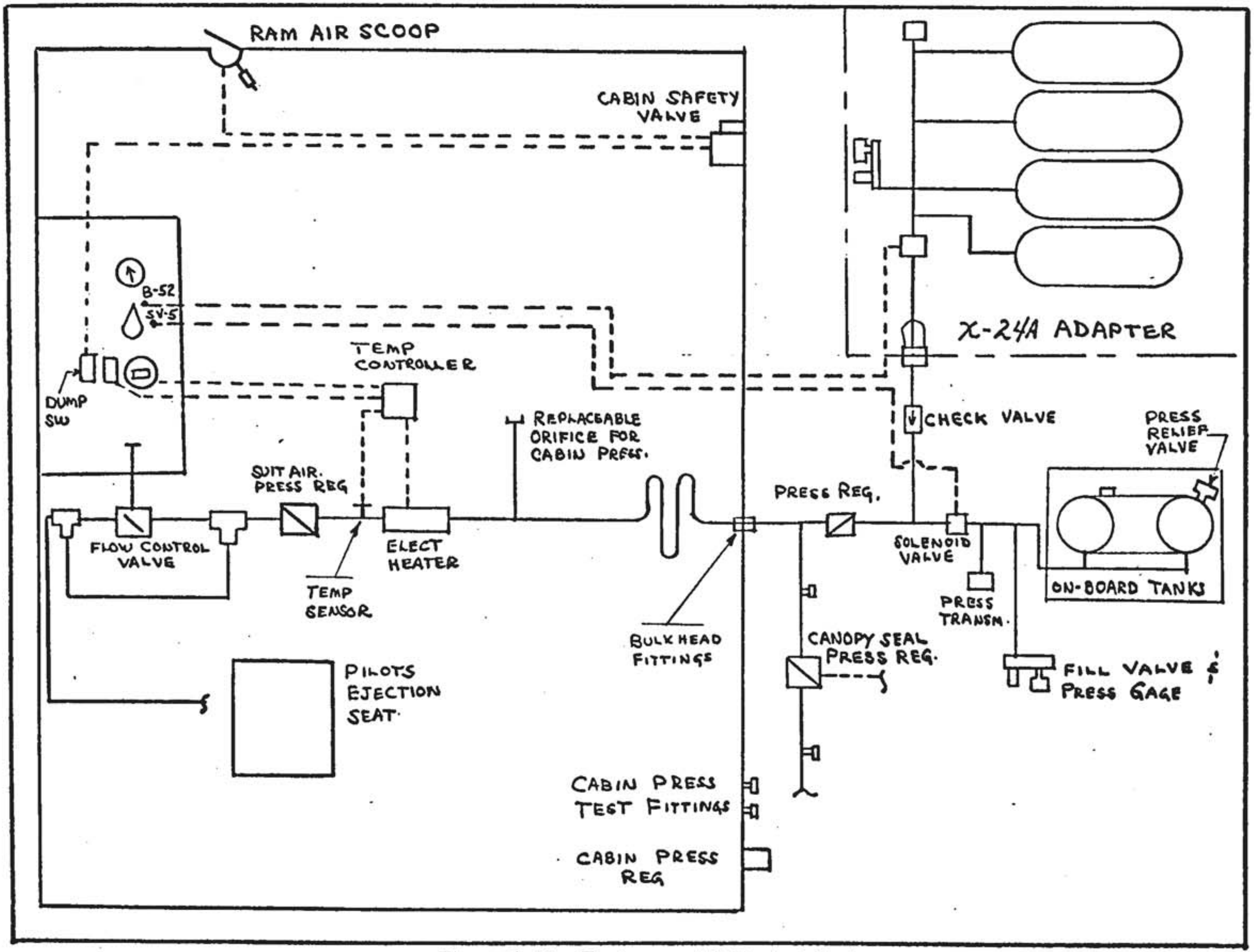


Figure 1-18. Environmental Control System.

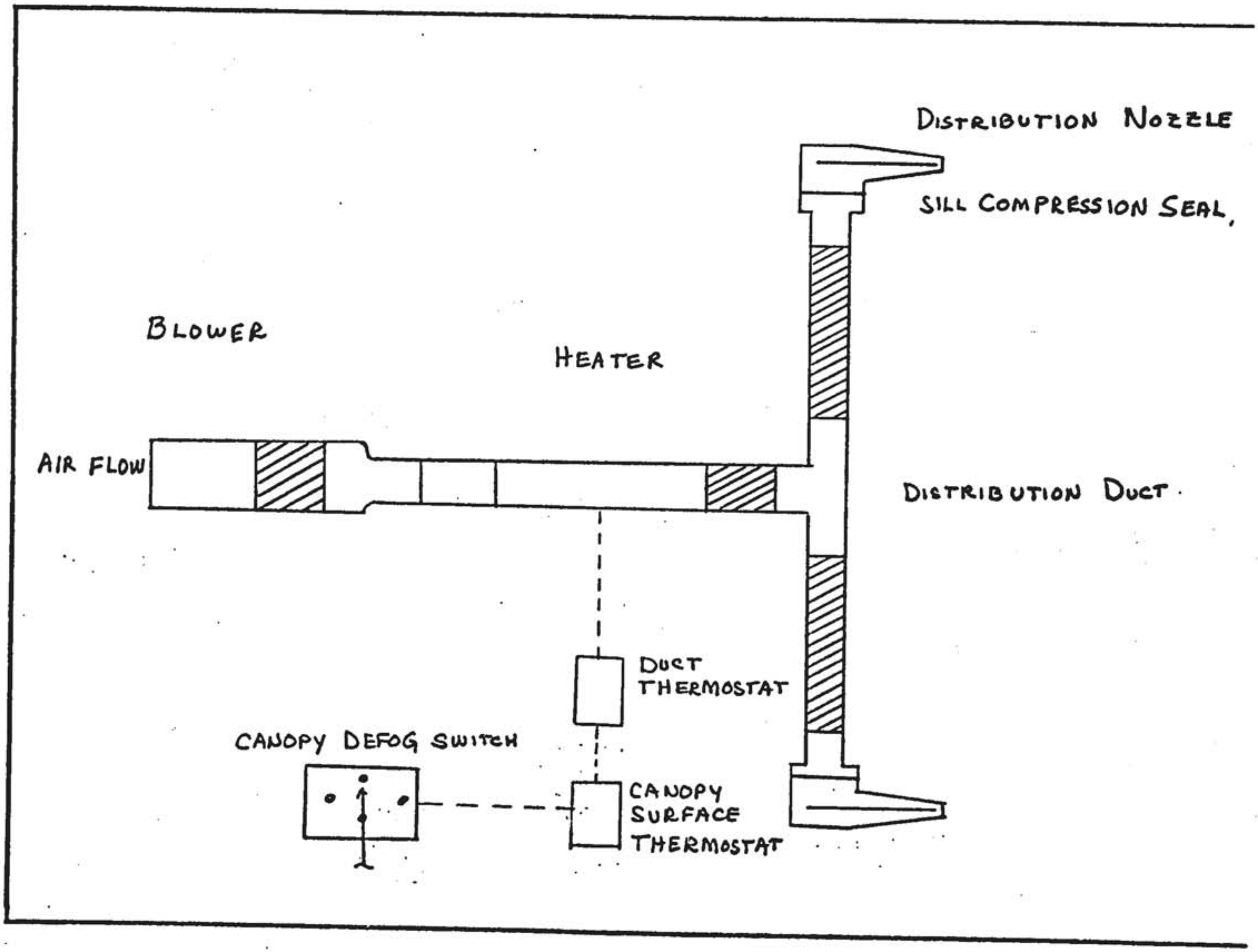


Figure 1-19. X-24A Canopy Defog System.

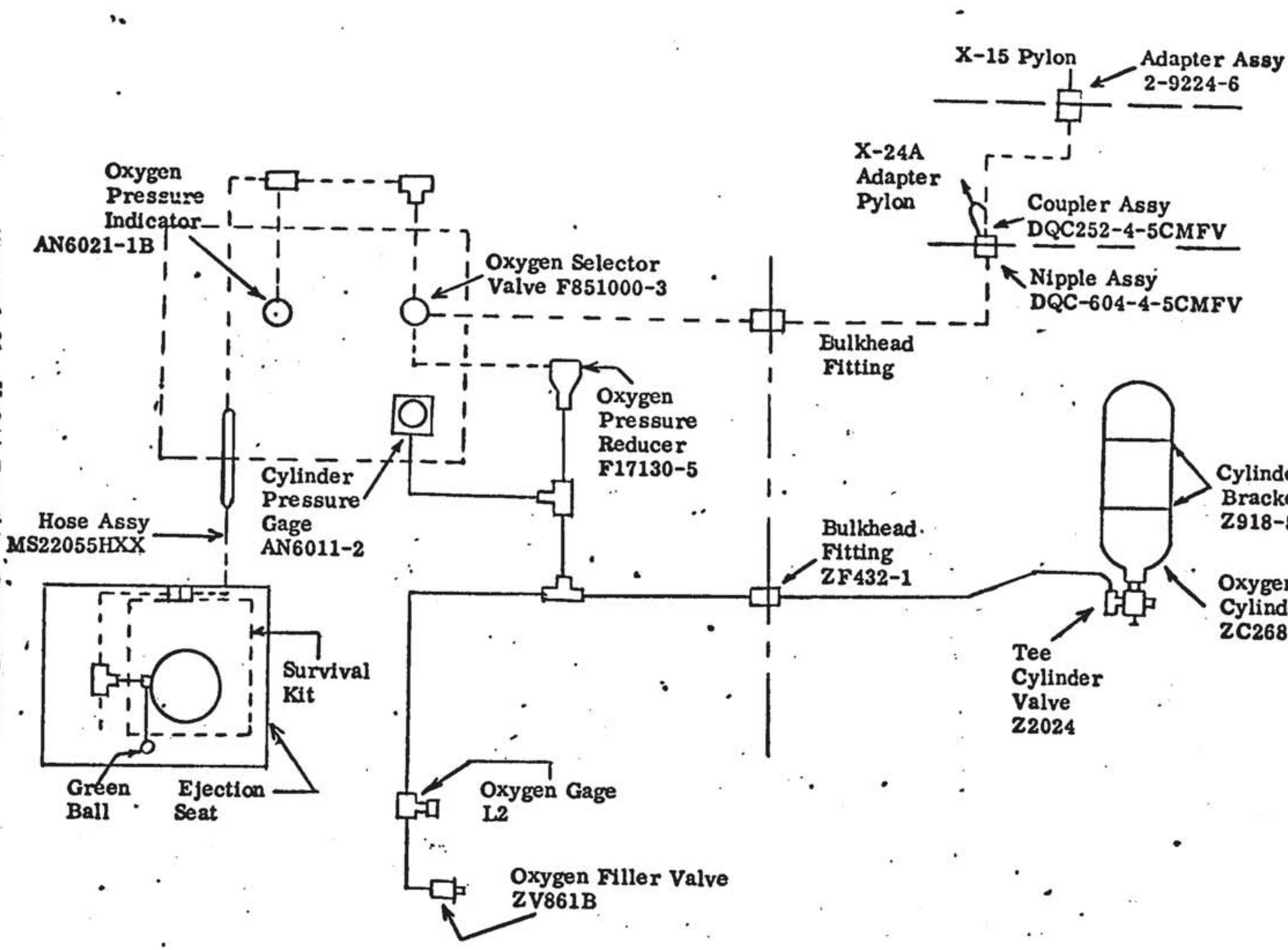


Figure 1-21. X-24A Breathing Oxygen System.

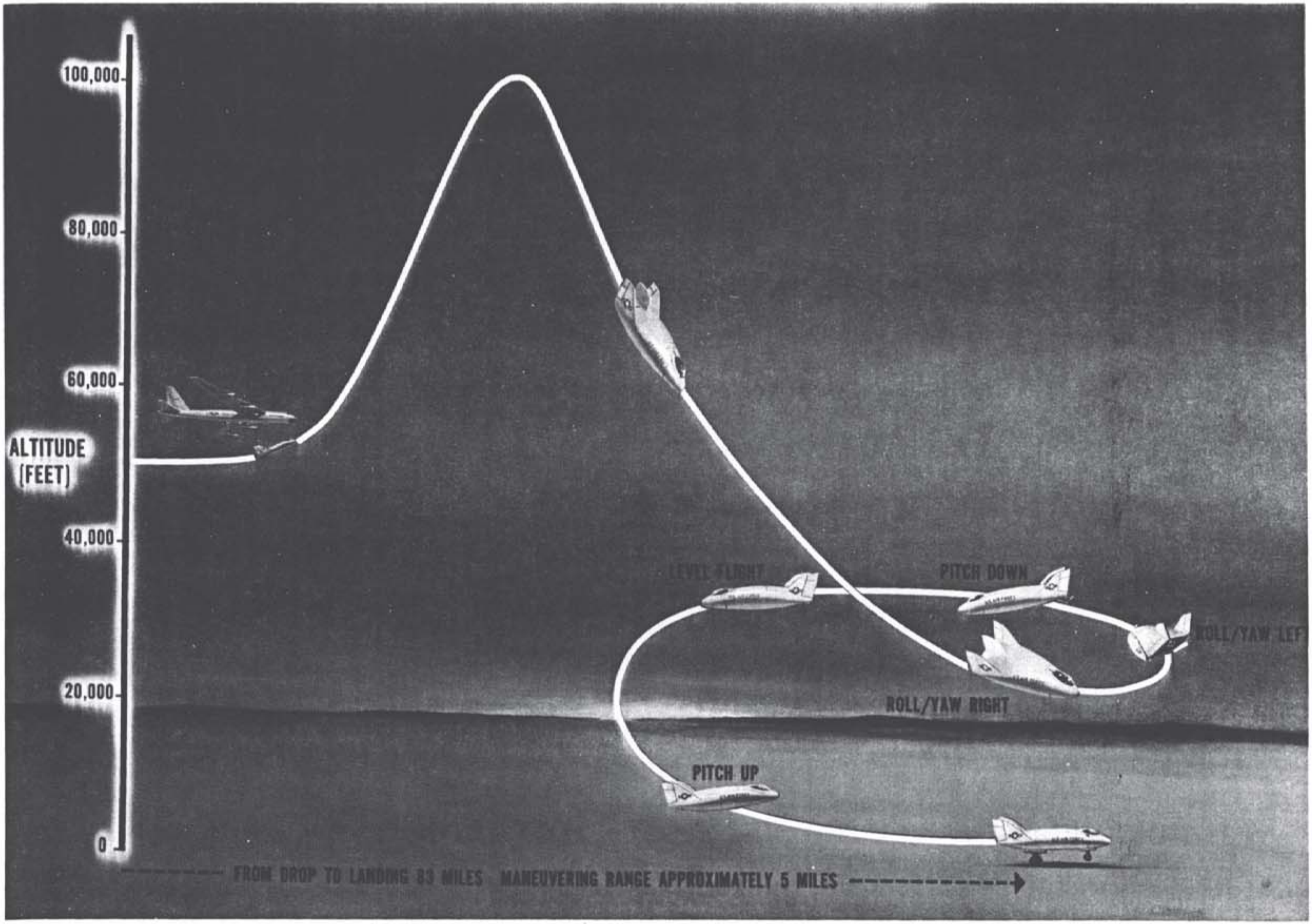


Figure 2-1. X-24A Flight Profile.

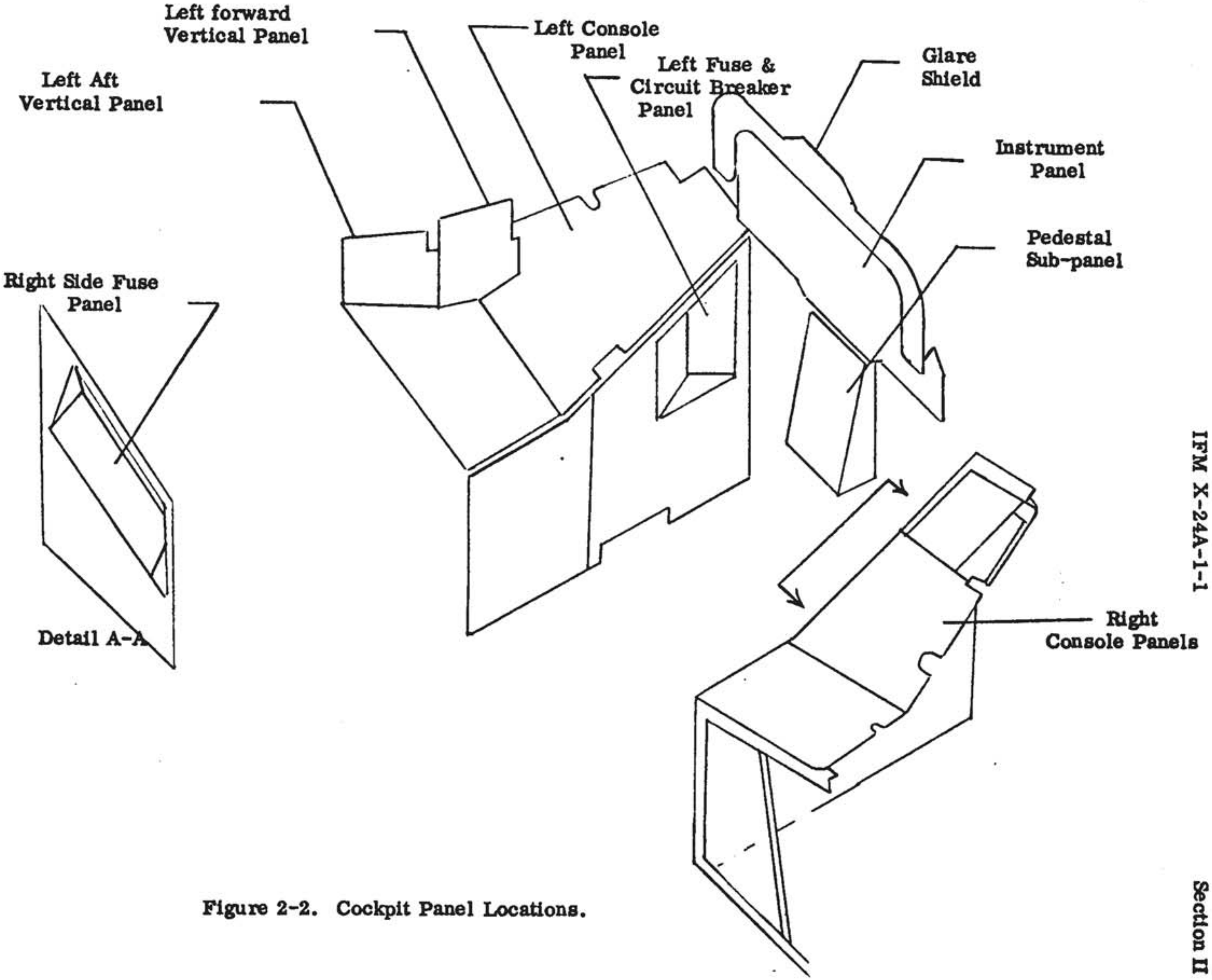


Figure 2-2. Cockpit Panel Locations.

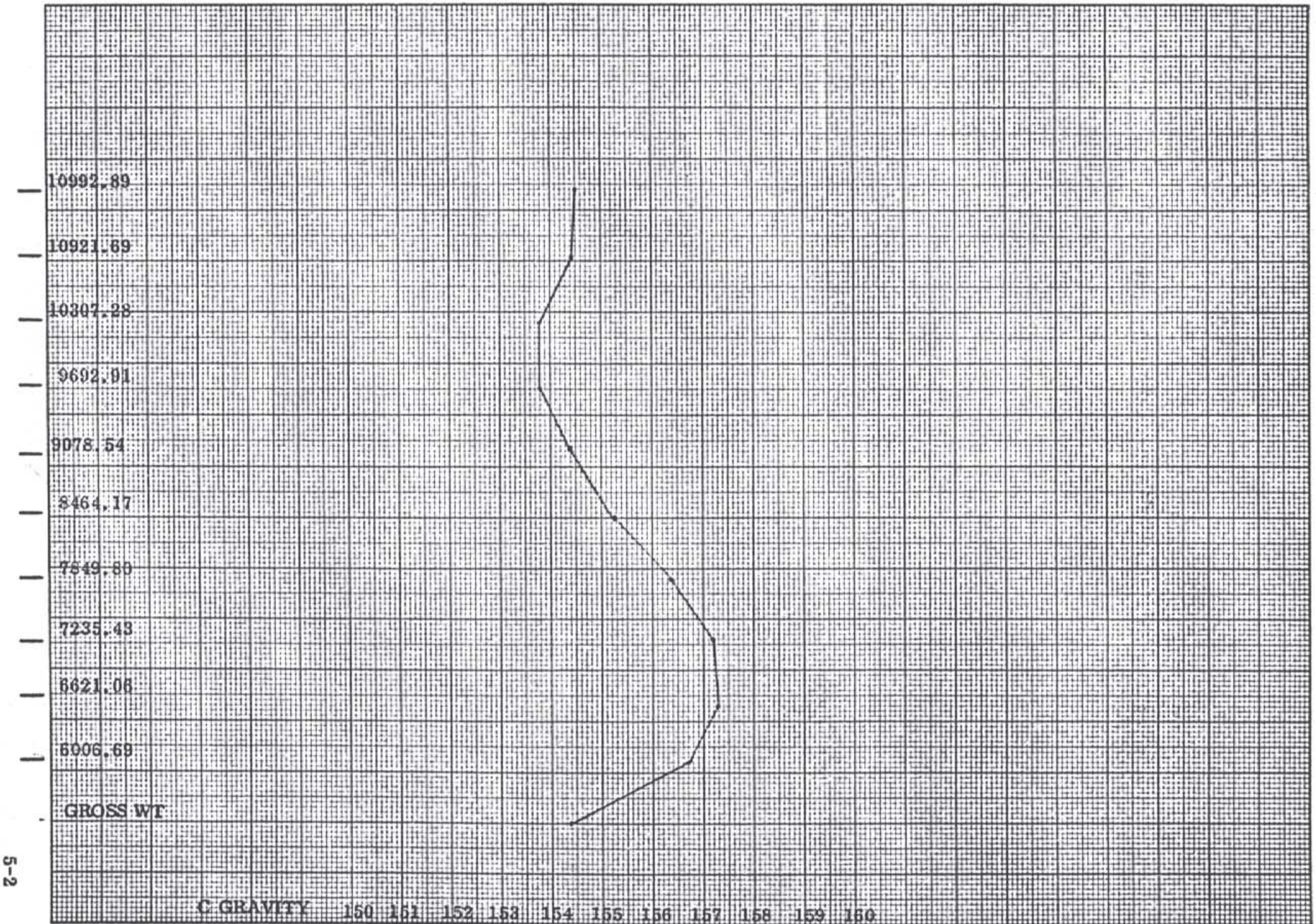


Figure 5-1. Operating Weight

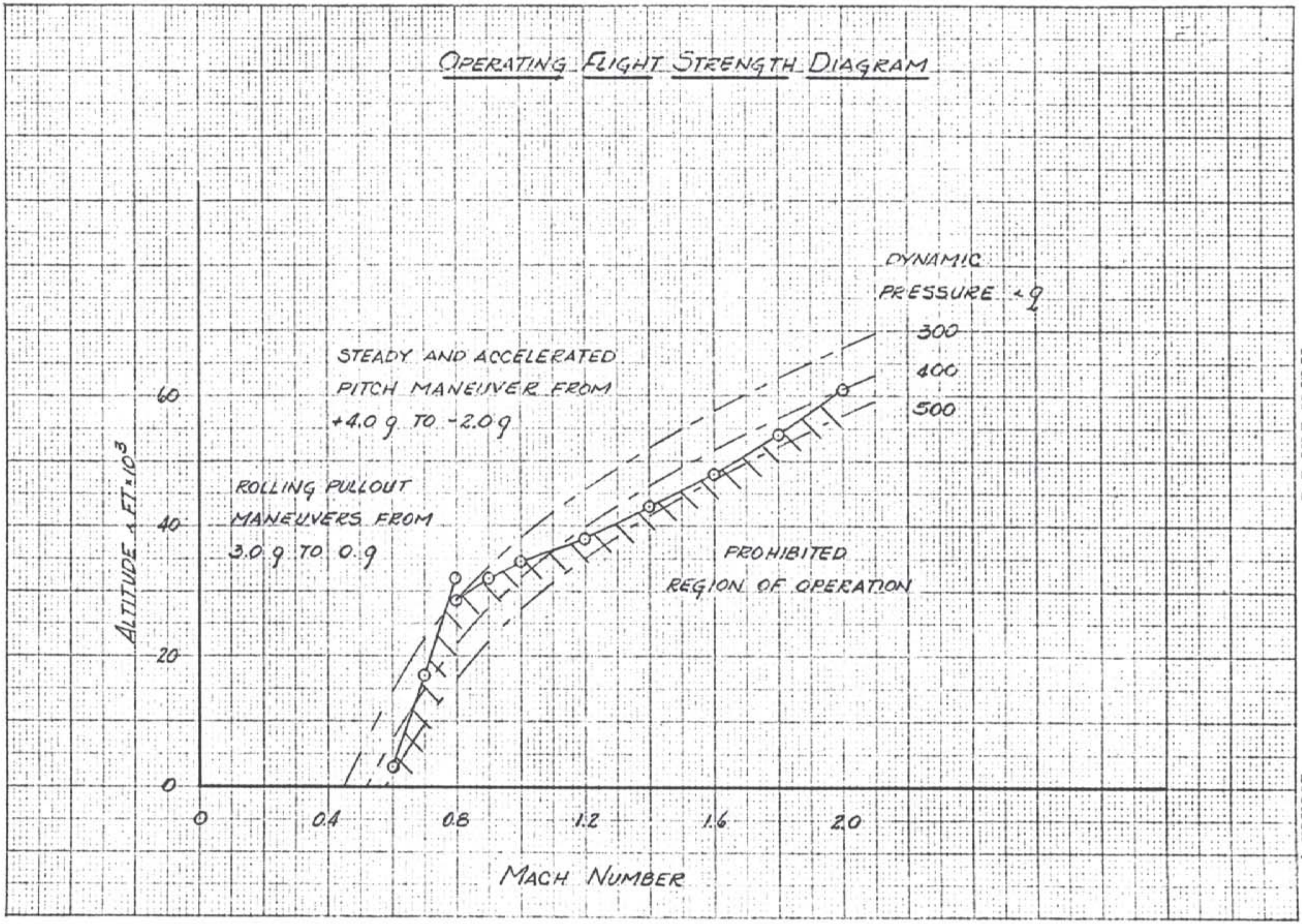


Figure 5-2. Operating Flight Strength Diagram.

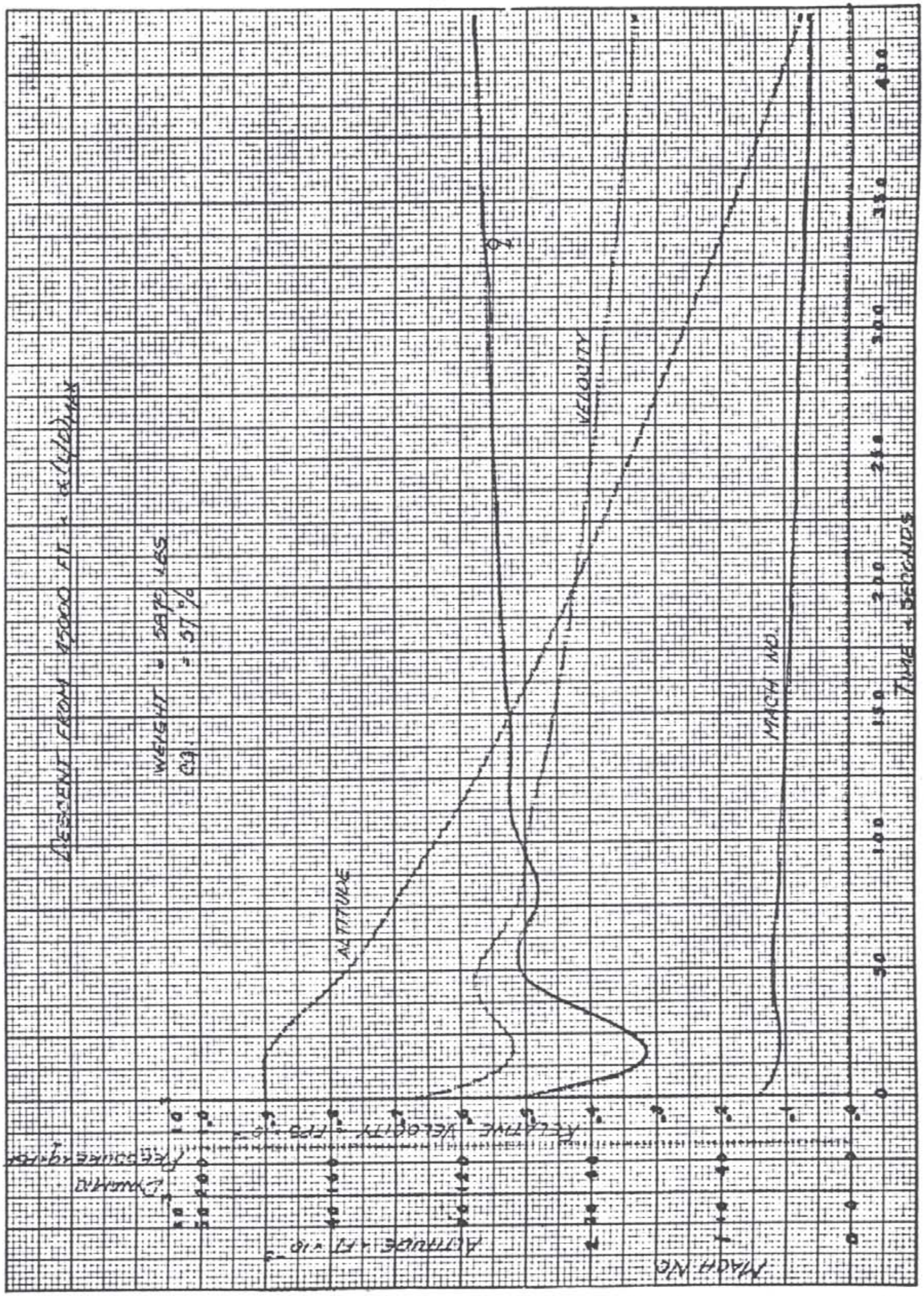


Figure 5-18. Descent From 45000 Ft. α (L/D) Max.

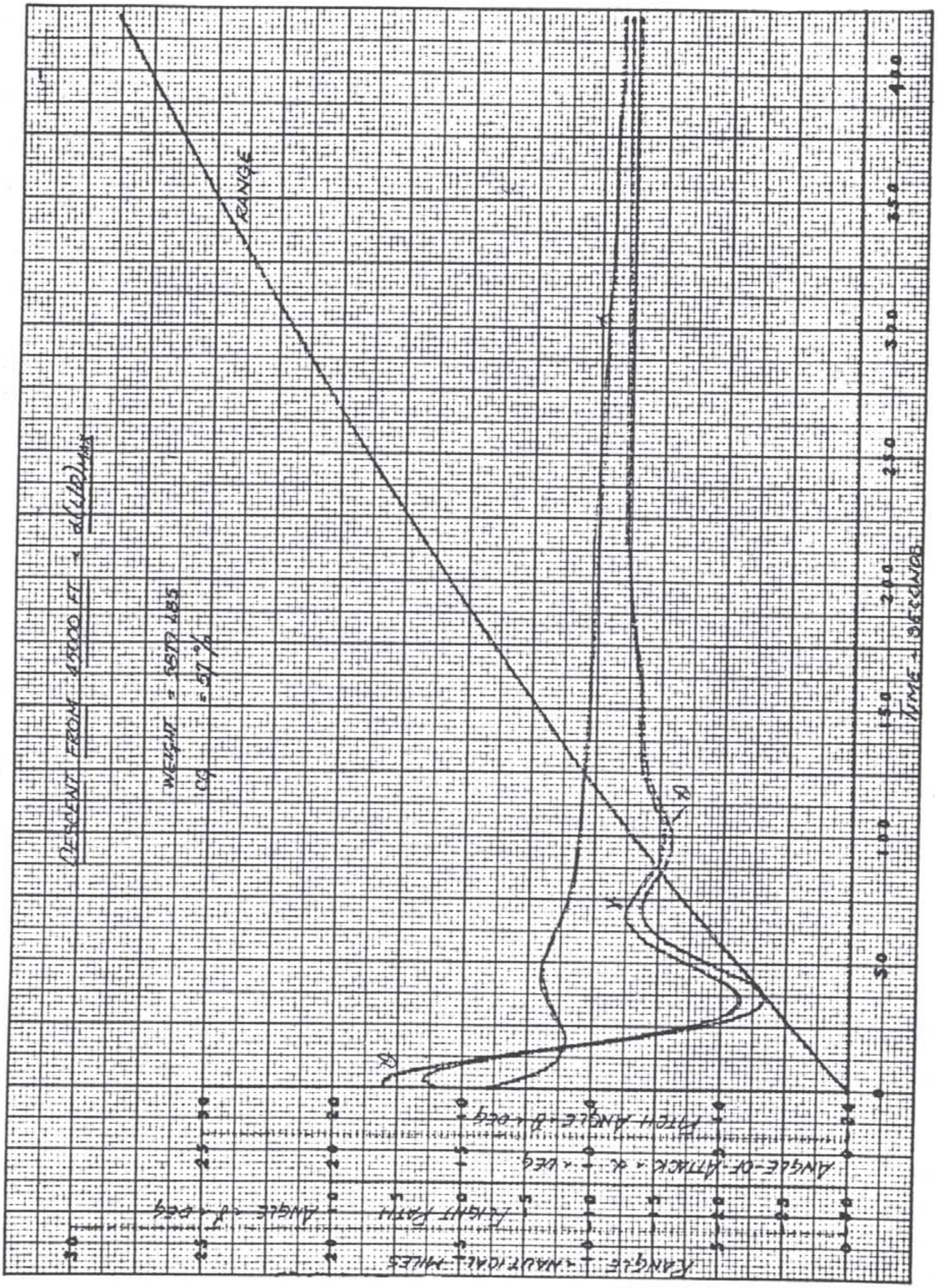


Figure 5-19. Descent From 45000 Ft α (L/D) Max.

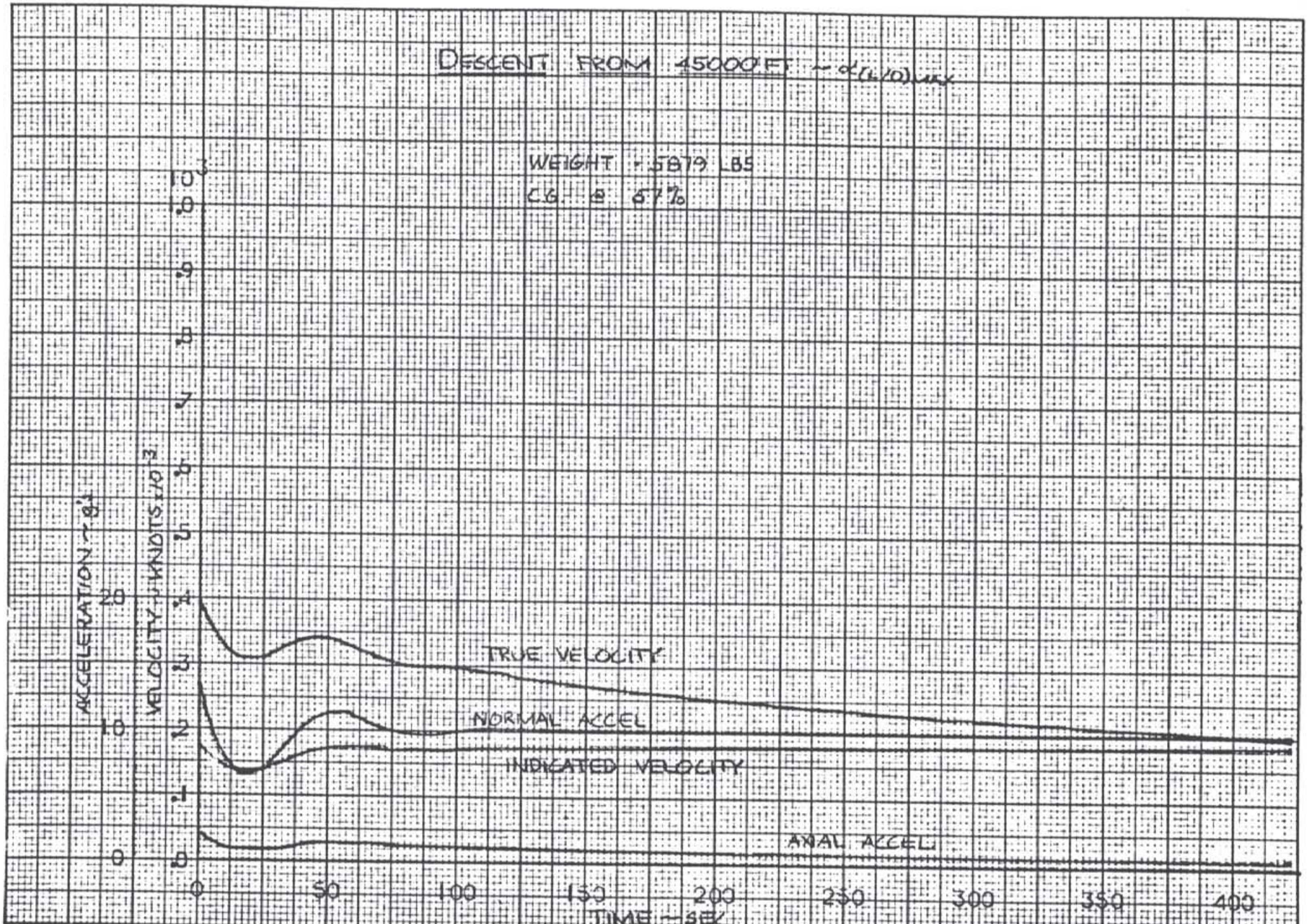


Figure 5-20. Descent From 45000 Ft. α (L/D) Max.

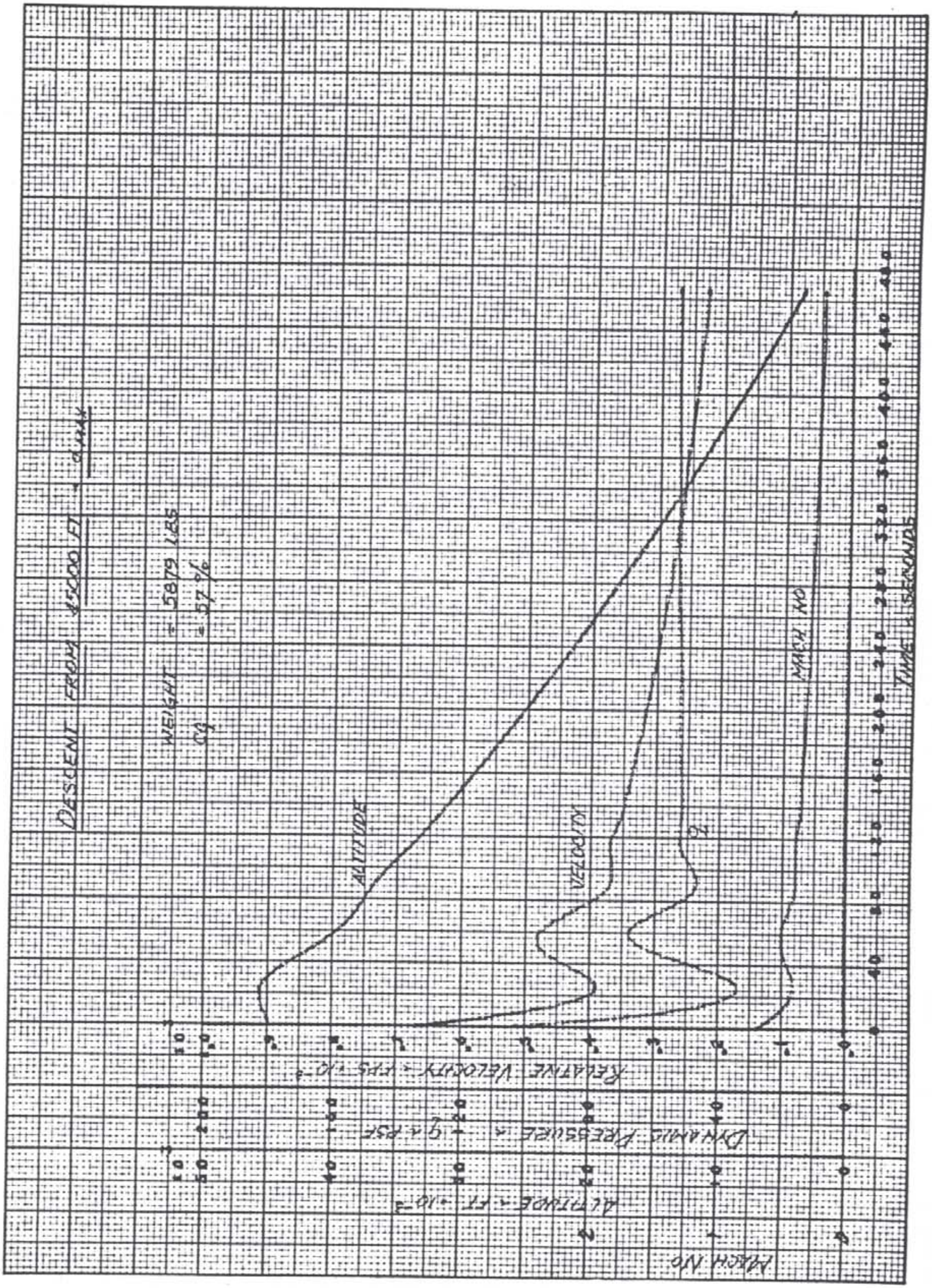


Figure 5-21. Descent From 45000 Ft. α Max.

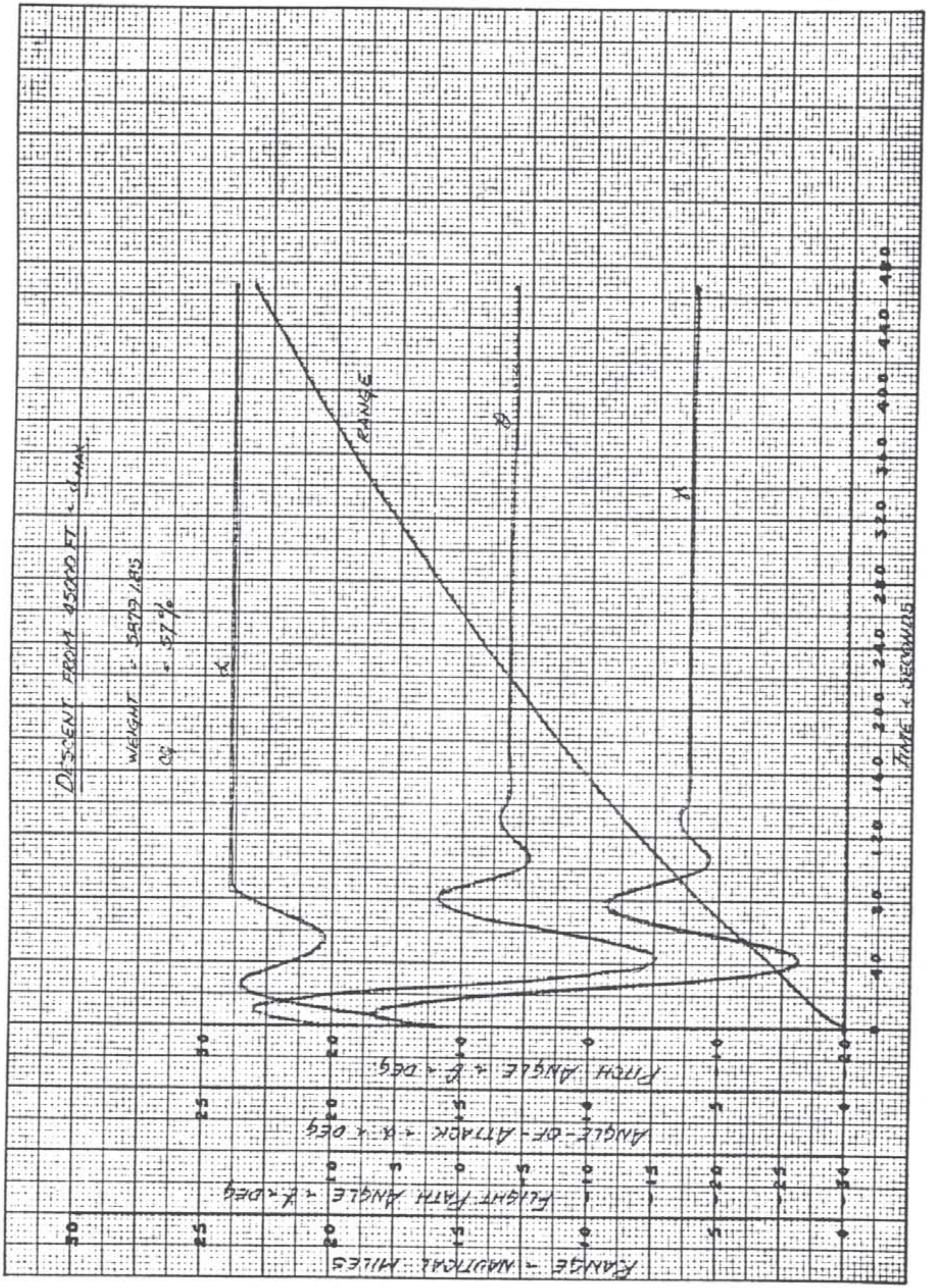


Figure 5-22. Descent From 45000 Ft. α Max.

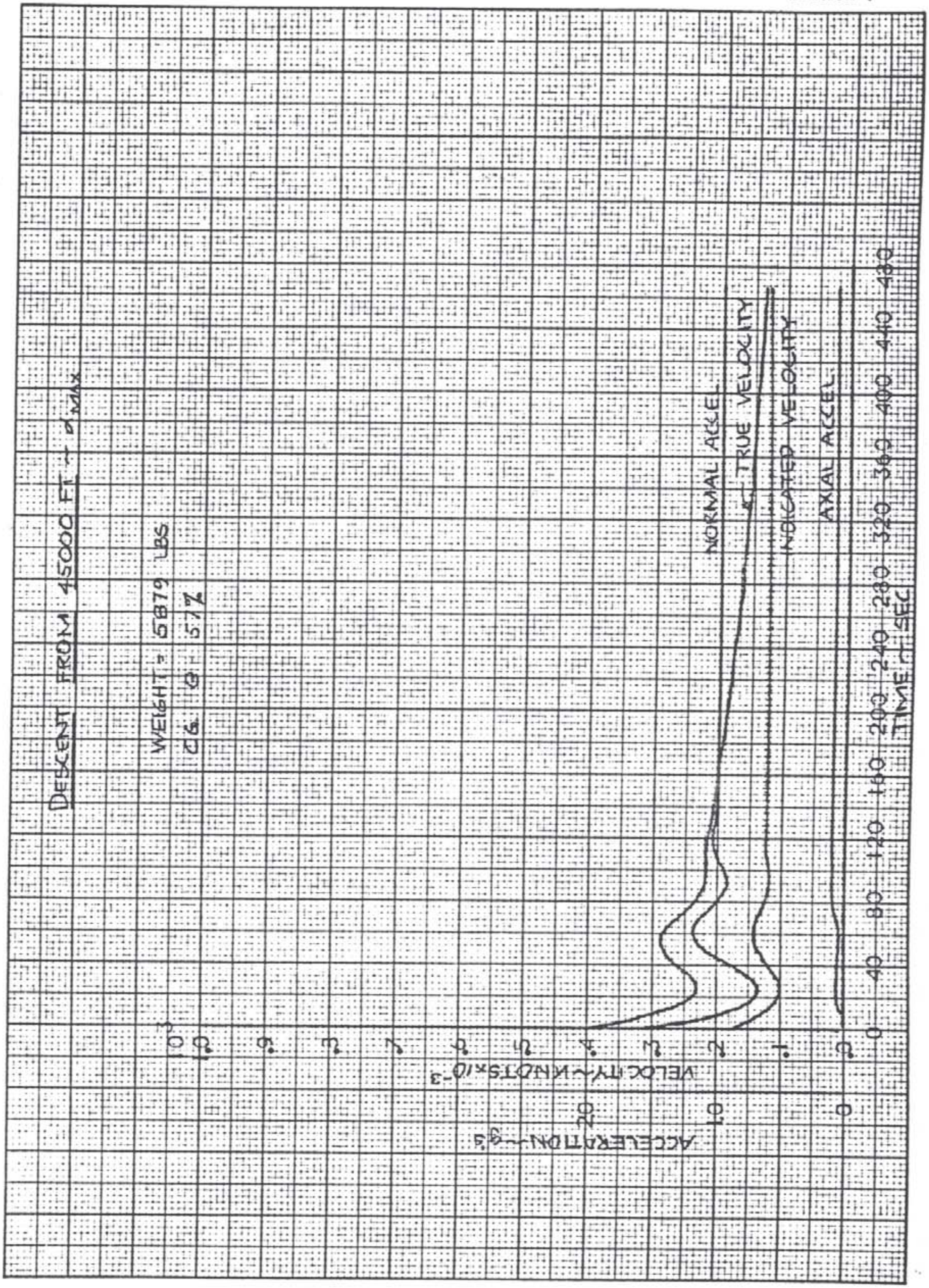


Figure 5-23. Descent From 45000 Ft. α Max.

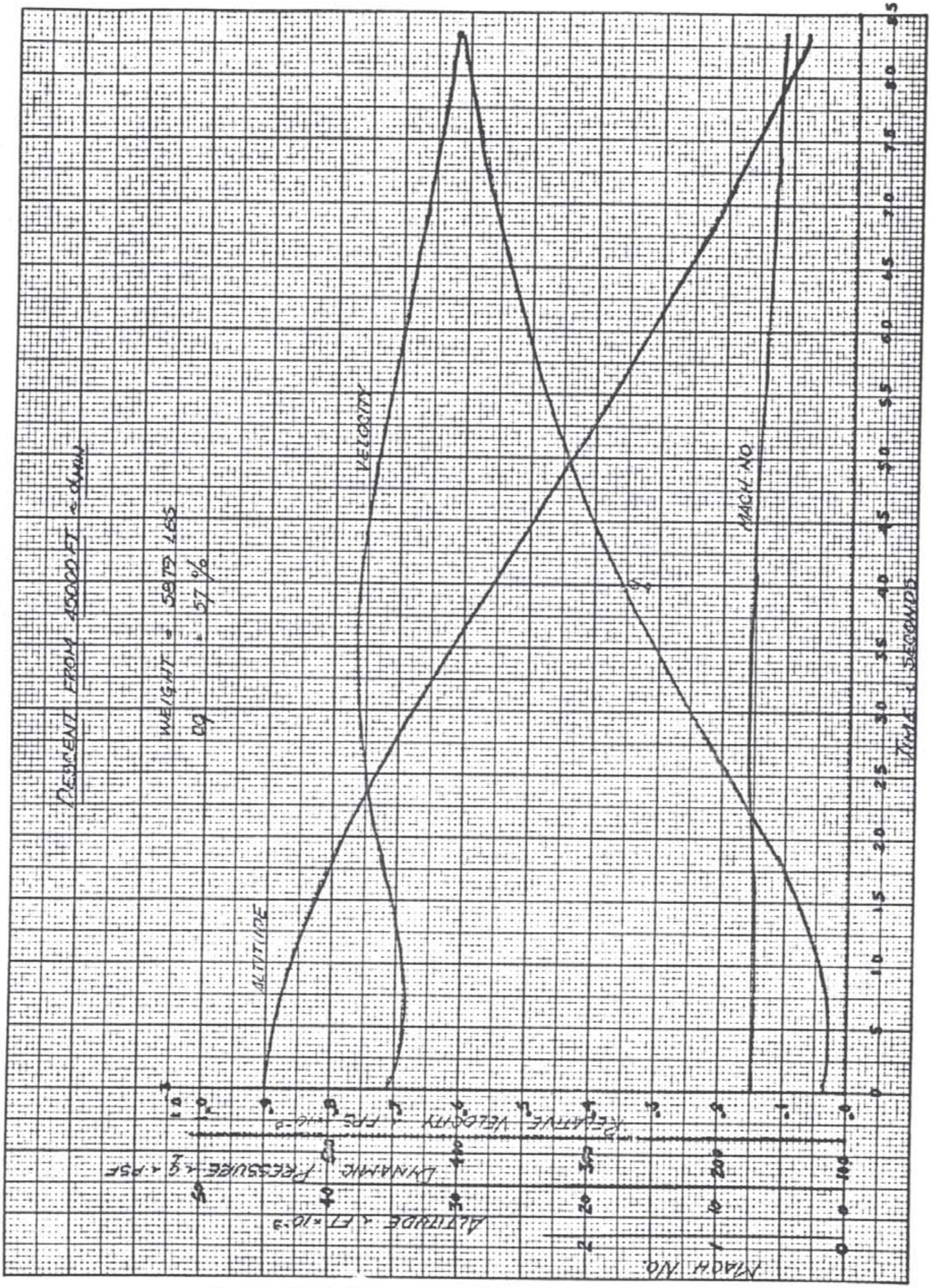


Figure 5-24. Descent From 45000 Ft. α Min.

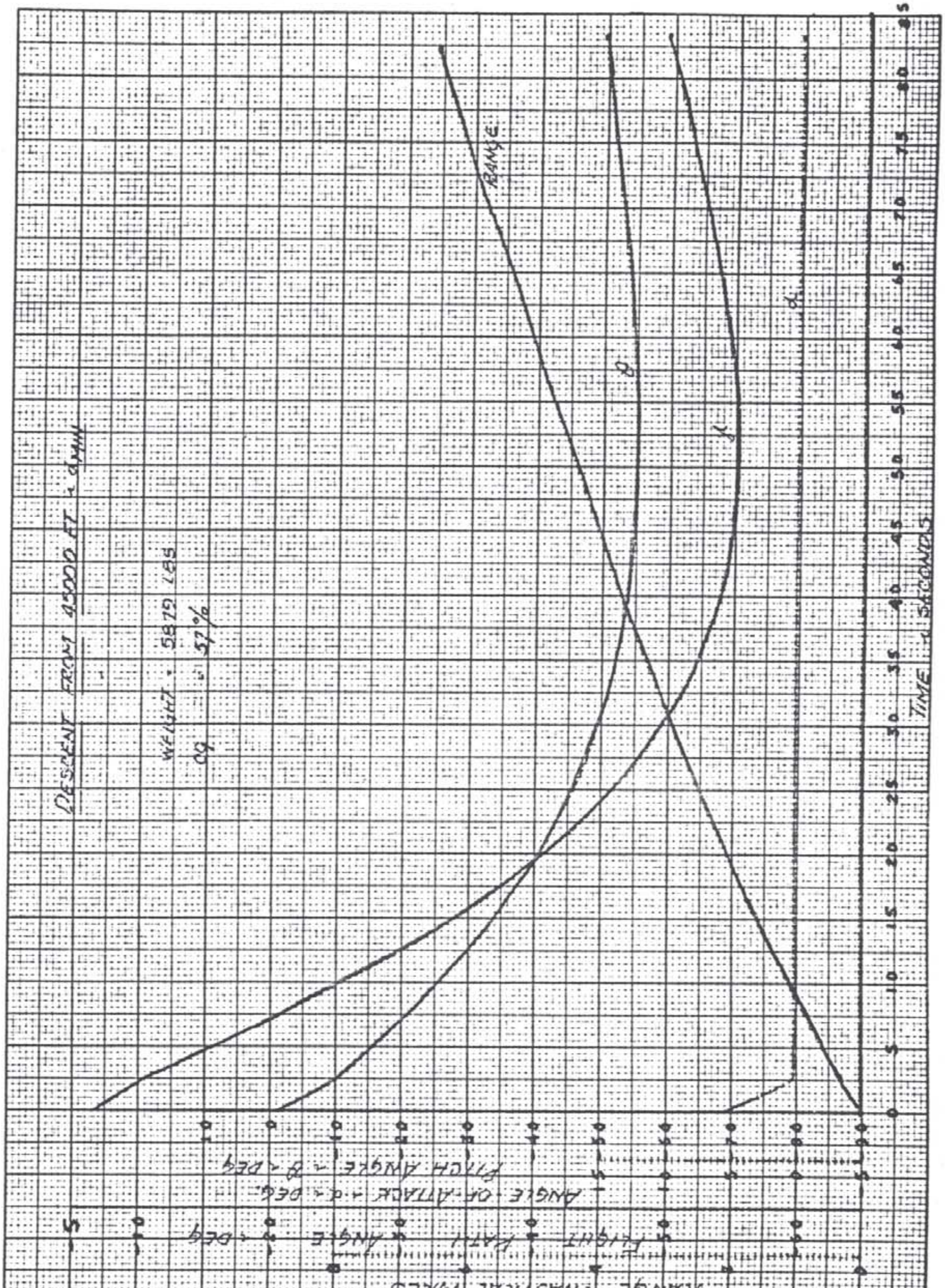


Figure 5-25. Descent From 45000 Ft. α Min.

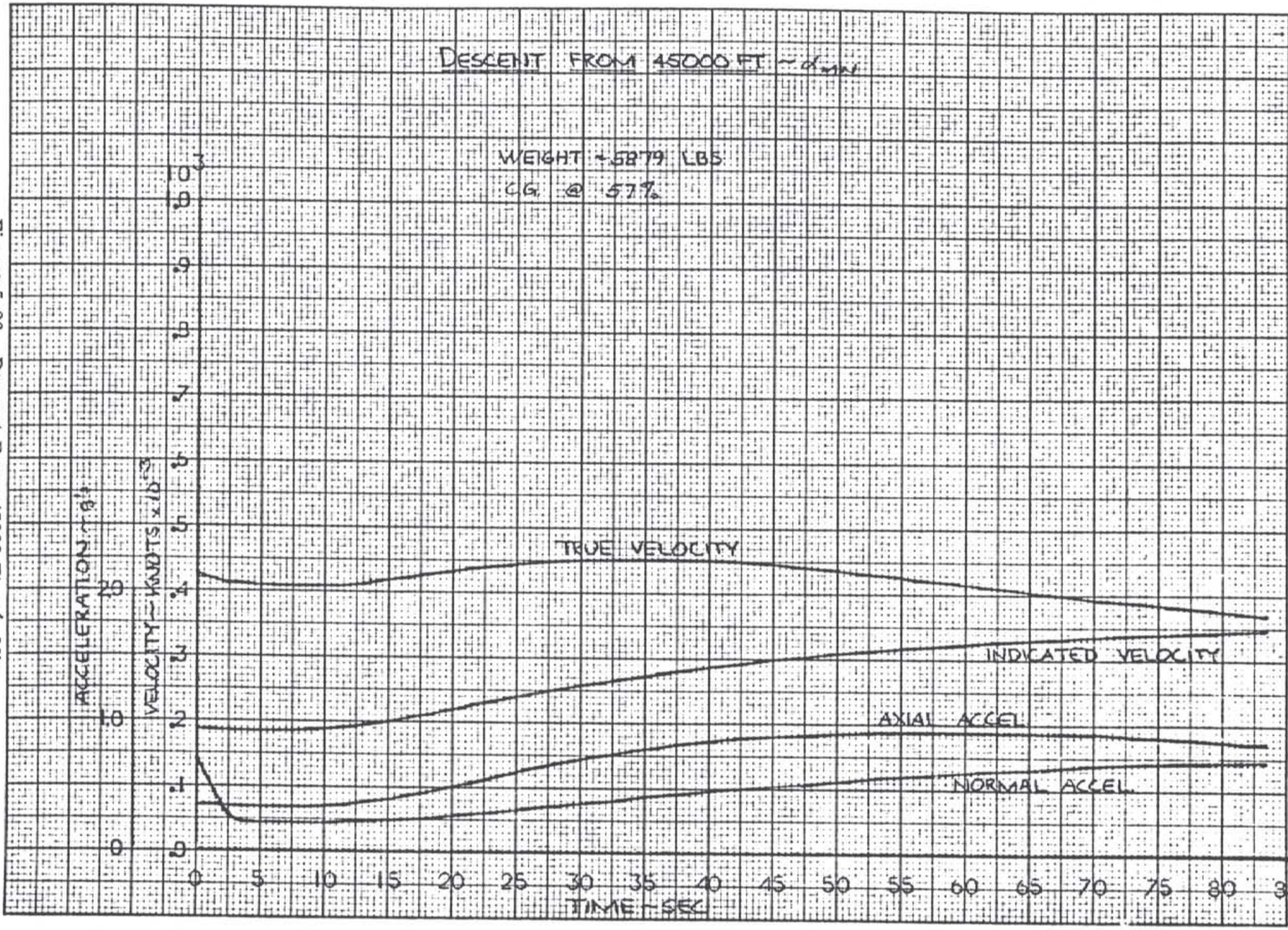


Figure 5-26. Descent From 45000 Ft. α Min.

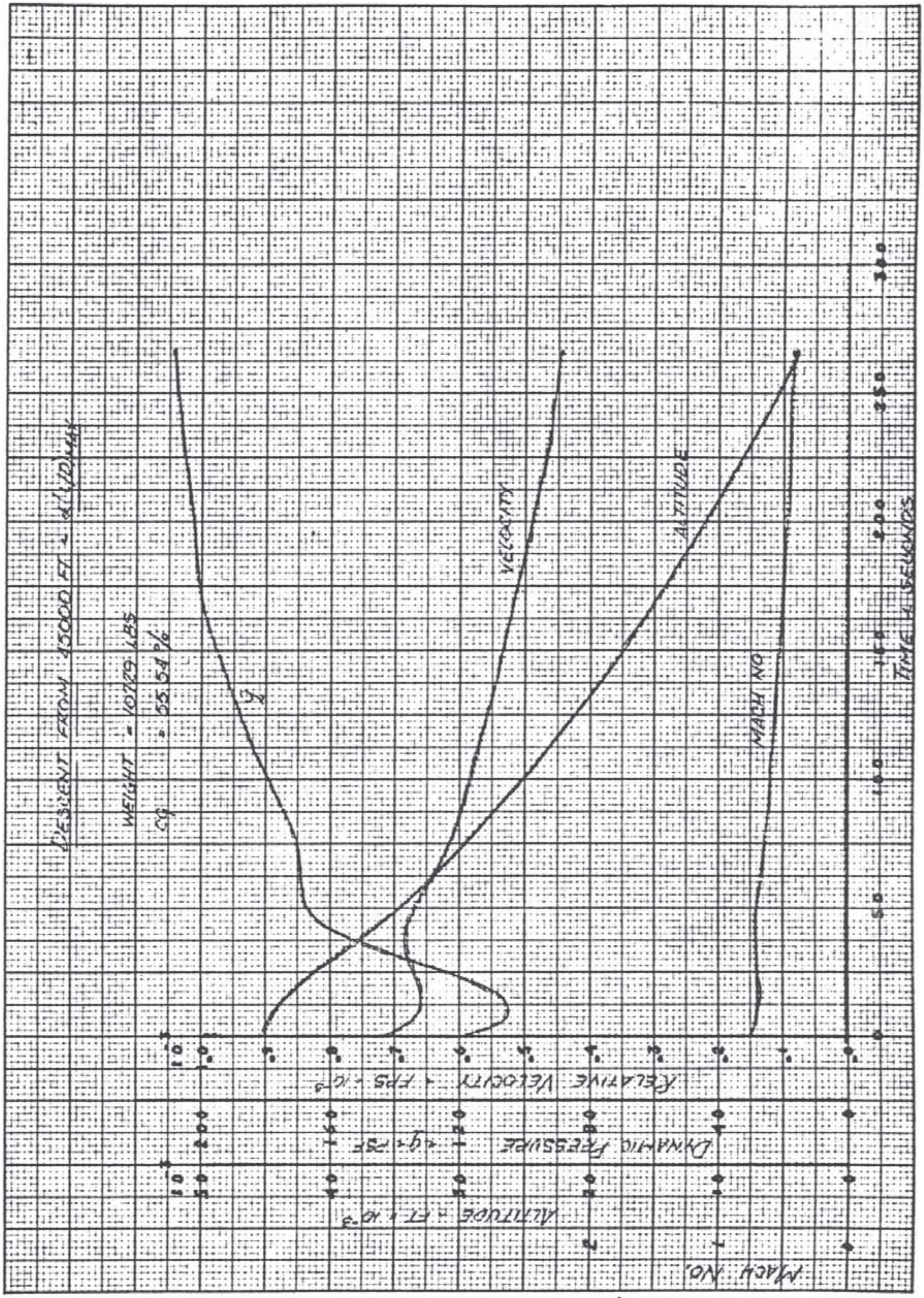


Figure 5-27. Descent From 45000 Ft. α Max.

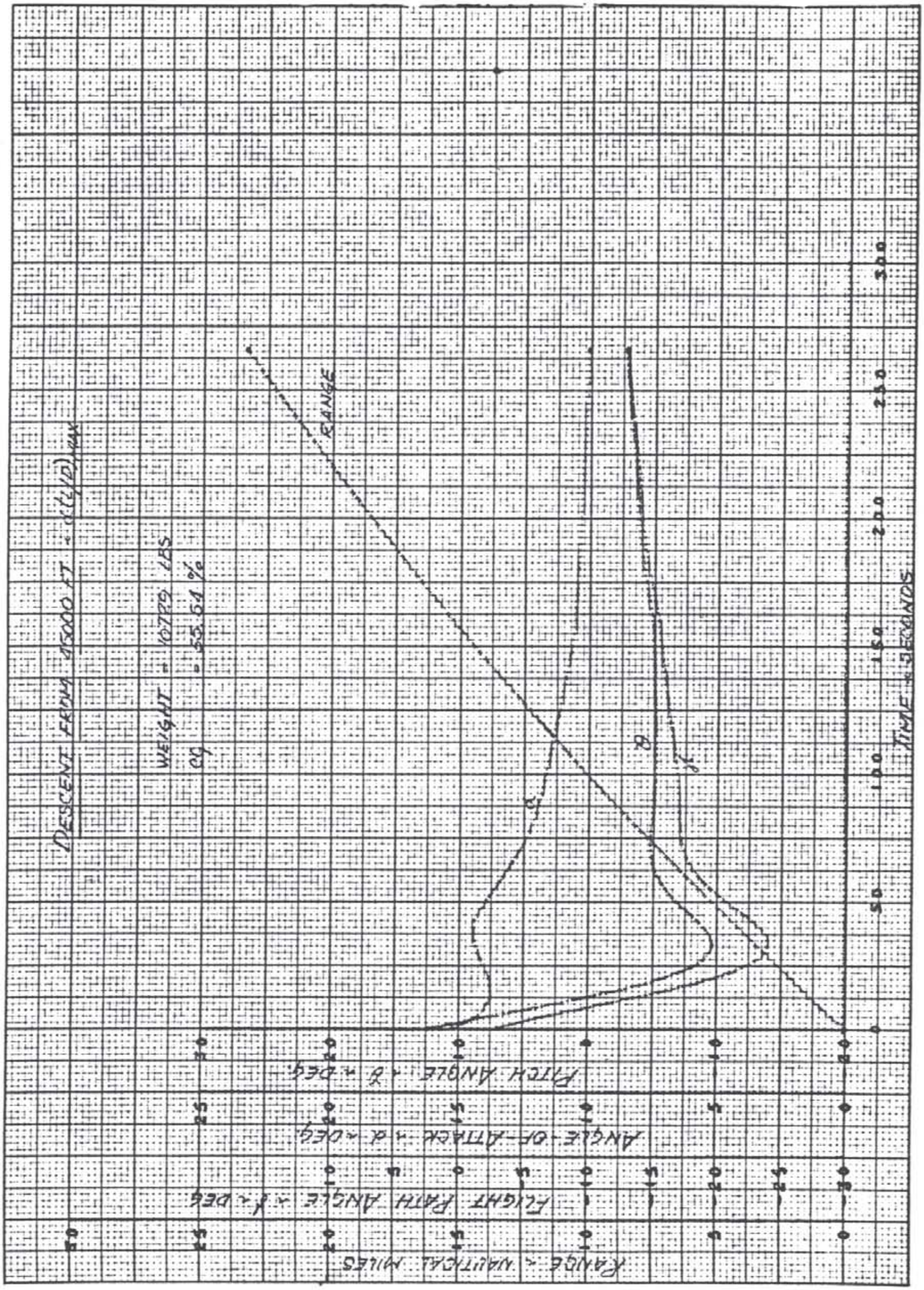


Figure 5-28. Descent From 45000 Ft. α (L/D) Max.

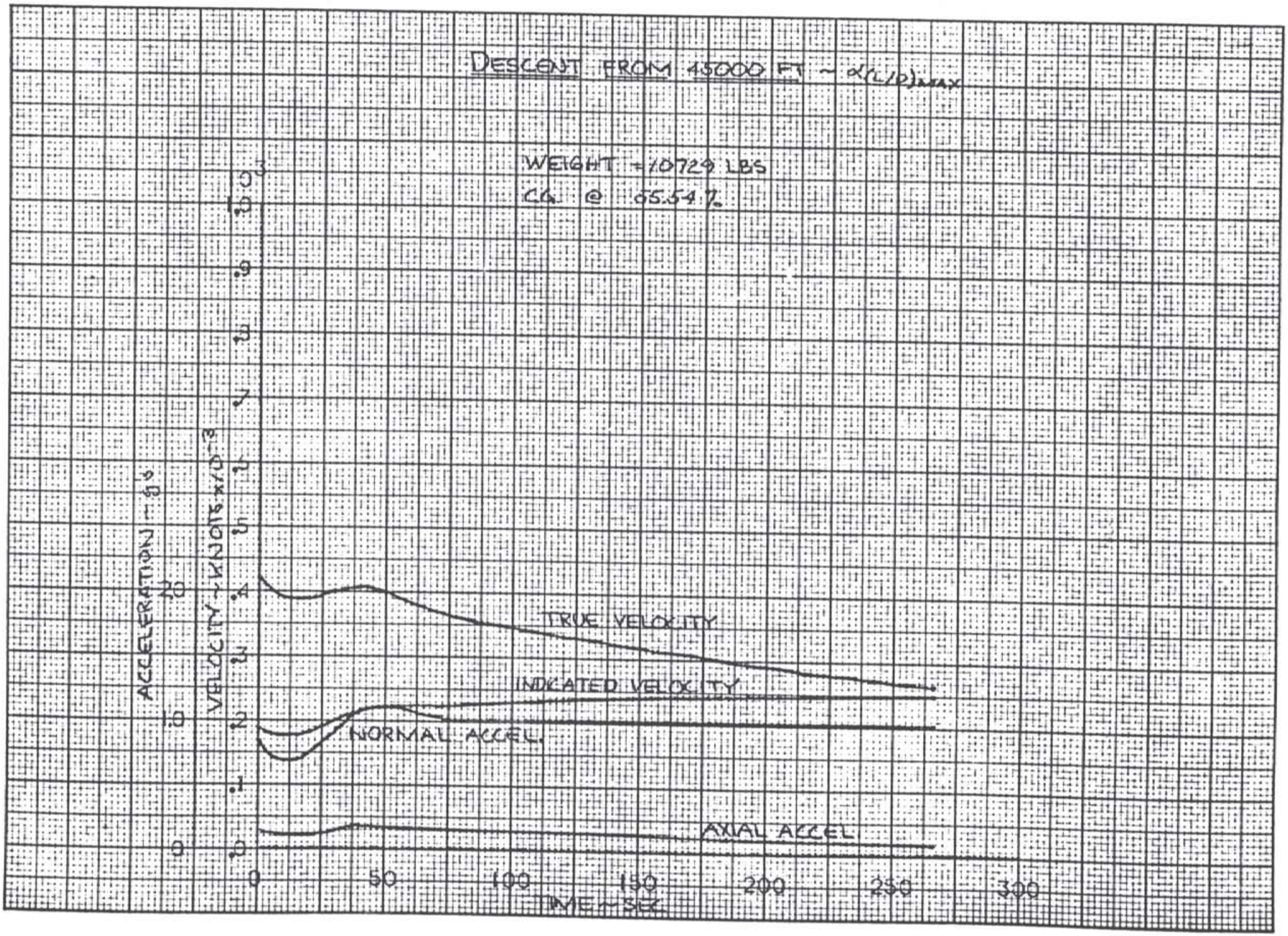


Figure 5-29. Descent From 45000 Ft. α (L/D) Max.

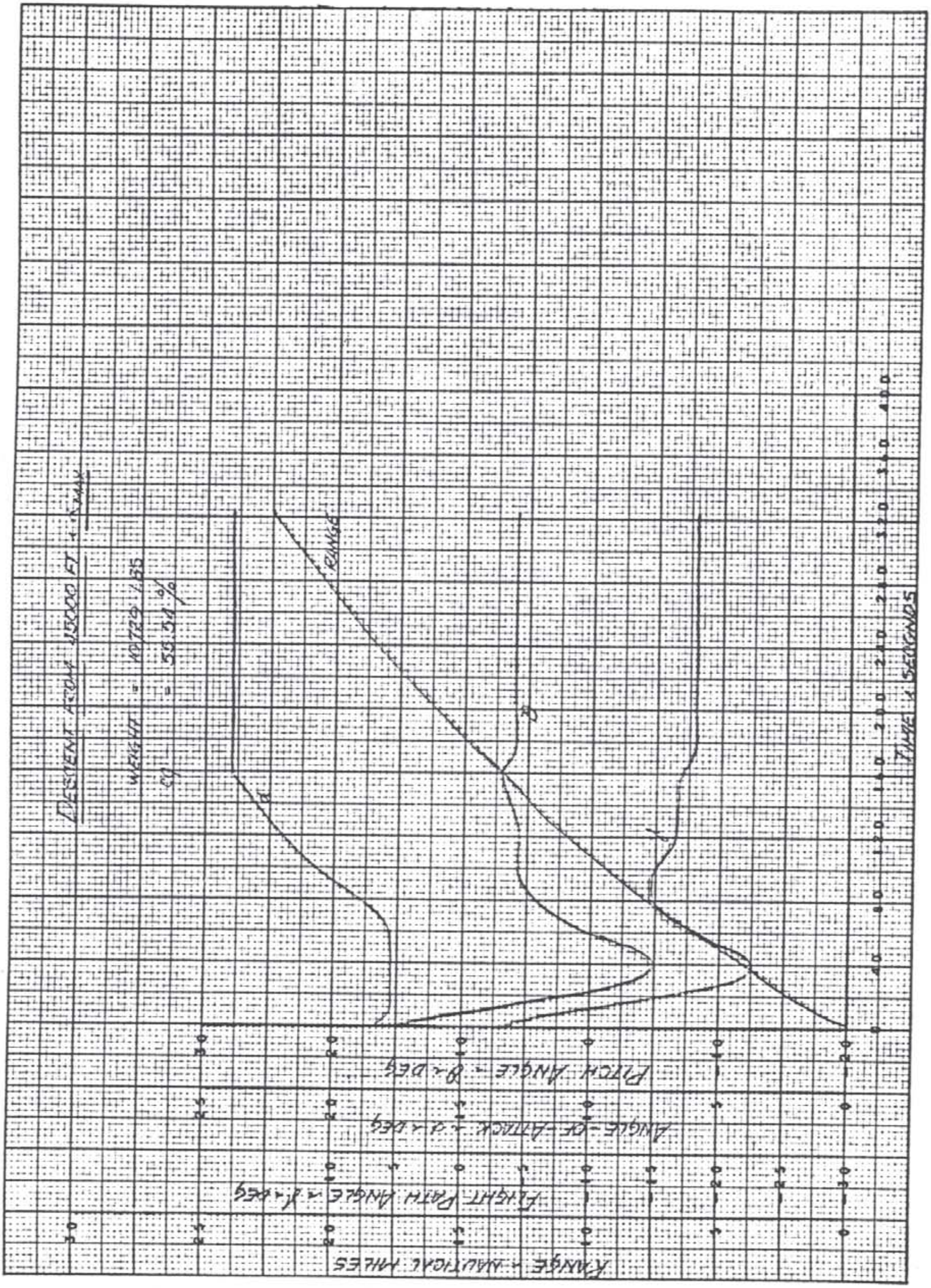


Figure 5-30. Descent From 45000 Ft. α Max.

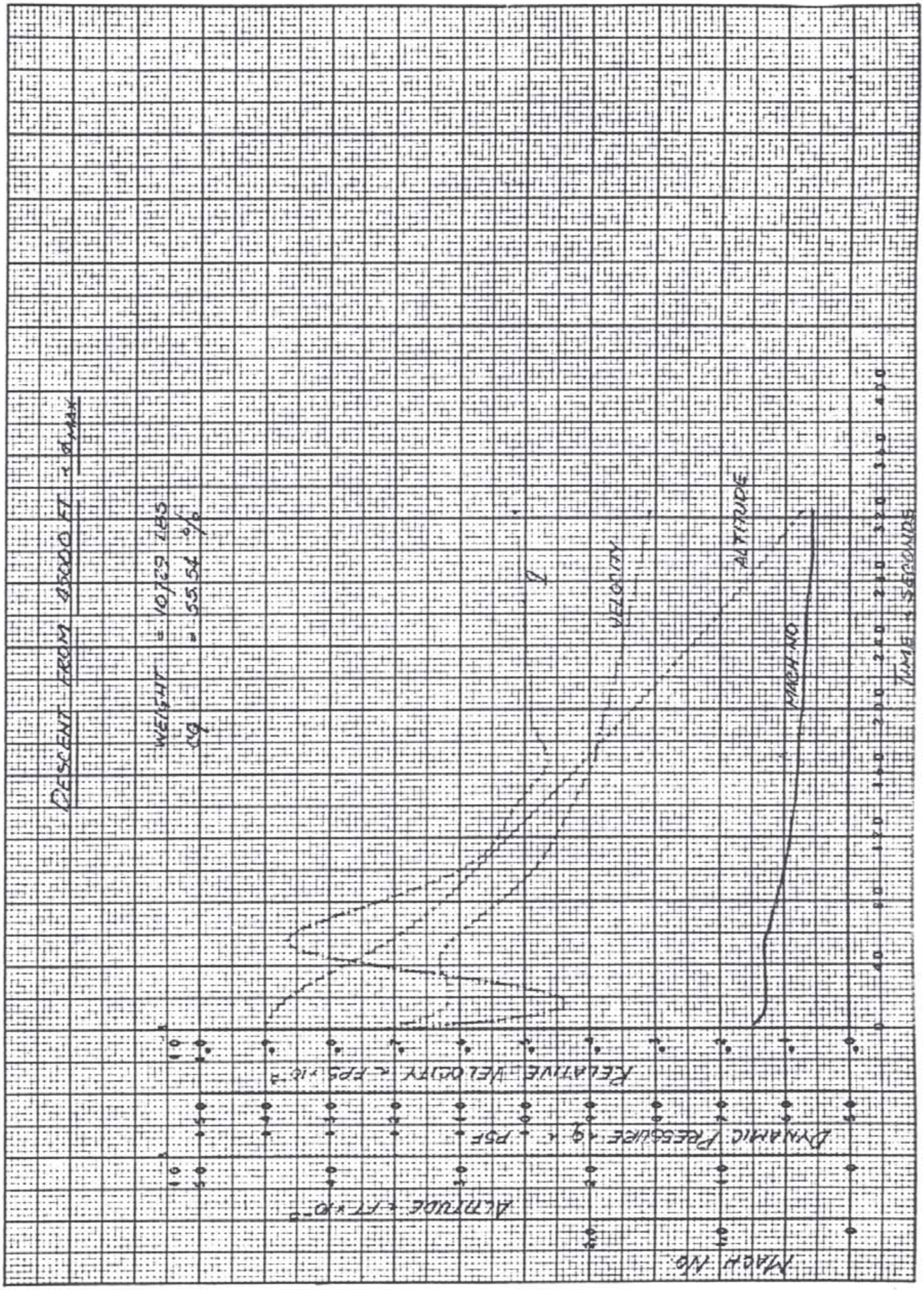


Figure 5-31. Descent From 45000 Ft. α Max.

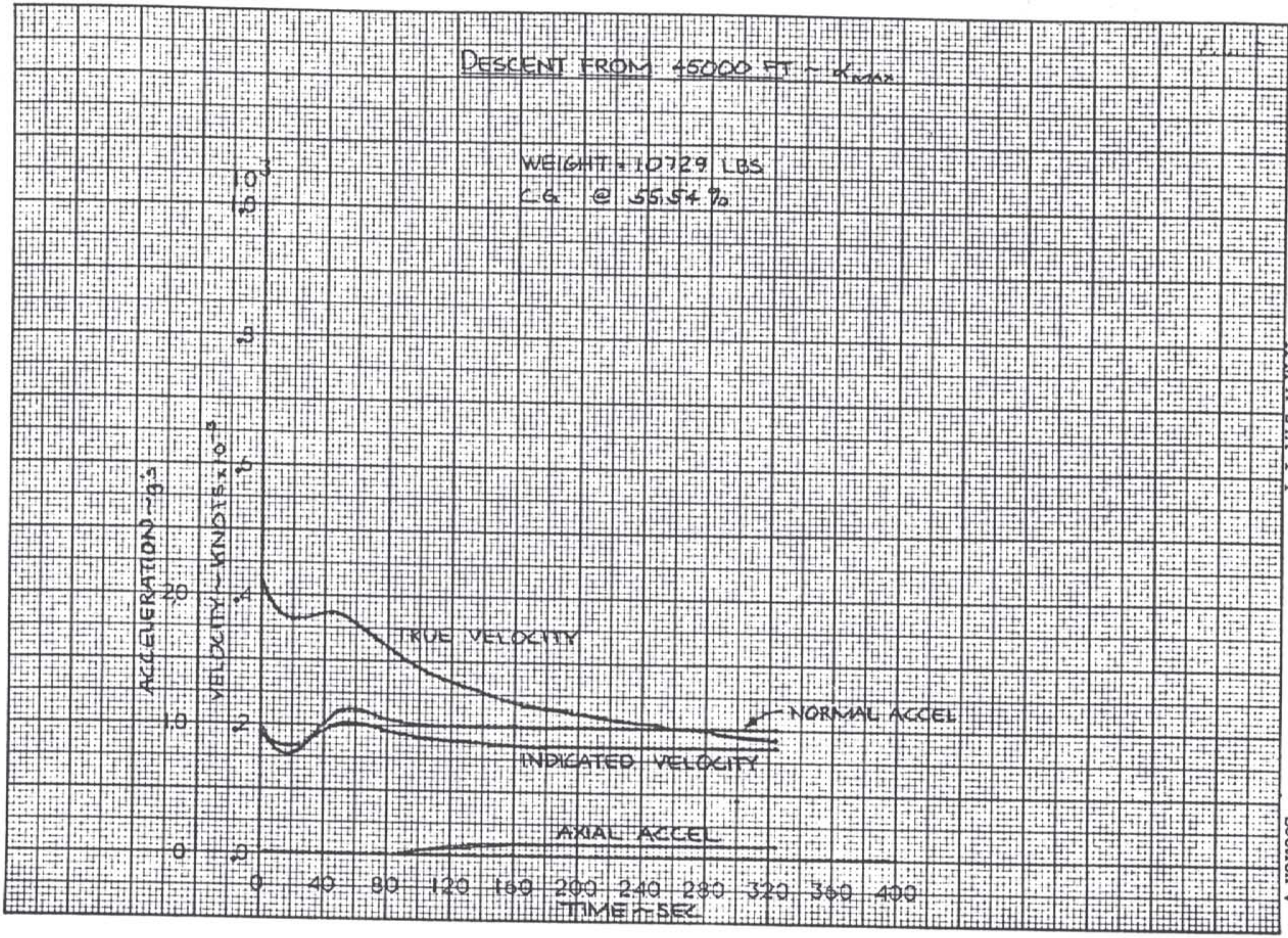


Figure 5-32. Descent from 45000 Ft. α Max.

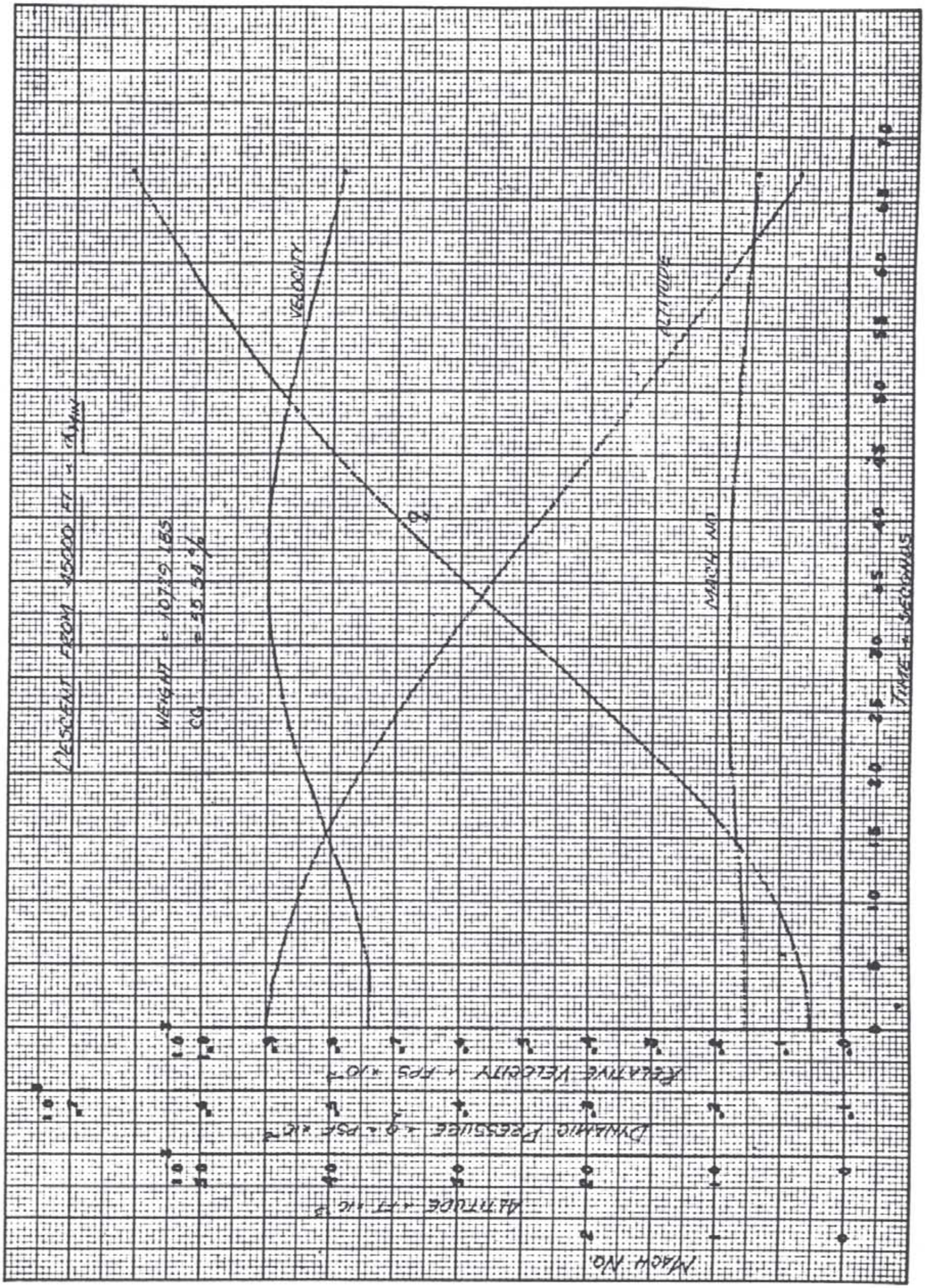


Figure 5-33. Descent From 45000 Ft. α Min.

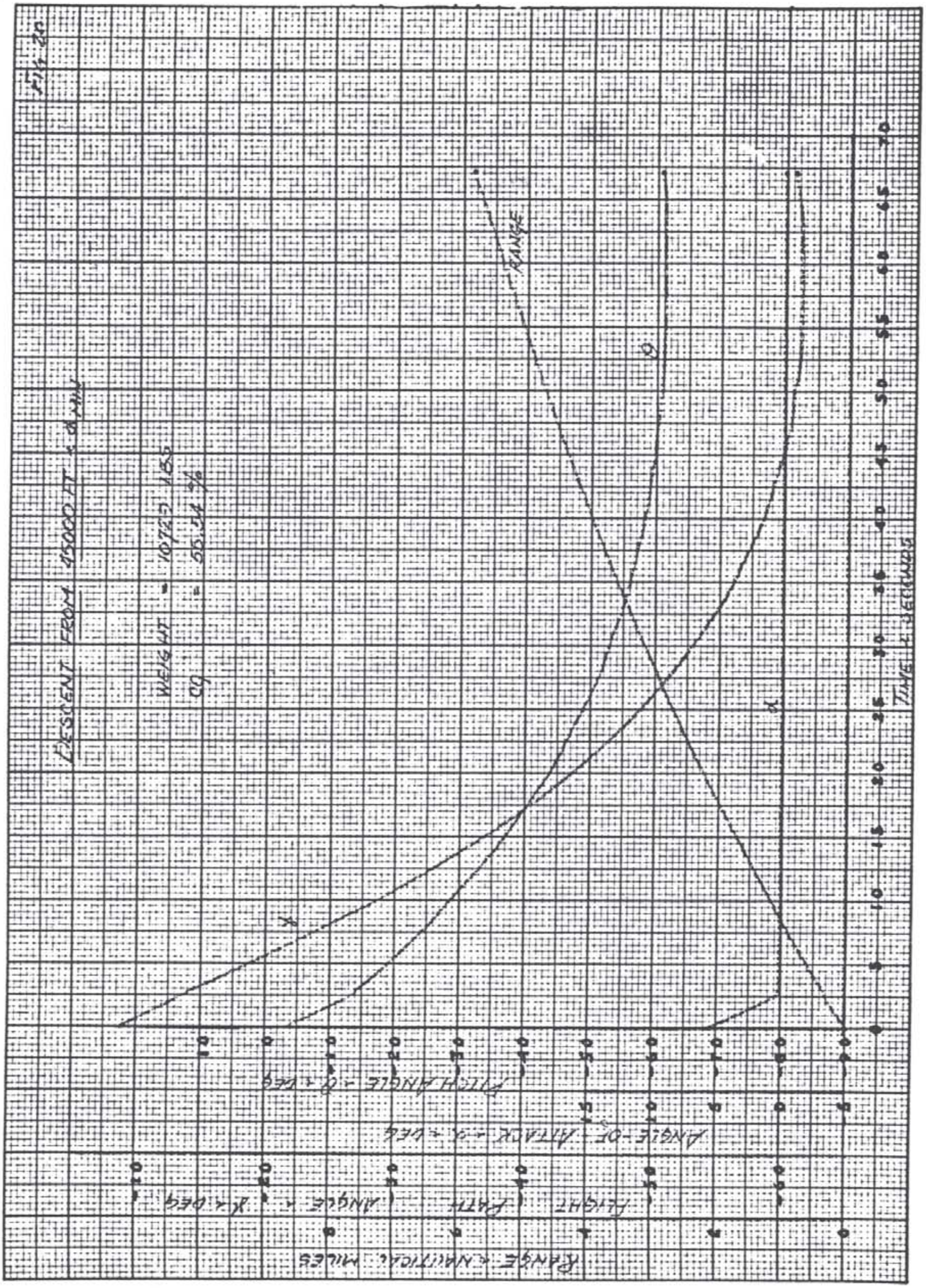


Figure 5-34. Descent From 45000 Ft. α Min

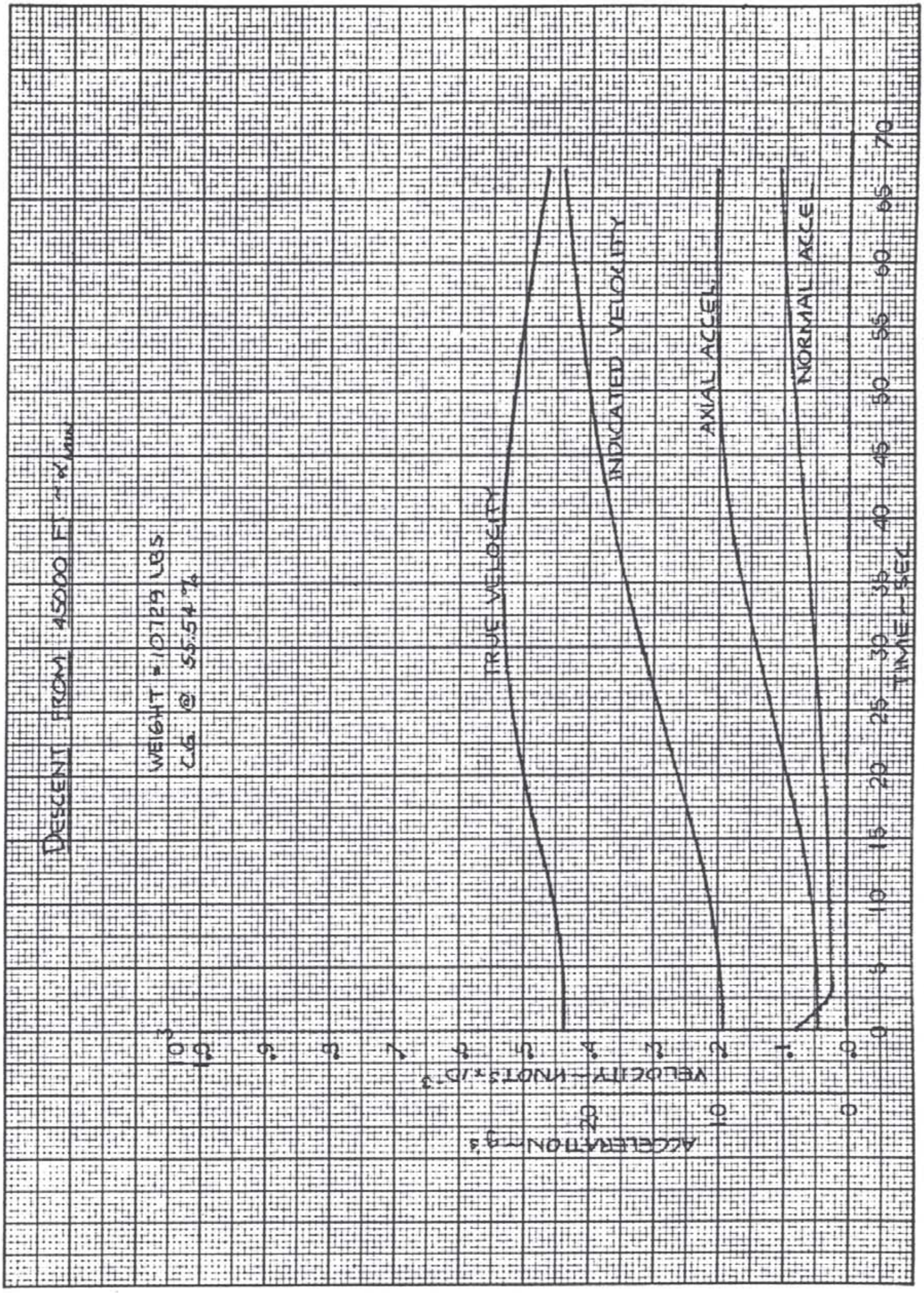


Figure 5-35. Descent From 45000 Ft. α Min.

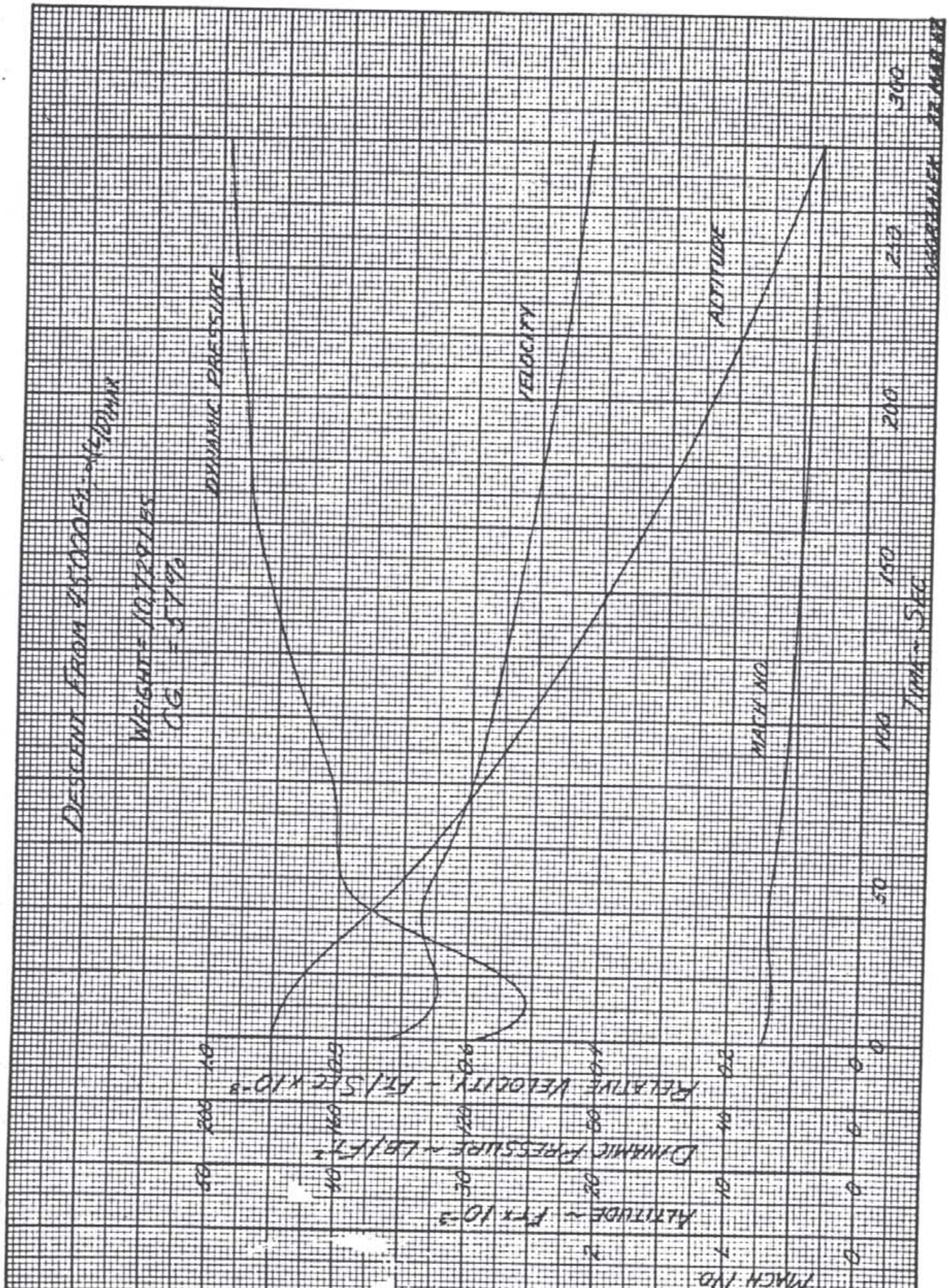


Figure 5-36. Descent From 45000 Ft. α (L/D) Max.

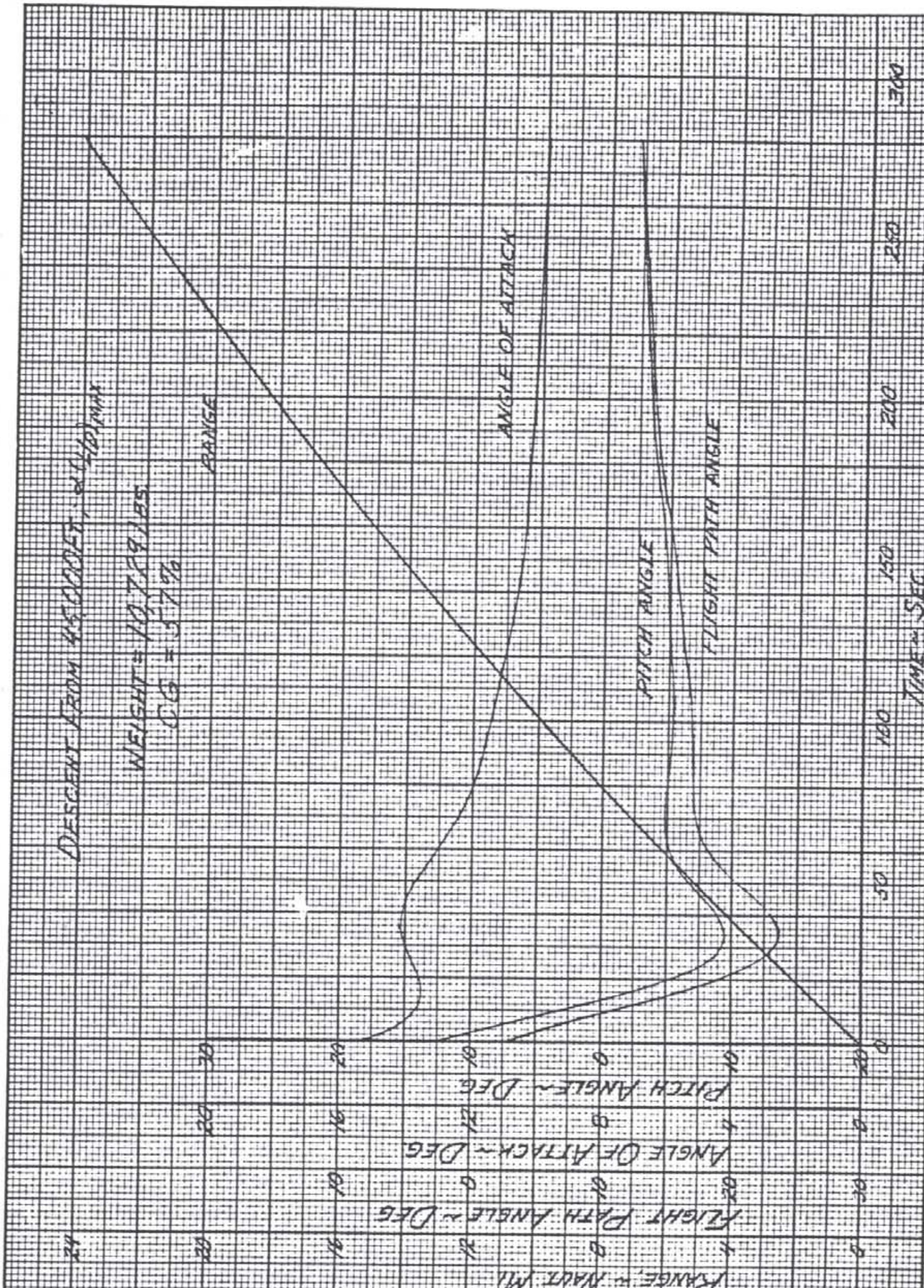


Figure 5-37. Descent From 45000 Ft. α (L/D) Max.

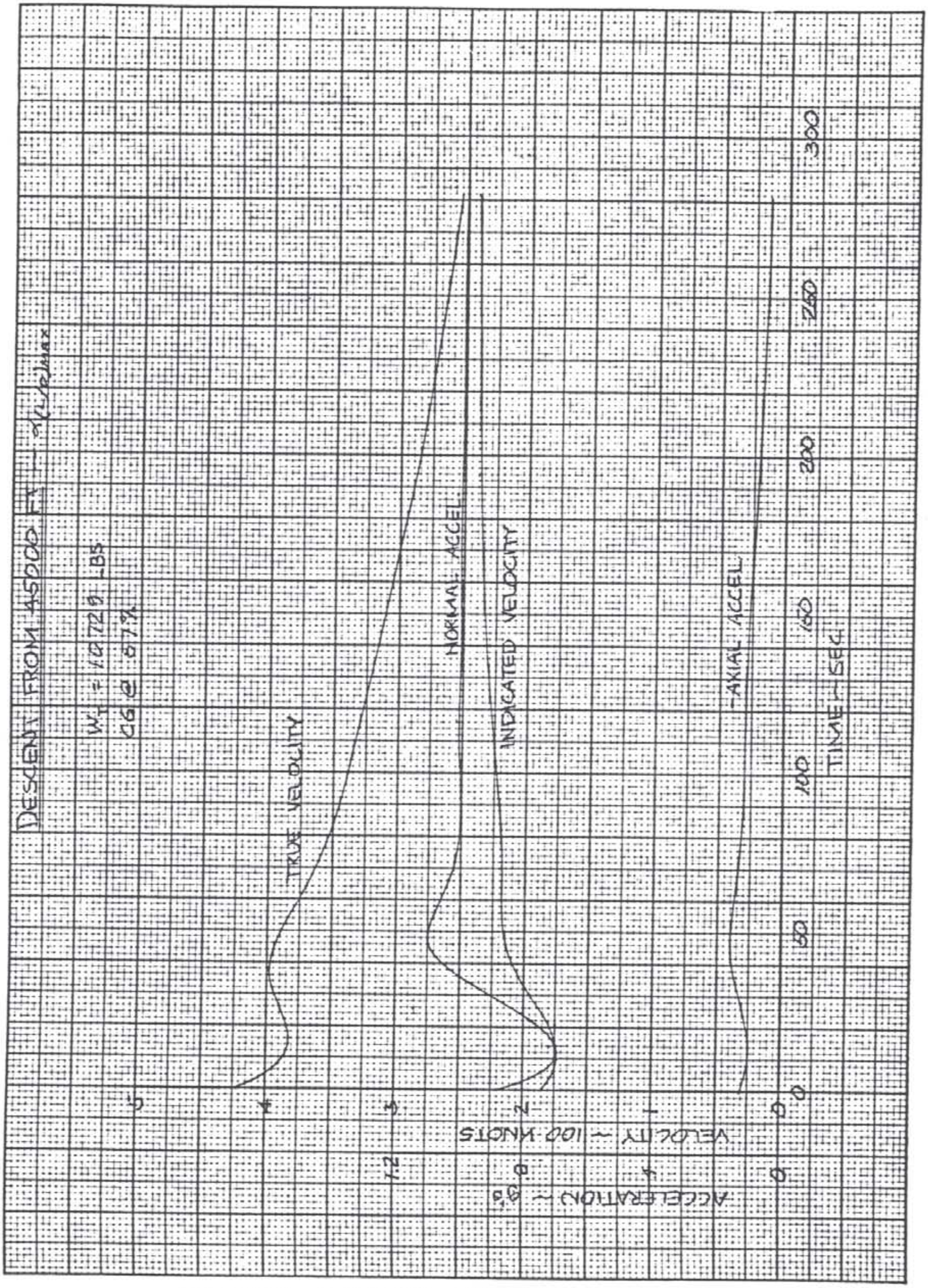


Figure 5-38. Descent From 45000 Ft. α (L/D) Max.

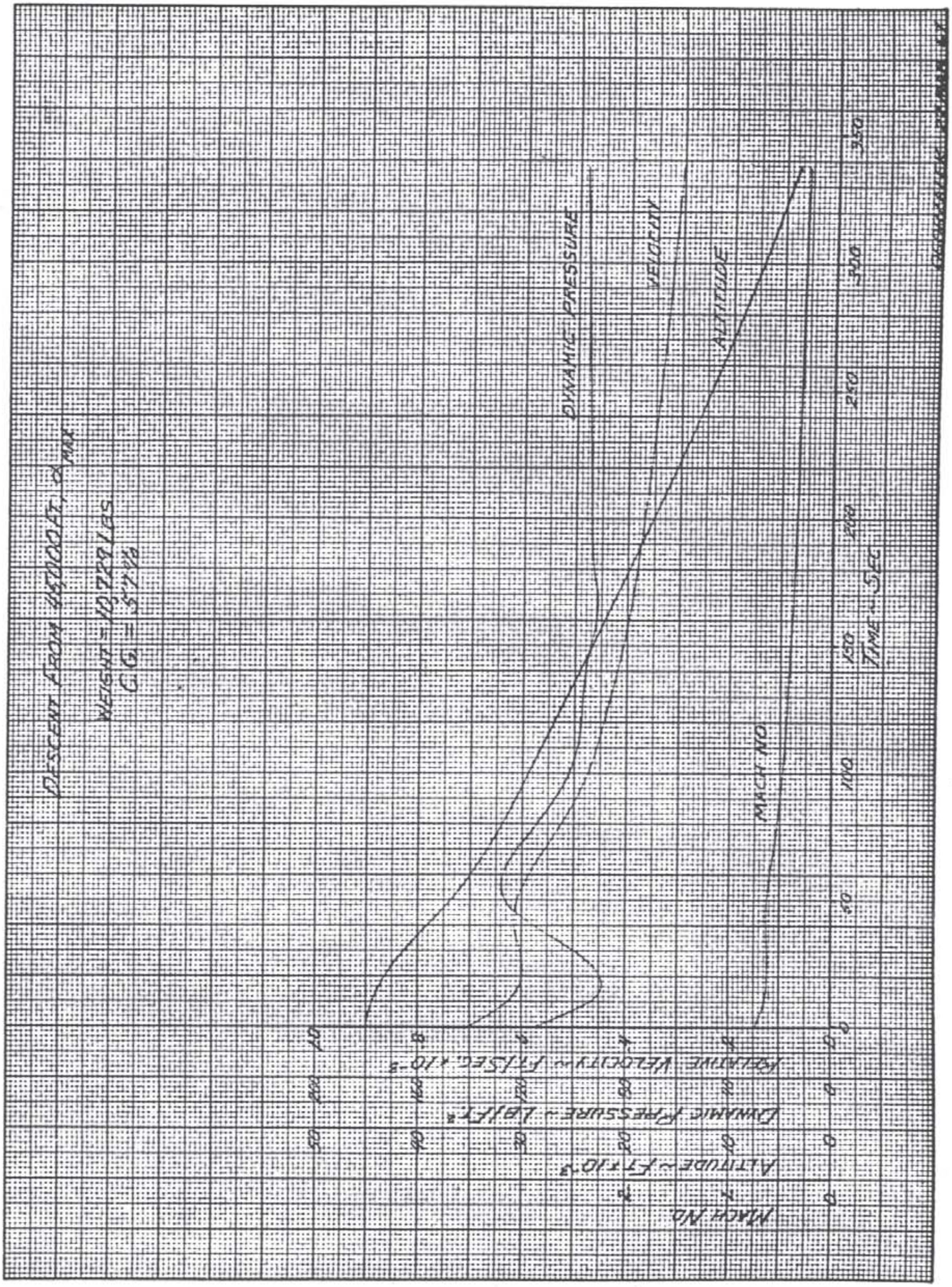


Figure 5-39. Descent From 45000 Ft. α Max.

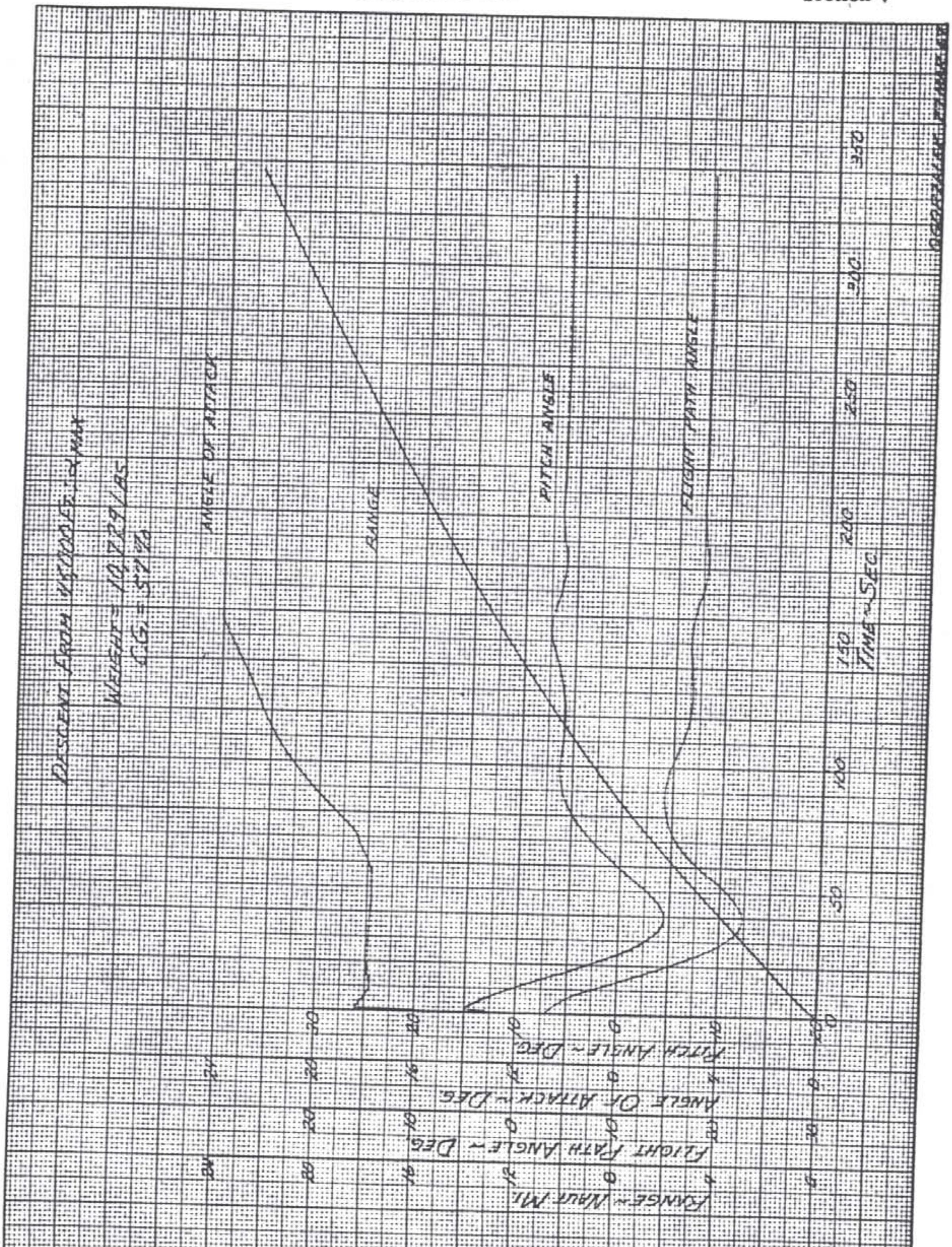


Figure 5-40. Descent From 45000 Ft. α Max.

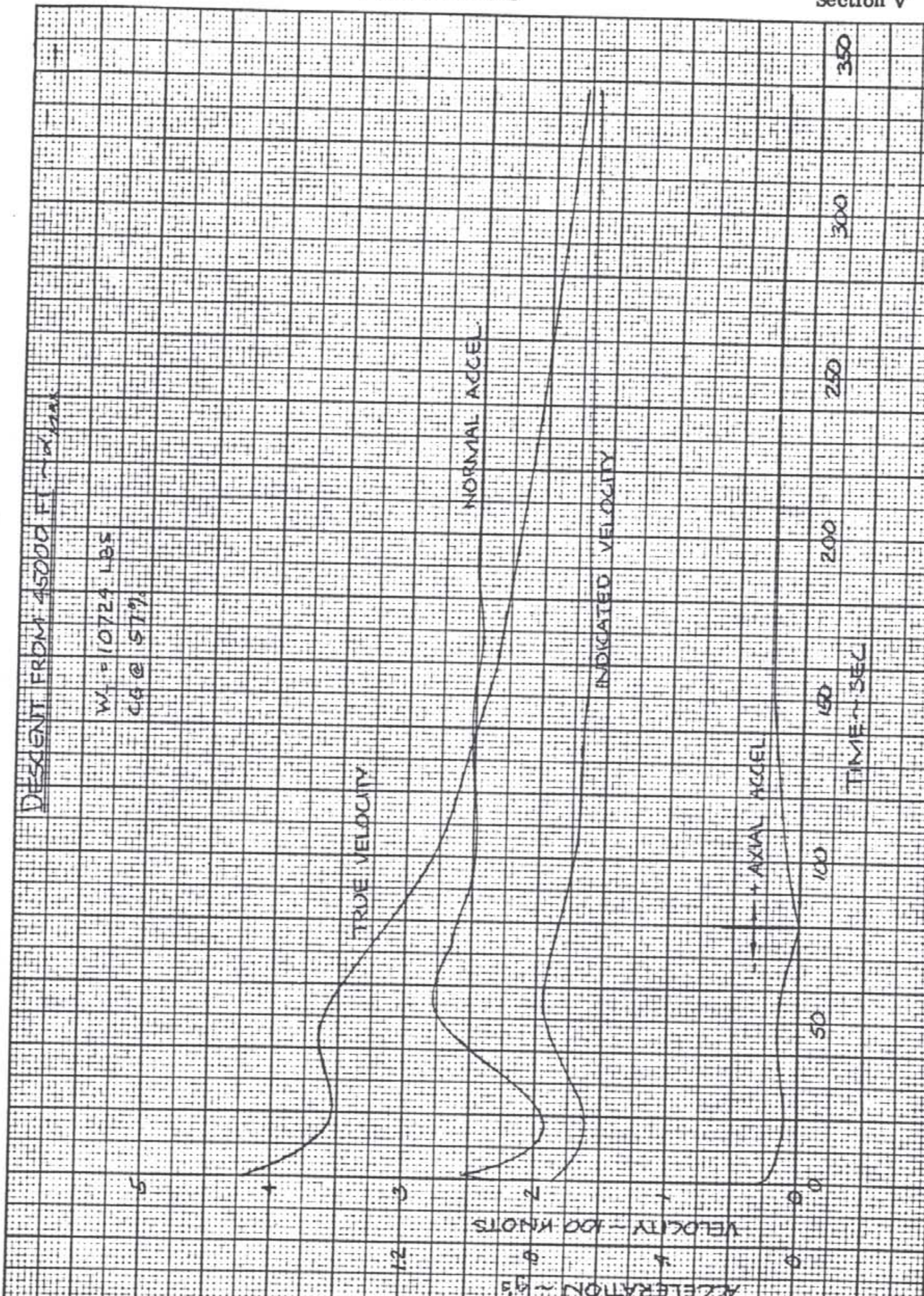


Figure 5-41. Descent From 45000 Ft. α Max.

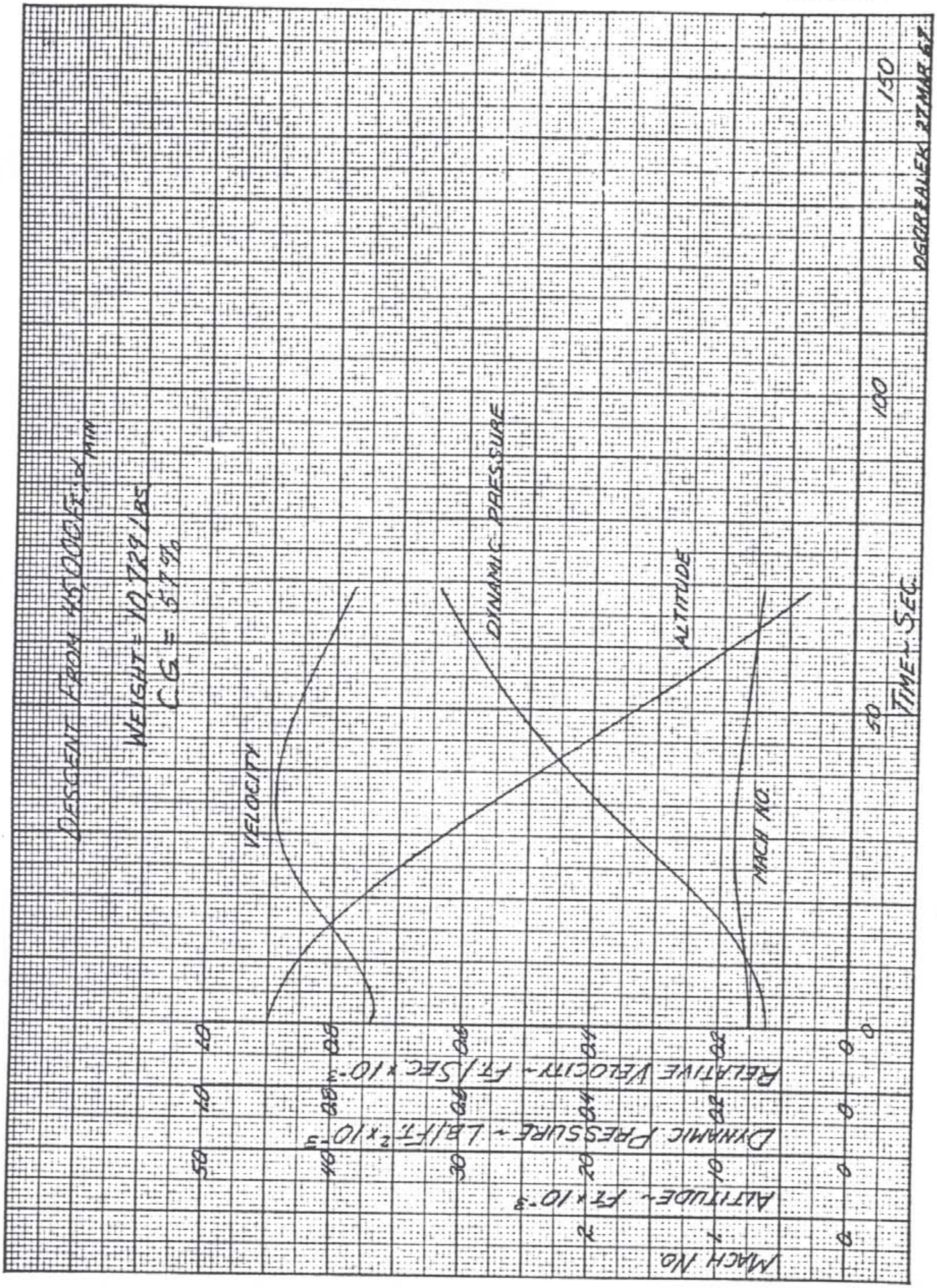


Figure 5-42. Descent From 45000 Ft. α Min.

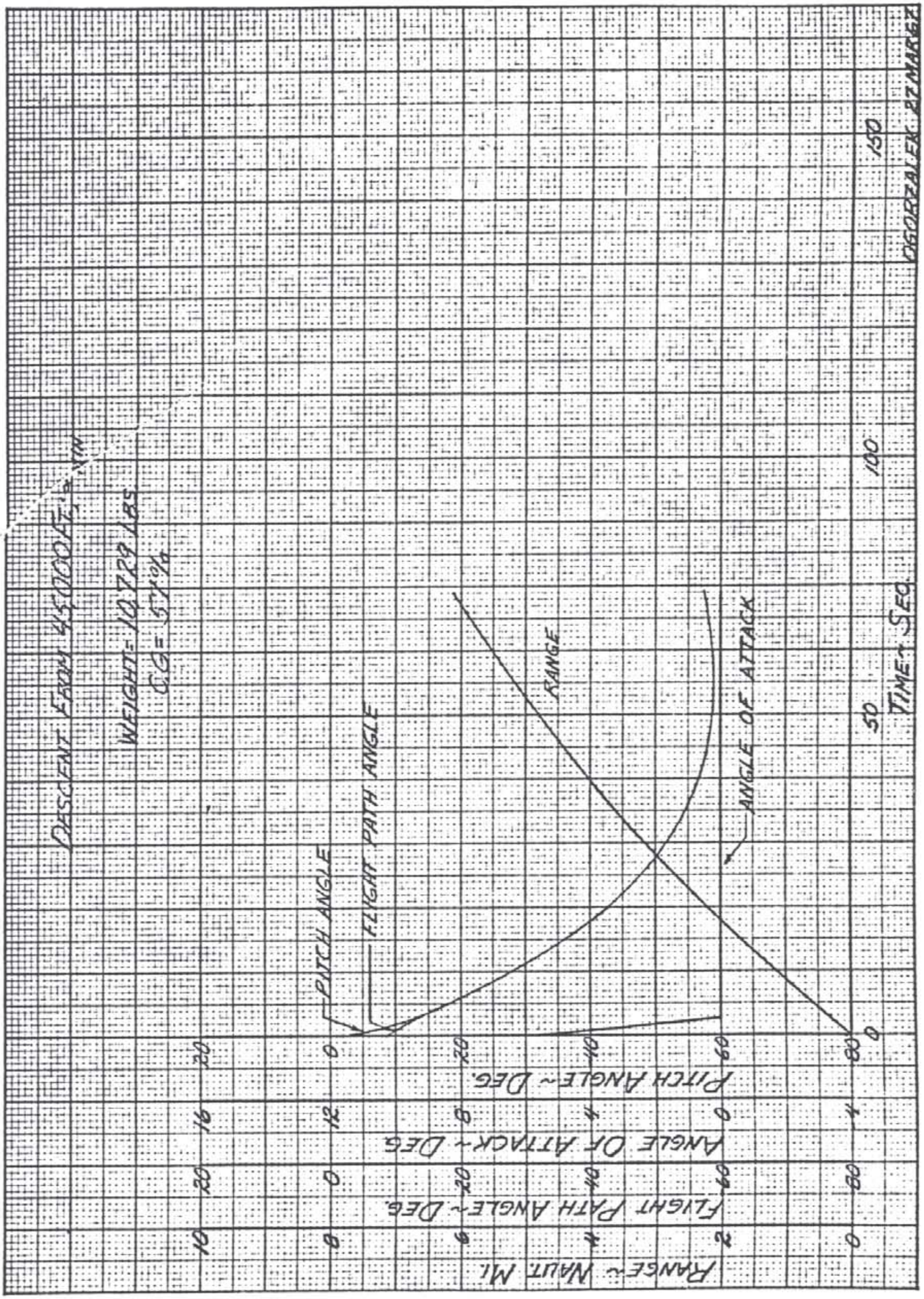


Figure 5-43. Descent From 45000 Ft. α Min.

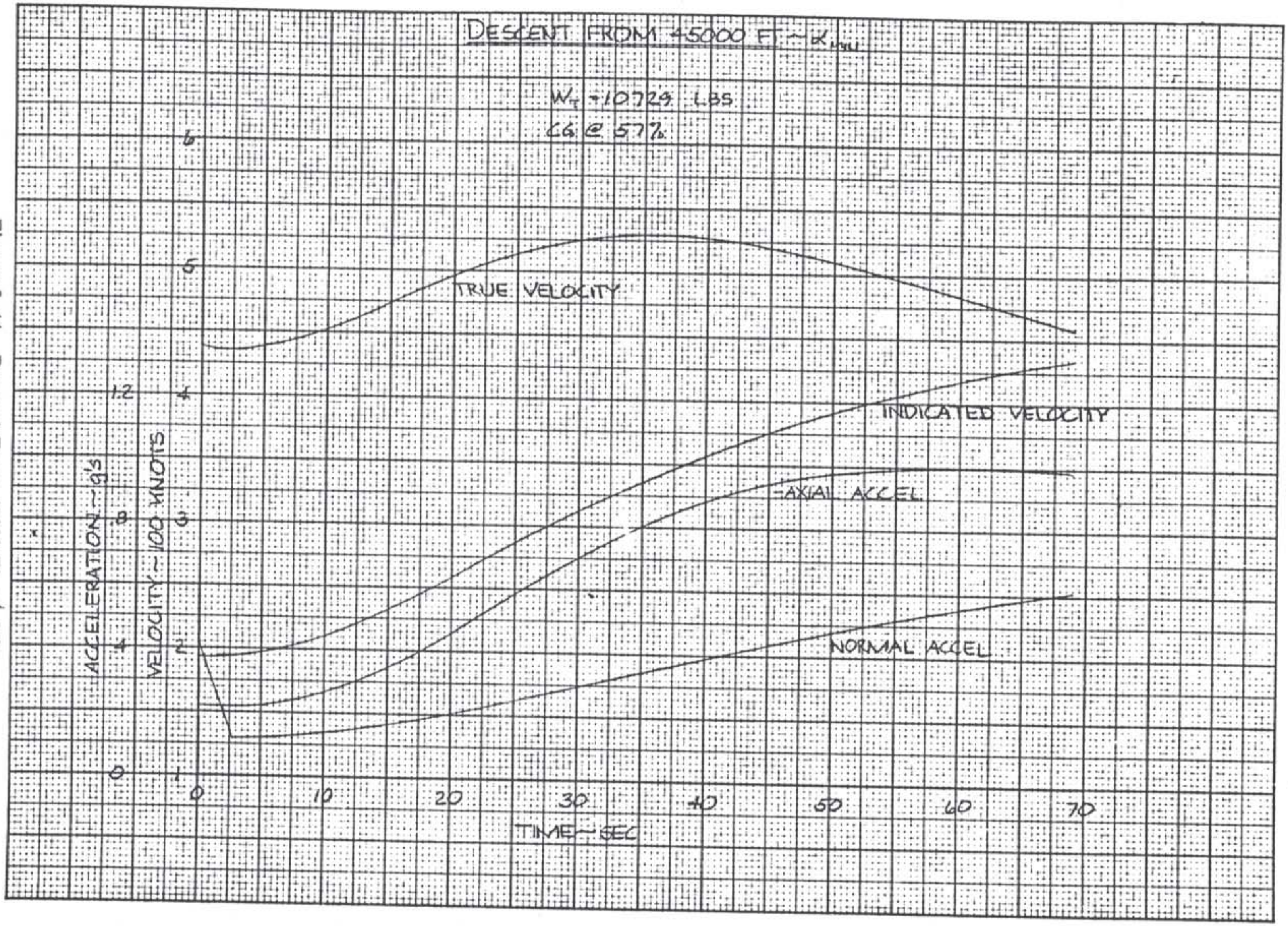


Figure 5-44. Descent From 45000 Ft. α Min.

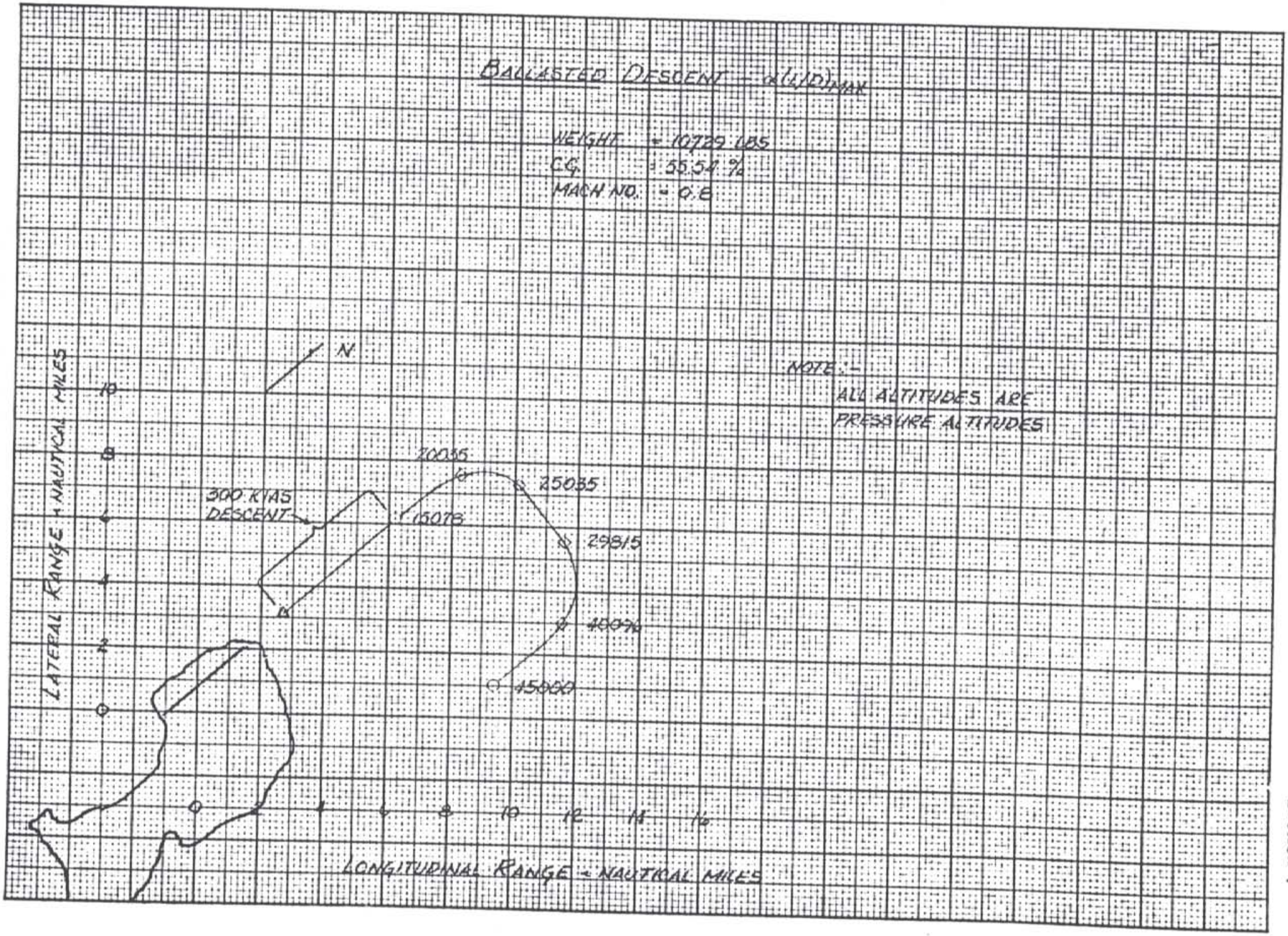


Figure 5-45. Ballasted Descent α (L/D) Max.

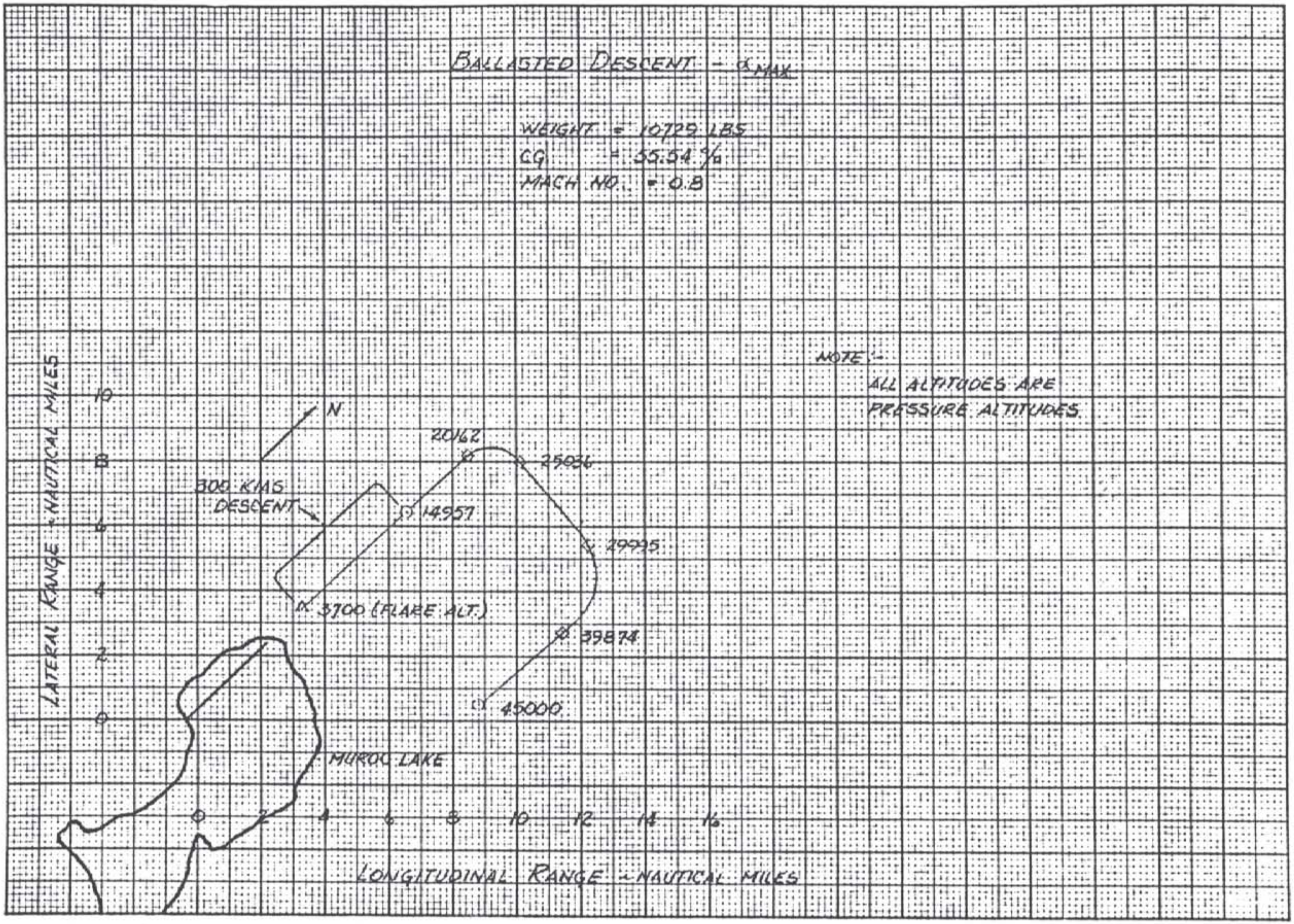


Figure 5-46. Ballasted Descent α Max.

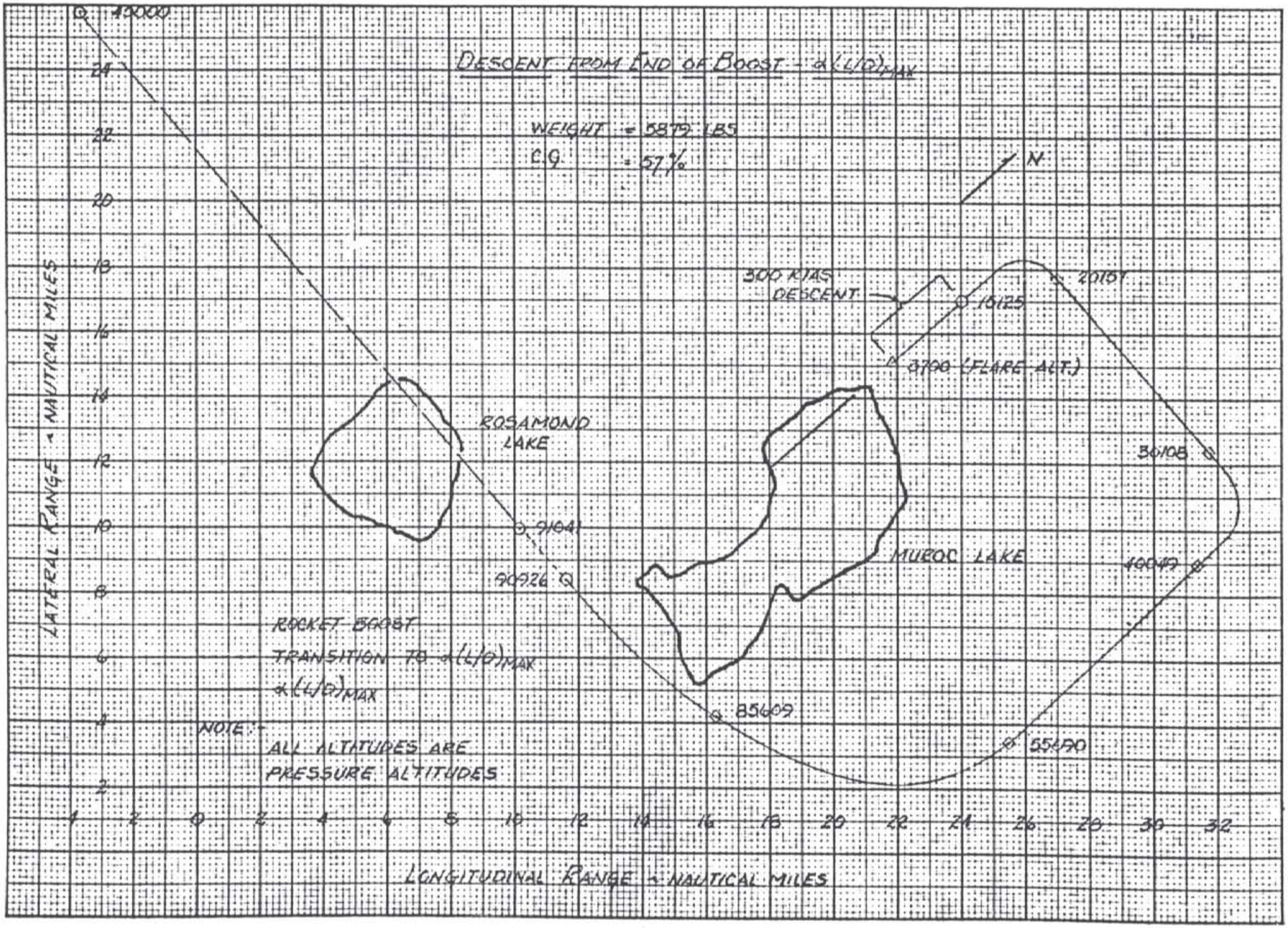


Figure 5-47. Descent From End of Boost α (L/D) Max.

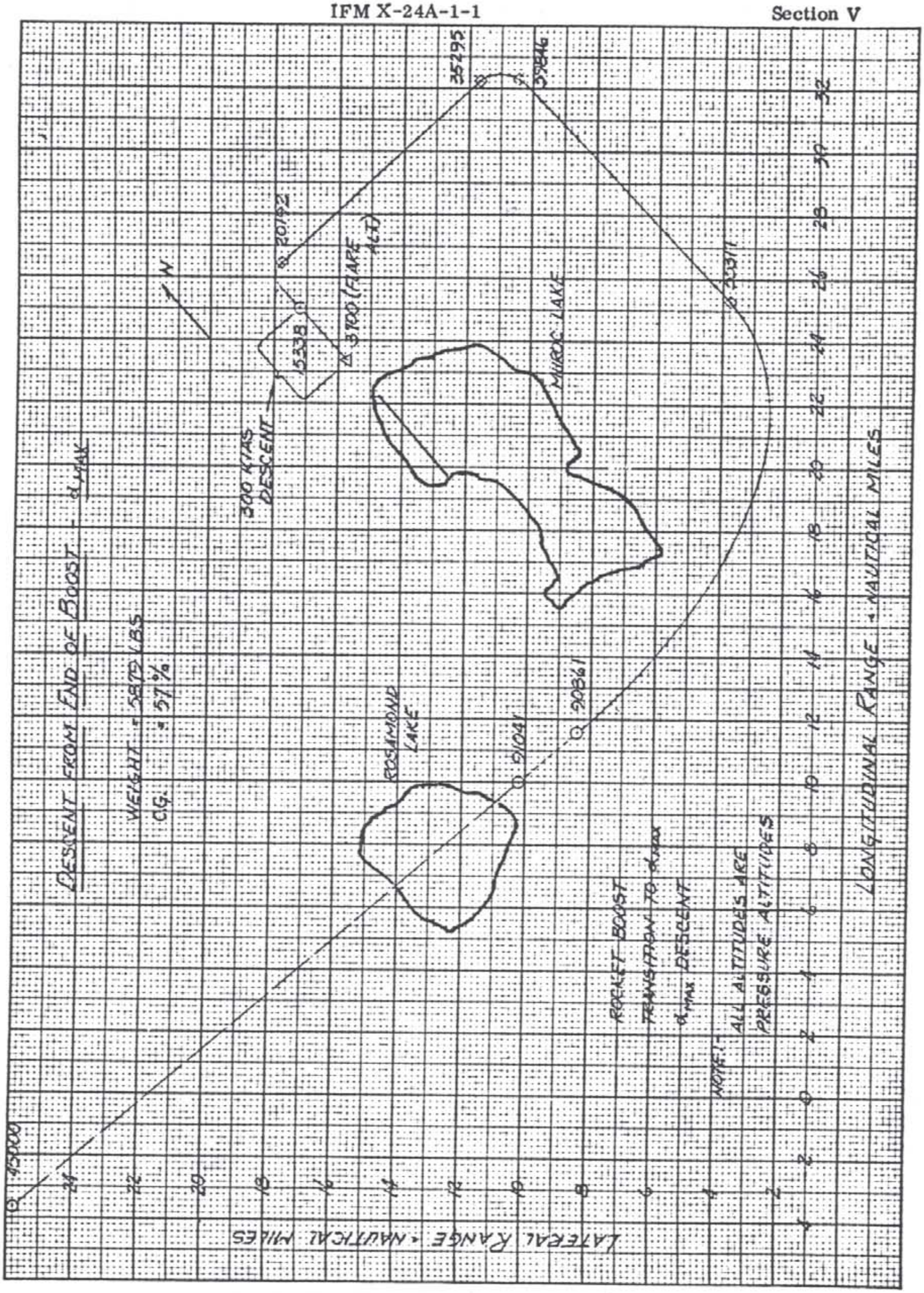


Figure 5-48. Descent From End of Boost α Max.

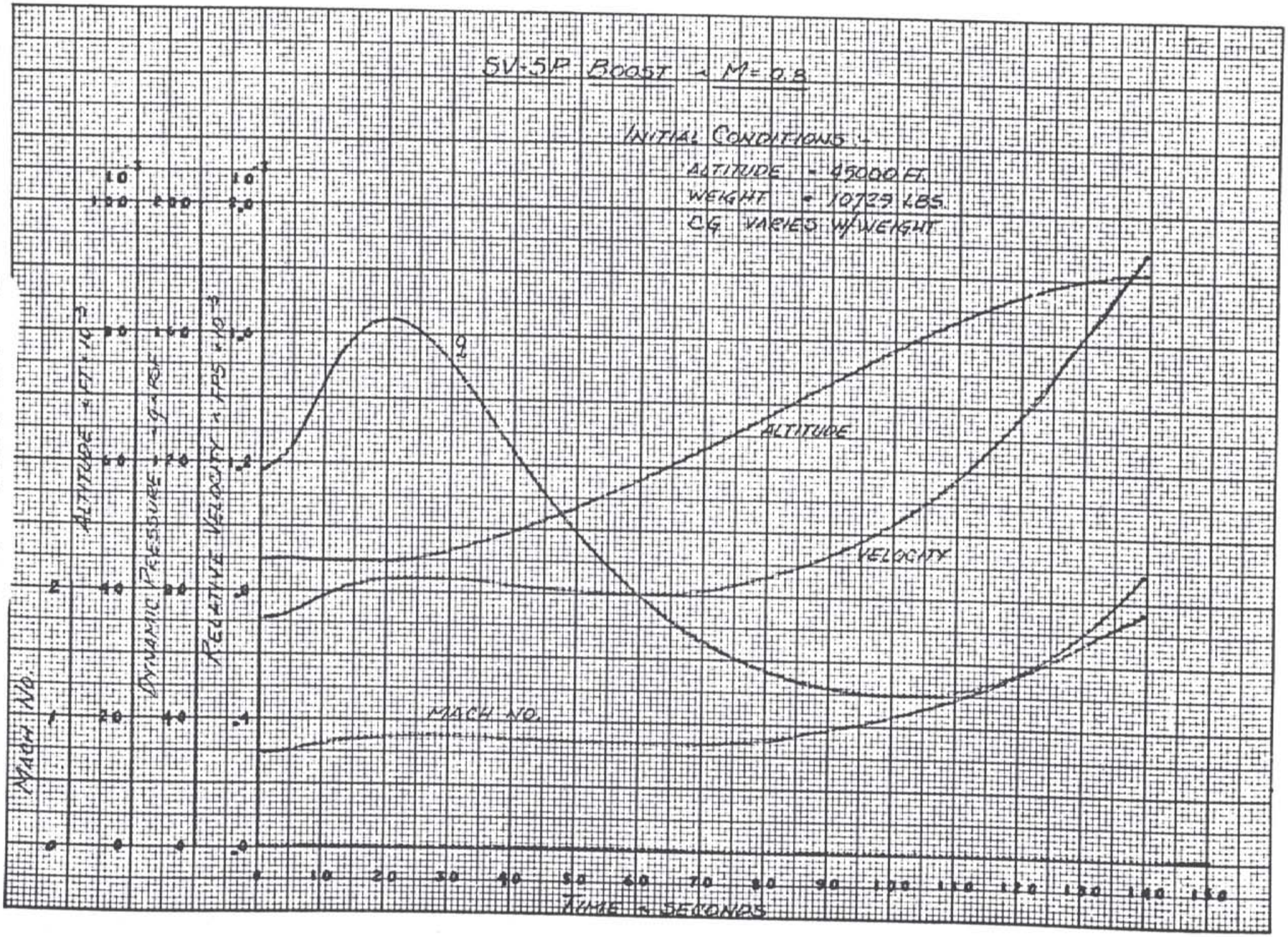


Figure 5-50. X-24A Boost ~ M=0.8.

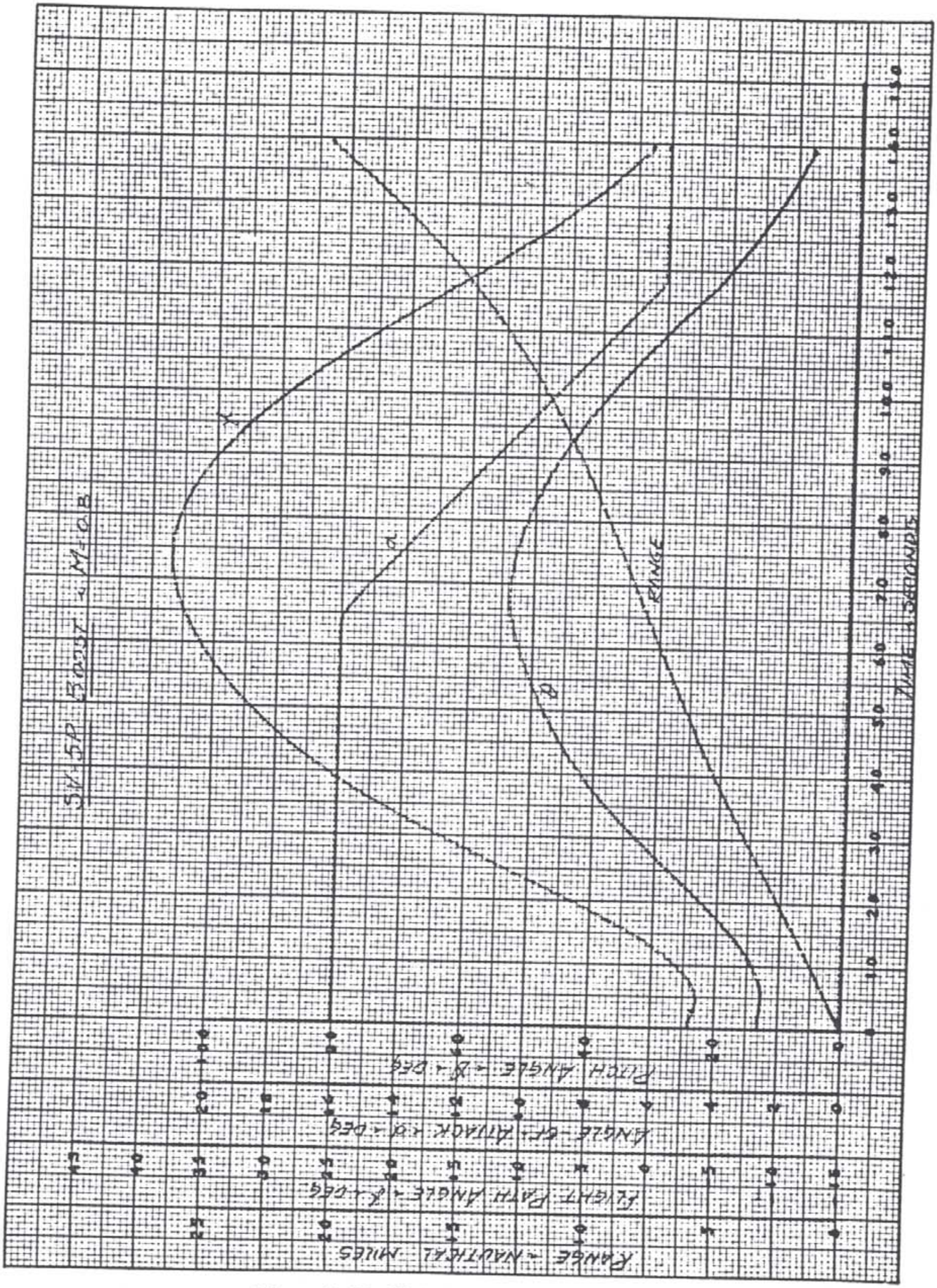


Figure 5-51. X-24A Boost, M=0.8.

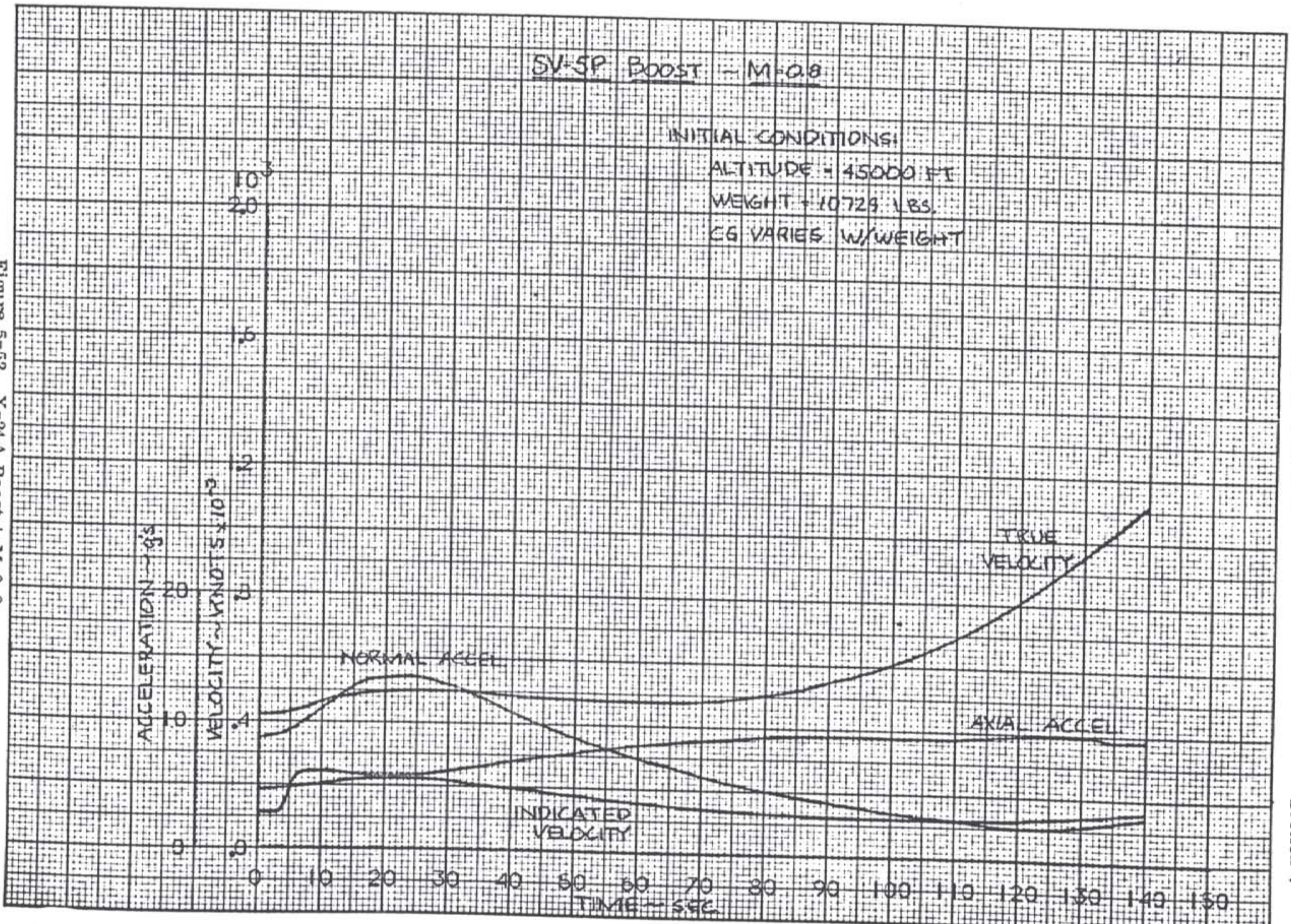


Figure 5-52. X-24A Boost λ M=0.8.

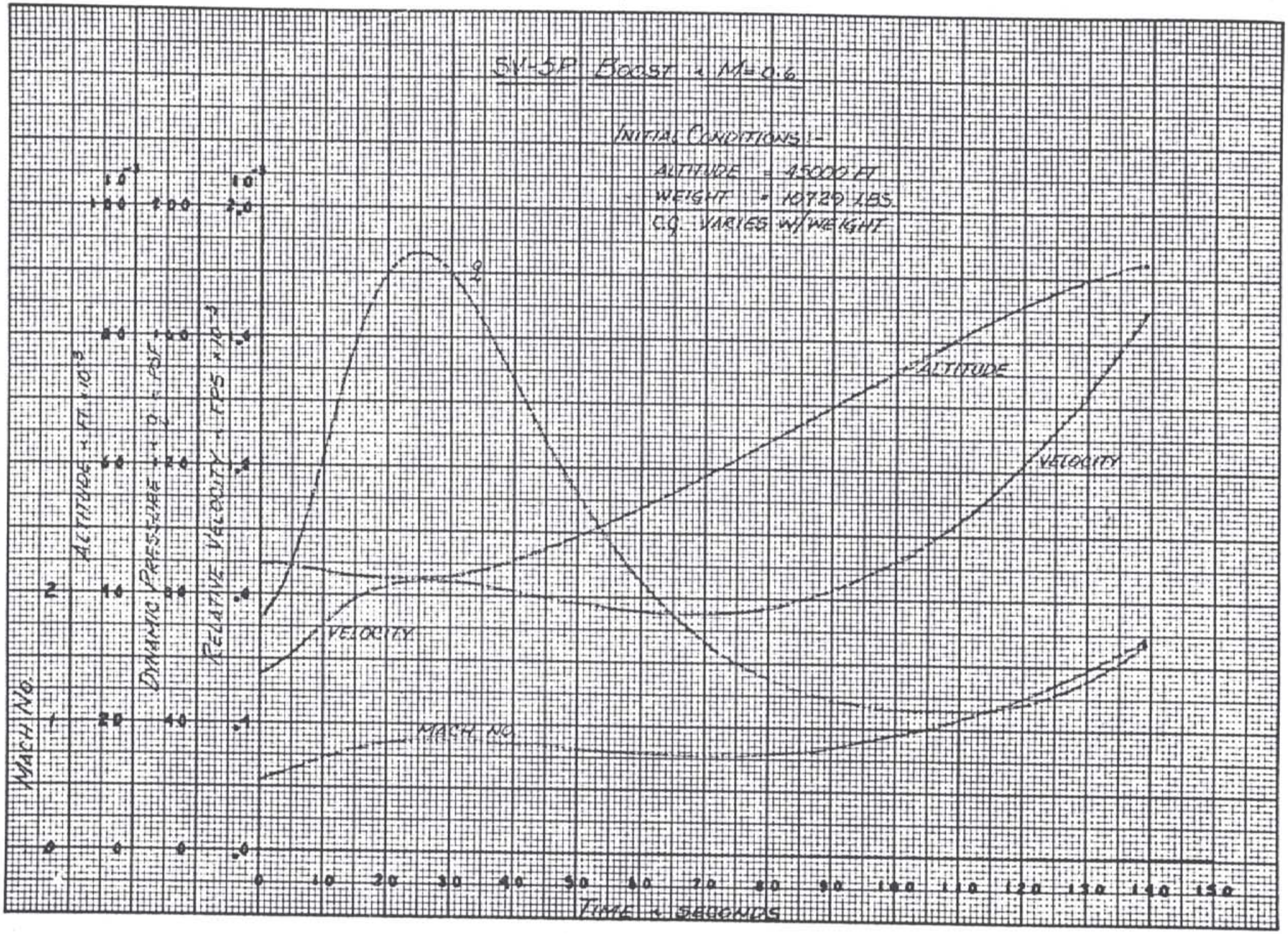


Figure 5-53. X-24A Boost ~ M=0.6.

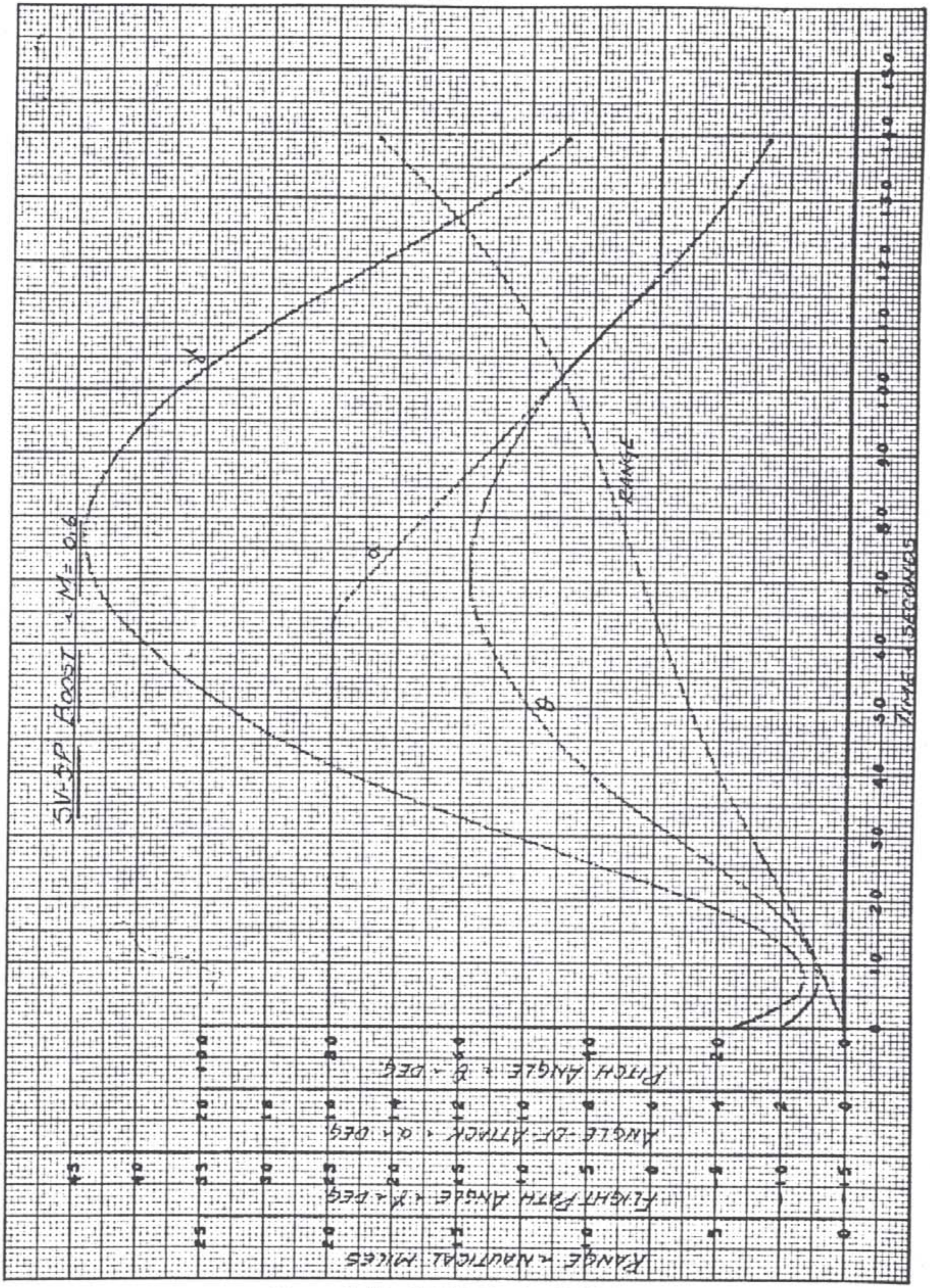


Figure 5-54. X-24A Boost ∠ M= 0.6.

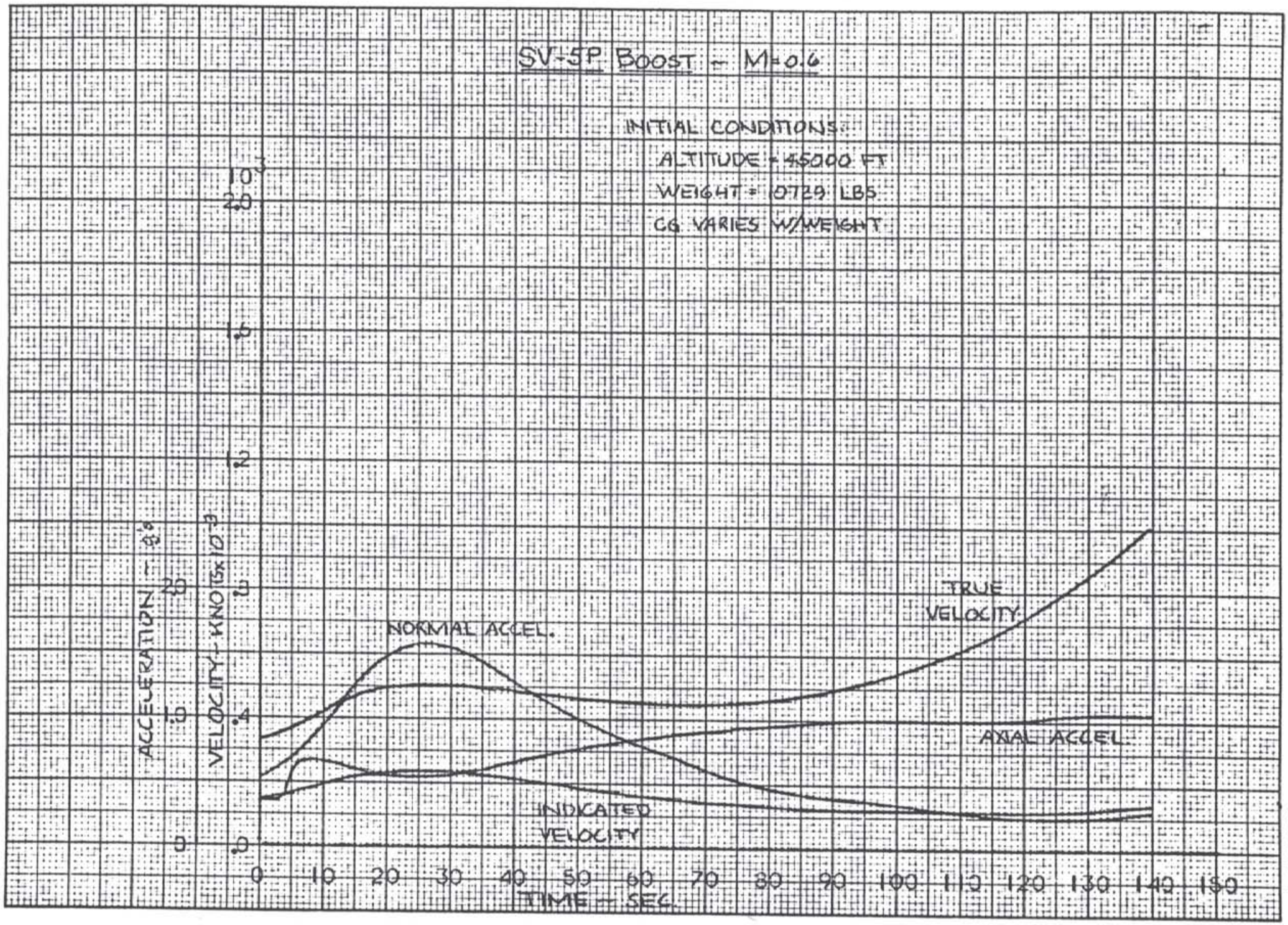


Figure 5-55. X-24A Boost ~ M=0.6.

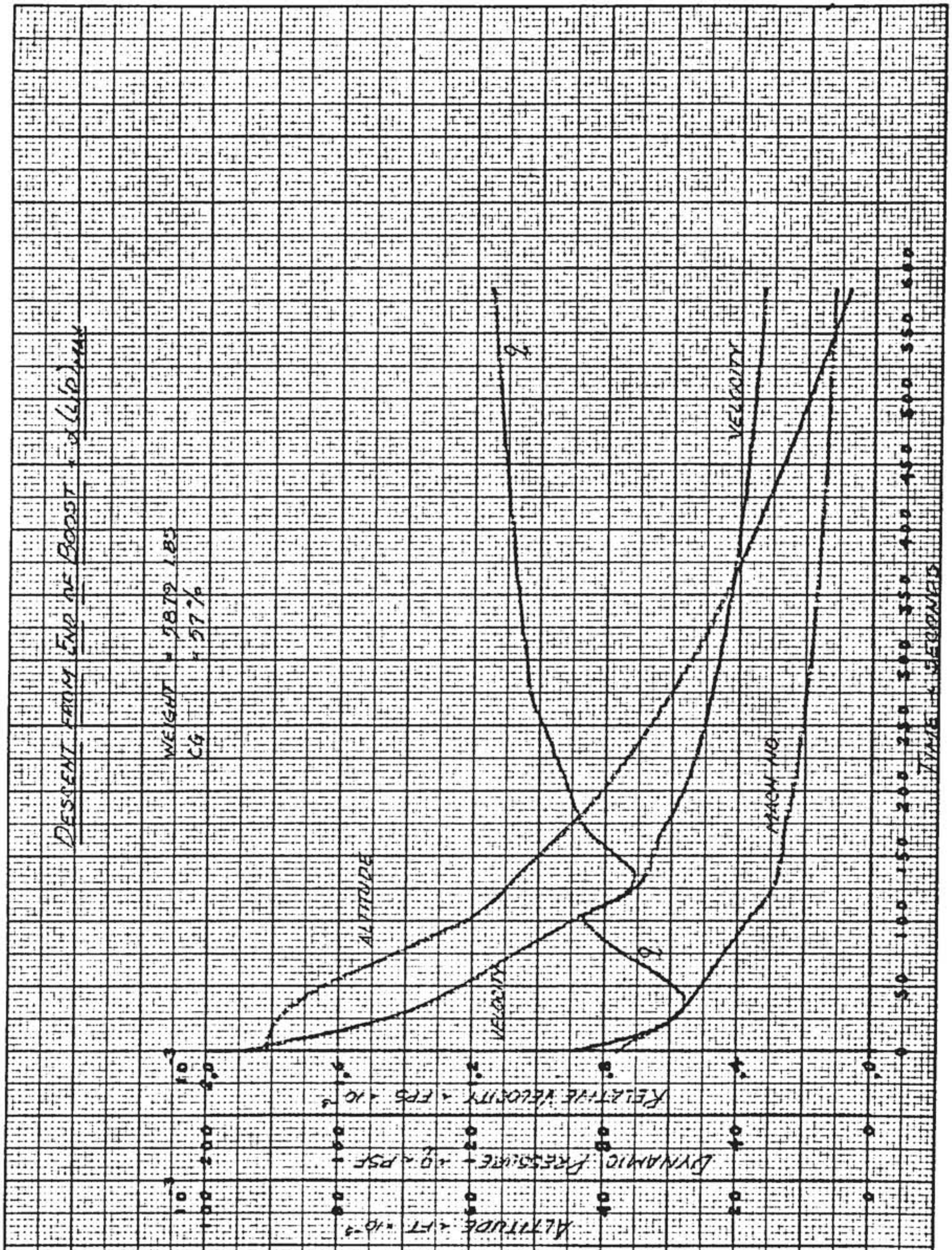


Figure 5-56. Descent From End of Boost α (L/D) Max.

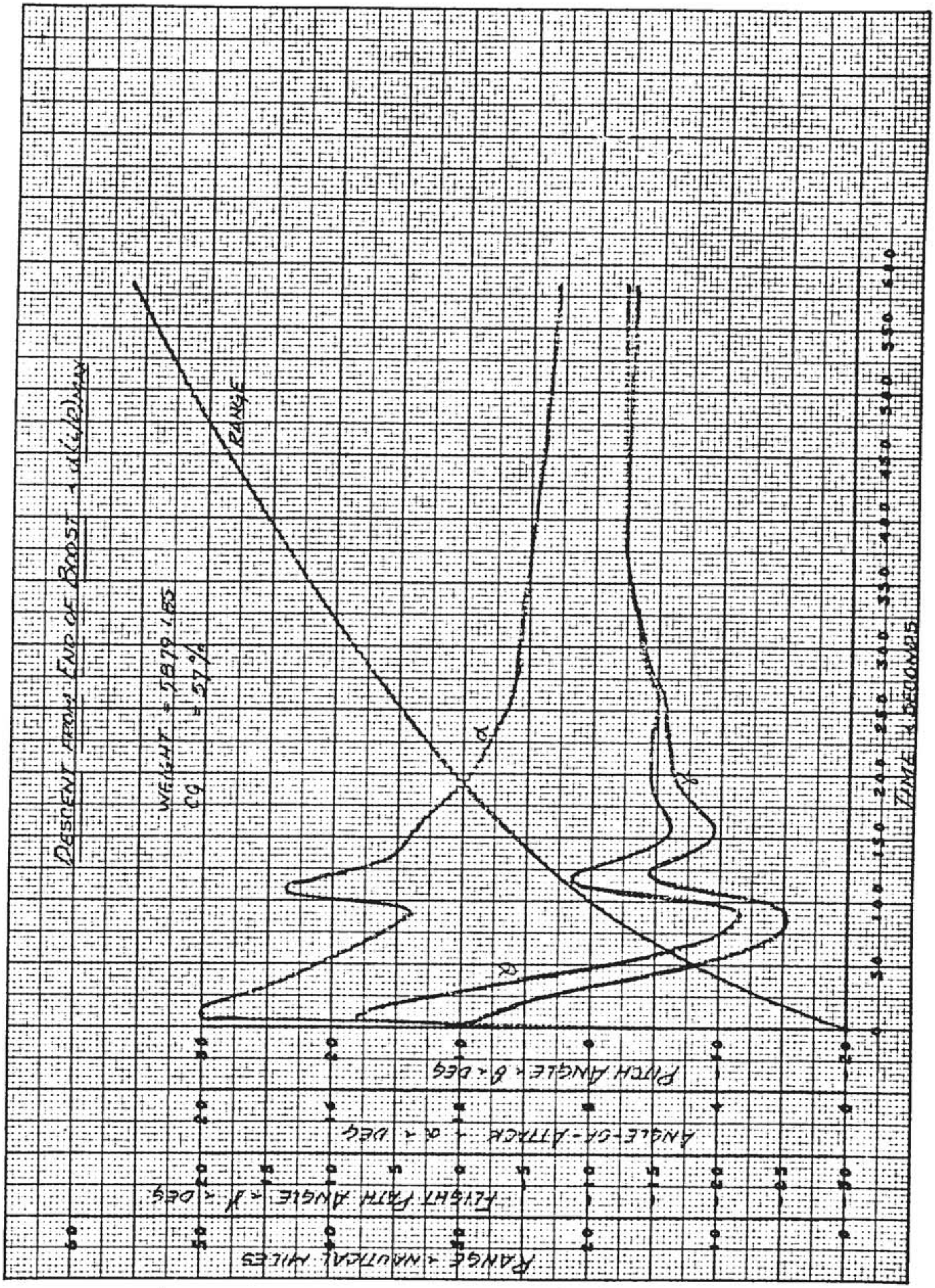


Figure 5-57. Descent From End of Boost α (L/D) Max.

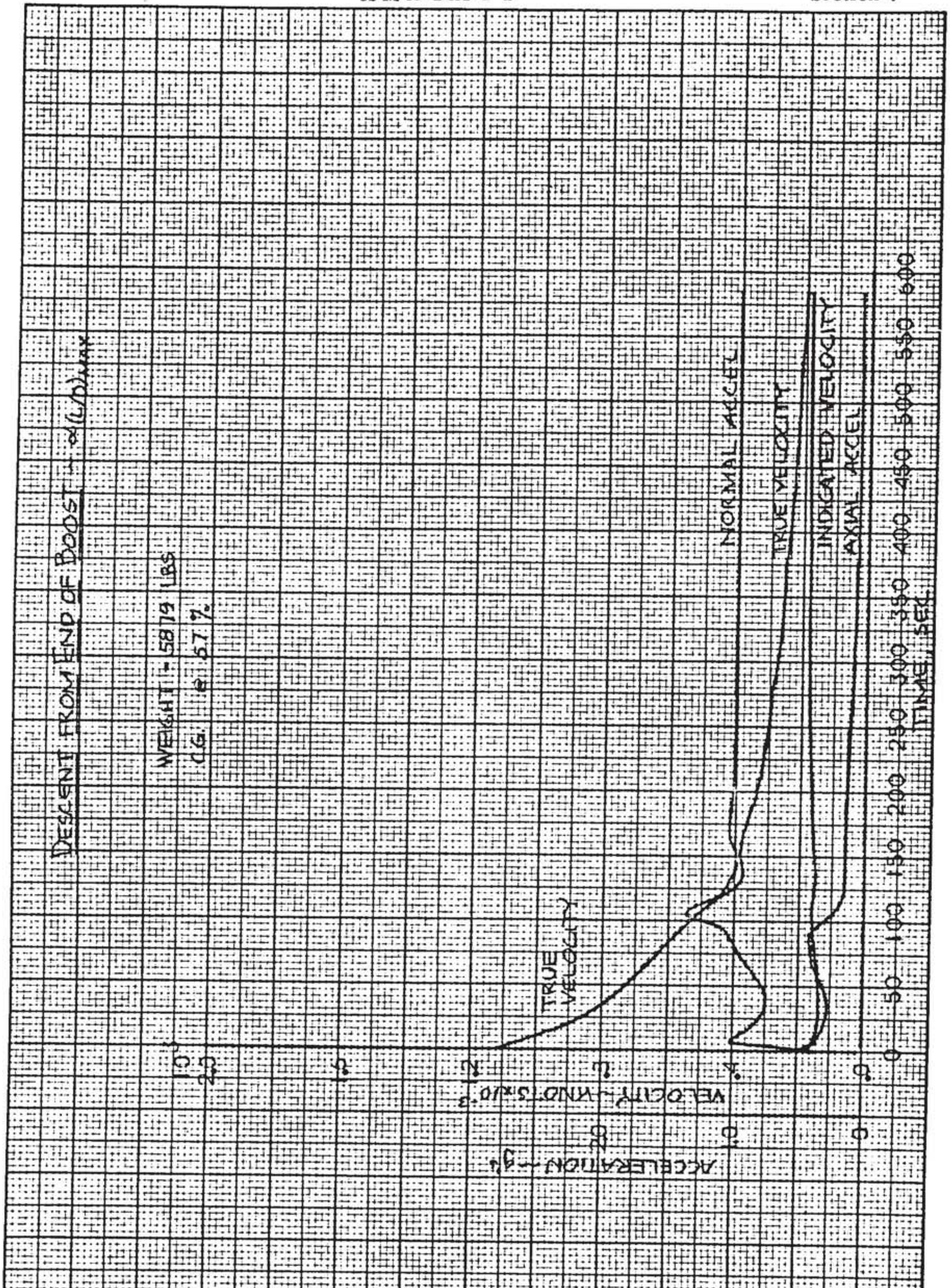


Figure 5-58. Descent From End of Boost α (L/D) Max.

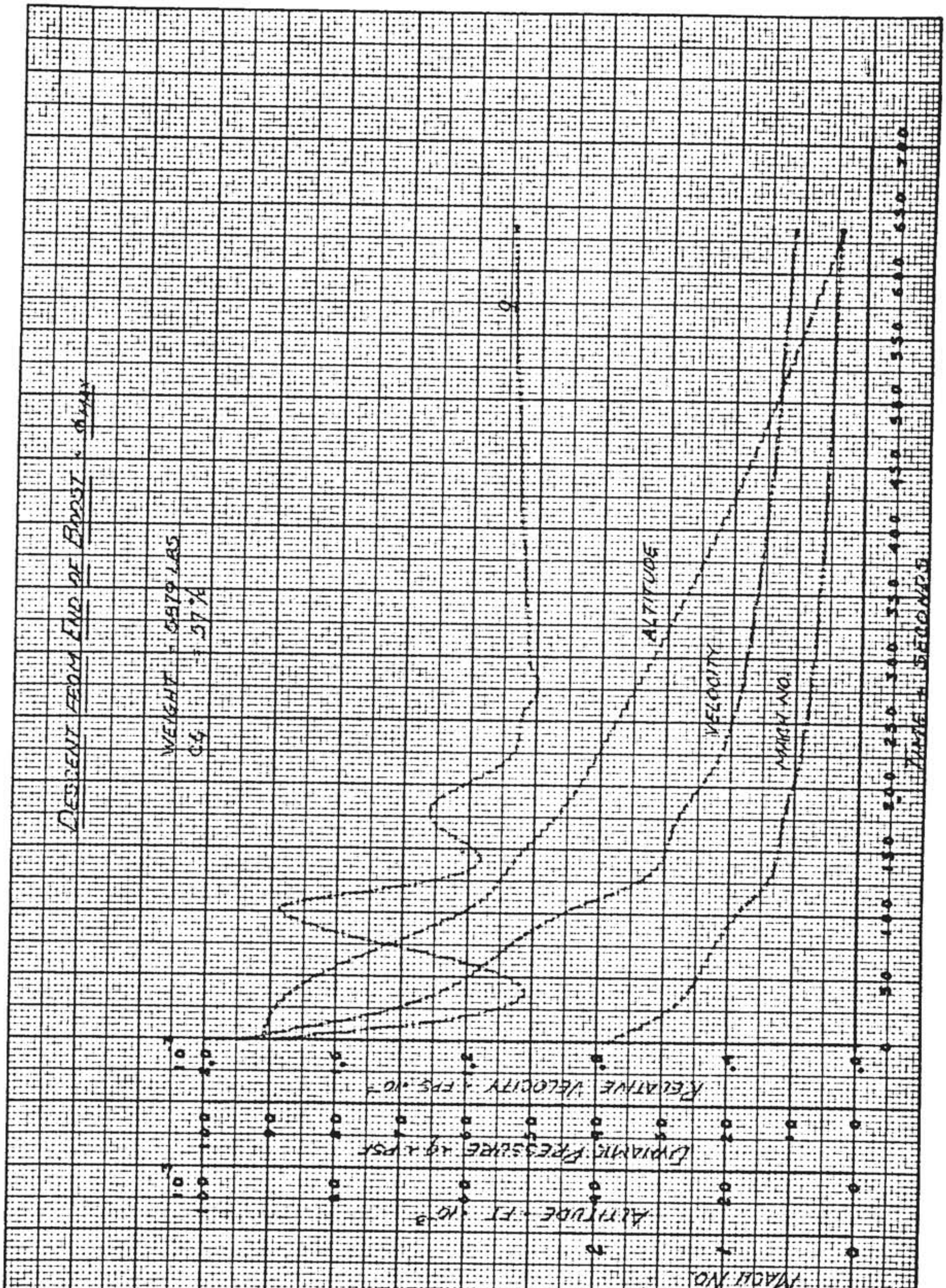


Figure 5-59. Descent From End of Boost α Max.

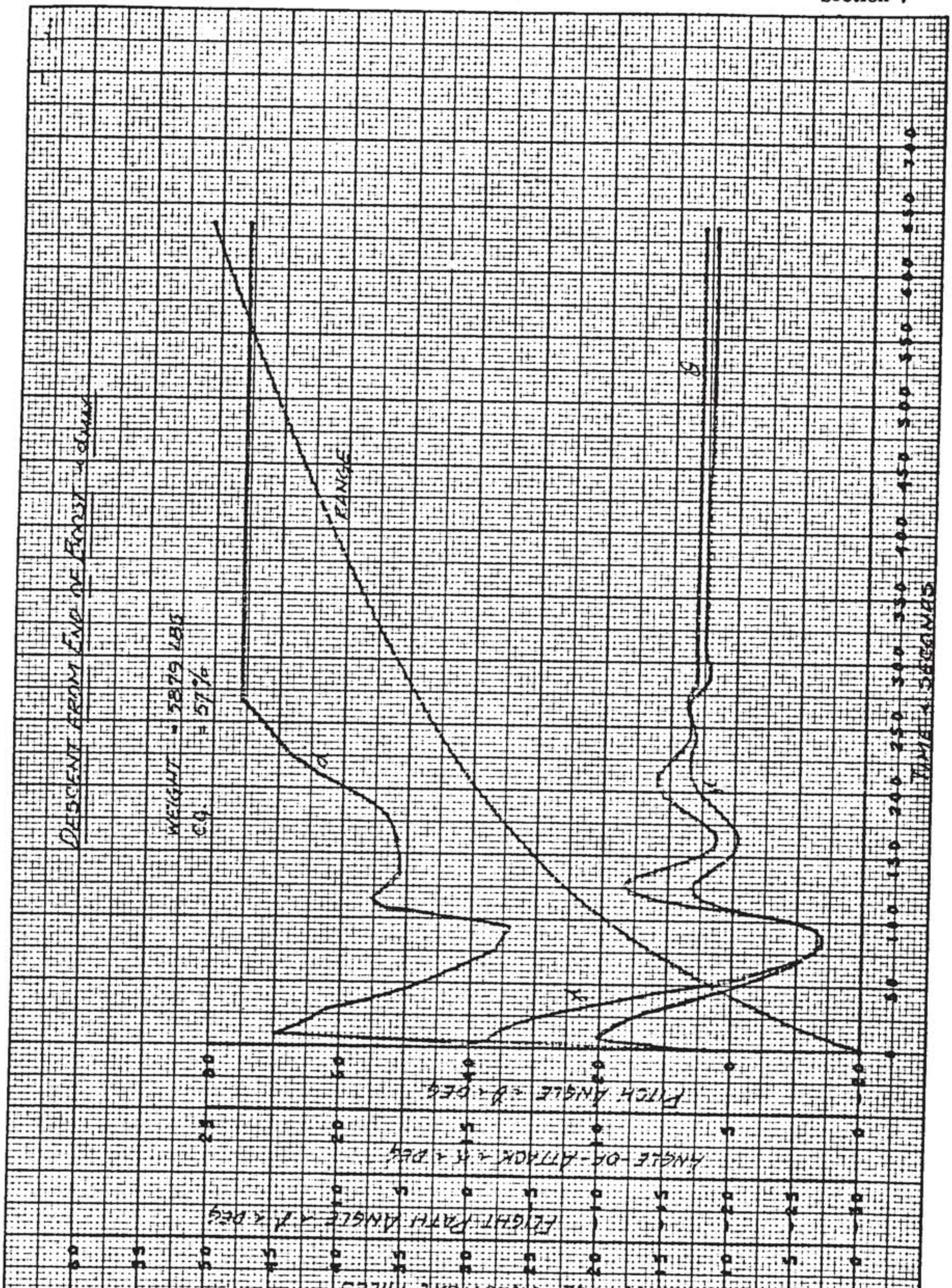


Figure 5-60. Descent From End of Boost α Max.

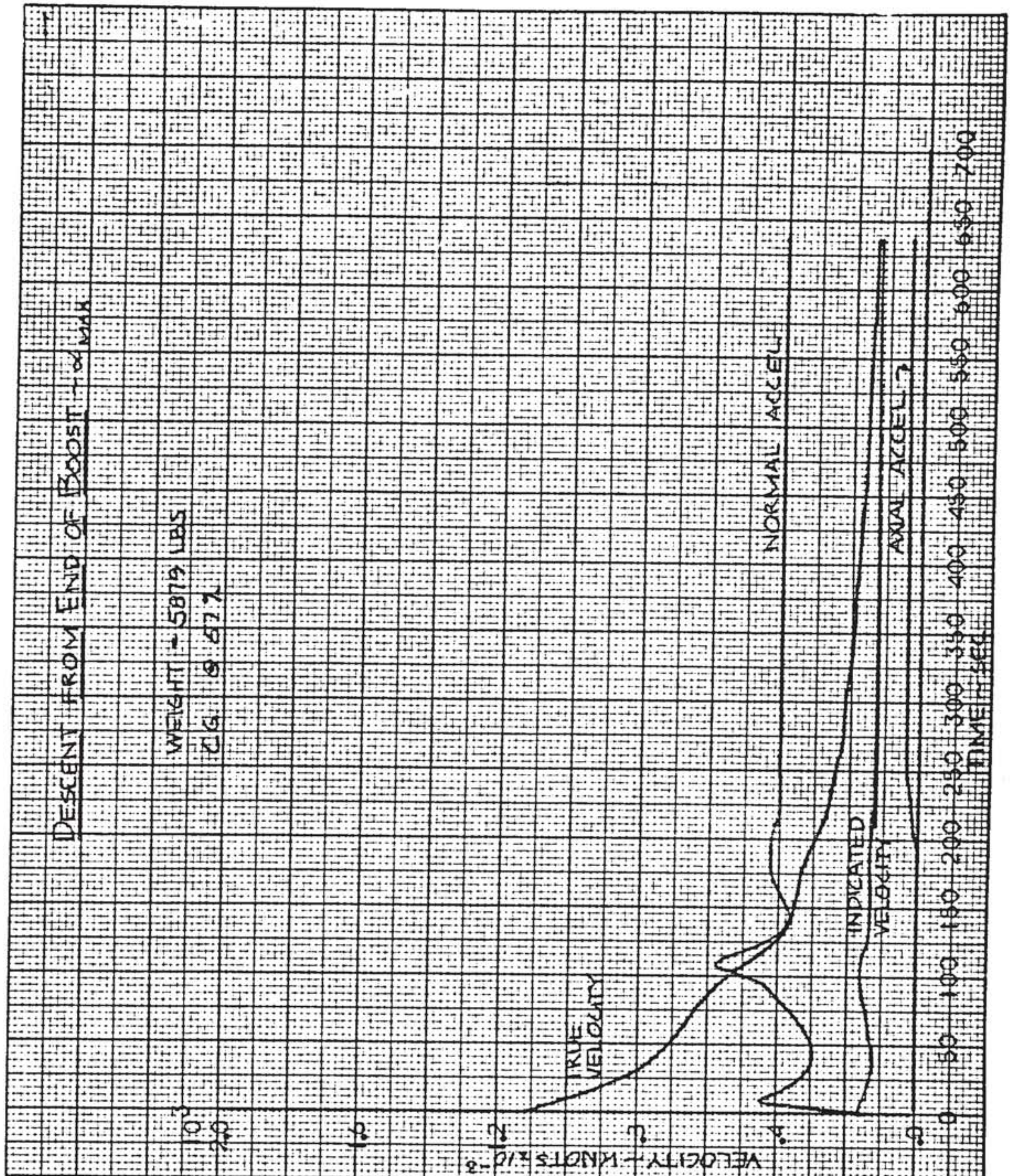


Figure 5-61. Descent From End of Boost α Max.

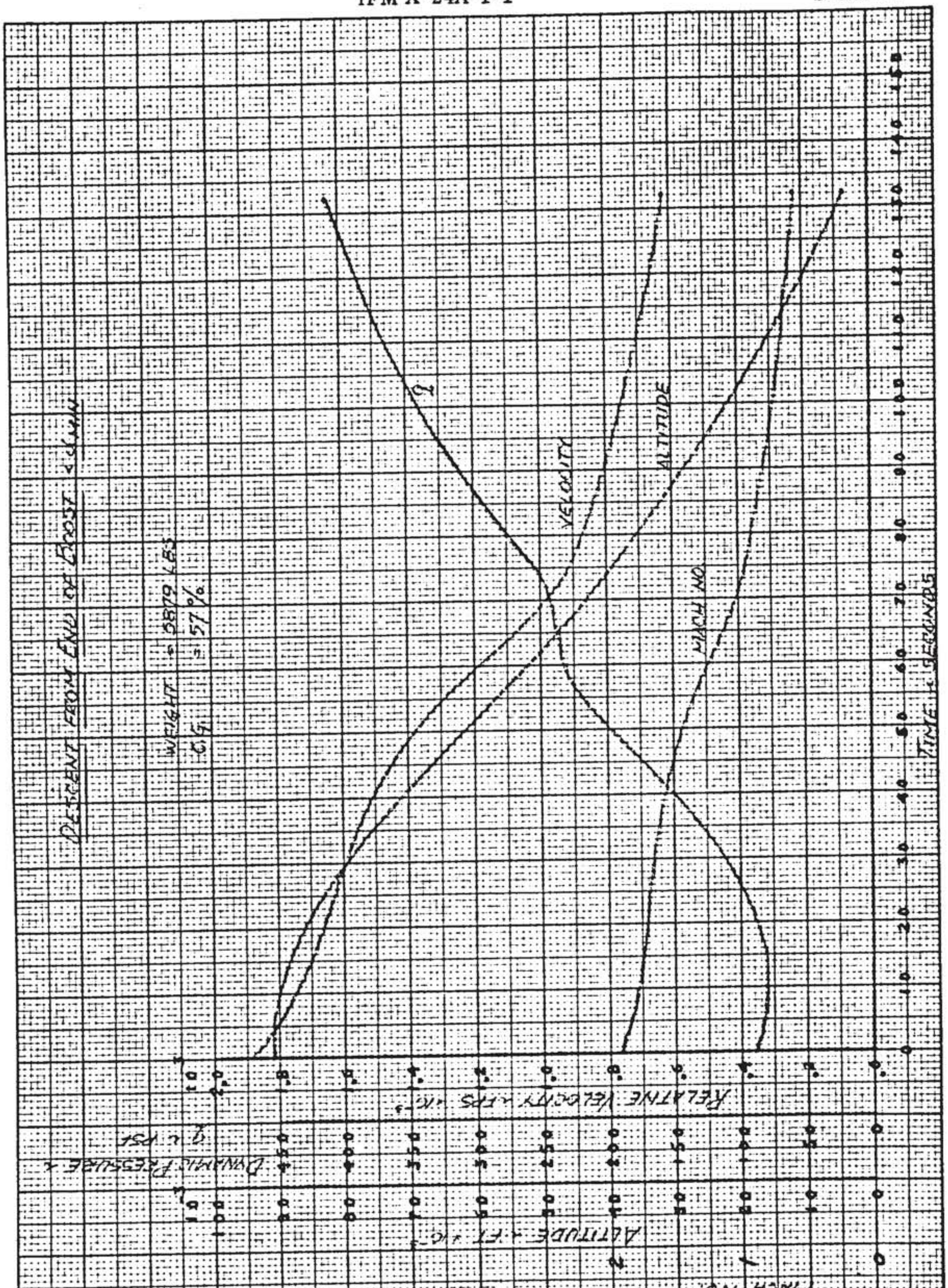


Figure 5-62. Descent From End of Boost α Min.

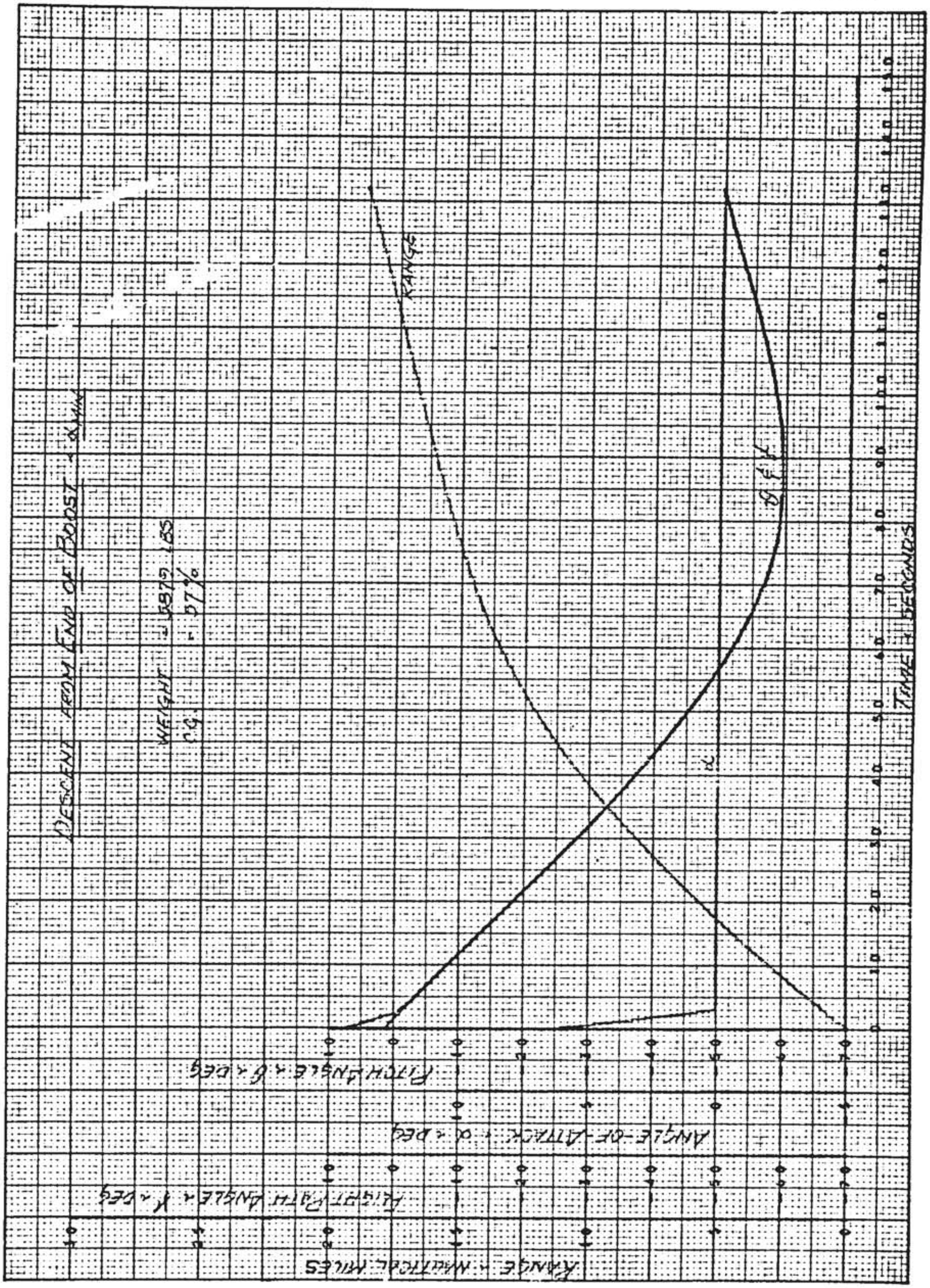


Figure 5-63. Descent From End of Boost α Min.

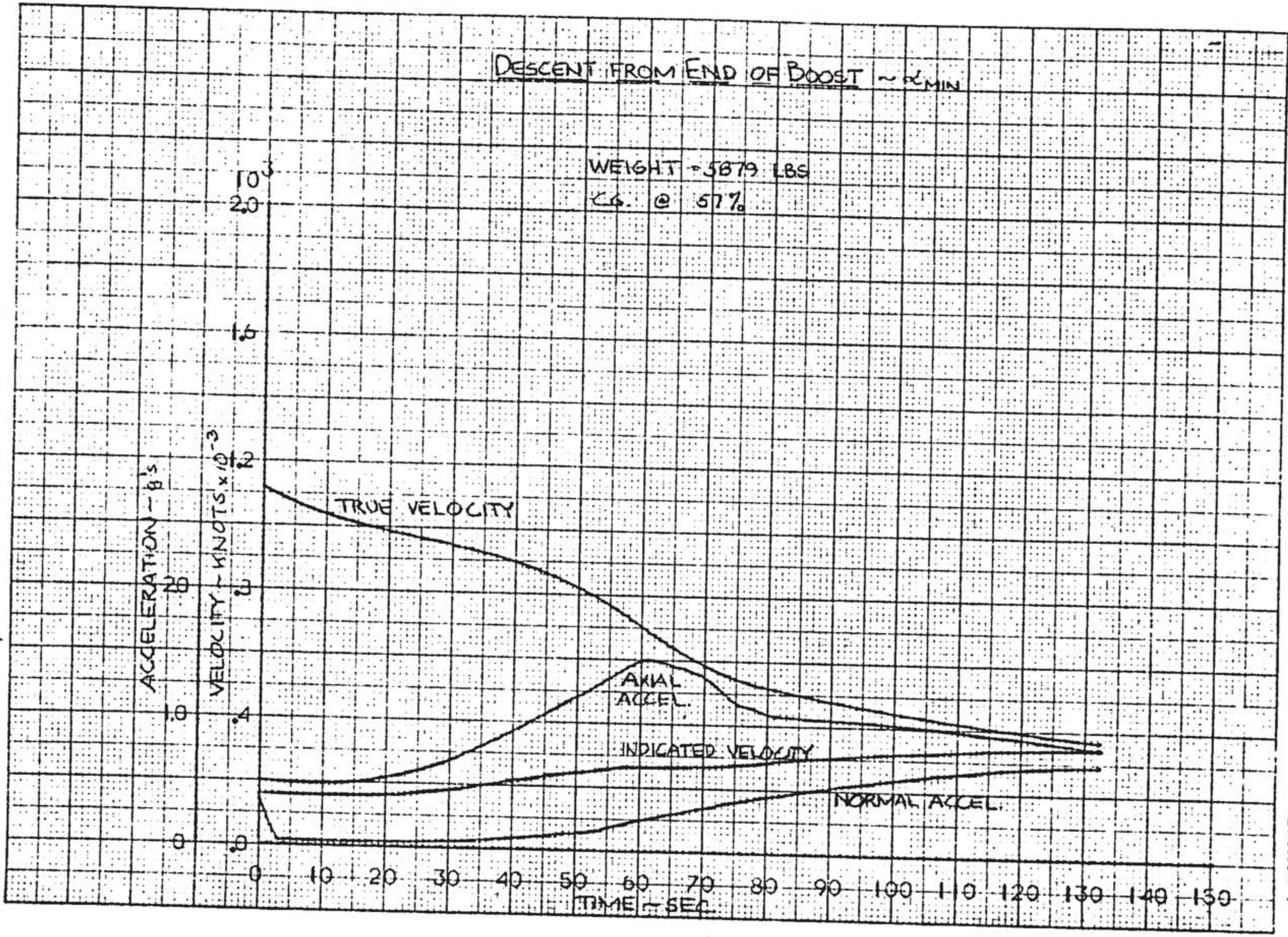


Figure 5-64. Descent From End of Boost α Min.

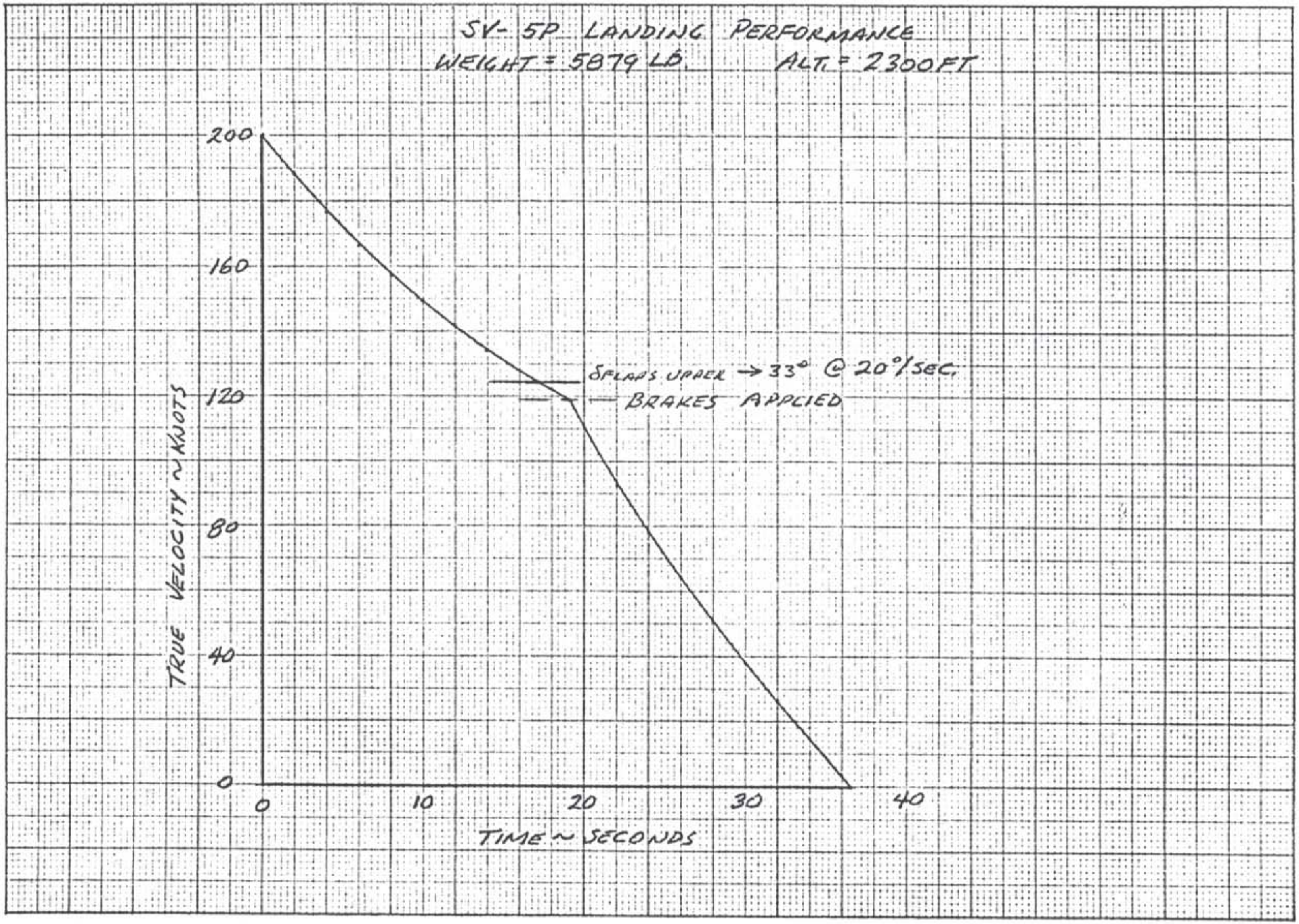


Figure 5-65. X-24A Landing Performance.

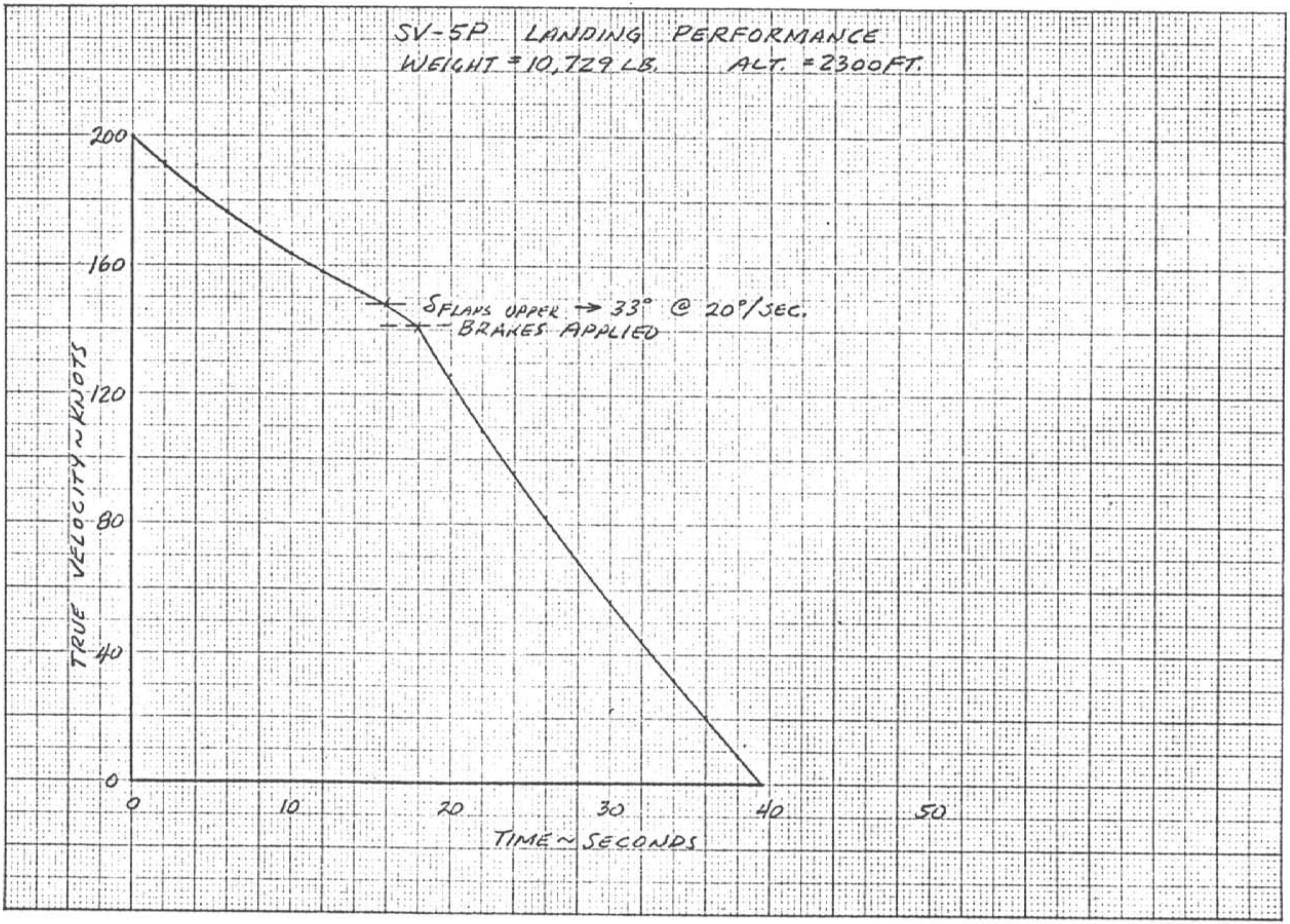


Figure 5-66. X-24A Landing Performance.

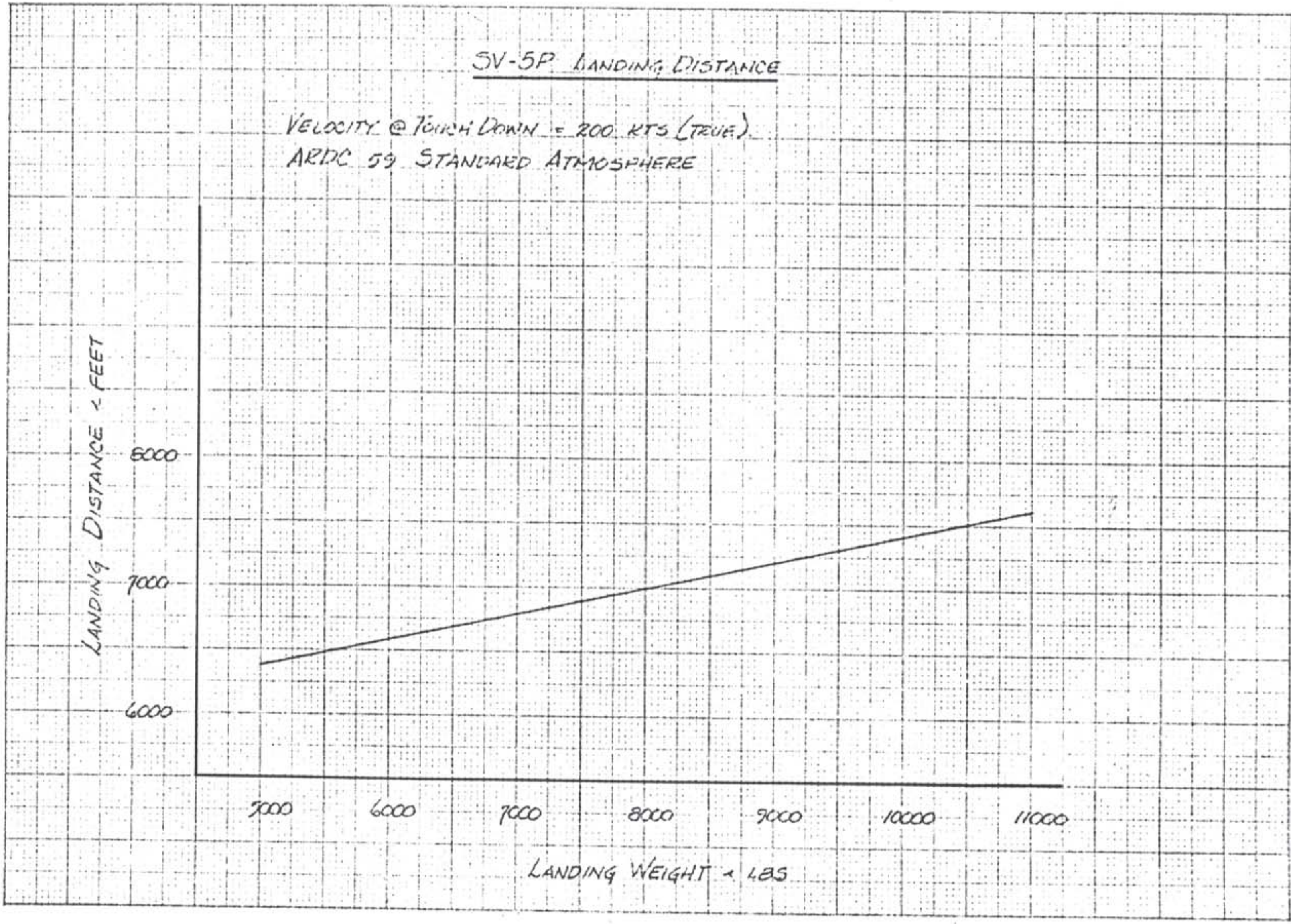


Figure 5-67. X-24A Landing Distance.

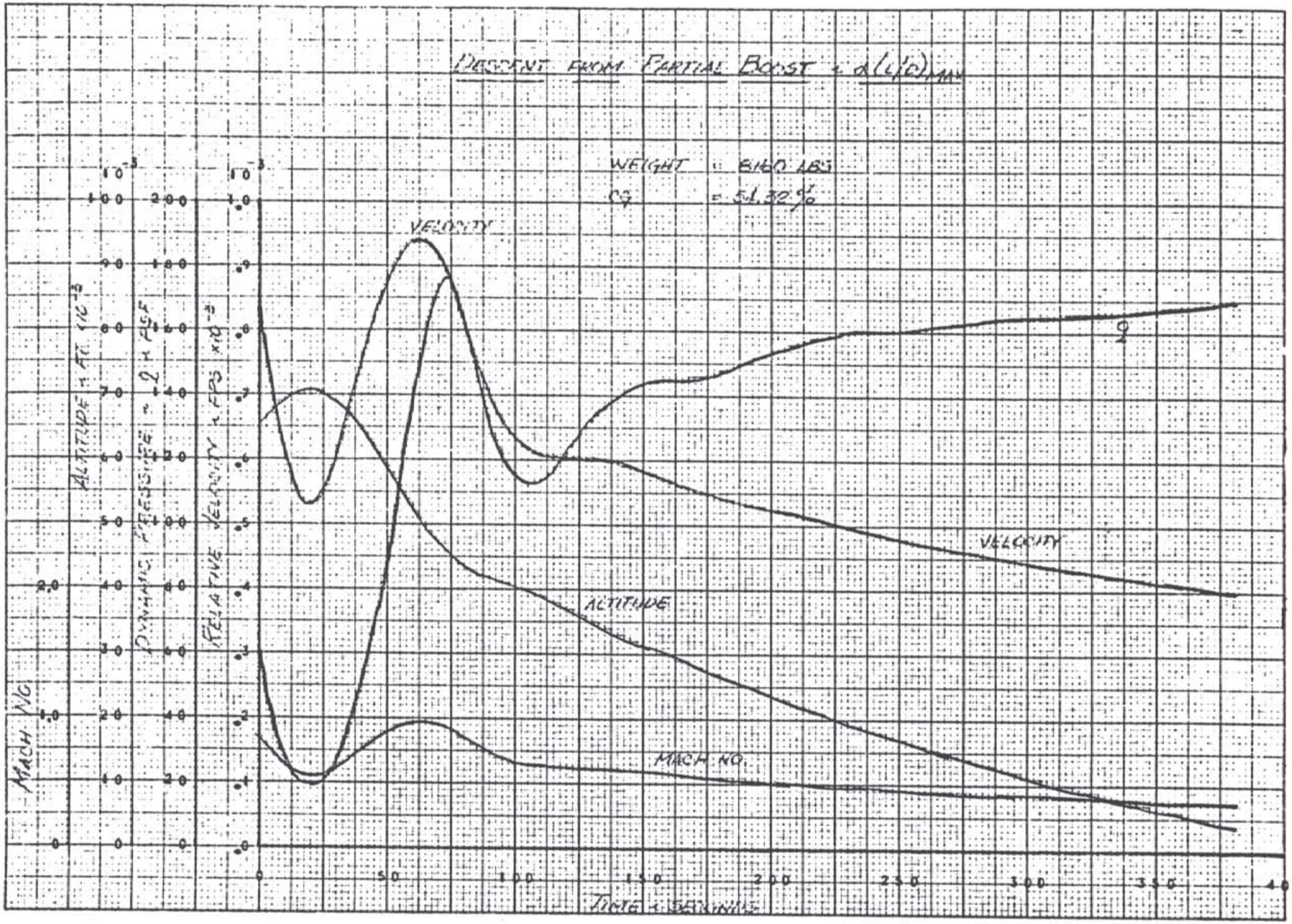


Figure 5-68. Descent From Partial Boost α(L/D) Max.

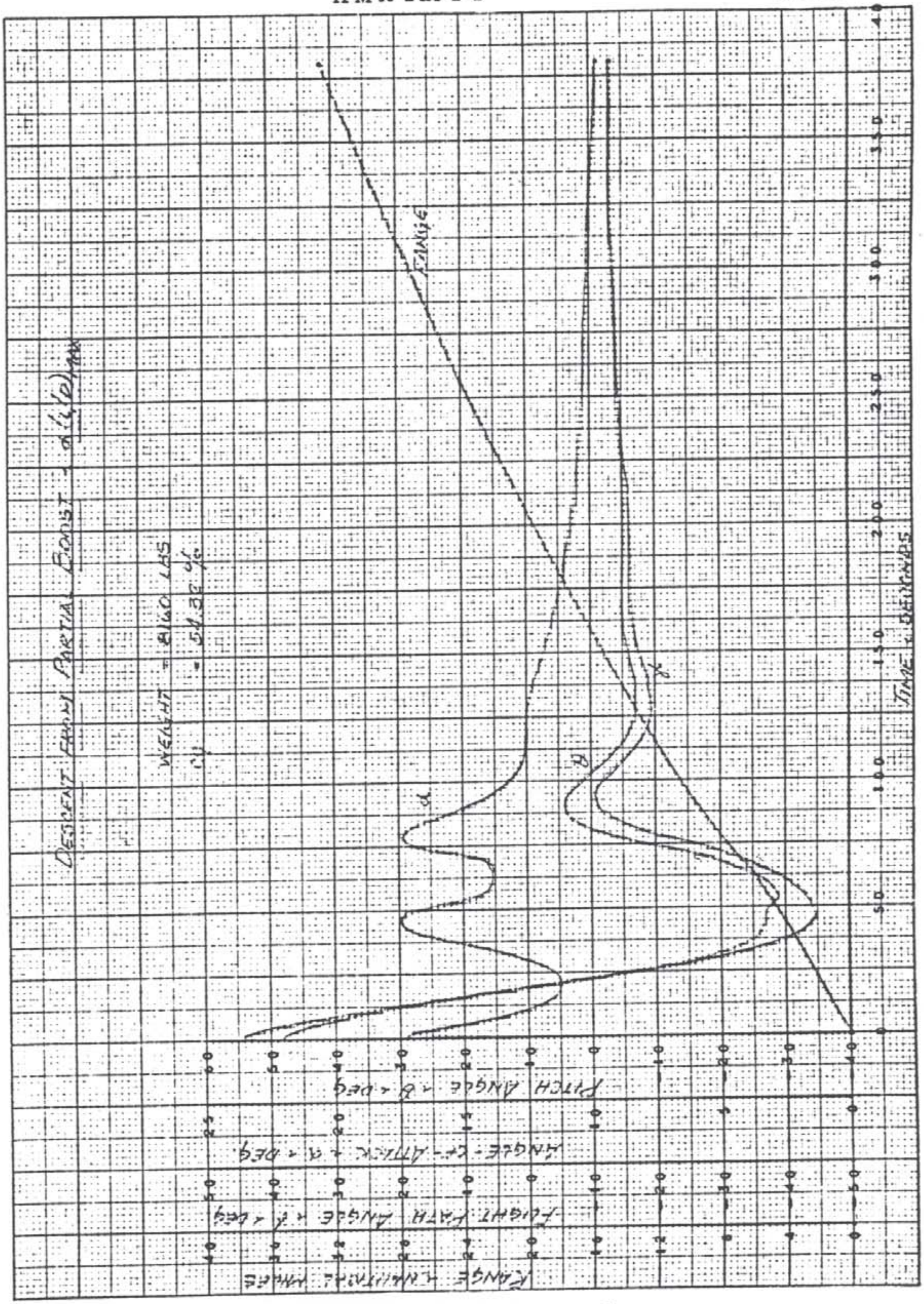


Figure 5-69. Descent From Partial Boost α (L/D) Max.

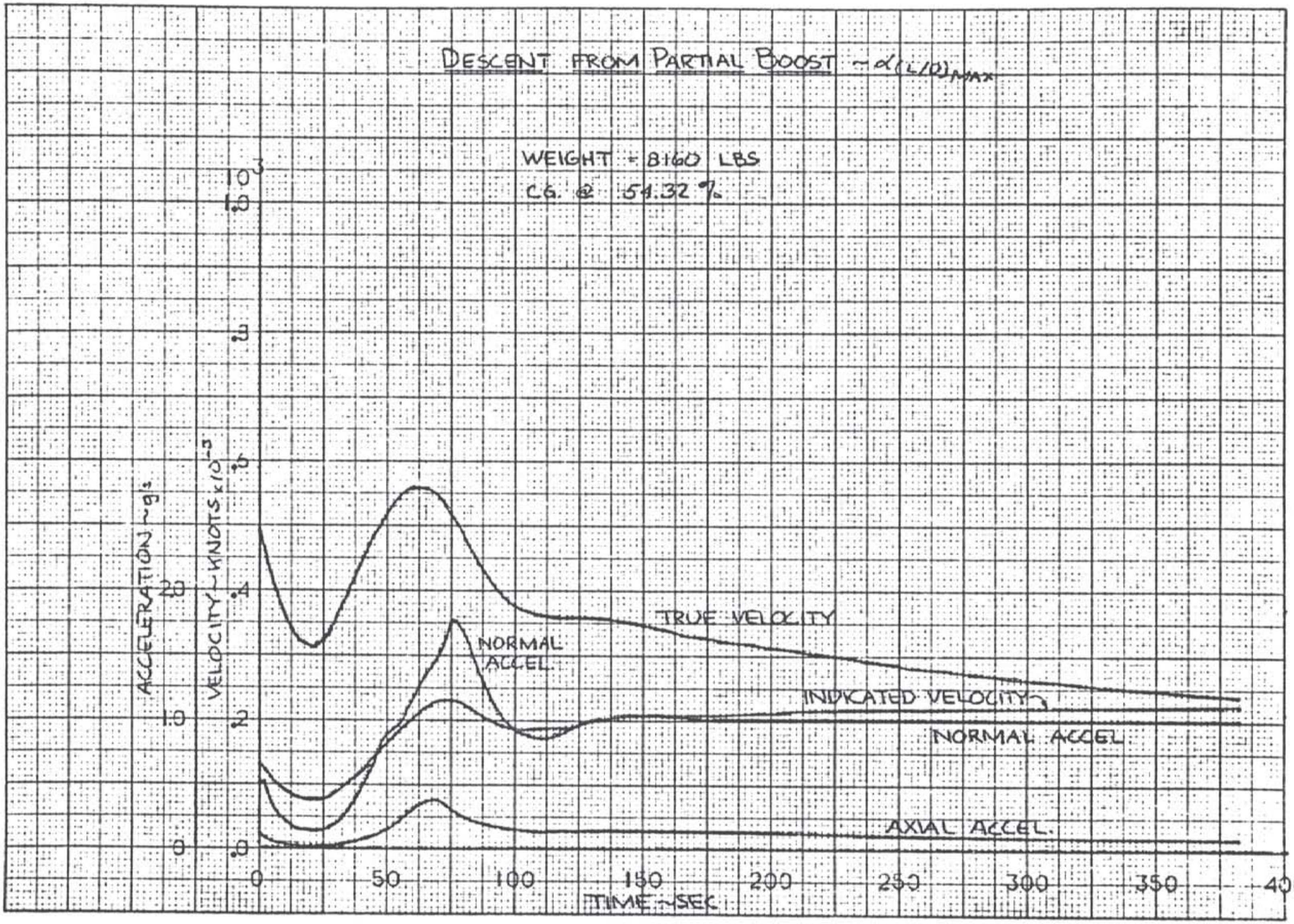
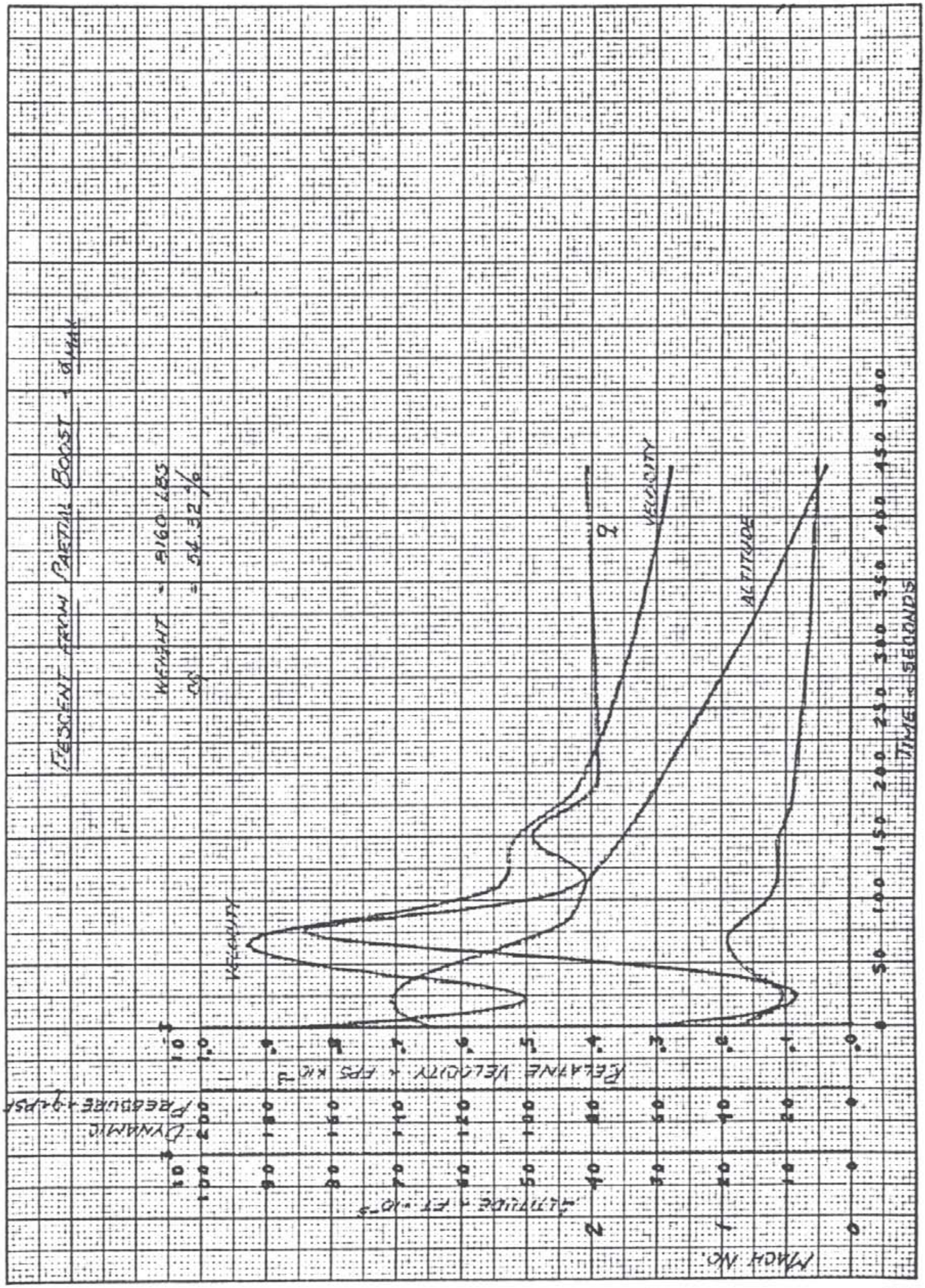


Figure 5-70. Descent From Partial Boost α (L/D) Max.



Figures 5-71. Descent From Partial Boost α Max.

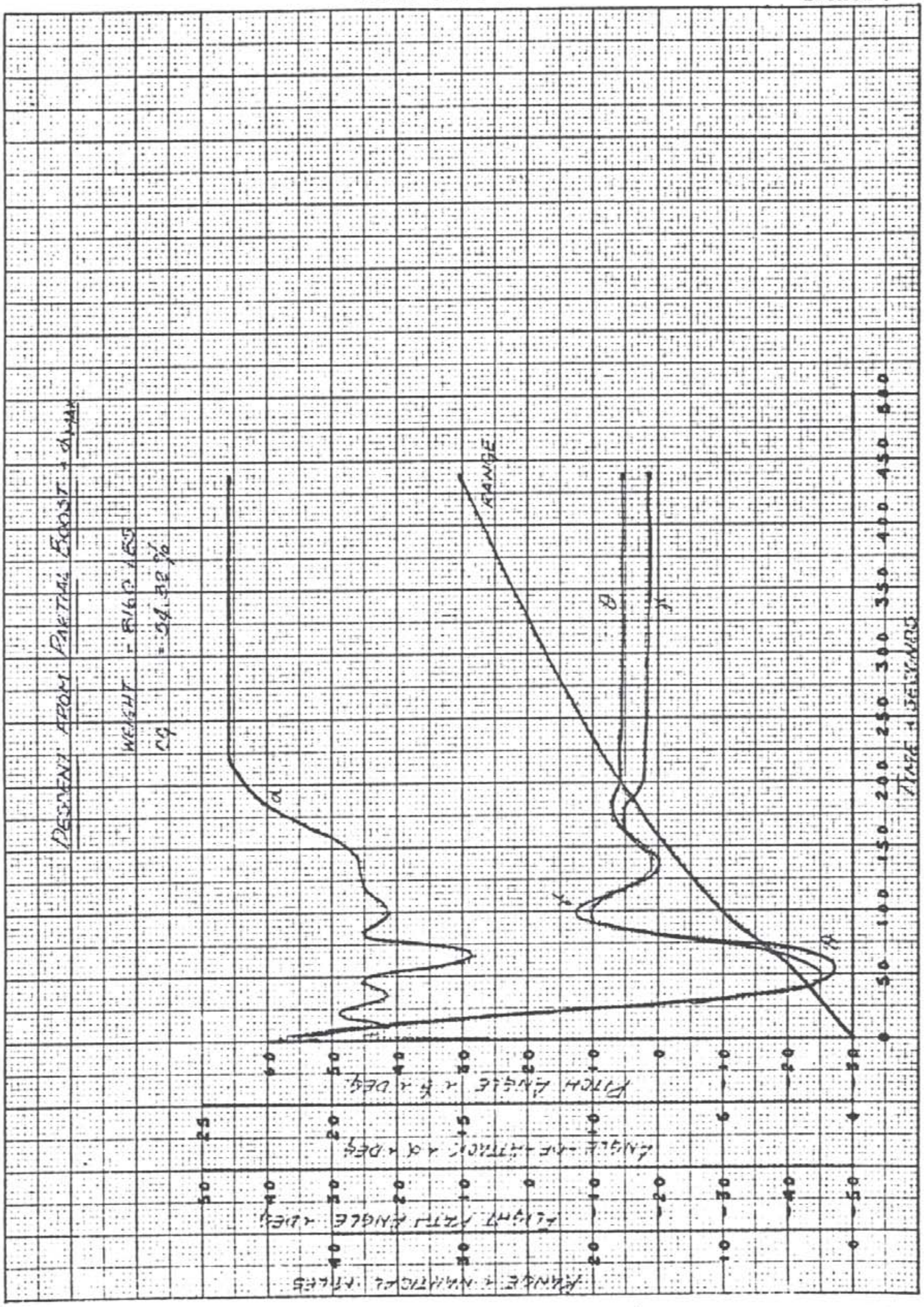


Figure 5-72. Descent From Partial Boost α Max.

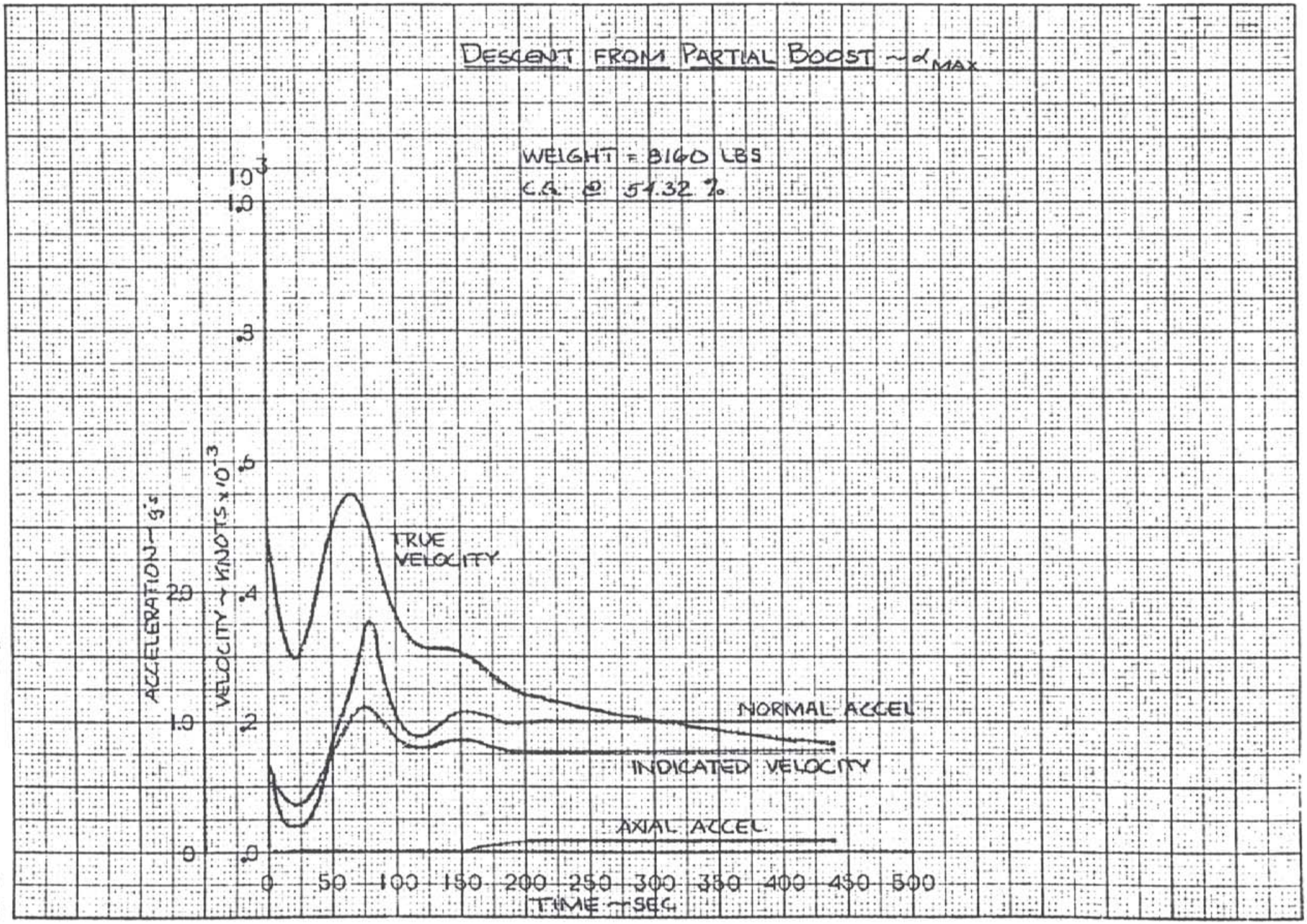


Figure 5-73. Descent From Partial Boost α Max.

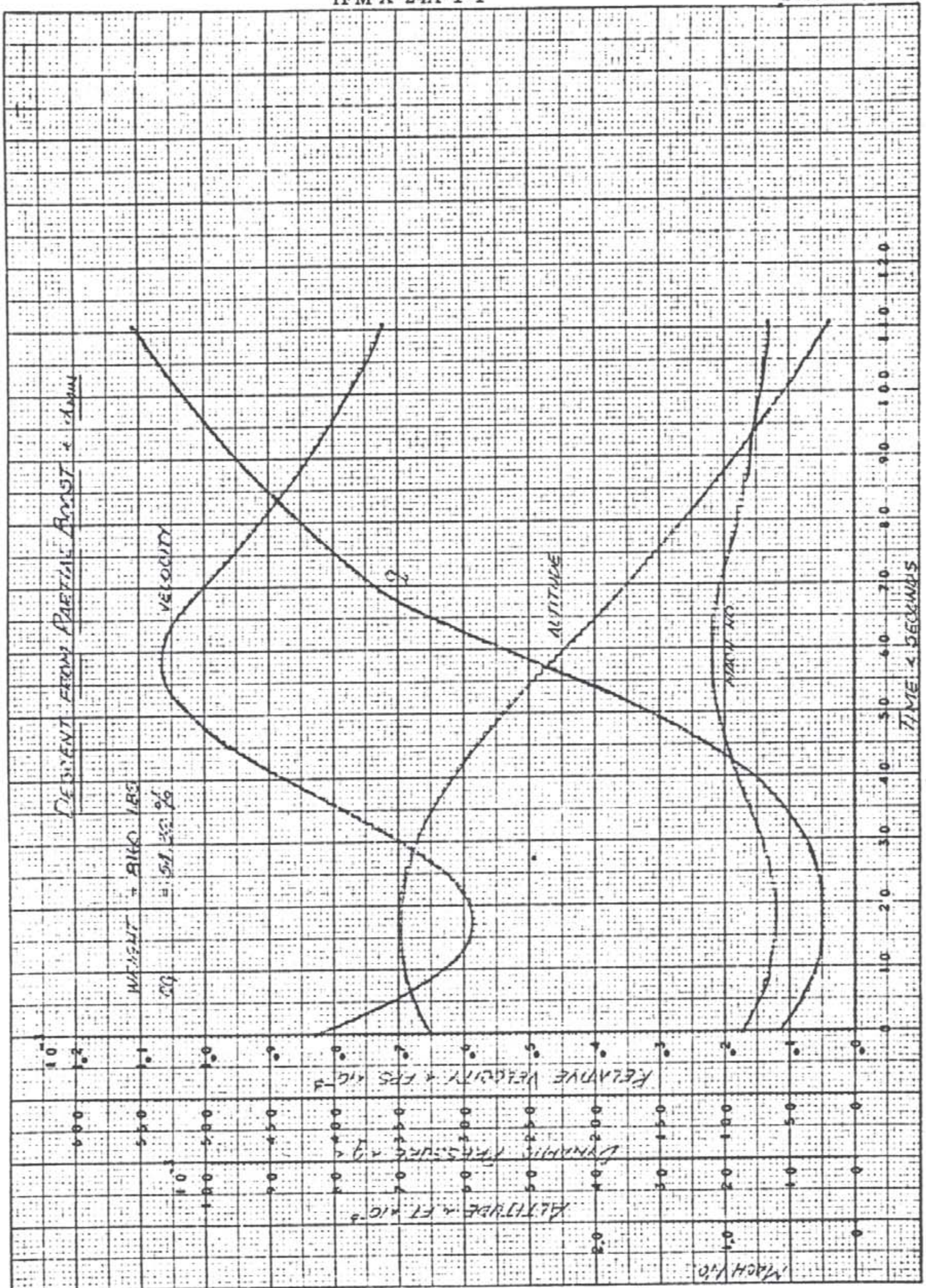


Figure 5-74. Descent From Partial Boost α Min.

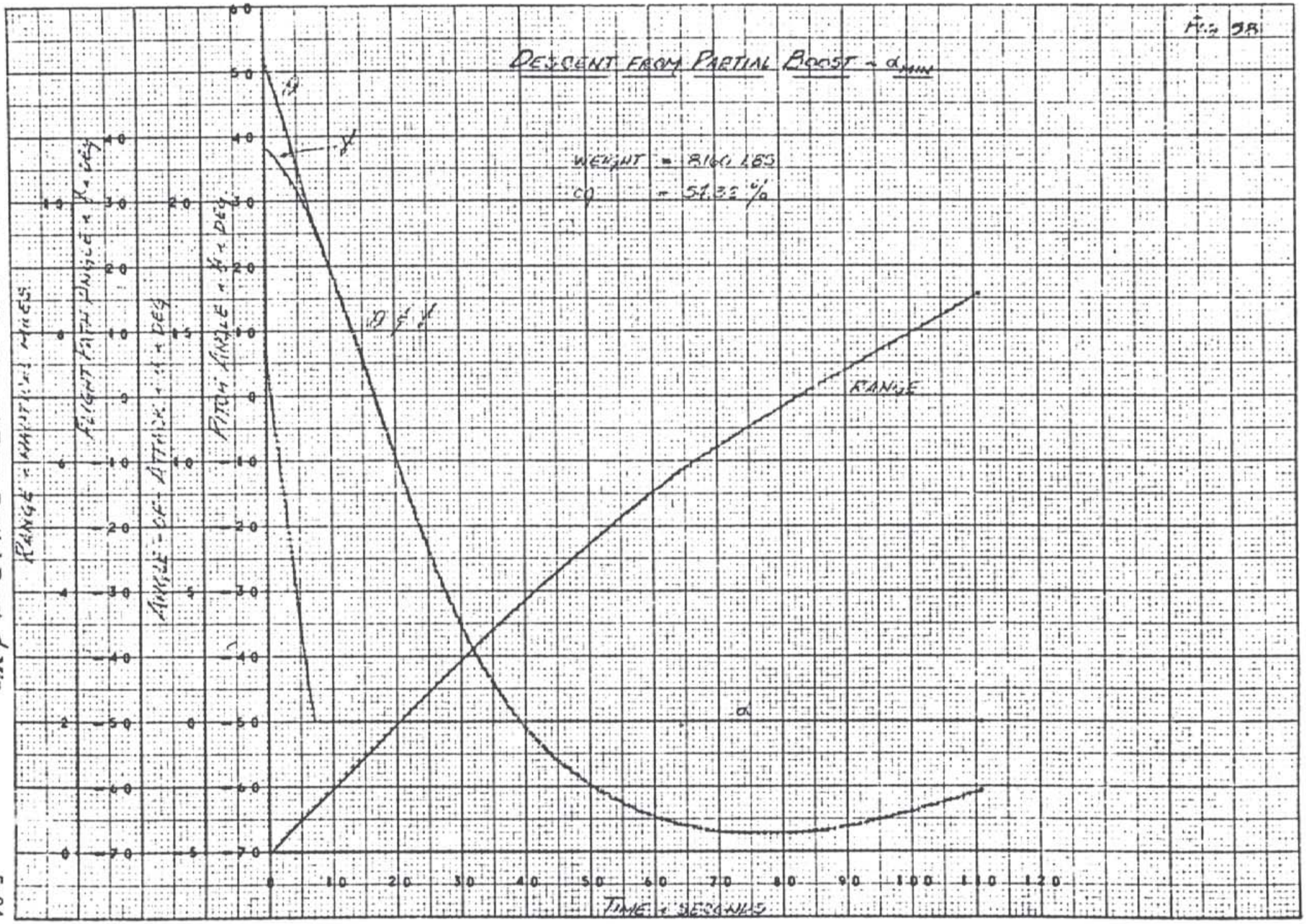


Figure 5-75. Descent From Partial Boost α Min.

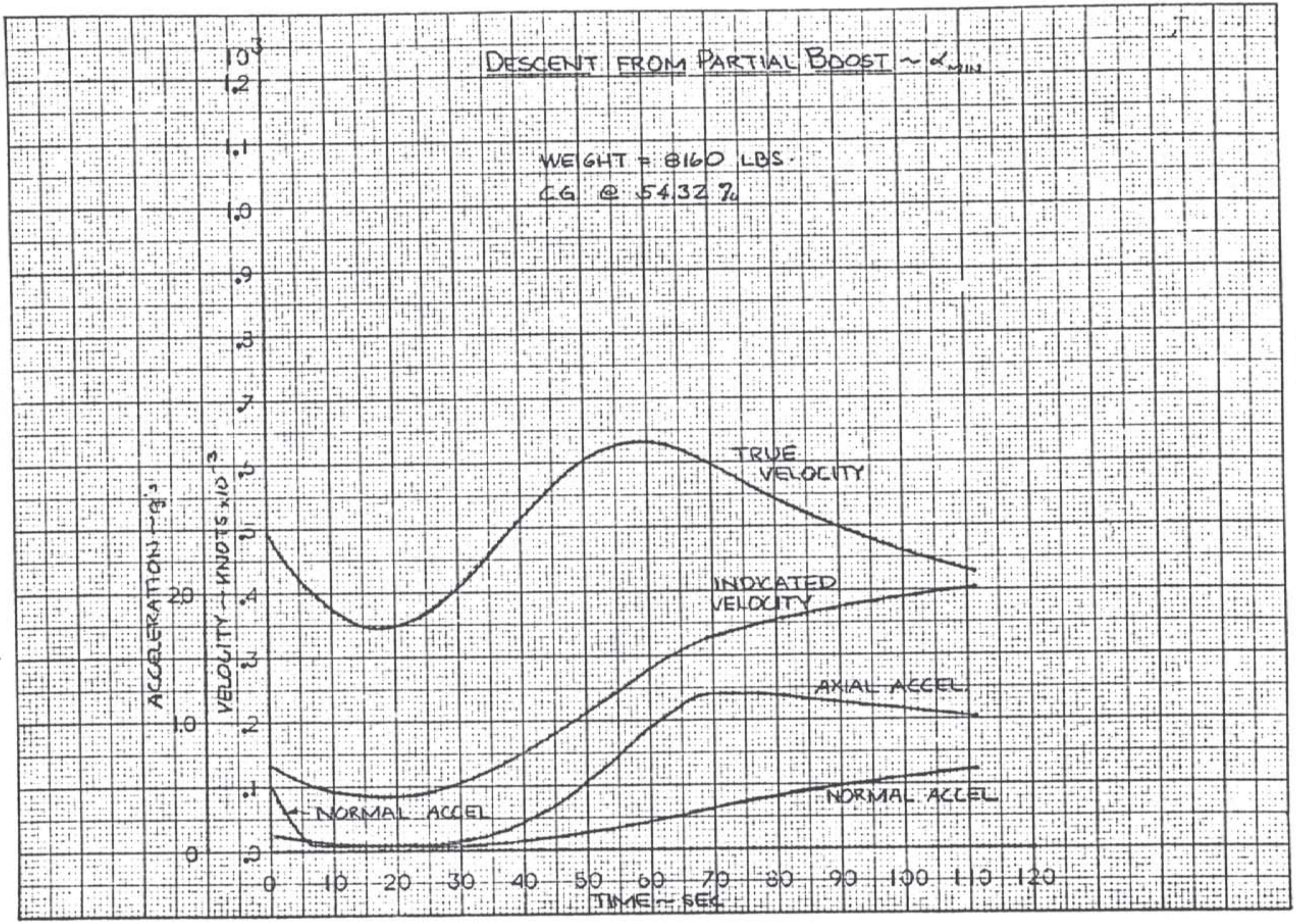


Figure 5-76. Descent From Partial Boost α Min.

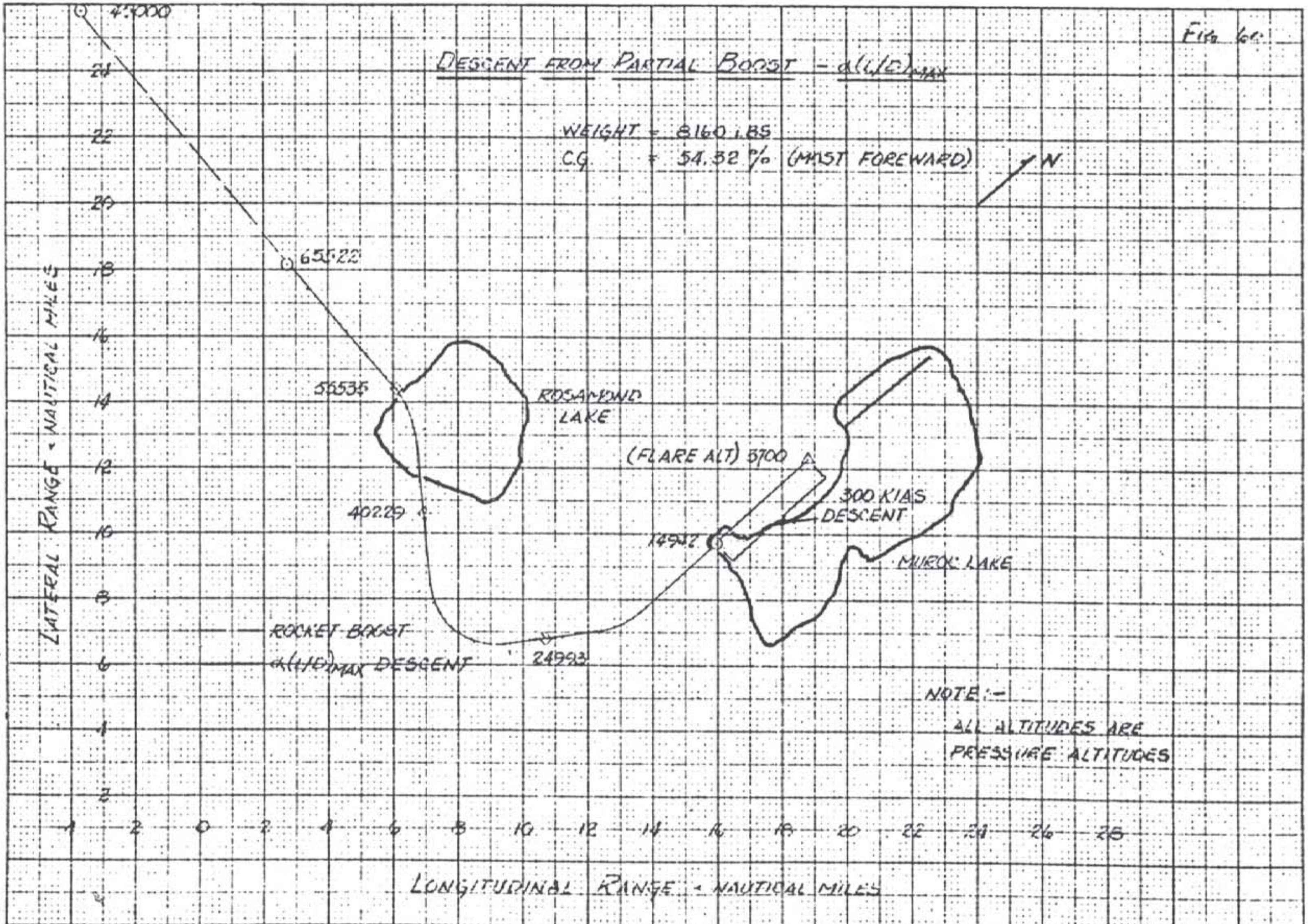


Figure 5-77. Descent From Partial Boost α (L/D) Max.

MACH NUMBER -- TRUE AIRSPEED CONVERSION CHART

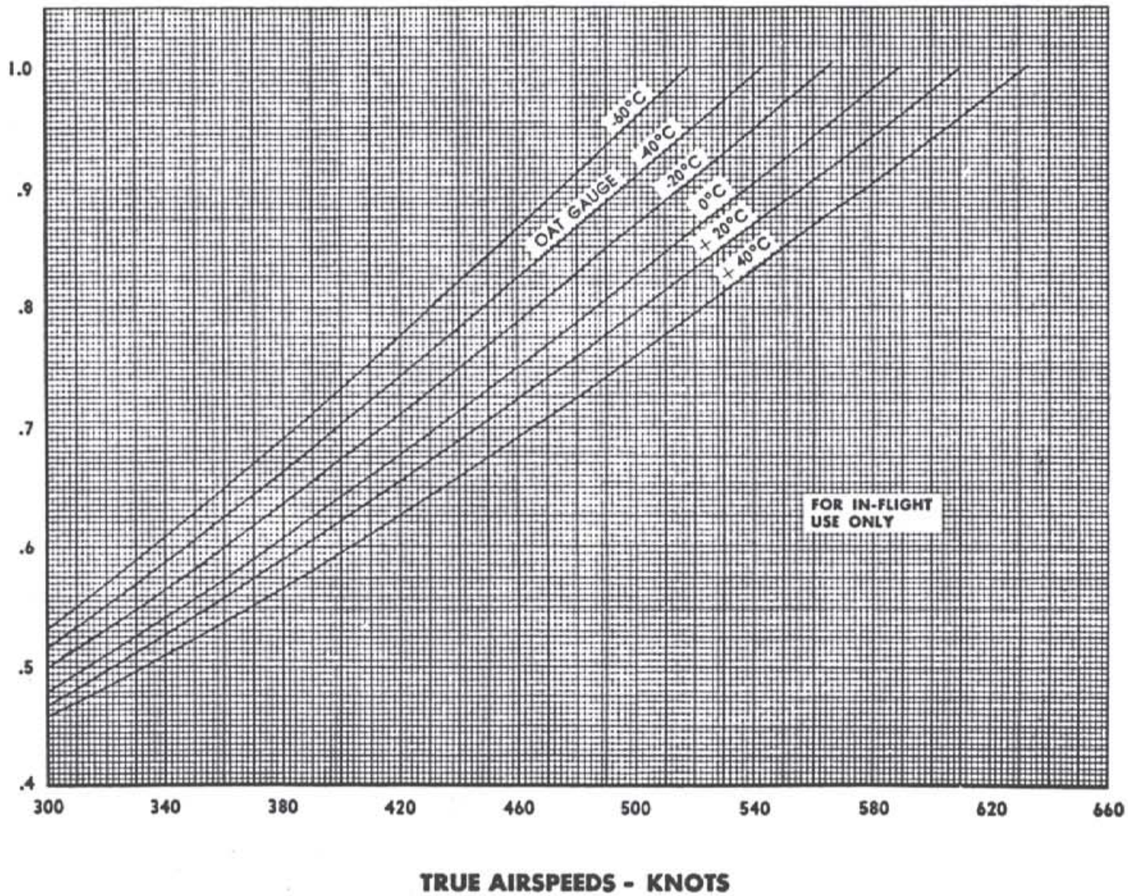


Figure 5-82. Mach Number--True Airspeed Conversion Chart.

MACH NUMBER — TRUE AIRSPEED CONVERSION CHART

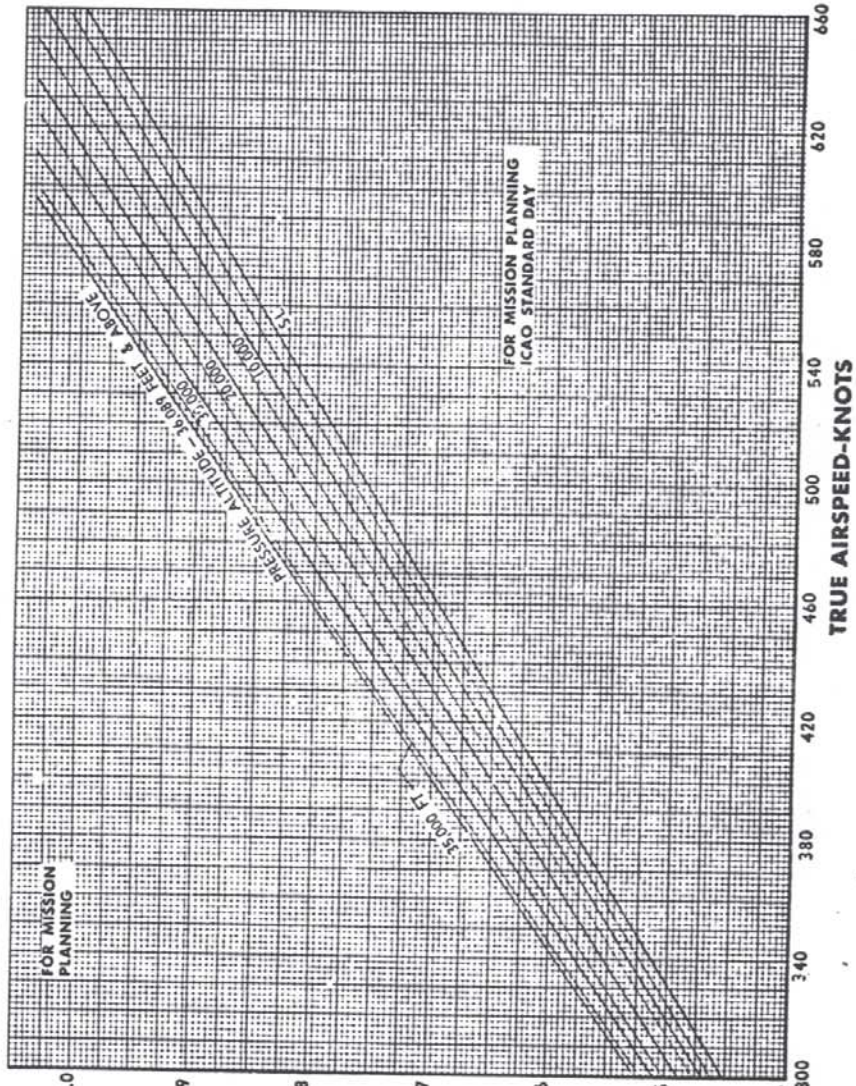


Figure 5-83. Mach Number--True Airspeed Conversion Chart.