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UNCLASSIFIED TITLE Design Considerations for Air Refueling
Receiver Installations with the KC-135A Flying Boom

MODEL KC-135A CONTRACT NO. _____

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**COMMERCIAL
AIRPLANE DIVISION**

THE **BOEING** COMPANY

TRANSPORT DIVISION · P. O. BOX 707 · RENTON, WASHINGTON

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ISSUE NO. _____ ISSUED TO _____

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APPROVED BY [Signature] 11-17-61

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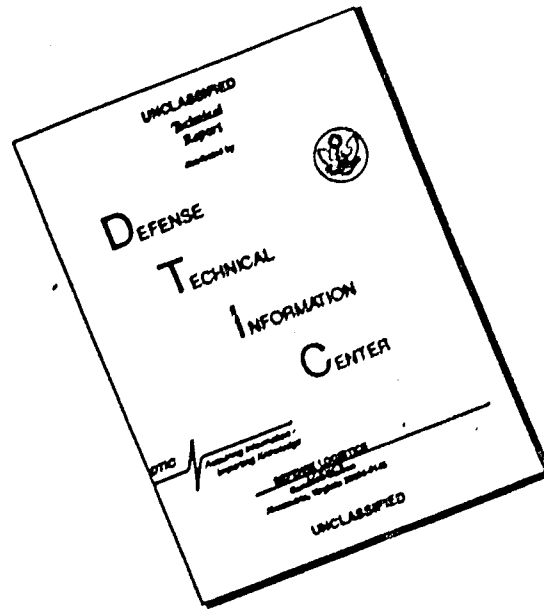
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INTRODUCTION

This document is intended to facilitate the distribution of information and recommendations pertaining to the general requirements for Receiver airplane installations to accomplish air refueling with the KC-135A Flying Boom Tanker.

The information and recommendations in this document represent the current practice of the Boeing Company; however, even though this method of refueling has been used extensively for more than a decade, changes are still being made. Therefore, formatting with new, higher performance aircraft may alter these recommendations.

In the event this document is utilized in the design of Receiver airplane components it is suggested that the Boeing Company be contacted to be sure that the data herein is up to date. It is also suggested that during the layout and design stage of a new installation that such data be forwarded to the Boeing Company for review of the proposed design.

Requests for data or for interchange of design information should be forwarded to:

The Boeing Company
Transport Division
P.O. Box 707
Renton, Washington

Attention: Chief Project Engineer-Military

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REFERENCES

1. T.O. 1C-135(K)A-1
KC-135A Aircraft Flight Manual
2. T.O. 1B-52G-1
B52G Flight Manual
3. The Boeing Company Document D6-5645
System Requirements Electrical Pulse
Aerial Refueling Signal (Boom Type)
4. The Boeing Company drawing 5-40678
Nozzle Assembly Universal
5. The Boeing Company drawing 5-40674
Receptacle Assembly Universal



LIST OF ACTIVE SHEETS

SYM **B**

SECTION	SHEET NUMBER	REV. SYM.	ADDED SHEETS					SECTION	SHEET NUMBER	REV. SYM.	ADDED SHEETS				
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REVISIONS			SYM A
SYM	DESCRIPTION	DATE	APPROVAL
A	Page 7: Dimension 4.4025 4.3775 was 4.2775 4.4125 4.2905 4.3775 4.2675 PRR 9500 Added pages d and e.	1-3-66	BN: J. WINTER CK: W. Young APP: <i>[Signature]</i>
B	PRR 9500 (1) PAGE 16: REVISED MAX & MIN PERFORMANCE LIMIT CURVES TO INCLUDE NOZZLE PRESSURE INFORMATION AT FUEL FLOW RATES BETWEEN ZERO & 300 GPM. (2) ADDED PAGE 32 TO SHOW BOOM ELEVATION HEAD PRESSURES. (3) PAGE 6: ADDED CALLOUT OF FIGURE 1-22. REASON: AIR FORCE REQUEST. OCAMA TASK 68-11-62		DRAWN: W. Young APPROVED: W. Young 10-24-64

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I. AIR REFUELING WITH THE FLYING BOOM

A. Inter-relation of Tanker and Receiver

1. Successful Air Refueling is dependent upon the flight characteristics of both the Tanker and Receiver aircraft while in formation, the functioning of the Tanker De-fueling equipment and the operation of the Receiver Air Refueling equipment. Since these functions are all inter-related, it is necessary that the designer of the Receiver installation be familiar with the Tanker considerations as well as those pertaining to the Receiver.

B. Flying Boom Refueling

1. The Flying Boom consists of a telescoping tubular fuel-tight unit attached universally at its forward end to the underside of the body of the Tanker airplane; with a nozzle on the aft end of the telescoping section for insertion into a suitable reception coupling on the upper surface of the Receiver airplane and two control surfaces (rudder) for maneuvering the nozzle into alignment with the Receiver airplane. The Tanker Receiver relationship during refueling is shown by figure 1-1.

C. Performance Considerations

1. In order to attain and maintain the forming position of the Tanker and Receiver aircraft during air refueling, it is essential that at the speed, altitude, weights and forming positions at which the operation will take place, both aircraft have power reserve and controllability adequate to provide the proper degree of maneuverability, rate of climb and speed control. When forming with a Flying Boom Tanker, the adjustments of speed and position required to maintain the forming position are primarily the responsibility of the Receiver Aircraft, so that it is particularly important that the Receiver have good control at the forming position and speeds, and have no disturbing or unpredictable operating characteristics at those speeds. For example, if the Receiver has automatic wing slots or automatic pitch control which would become operative during forming, provisions should be made for locking out the automatic control with the surface in the most favorable position, to avoid sudden changes in the flight characteristics resulting from automatic operation of the controls. Stability and control of the Receiver about all three axes should be good at forming speeds both in and near the boom envelope to reduce the time required to get into the forming position. Speed control by throttles or speed brakes should be rapid, positive and capable of fine adjustment, to avoid over-run or lag of the Receiver with respect to the Tanker while in contact and to facilitate getting into the forming position.





CALC			REVISED	DATE	TANKER- RECEIVER RELATIONSHIP	
CHECK						
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APPD						PAGE 2
					BOEING AIRPLANE COMPANY RENTON, WASHINGTON	

I. AIR REFUELING WITH THE FLYING BOOM (continued)

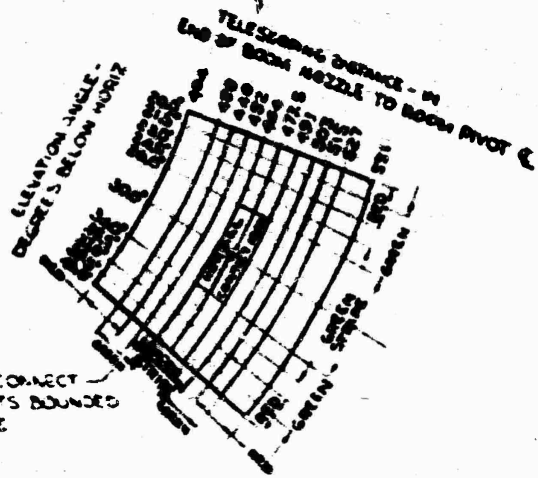
- C. 2. During a normal Air Refueling contact, the Tanker pilot maintains constant airspeed, altitude and heading, which means that as the Receiver takes on fuel, an increasing amount of power is required by the Receiver to stay in the Tanker envelope. Since the Receiver is operating in the downwash of the Tanker, additional thrust is required to stay in formation. These effects are sufficiently great with some Receivers to require the use of afterburner and special techniques such as descent refueling in order to transfer the desired quantity of fuel.

D. Operating Envelope

1. The Flying Boom as installed on the KC-135A Tanker has certain mechanical and disconnect limits which are shown by figure 1-2. The position of the boom in elevation and extension actuates colored lights on a step basis against a white light background which represent the disconnect limits. These lights are located symmetrically on the bottom of the Tanker body (see figure 1-2). These lights serve as a graphic aid to assist the Receiver pilot in maintaining the optimum position within the boom envelope. During contact if the Receiver position relative to the Tanker moves the boom such that an azimuth, elevation or extension limit is exceeded, the Boom is disconnected and an automatic retraction initiated. Automatic disconnect is also initiated whenever the fuel pressure in the Receiver refuel manifold exceeds the pressure switch setting. Voluntary disconnect may be effected at any time by the Boom Operator in the Tanker or by the Receiver Pilot by use of their disconnect switches. The Receiver Pilot may also effect a disconnect at any time by reducing power. The Receiver then drops back and the boom extension limit is exceeded which initiates an automatic disconnect. When not in contact with a Receiver, the Boom Operator has complete control at all times of the telescoping, hoisting and directional movement of the Boom.

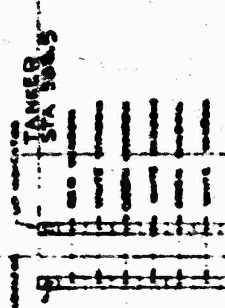
E. Operating Features

1. The Flying Boom has a universal joint for its primary attachment to the Tanker airplane. The Boom Nozzle also has a universal joint and an erection spring at the ball joint. The whole nozzle swivels relative to the telescoping tube at its attach point which in turn is a part of a spring and friction compression shock absorber unit that reduces impact loads upon contact. These features together with the telescoping action of the Boom tube permit the relative displacement of the Receiver to the Tanker vertically, laterally and longitudinally.
2. As mentioned above, release of the Boom nozzle from the reception coupling of the Receiver may be effected in a number of ways. In every case certain mechanisms in the Tanker are operated when the release is initiated by

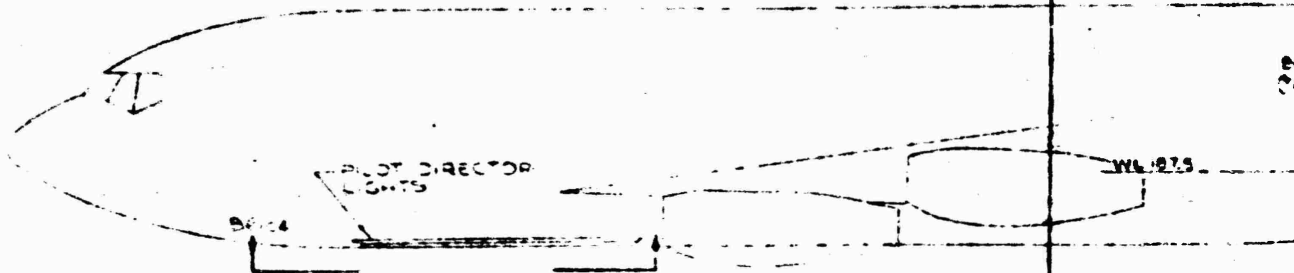


AUTOMATIC DISCONNECT OCCURS AT LIMITS BOUNDED BY HEAVY LINE

BASIC RELATIONSHIP OF LIGHT CONES TO REFUELING DISCONNECT ENVELOPE

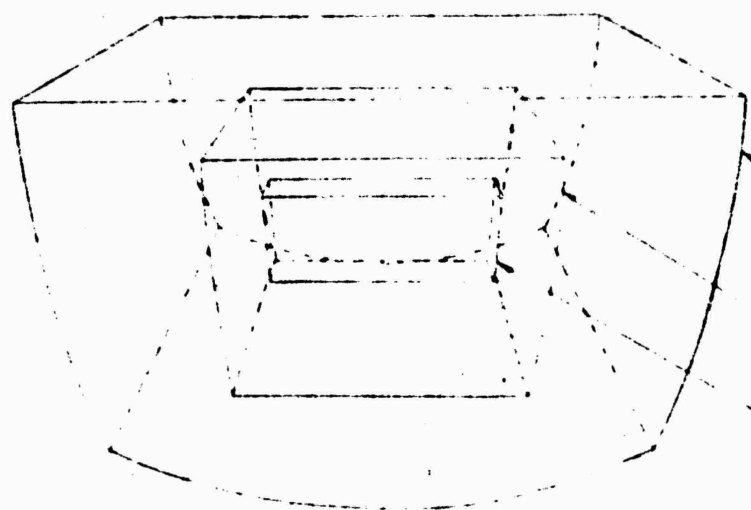


B6



BOOM OPERATOR OF ZERO AZIMUTH UPWARD VISION ANGLES IN ENVELOPE

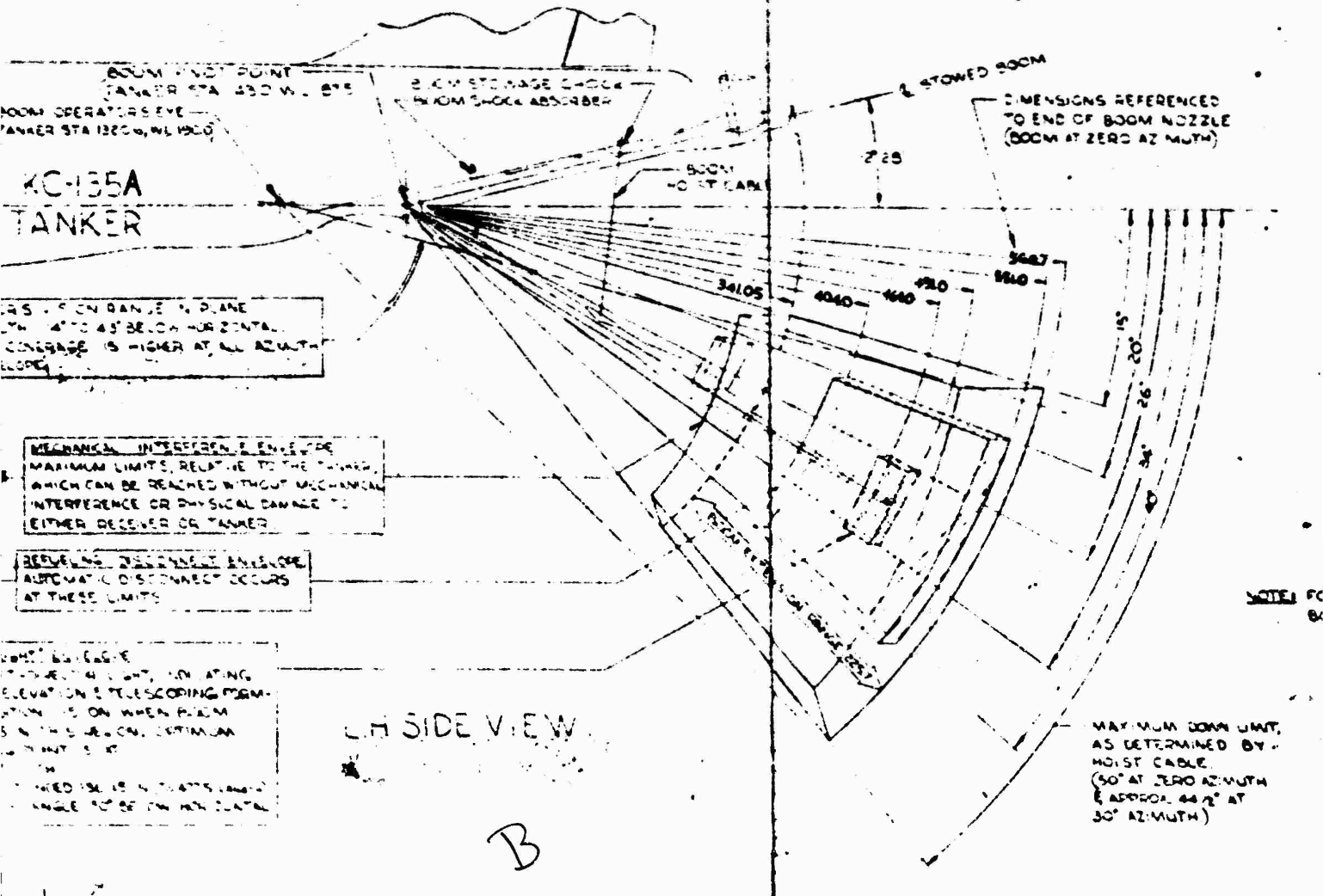
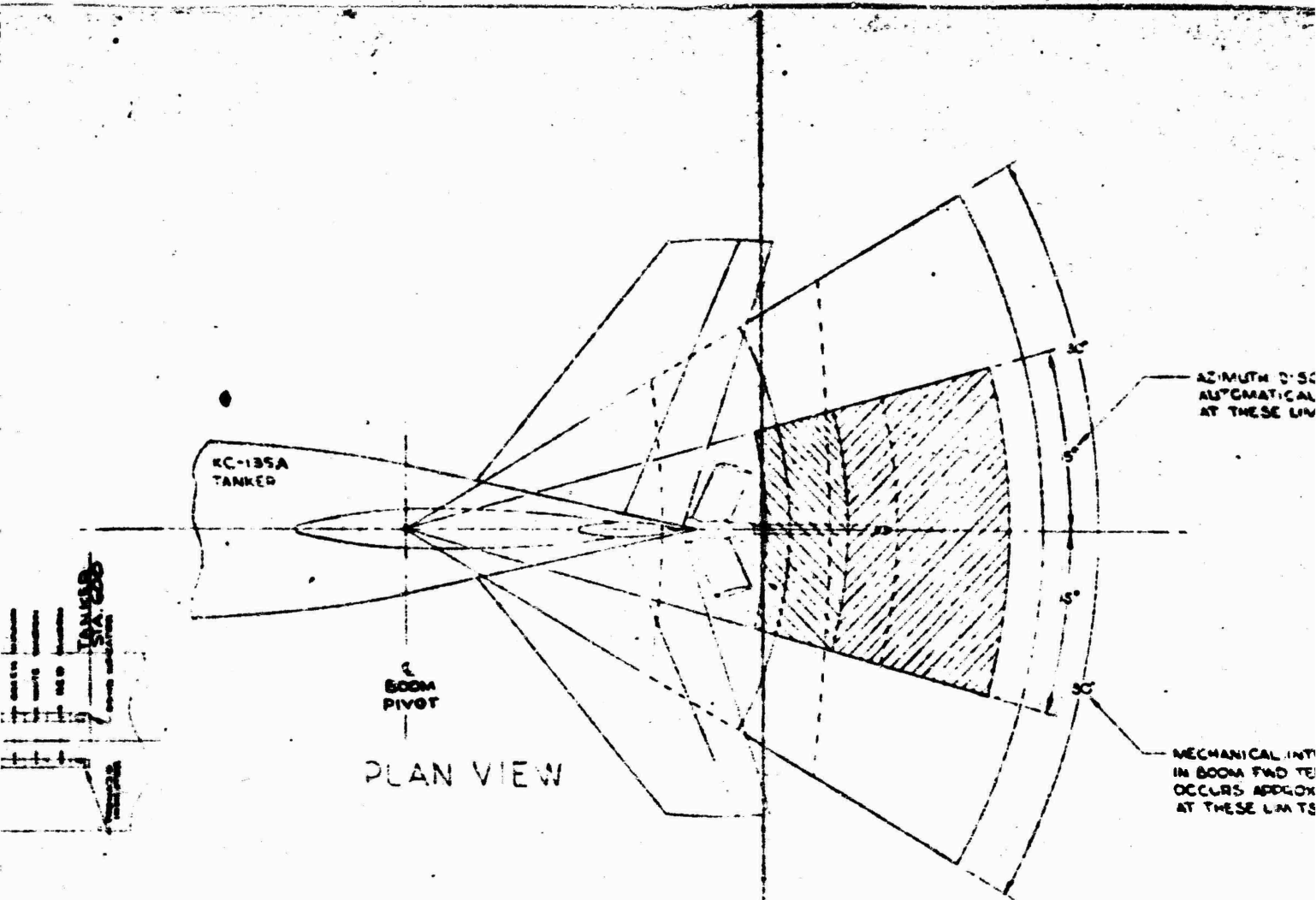
NOT REPRODUCIBLE



A

REAR VIEW

SEEKING LIGHT CONE OF NOZZLE AT AN ANGLE OF 10 DEGREES IS FORMING 250 FT RADIUS BOOM PIVOT ELEVATION



BOOM PIVOT POINT
TANKER STA 1330 W. 875

BOOM OPERATOR'S EYE
TANKER STA 1320 W. 11500

BOOM RANGE IN PLANE
THAT IS 45° BELOW HORIZONTAL
CONVERGENCE IS HIGHER AT ALL AZIMUTH
ANGLES

MECHANICAL INTERFERENCE ENVELOPE FOR
MAXIMUM LIMITS, RELATIVE TO THE TANKER,
WHICH CAN BE REACHED WITHOUT MECHANICAL
INTERFERENCE OR PHYSICAL DAMAGE TO
EITHER RECEIVER OR TANKER

RECEIVING DISCONNECT ENVELOPE
AUTOMATIC DISCONNECT OCCURS
AT THESE LIMITS

BOOM TELESCOPE
ELEVATION & TELESCOPING MECHANISM
IS ON WHEN PIVOT
IS IN THE DOWN POSITION
LIMITS

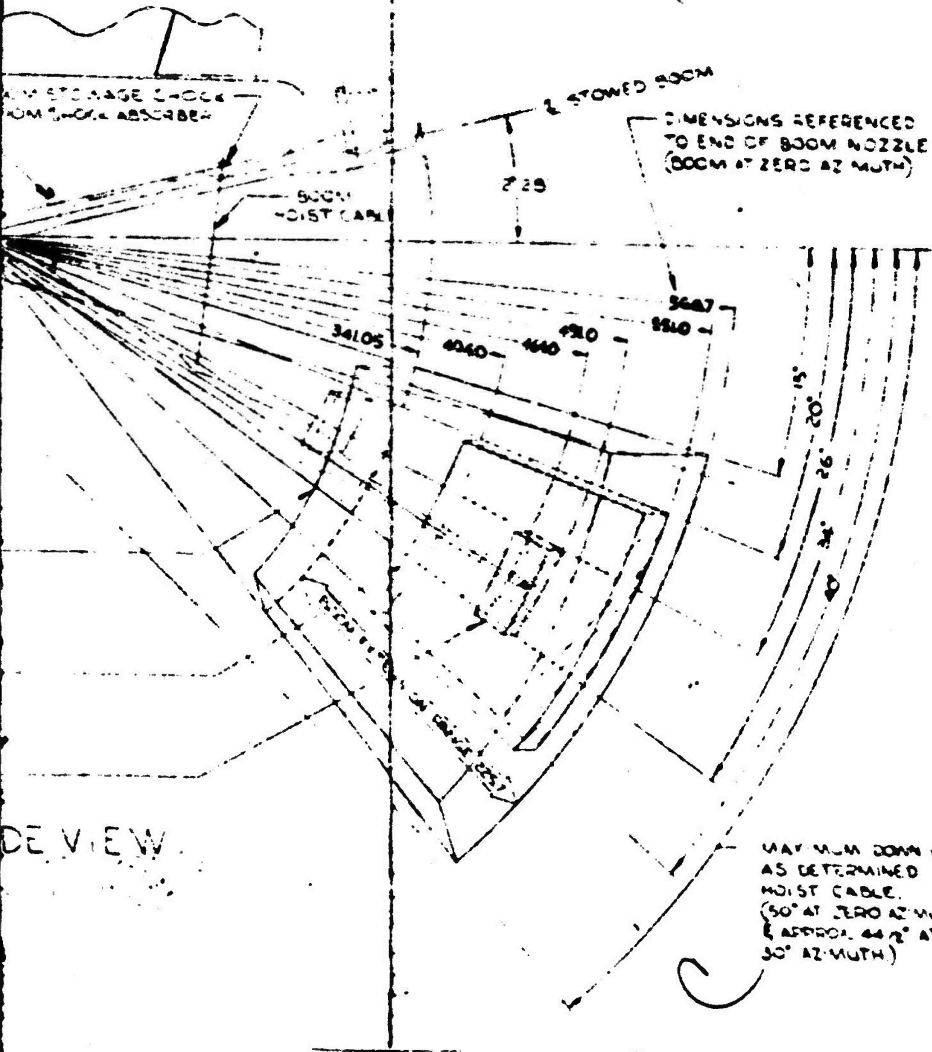
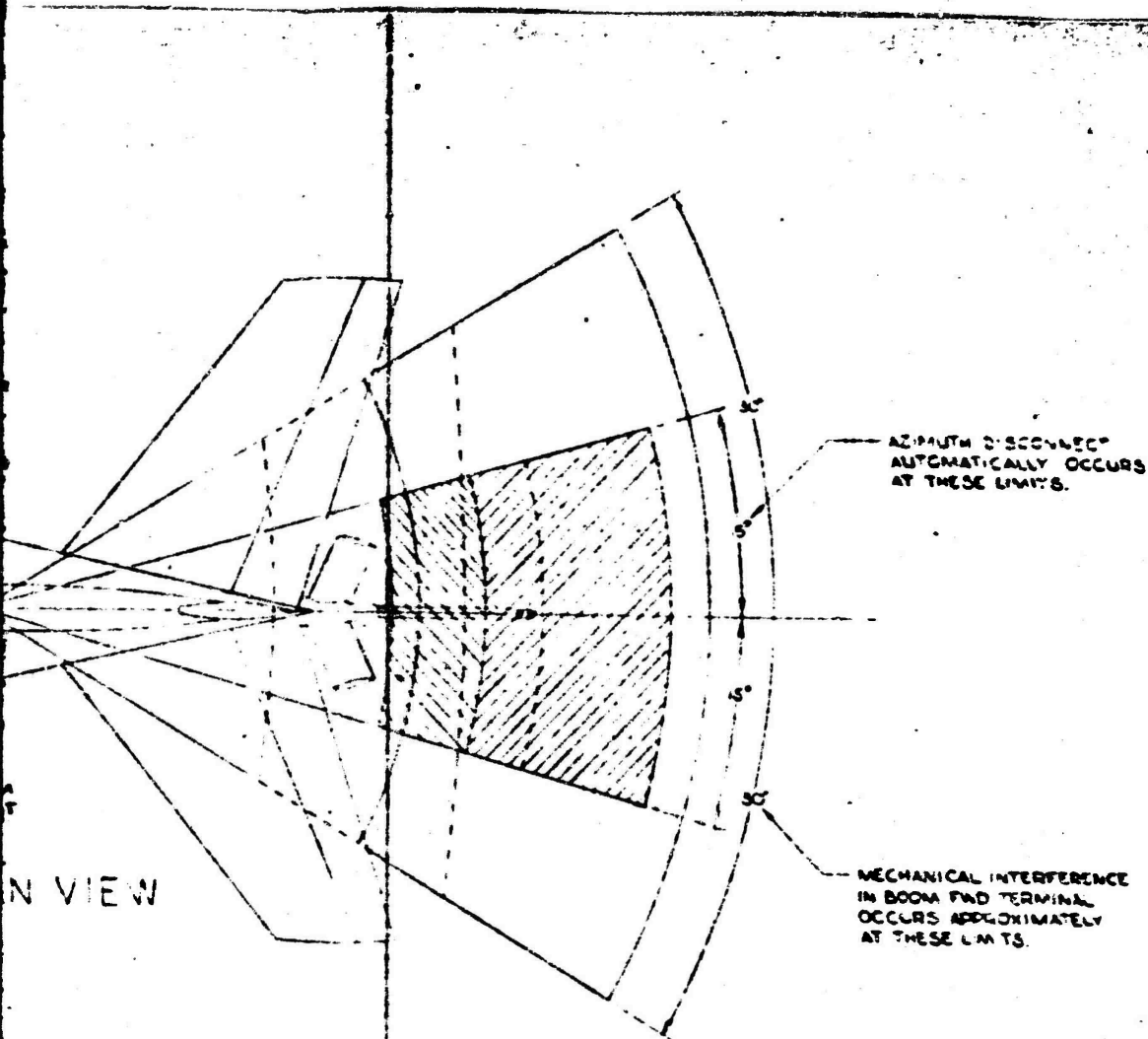
LEFT SIDE VIEW

B

DIMENSIONS REFERENCED
TO END OF BOOM NOZZLE
(BOOM AT ZERO AZIMUTH)

NOTE: FOR
80

MAXIMUM DOWN LIMIT,
AS DETERMINED BY
HOIST CABLE
(50° AT ZERO AZIMUTH
(APPROX. 44° AT
30° AZIMUTH))



NOTE: FOR THIS DIAGRAM AIRPLANE BODY IS ASSUMED TO BE LEVEL

BOOM ENVELOPE

FIGURE 1-2

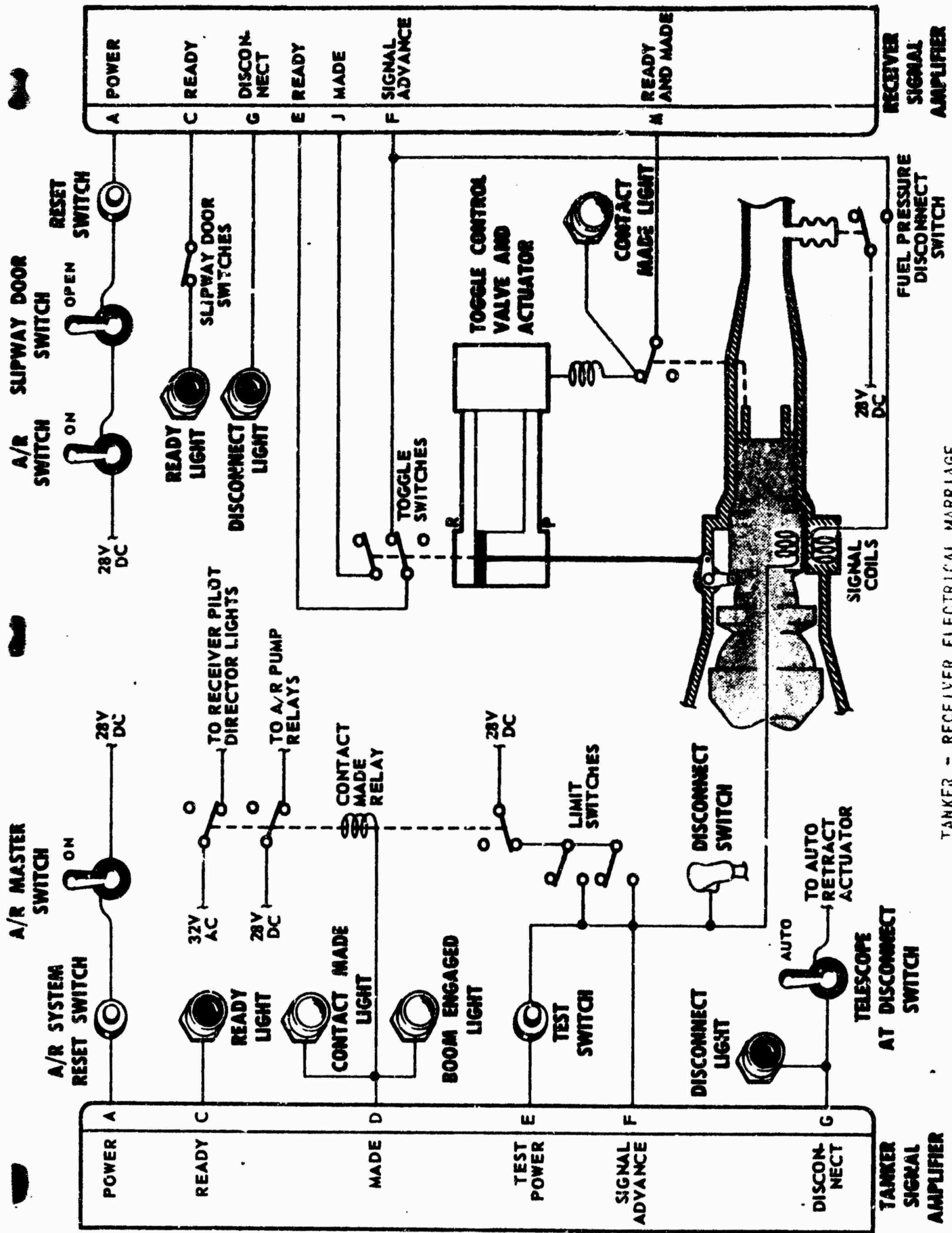
MAXIMUM DOWN LIMIT, AS DETERMINED BY HOIST CABLE, (50° AT ZERO AZIMUTH & APPROX. 44.2° AT 30° AZIMUTH)

I. AIR REFUELING WITH THE FLYING BOOM (continued)

E. 2. (continued)

the Receiver, or conversely, certain mechanisms in the Receiver are operated when the release is initiated by the Tanker. With the Flying Boom Air Refuel System the link which makes this action possible is a pair of induction coils, one in the reception coupler and the other in the nozzle. An electrical impulse in either coil sets up a corresponding impulse in the other coil, which after amplification, controls the actuation of the necessary mechanisms. The design requirements and circuitry for this vital link of the Air Refuel system is described by D6-5645. A typical Tanker Receiver relationship is shown by figure 1-3.

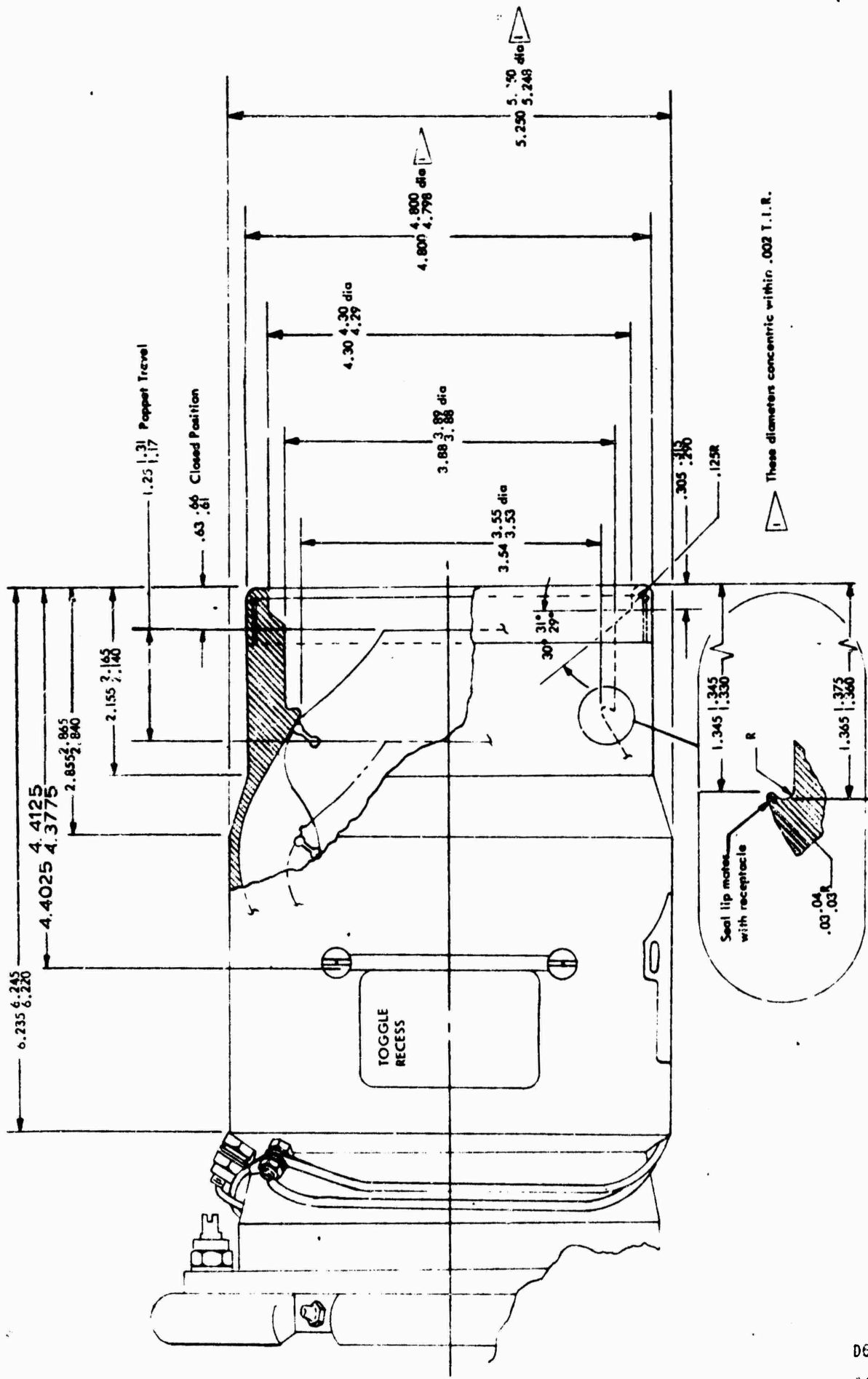
3. Both the Tanker Boom Nozzle and the Receiver Receptacle have an integral shutoff valve. These valves are opened simultaneously by the act of forming. The optimum travel to open the nozzle poppet valve is shown by figure 1-4. At disconnect, both valves are closed by spring force. The Boom nozzle poppet valve, however, is permitted to close rapidly until almost closed where it is snubbed to a slow rate of closure for the balance of travel. This makes the total amount of fuel spillage small and reduces the surge pressure (water hammer) in the tanker fuel system to an acceptable level when the fuel flow rate at the time of disconnect is high.
4. While the Receiver is in contact with the Tanker, the Receiver can extend or telescope the Boom.
 - a. For normal operation, with the Boom telescope control lever in the "Contact" position,
 - (1) the force needed for the Receiver to extend the boom is 1,400 lbs.
 - (2) the force needed to telescope the Boom is 200 lbs.
 - b. Accidental or improper use of the telescope control by the Boom Operator.
 - (1) Telescope control in "Extend" while in contact exerts a 1400 lb. compression force on the Receiver.
 - (2) Telescope control in "Retract" (Receiver latched on and within normal Tanker envelope, with the Receiver closing or stationary relative to the Tanker) the Tanker exerts a tension force of 2000 lbs. on the Receiver.
 - (3) Telescope control in "Retract" (Receiver latched on and within normal Tanker envelope, with the Receiver falling off relative to the Tanker) the Tanker exerts a 2350 lb. tension force on the Receiver.



TANKER - RECEIVER ELECTRICAL MARRIAGE

FIGURE 1-3

A



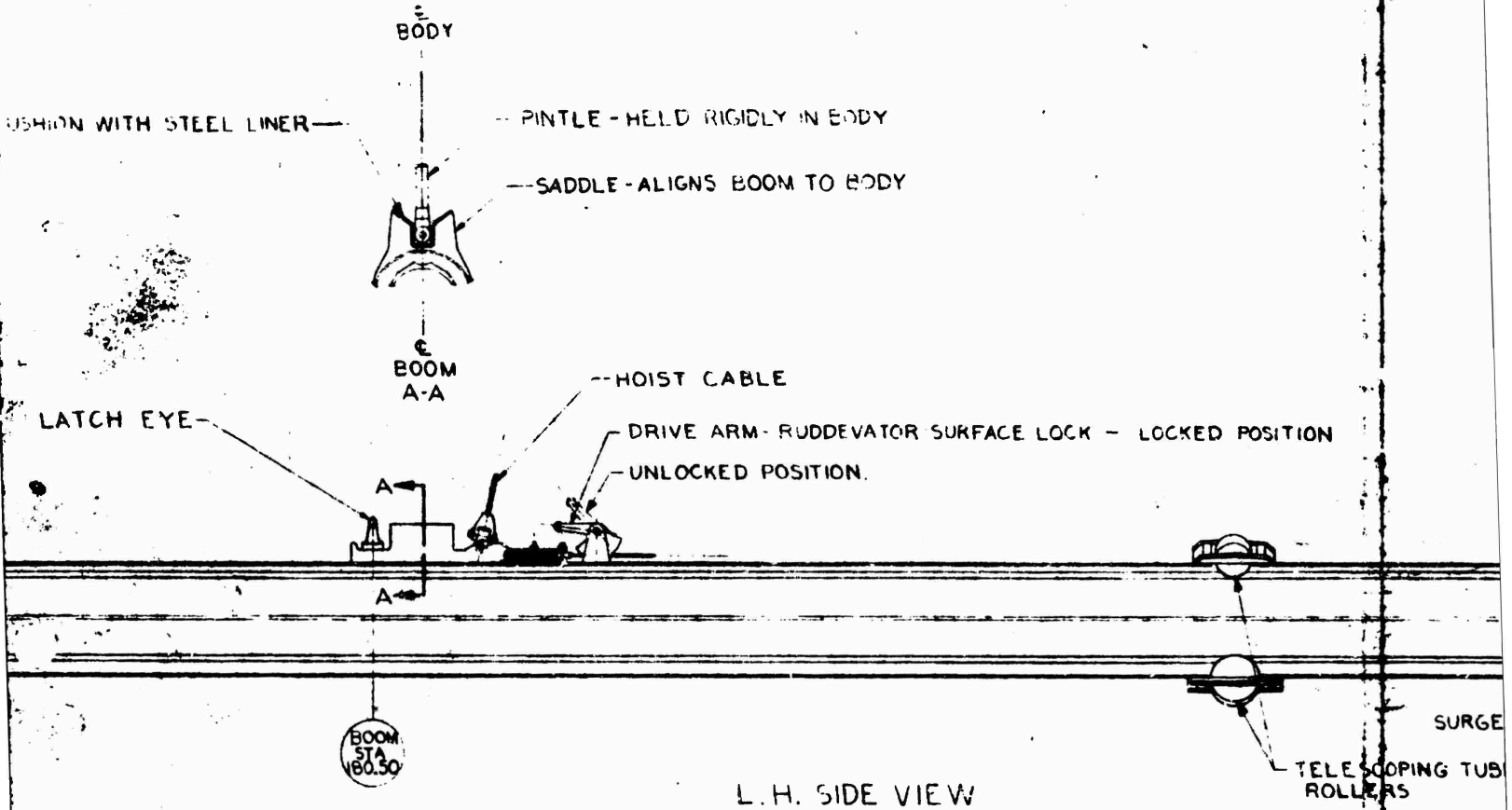
SECTION 1.5 - DIMENSIONS

AIR REFUELING WITH THE FLYING ROOM (continued)

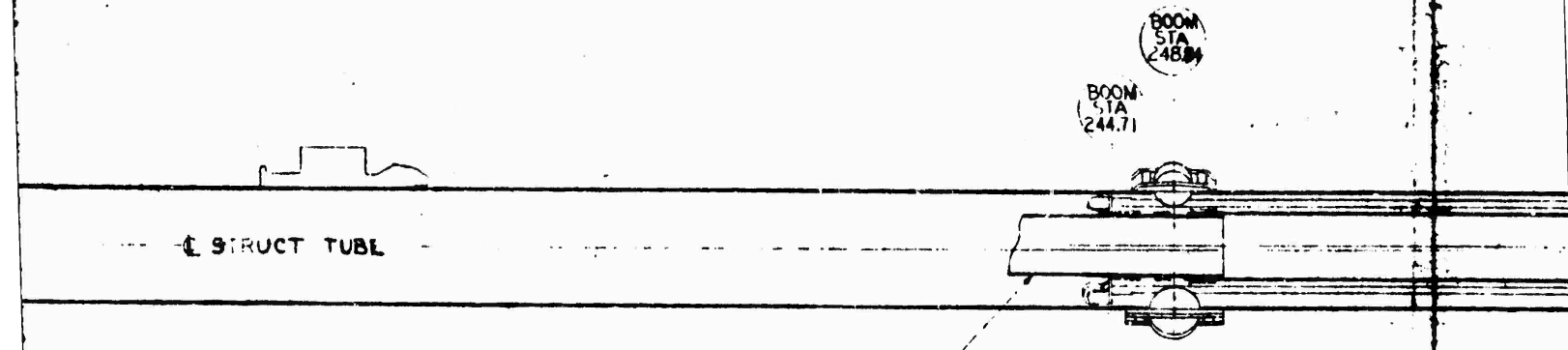
5. The Boom recoil assembly is a coil spring and friction brake unit designed to reduce the impact load on the receiver from a normal contact (see figure 1-5). Since the effect of impact loads on the Receiver structure is also a function of the spring rate of the receptacle installation the following Boom data is listed for use in impact calculations:
- (a) The total weight of the telescoping unit (tube, surge boots, liners, recoil unit, nozzle, fuel, etc.) is 315 pounds.
 - (1) Of this 315 pound total weight, 53 pounds are not affected by the recoil unit.
 - (b) The preload on the recoil spring is 435 ± 44 pounds. The spring rate is 100 pounds per inch. The maximum recoil travel is 2.80 inches.
 - (c) The brake unit exerts a snubbing force of $300 \frac{415}{200}$ pounds. This force is exerted on both compression and extension of the recoil unit.
 - (d) The extension rate of the telescoping tube is limited by means of a hydraulic flow limiter to a maximum of 4 feet per second.
 - (e) The telescoping tube retraction rate is limited hydraulically to a maximum of 10 feet per second. This limit is active both on a manual and automatic retraction.

F. Formating Procedure

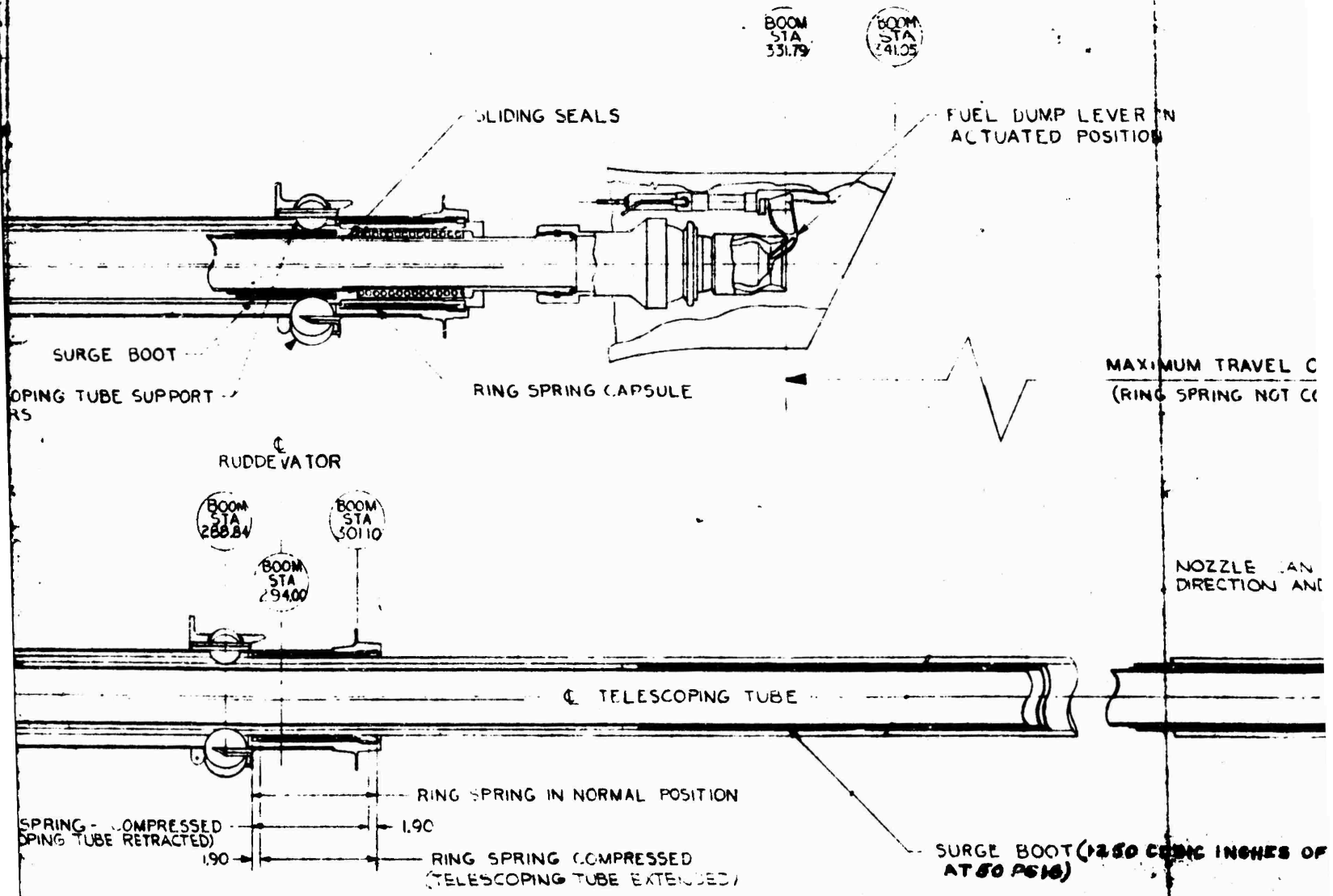
After the Tanker and Receiver have established visual contact through use of rendezvous equipment and the Receiver is approximately one-half mile away the Boom operator lowers the boom to the trail position. Except during Radio silence, the Boom Operator contacts the Receiver and states "Tanker Ready" when the Receiver reaches the observation position. From this point the Boom Operator talks the Receiver into the formating position. When the Receiver is in a good formating position, and stable, the Boom Operator extends the Boom and seats the Boom in the receptacle. The Boom Operator then reports "Tanker Contact". Normally the Tanker fuel panel is set up by the co-pilot so that fuel transfer is started by the signal system upon contact.



L.H. SIDE VIEW
TELESCOPING TUBE RETRACTED
OVERALL LENGTH 28' 5.05"



L.H. SIDE VIEW
BOOM FULLY EXTENDED
OVERALL LENGTH 47' 2.75"
CENTERLINE DIAGRAM

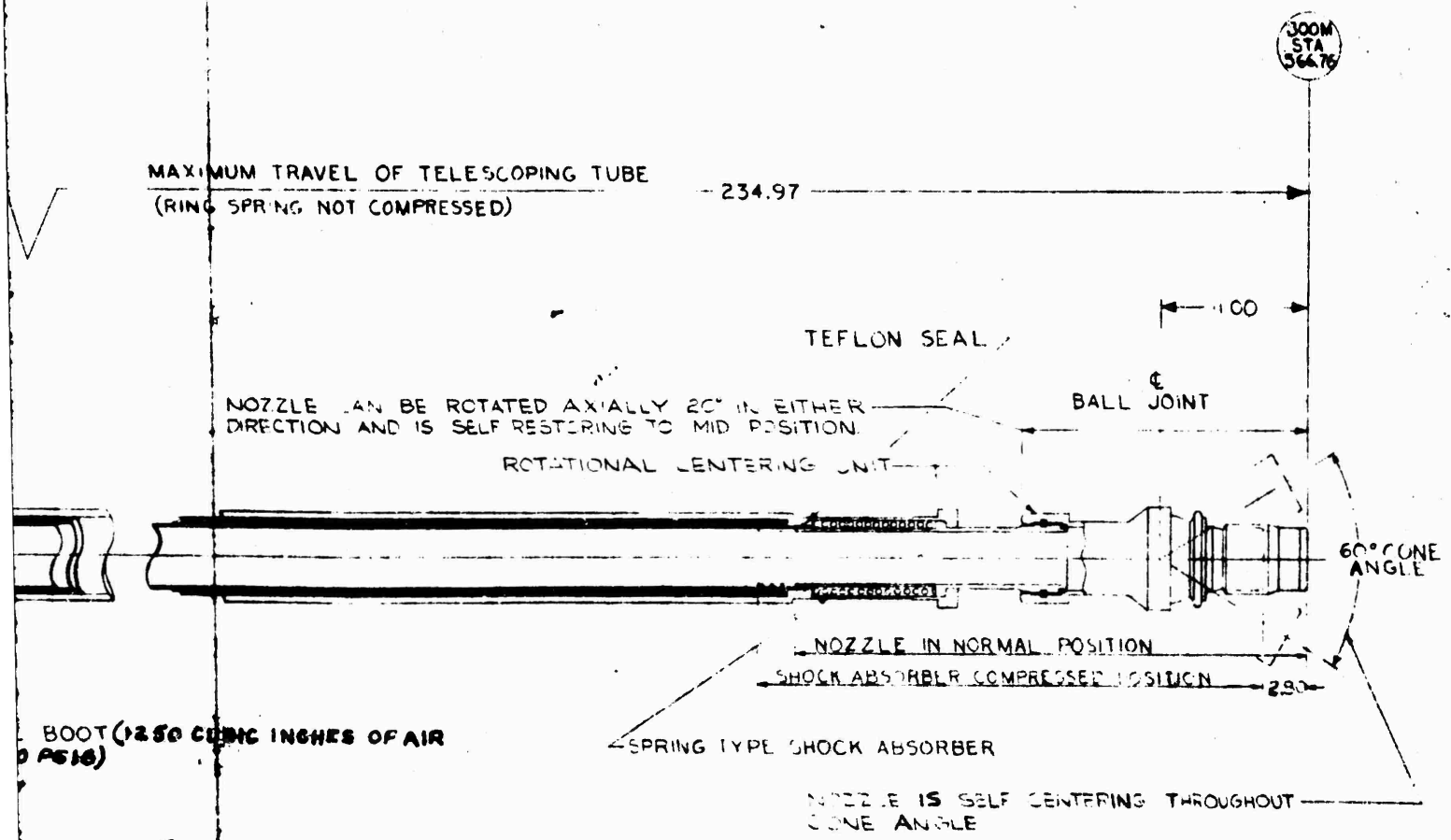


B

BOOM DIMENSIONS

FIGURE 1-5

EL DUMP LEVER IN
TUATED POSITION



II. KC-135A FLYING BOOM TANKER

A. The Airplane

1. The KC-135A is a four engine, swept wing, long range, high altitude, high speed airplane that is primarily a Tanker but may also be used as a cargo carrier or a troop transport. The normal crew consists of a pilot, co-pilot, navigator and Boom operator. As a Tanker, the Boom transfer a major portion of the 175,000 to 195,000 load to other airplanes for refueling in flight. of fuel transferred is a function of type of mission e Tanker is performing. Figure 1-6 shows the effect of on transferable fuel.
2. The KC-135 airplane is equipped with two different Flying Boom configurations. The original configuration designated the Standard Boom limits the airplane speed with the boom down. The latest configuration designated the Hi-Speed Boom has the same speed limits as the airplane in a clean configuration. These limits are shown by figure 1-7. A system schematic for the Boom is shown by figure 1-8.
3. The air refuel fuel system on the KC-135A Tanker consists of 4 hydraulically driven pumps located in the forward and aft body tanks manifolded into the Boom through a pressure regulating valve and a flowmeter. A schematic of the air refuel fuel system is shown by figure 1-9. The entire airplane fuel system is designed and calibrated for JP-4 in accordance with MIL-J-562h. However, alternate fuels can be used for both air refueling other aircraft and by the Tanker. When these alternate fuels are used by the Tanker certain compromises on performance and limitations result. A tabulation of alternate fuels and their limits on the Tanker is shown by figure 1-10.
4. The rate of fuel transfer is controlled by the operation of one, two, three or four refueling pumps plus the effect of the fuel pressure regulator in the Tanker. With this method of control the pressure loss from the Receiver for any flow condition plays an important part in the total flow rate. A plot of pressure vs flow rate is shown by figure 1-11.
5. A set of Receiver pilot director lights is located symmetrically on the bottom of the Tanker (see figure 1-2). These lights assist the Receiver pilot in main aining a nominal forming position. They are most effecti for Receivers having a receptacle located aft of the pilot's line of vision. The Boom telescoping tube is color banded for those Receivers having the receptacle in front of the pilot. For night refueling the pilot director lights and floodlights which silhouette the Tanker are used. These lights are shown by figure 1-12.

**FUEL TRANSFER CAPABILITIES
BUDDY MISSION**

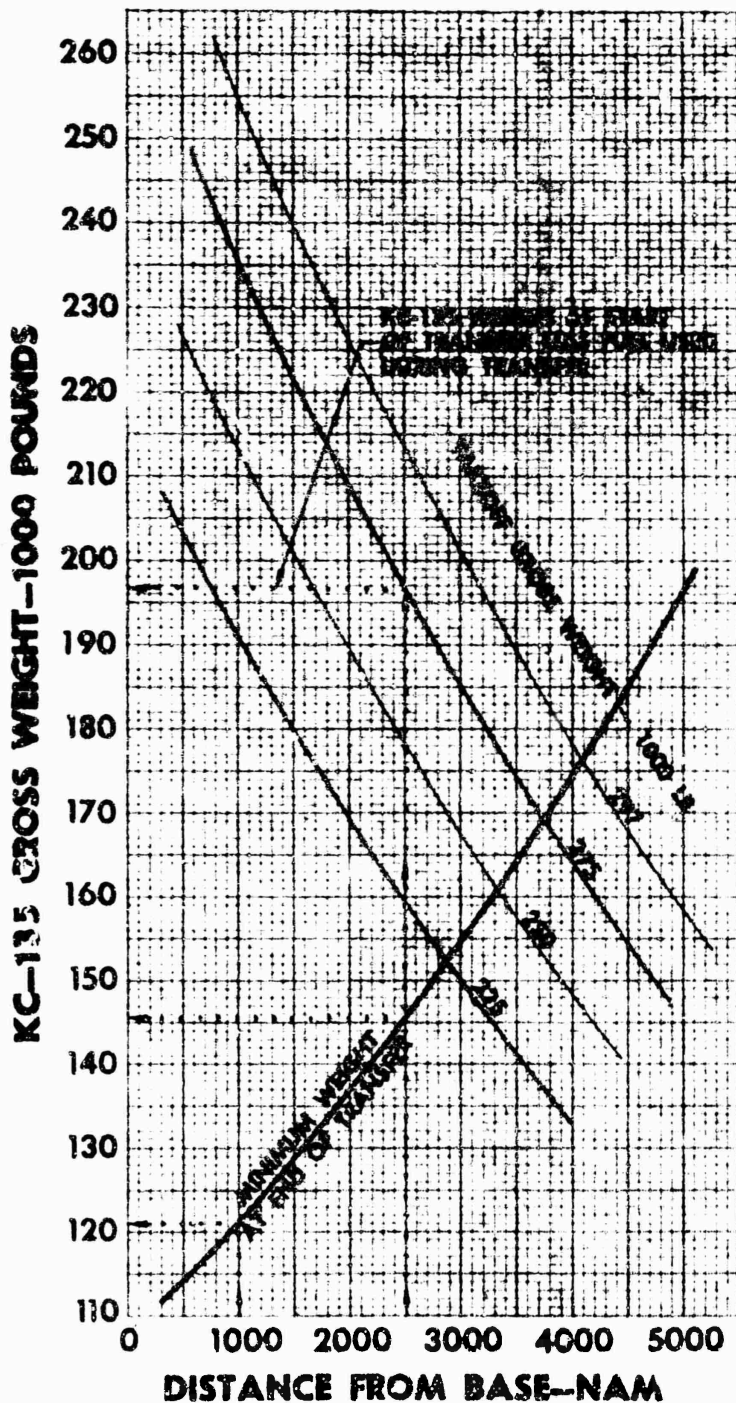
AIRPLANE
KC-135A

ENGINES
J57-F-89W

DATE: MARCH 1958

DATA BASIS: FLIGHT TEST

NOTE
THIS PLOT TO BE USED ONLY
FOR PRELIMINARY ESTIMATING
IN MISSION PLANNING



CONDITIONS:

MRT CLIMB

10 MINUTE RENDEZVOUS AT END OF INITIAL CLIMB

99% MAXIMUM RANGE CRUISE

REFUELING ACCOMPLISHED BETWEEN 25,000 AND 35,000 FT ALTITUDES AT 900 GPM

NORMAL DESCENTS

LANDING WEIGHT = 107,000 LB

ALL FUEL CONSUMPTION INCREASED 9% FOR SERVICE TOLERANCE

REFUELING ACCOMPLISHED AT 450 TAS OR 800M PLACARD WHICHEVER IS LOWER

ICAO STANDARD DAY

BUDDY MISSION

EXAMPLE:

GIVEN:

Takeoff weight = 275,000 LB

Rendezvous at end of tanker initial climb

Complete refueling 2500 NAM from base

FIND:

1a. Minimum Gross Weight at end of refueling to allow return 2500 NAM to base

b. Transferable fuel

2a. Minimum Gross Weight at end of refueling to allow tanker to proceed 1000 NAM to alternate

b. Transferable fuel

SOLUTION:

1a. At 2500 NAM minimum Gross Weight = 145,200 LB

b. Gross Weight less fuel used during transfer = 196,800 LB Transfer fuel 196,800 - 145,200 = 51,600 LB

2a. At 1000 NAM minimum Gross Weight = 121,000 LB

b. At 2500 NAM, Gross Weight less fuel used during transfer = 196,800 LB Transfer fuel 196,800 - 121,000 = 75,800 LB

FIGURE 1-5

06-7941

MAXIMUM SPEED
KC-135A
LEVEL FLIGHT BOOM DOWN
4 ENGINES NRT

AIRPLANE KC-135A ENGINES J57-P-59W

DATE: MARCH 1958
 DATA BASIS: FLIGHT TEST

CONDITIONS:

BOOM IN TRAIL
 4 ENGINES AT
 NORMAL RATED THRUST
 ICAO STANDARD DAY

KC-135A TANKER

NOTE
 REFER TO TEXT FOR EXPLANATION
 OF BOOM PLACARD SPEEDS.

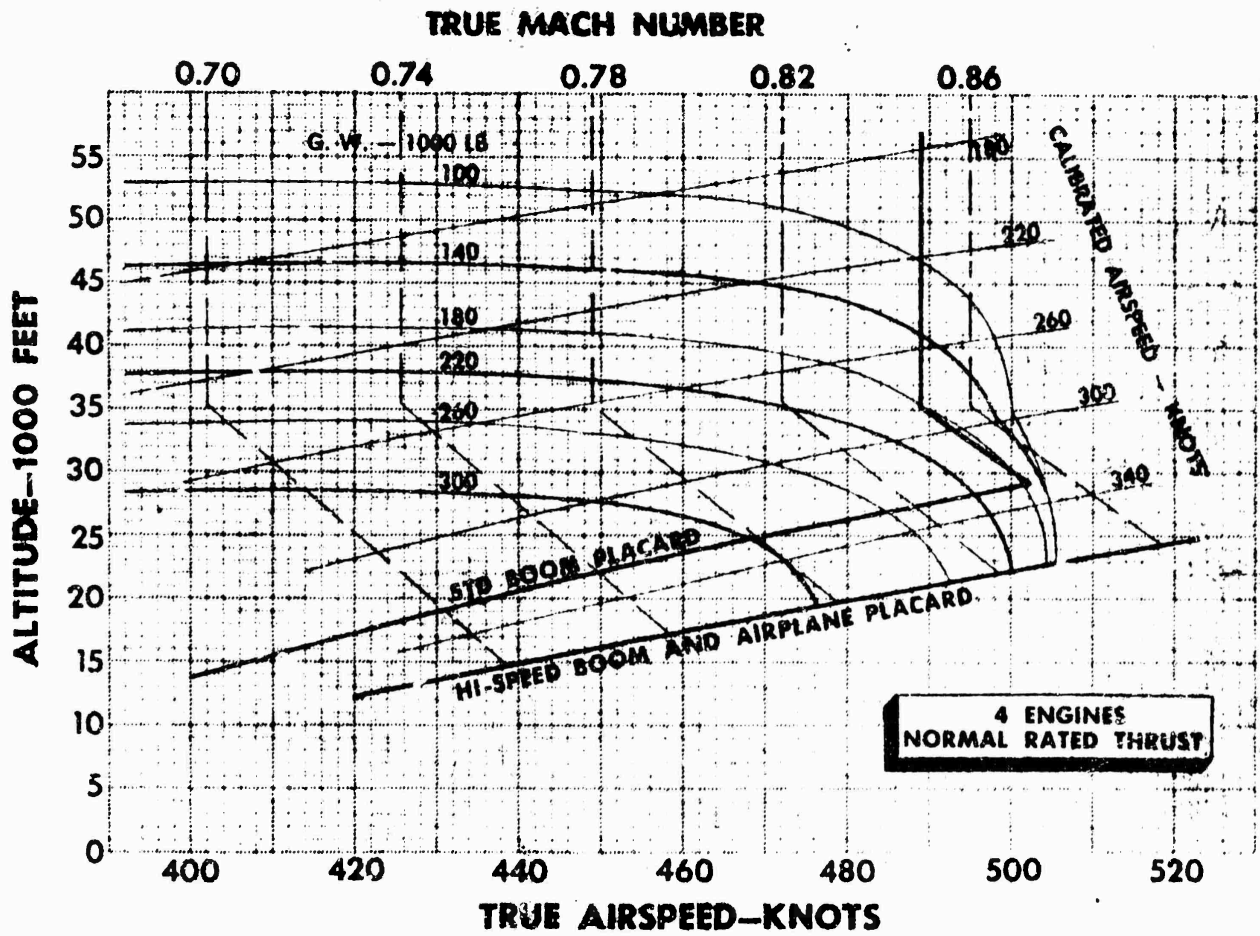
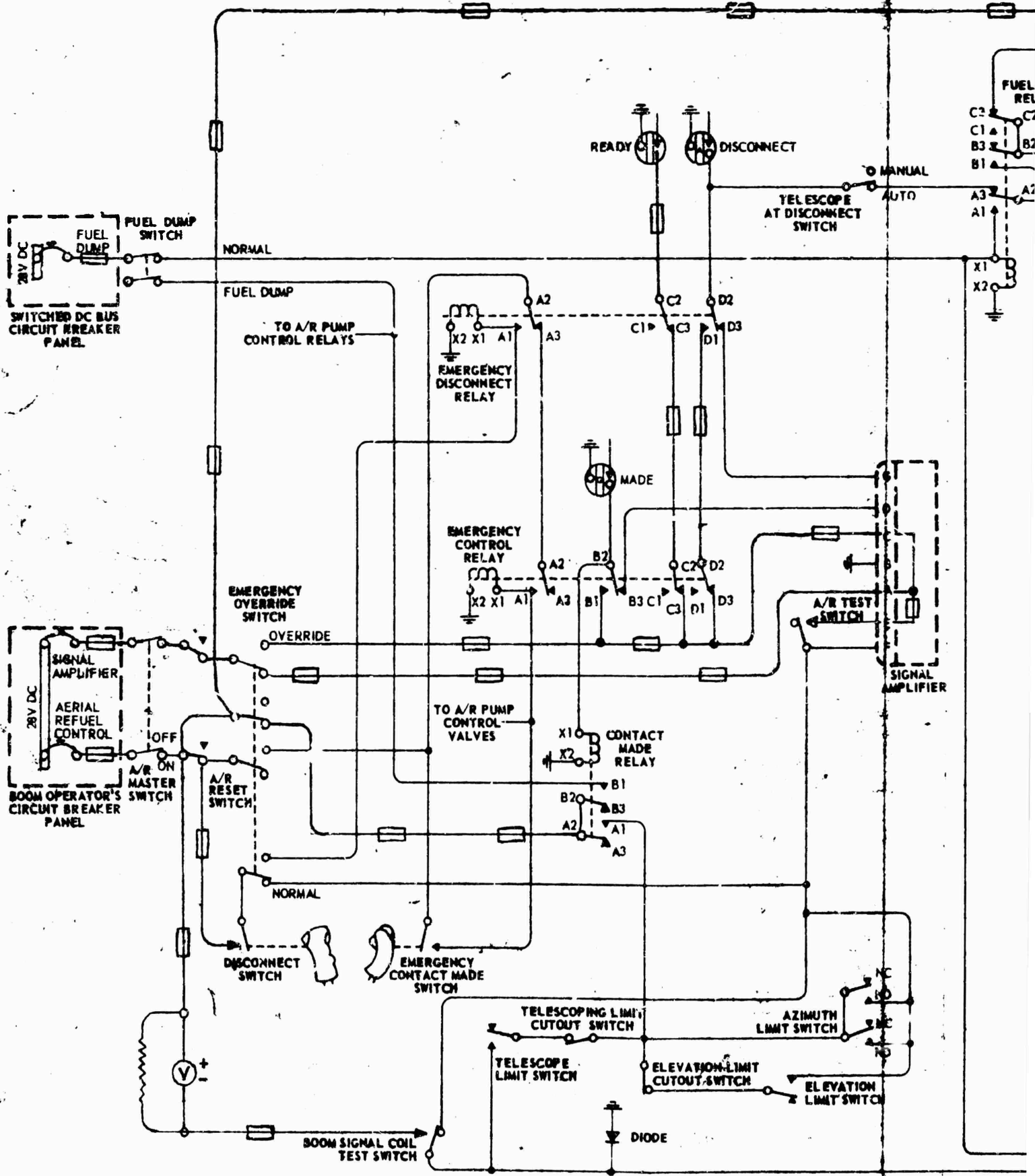
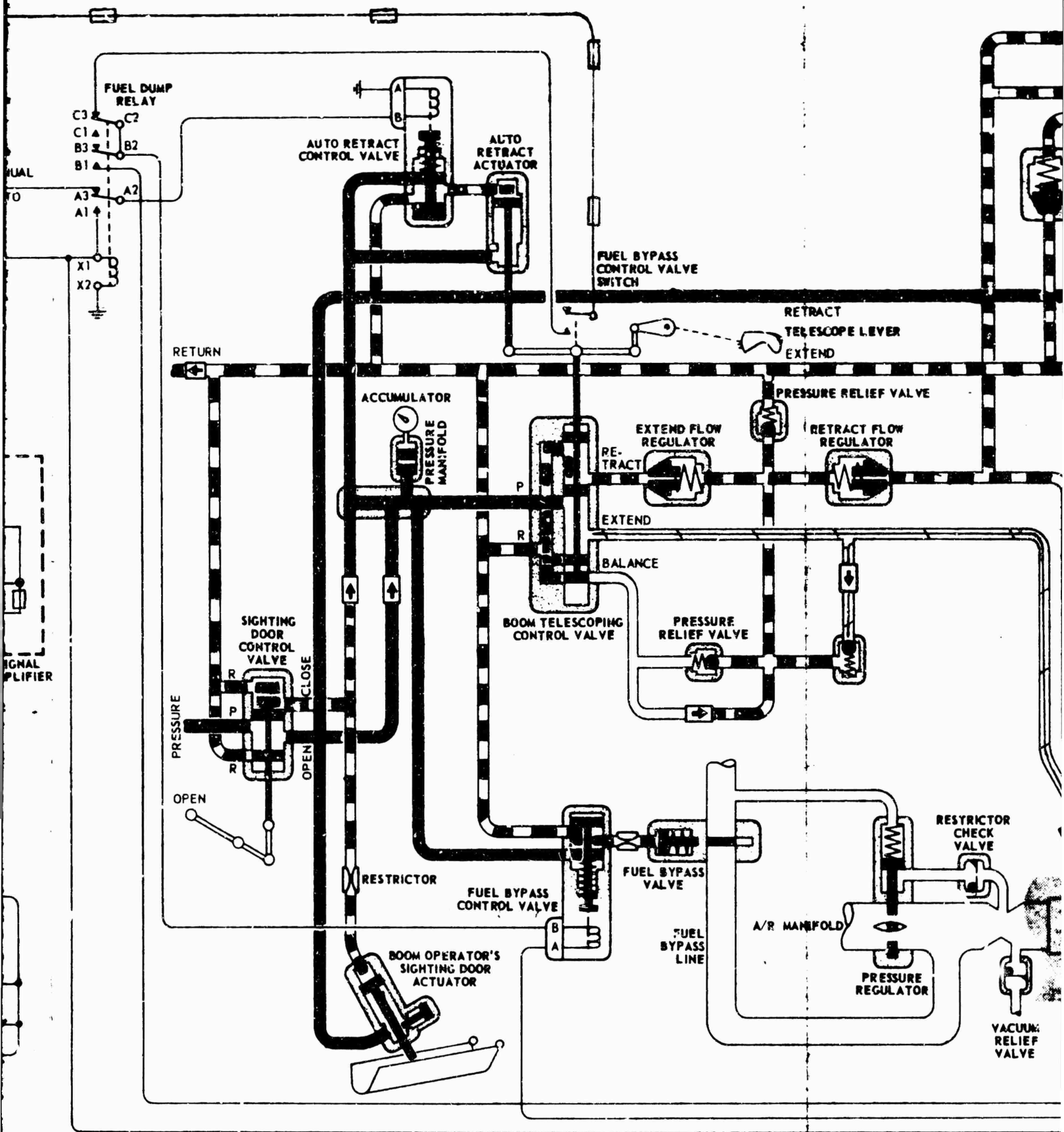


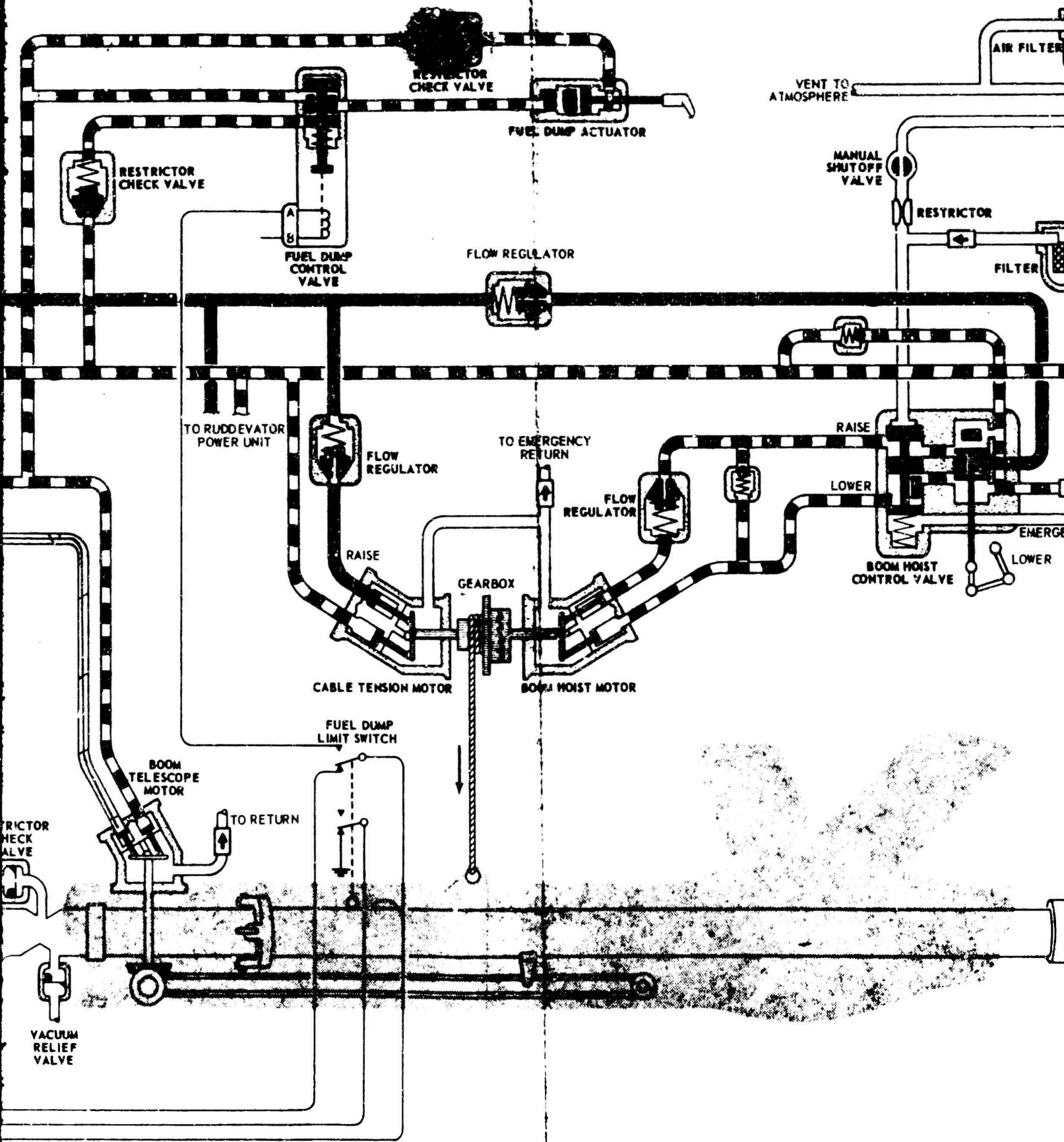
FIGURE 1-7

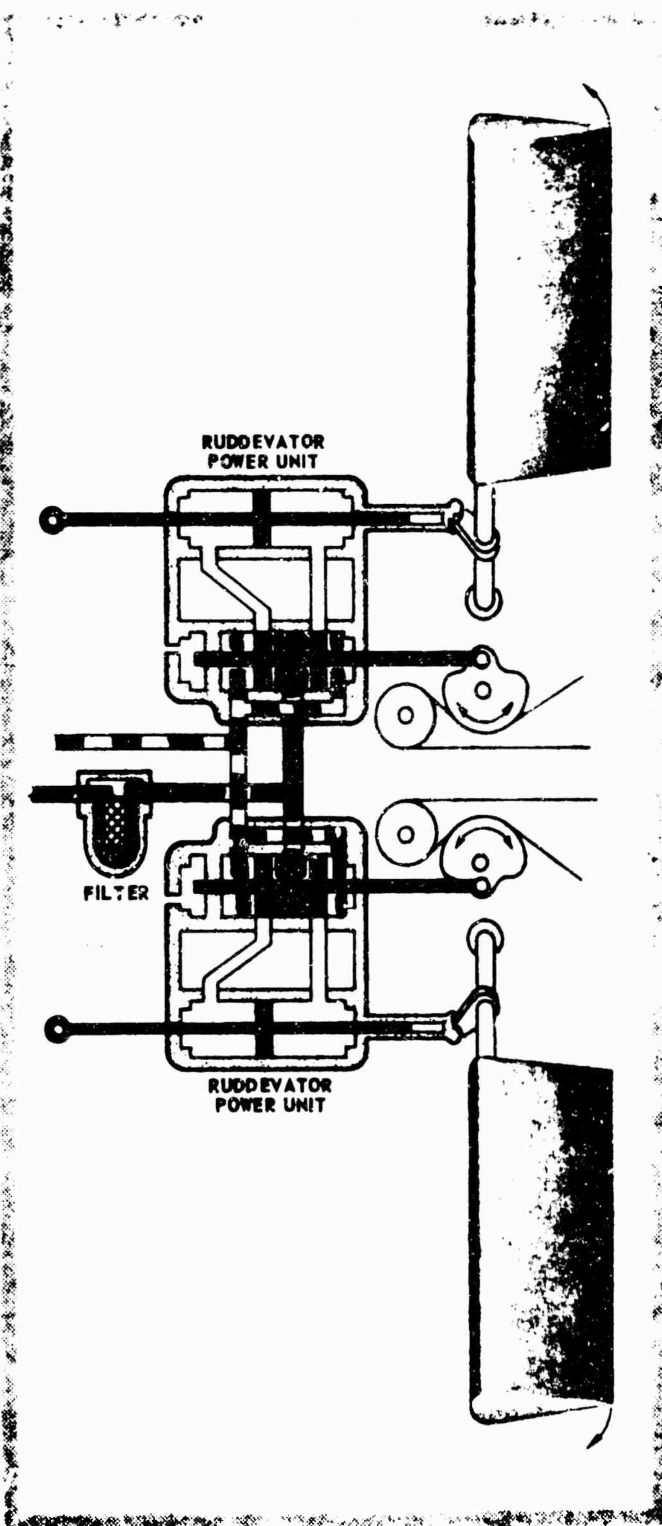
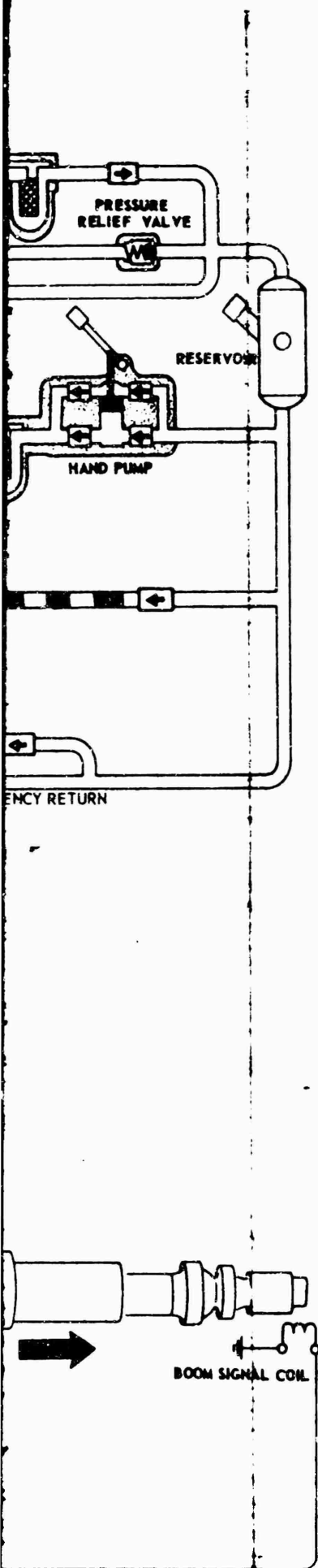


A



B





CONDITION:
SIGHTING DOOR OPEN
BOOM LOWERING AND EXTENDING
READY

- BOOM SYSTEM PRESSURE
- RETURN PRESSURE
- BOOM EXTEND PRESSURE
- 24V DC CIRCUIT ENERGIZED

SIGHTING DOOR RETURN

BOOM LOWER RETURN

BOOM RETRACT RETURN

BY ELECTRICITY ENERGIZED

AIRPLANE INCORPORATED WITH
U.S. PATENT 2,800,000

BOOM SYSTEM (continued)

FIGURE 1

D

AIR REFUELING FUEL SYSTEM

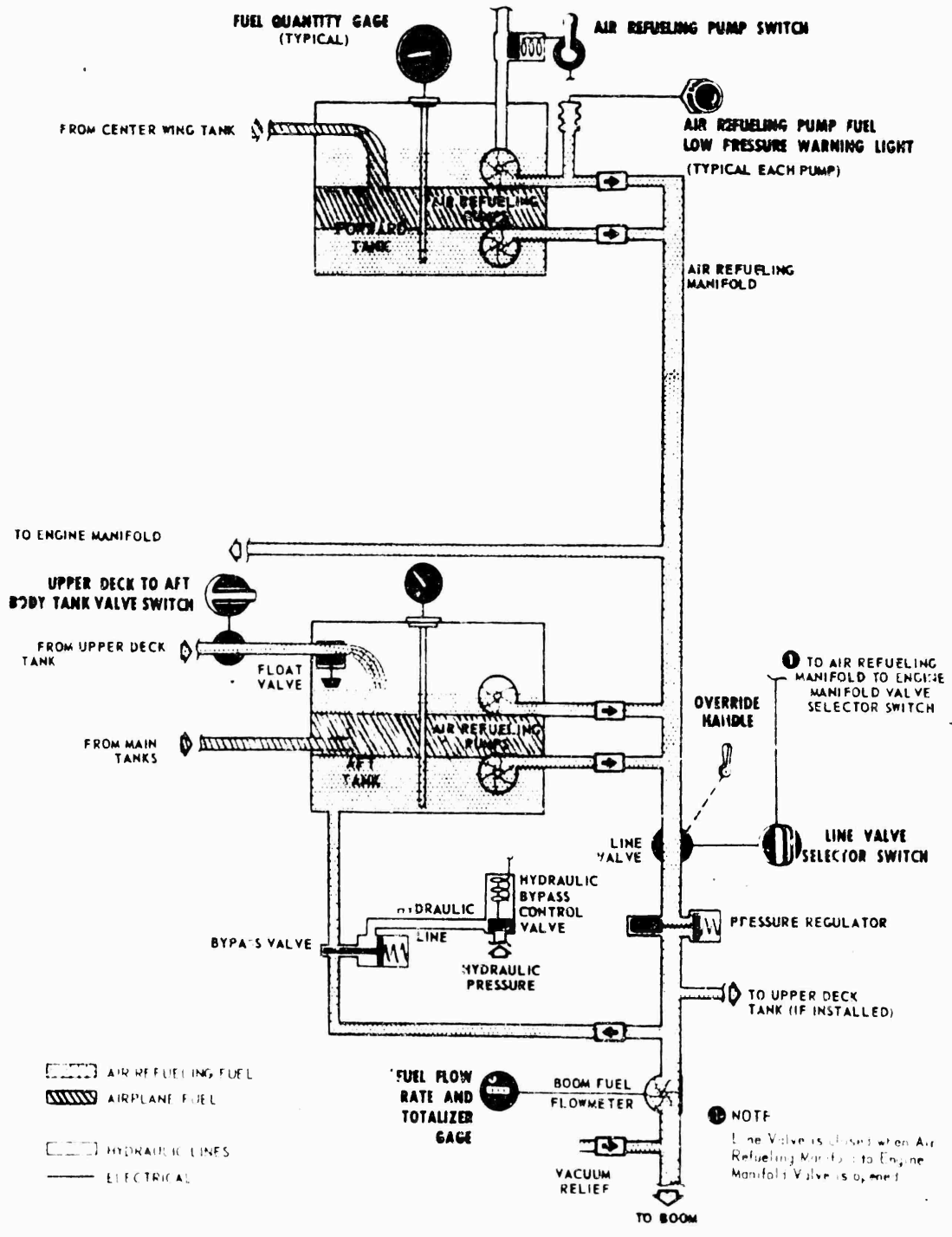


FIGURE 1-9

ALTERNATE FUEL GRADE PROPERTIES AND LIMITS

FUEL TYPE	GASOLINE			AVIATION GASOLINE			KEROSENE TYPE				
	JP 3	MIL-J-5624D	NONE	MIL-G-5572	MIL-J-5624D	F-12, F-15 F-18, F-22	JP-5	JP-6	BRITISH	BRITISH	COMMERICAL
GRADE											
SPECIFICATION											
NATO SYMBOL											
SPECIFIC GRAVITY											
Maximum at 60 °F	.780			.730	.845	.840	.825	.850			.82 (AVG)
Minimum at 60 °F	.739			.680	.788	.780	.795	.780			
FREEZING POINT °F	-76			-76	-55	-65	-40	-40			-40 TO -62
LIMITS (Listed Below)	A D			A D	B D	B D	B D	B D			C D

- A. Follow Climb Restrictions.
- B. Avoid flying at altitudes where indicated OAT is below fuel freeze point.
- C. Prior to using commercial fuel, obtain freeze-point property from vendor or airline supplying the fuel then follow Limit "B" above.
- D. Do not attempt takeoff with inoperative boost pumps.

FIGURE 1-10

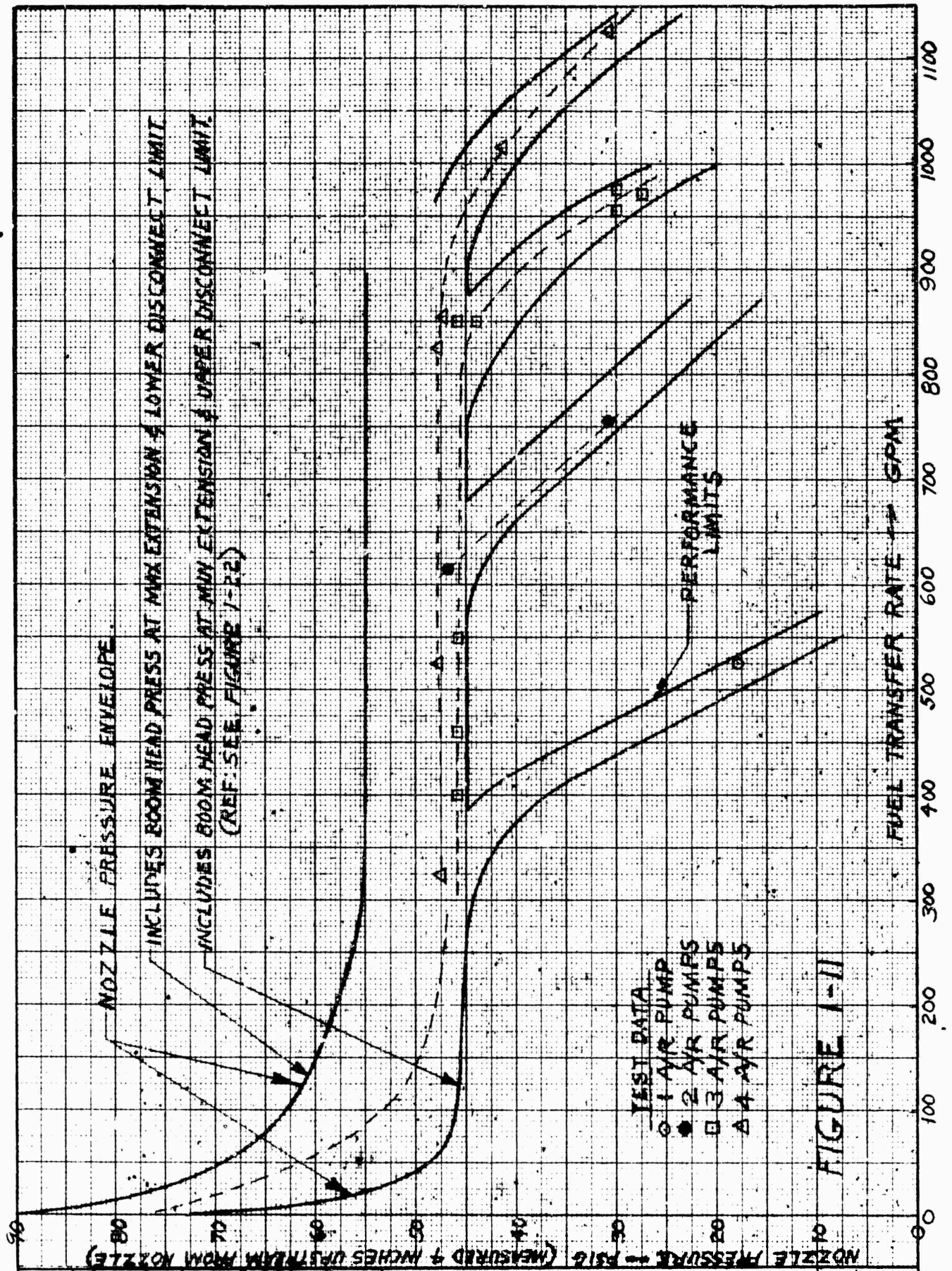


FIGURE 1-11

CALC			REVISED	DATE
CHECK	E.O.	9/1/60	K.F.E.	9/9/60
APR			H.M.H.	12/23/68
APR				

AIR REFUELING SYSTEM
NOZZLE PRESSURE VS.
FUEL TRANSFER RATE

KC-135A
D6-7991

THE BOEING COMPANY

AIR REFUELING FLOODLIGHT ILLUMINATION

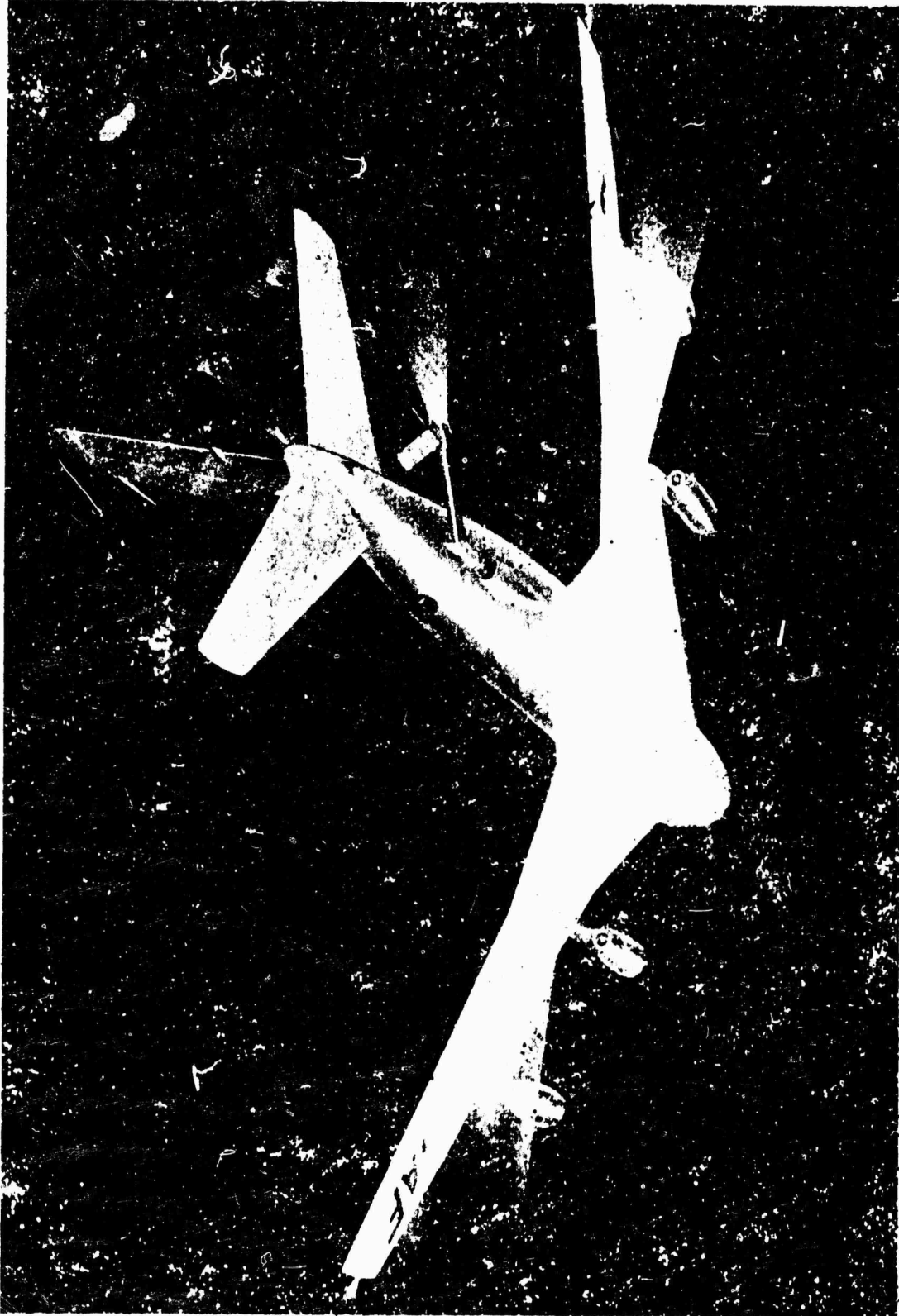


FIGURE I-12

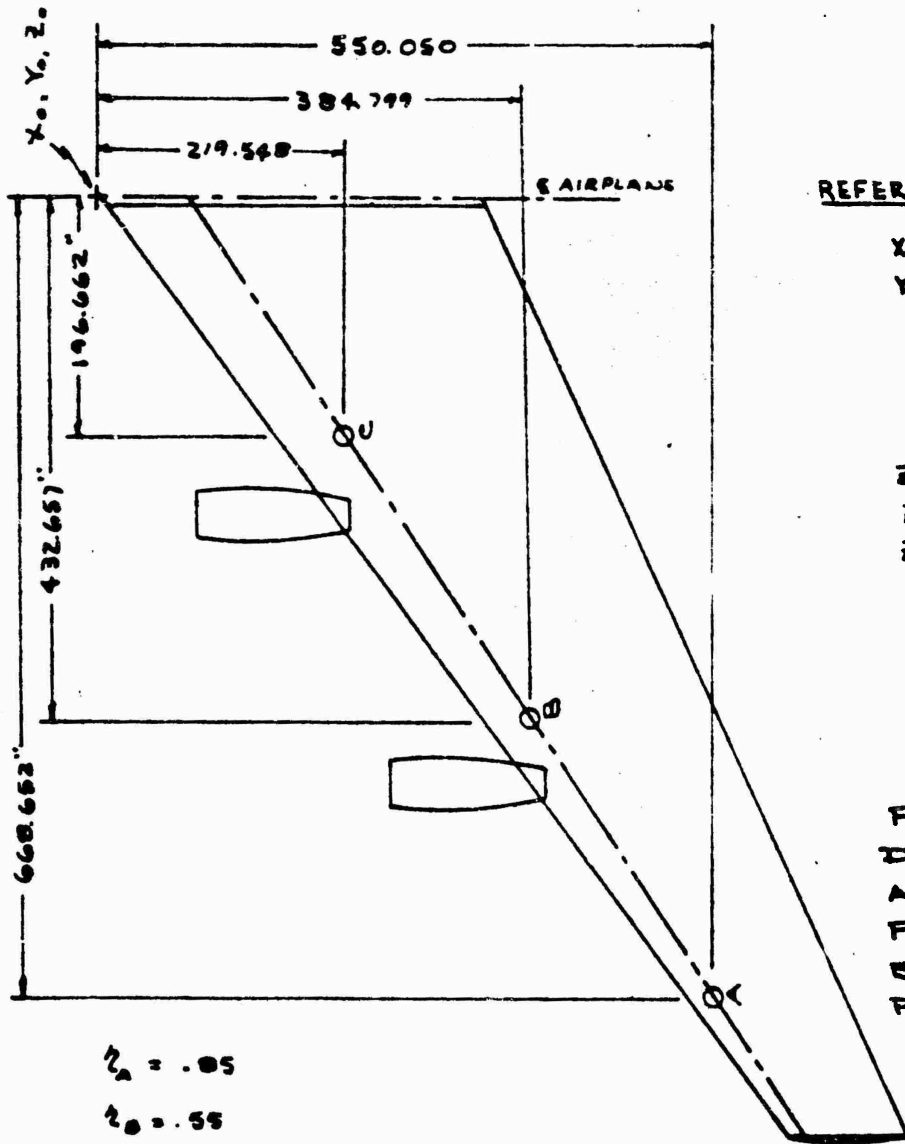
II. KC-135 FLYING BOOM TANKER

- A. 6. The performance of the KC-135A as a Tanker is shown by figure 1-6. This same plot shows the effect of gross weight at the time of transfer on performance. A representative downwash field for the KC-135A is shown by figures 1-13, 1-14, 1-15 and 1-16. Figure 1-13 serves as a legend for figures 1-14, 1-15 and 1-16 which are plots of the downwash in a plane parallel to a vertical plane thru the Tanker center line. The downwash angles are of particular concern to the Receiver because they require a constant climb angle to overcome.
7. Figure 1-4 shows the pertinent dimensions of the Boom nozzle. Figure 1-5 gives the clearance outline of the Boom, relative motion points and other information.
8. The KC-135A has certain rendezvous electronic equipment which aids forming at ranges up to 200 miles. This equipment falls into two categories:
- (a) Communication transmitter to direction finder.
 - (b) Search radar to radar beacon.

The particular Tanker equipment and the required Receiver equipment to establish one of these links is listed by figure 1-17. It is recommended that Receivers be capable of completing at least two of the links listed in this chart.

9. In addition to the equipment listed by figure 1-17 the Tanker has numerous electronic navigational aids. This equipment makes it possible for the Tanker to locate and orbit within any predetermined area without depending upon ground based navigational aids.

HORSESHOE VORTEX REFERENCE POINTS
AND REFERENCE POINT ORIGIN LOCATIONS
 KC-135A



REFERENCE POINT ORIGIN

X_0 = BODY STATION 533.822
 Y_0 = INTERSECTION OF
 LEADING EDGE AND
 CENTERLINE OF
 SYMMETRY OF
 AIRPLANE.

Z_{0A} = BODY WL 280.869
 Z_{0B} = BODY WL 235.199
 Z_{0C} = BODY WL 198.669

PROFILES OF CONSTANT
 DOWNWASH ANGLES
 ARE PLOTTED ON VERTICAL
 PLANES EXTENDING
 BACK FROM REF
 POINTS A, B, AND C.

$\lambda_a = .05$

$\lambda_b = .55$

$\lambda_c = .25$

NOTE:

(1) $\lambda = \gamma/\alpha_0 = \gamma/100.25$

(2) DOWNWASH FIELDS PLOTTED IN PLANES
 OF HORSESHOE VORTEX REFERENCE POINTS A, B, & C.

CALC	FLINN	11-8-61	REVISED	DATE	DOWNWASH FIELDS KC-135A	
CHECK						
APR					THE BOEING COMPANY RENTON, WASHINGTON	PAGE
APR						19

DOWNWASH FIELD ~ K-135A

CONDITIONS:

PLANE A

M = 1.50

GW = 275000 LBS.

ALT = 30,000 FT

LOAD FACTOR = 1.0

$z = \frac{y}{b/2} = 3.85 \quad (b/2 = 786.65')$

DOWNWASH VORTICES

REFERENCE POINT A

Y = 448.652

REFERENCE POINT LOCATION

GROUND LEVEL 100 FEET

GROUND STATION 111.811

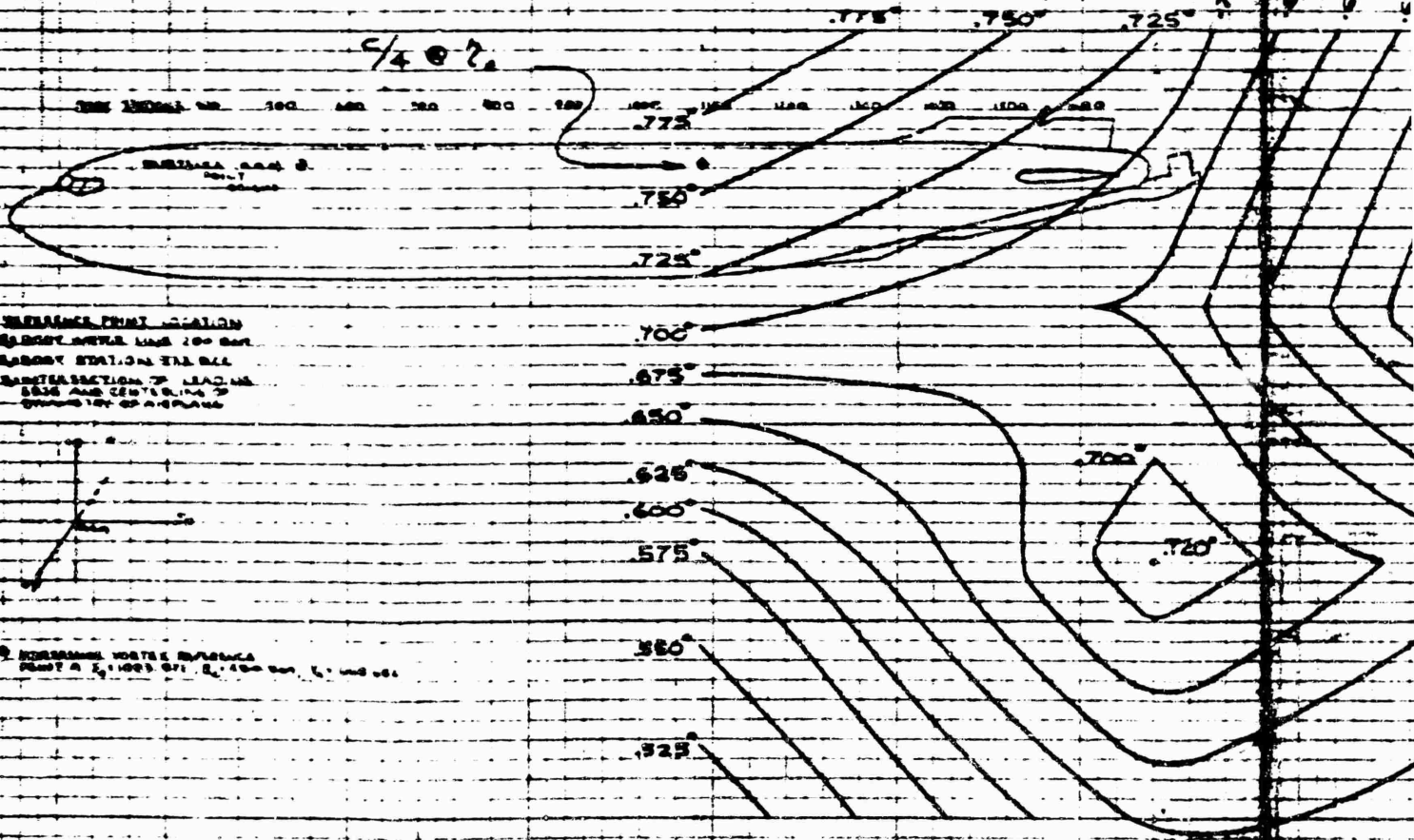
SECTIONAL SECTION OF LEADING

EDGE AND CENTERLINE OF

WING PLAN



DOWNWASH VORTICE REFERENCE POINT A Y = 448.652 Z = 100.000 FT



NOT REPRODUCIBLE

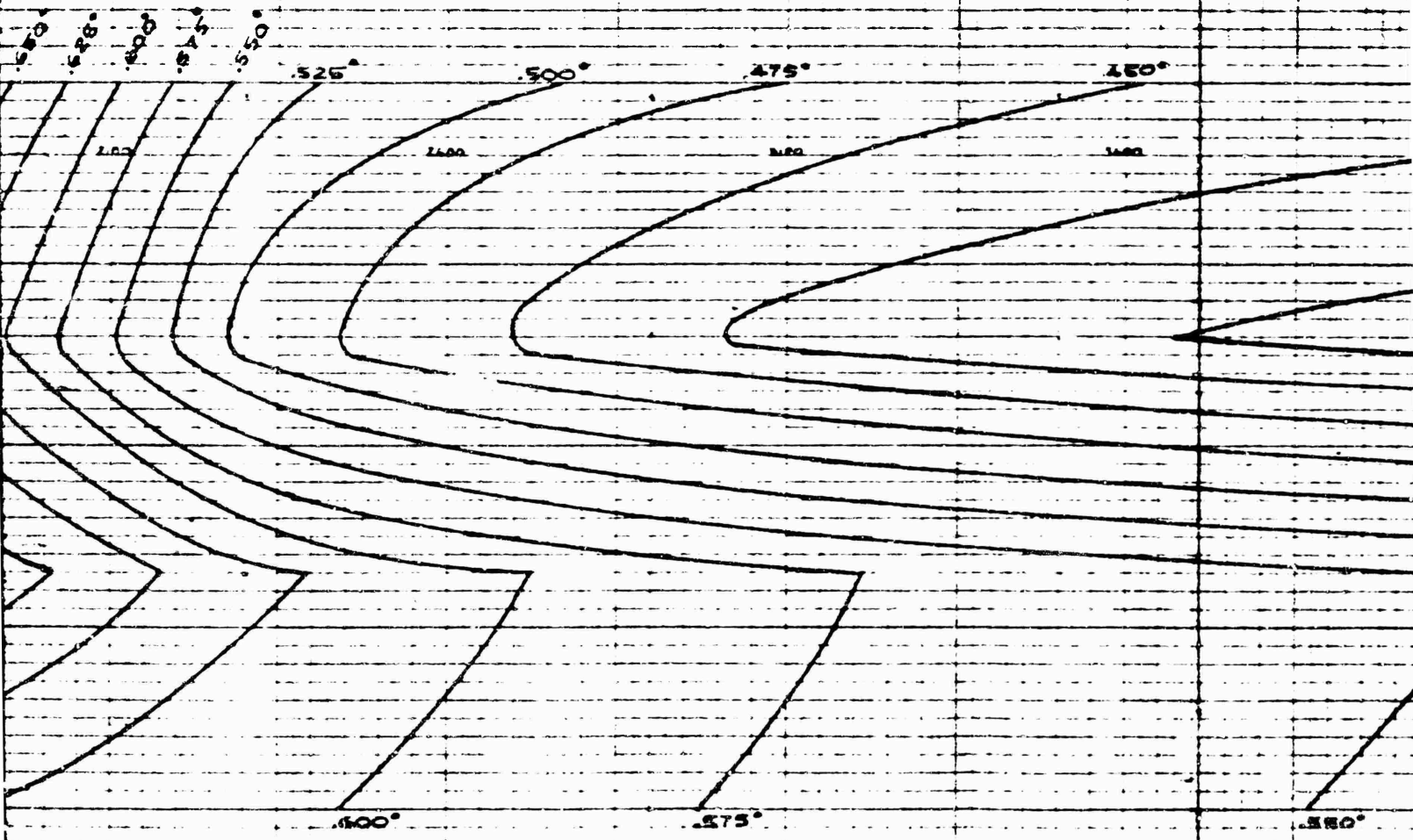
BARRELS

CALC: ELINN 10-23-61

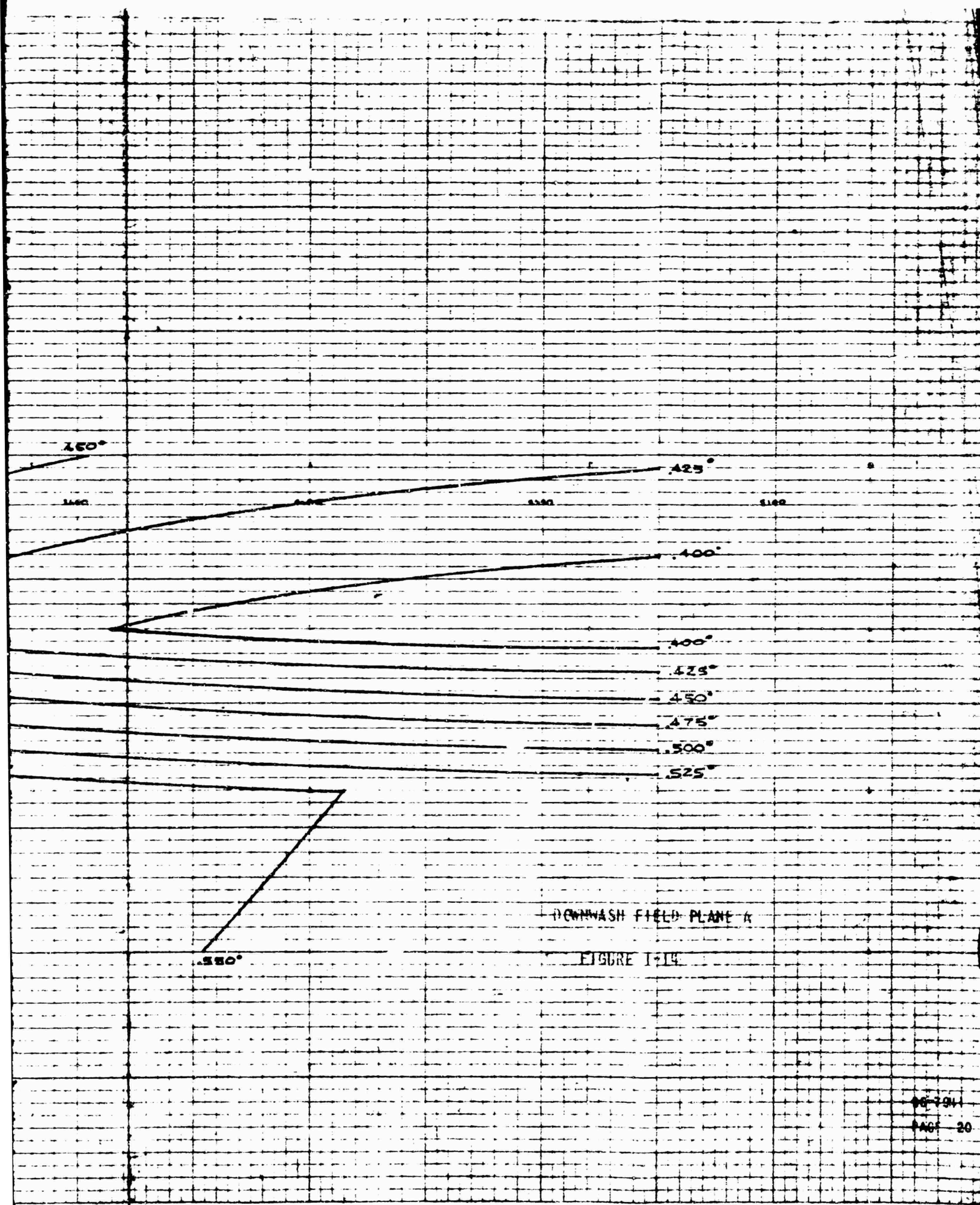
CHECK: P. SUNGCLAND

APP: T-1

PROFILE LINES OF CONSTANT DOWNWASH ANGLE



B



DOWNWASH FIELD PLANE A

FIGURE 1-14

DOWNWASH FIELD - KC-135A

HORIZONTAL VORTEX

REFERENCE POINT B

Y = 432.637

CONDITIONS:

M = .80

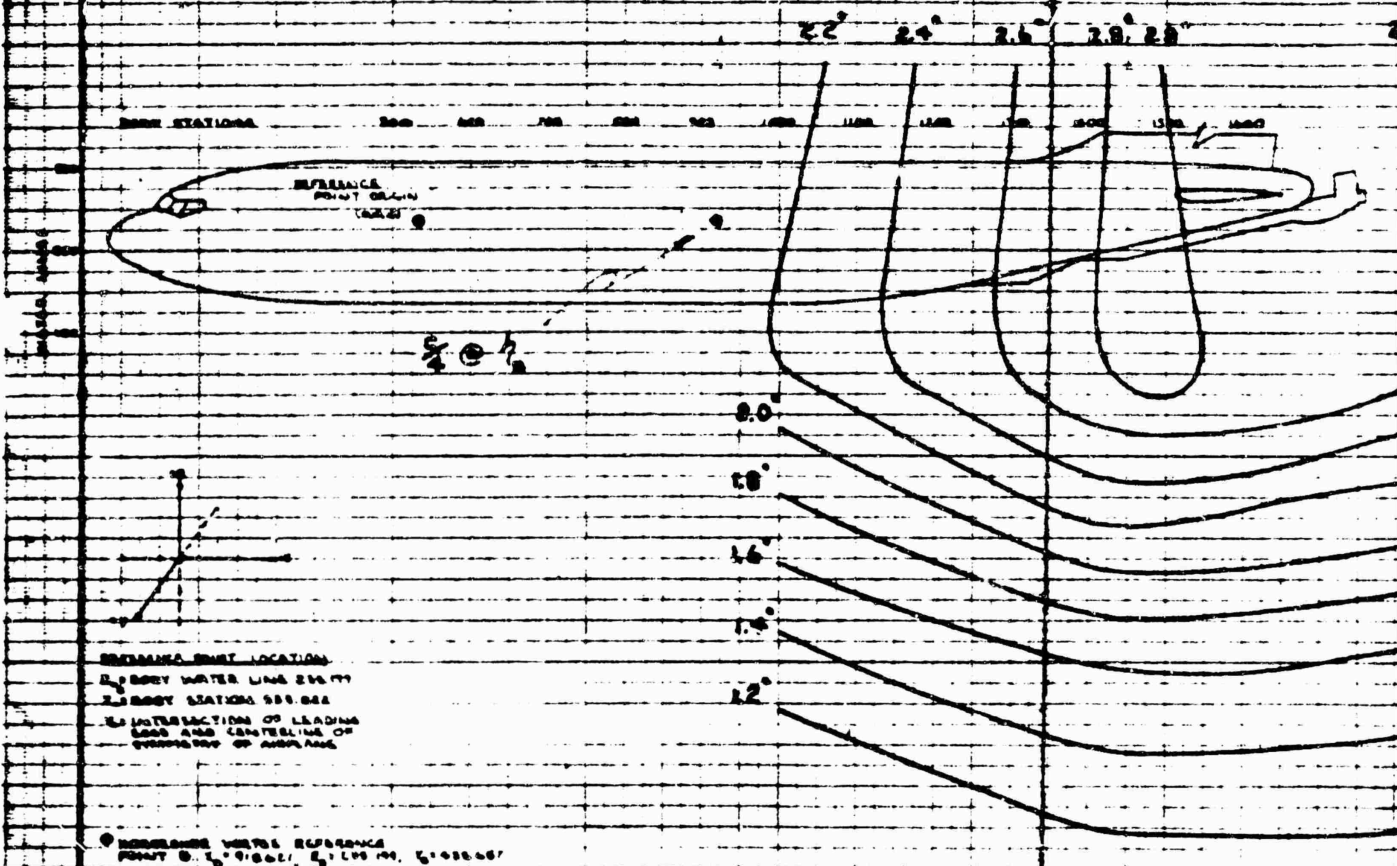
GW = 275,000 LBS

ALT = 30,000 FT.

LOAD FACTOR = 1.0

$\eta = \frac{1}{2} = .55$ ($\frac{1}{2} = 756.65'$)

PLANE B

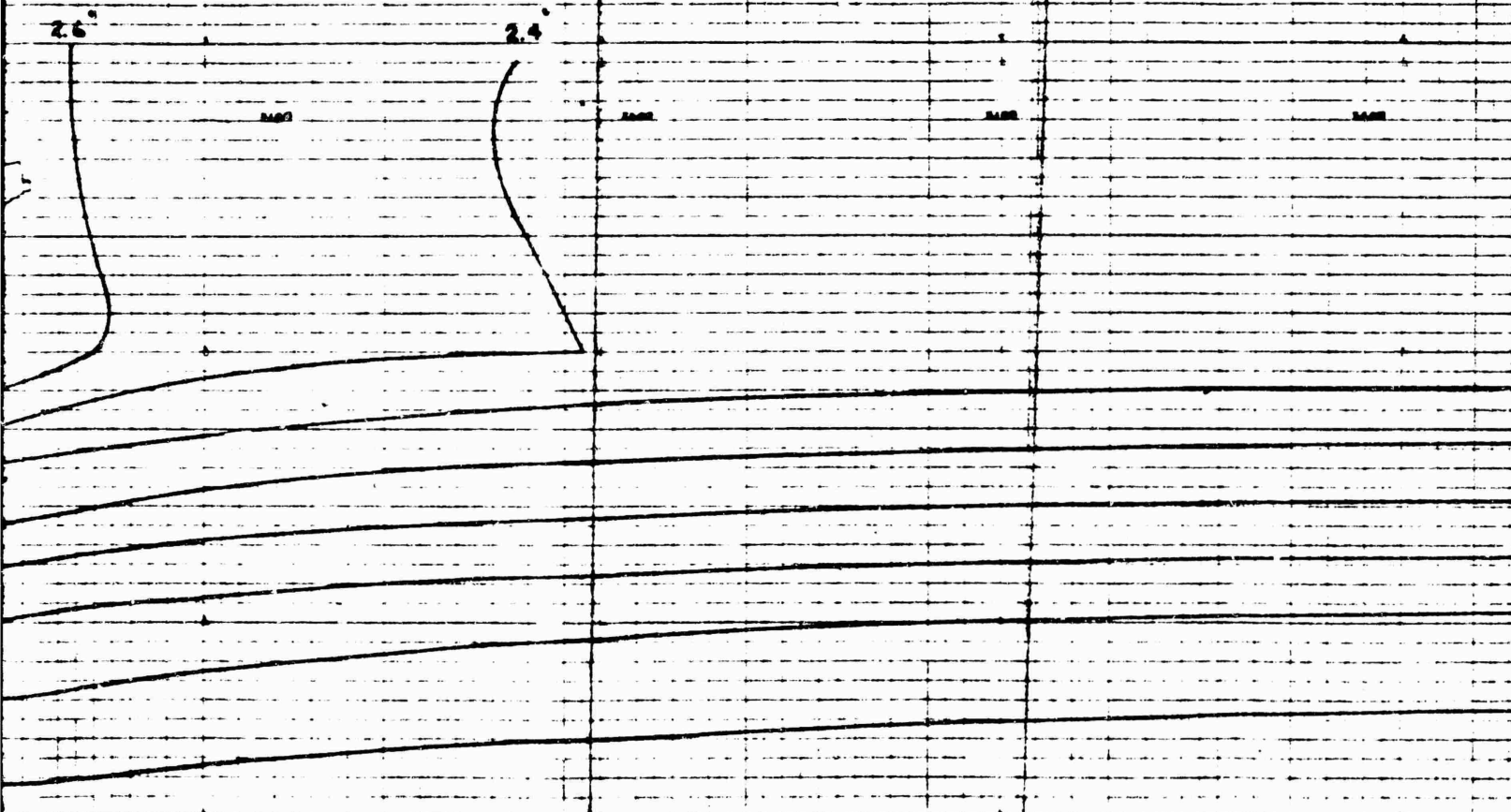


BACKS
CALC: FLINN 10-23-61

CHECK: B. SUTHERLAND
M: [Signature]

B

PROFILE LINES OF CONSTANT DOWNWASH ANGLE



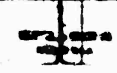
B

2.2
2.0
1.8
1.6
1.4
1.2

DOWNWASH FIELD PLANE B

FIGURE 16

NOT REPRODUCIBLE



C

KE

DOWNWASH FIELD - KC-135A

CONDITIONS:

PLANE C

$M = .80$

G.W. = 275,000 LBS.

ALT. = 20,000 FT.

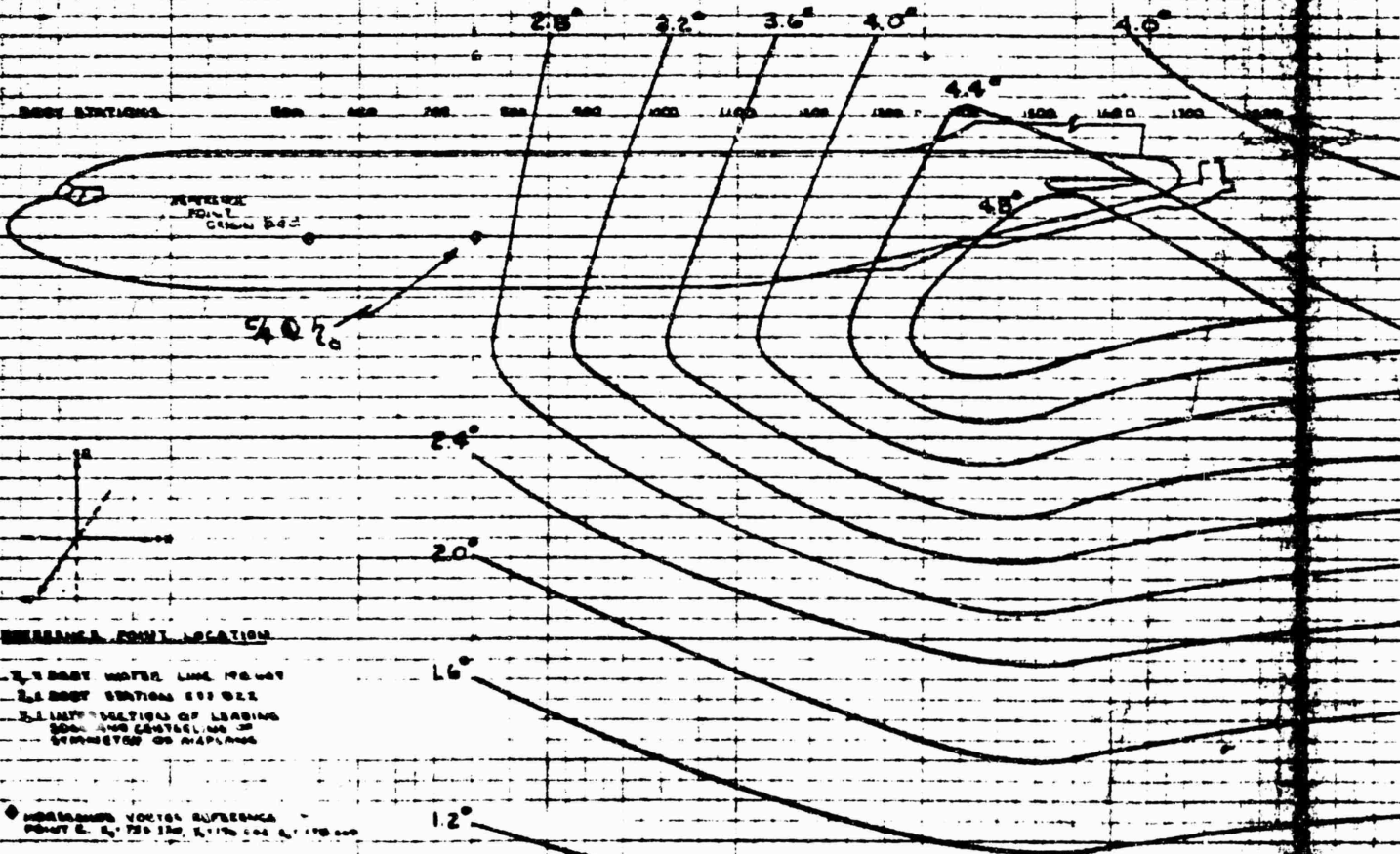
LOAD FACTOR = 1.0

$\eta = \gamma/\theta_{1/2} = 0.25$ ($\theta_{1/2} = 786.65^\circ$)

HORSESHOE VORTEX

REFERENCE POINT C

K-174662



REFERENCE POINT LOCATION

- 1. VORTEX CENTER LINE
- 2. DOWNWASH SECTION
- 3. VORTEX SECTION OF LEADING EDGE
- 4. CENTER OF GRAVITY

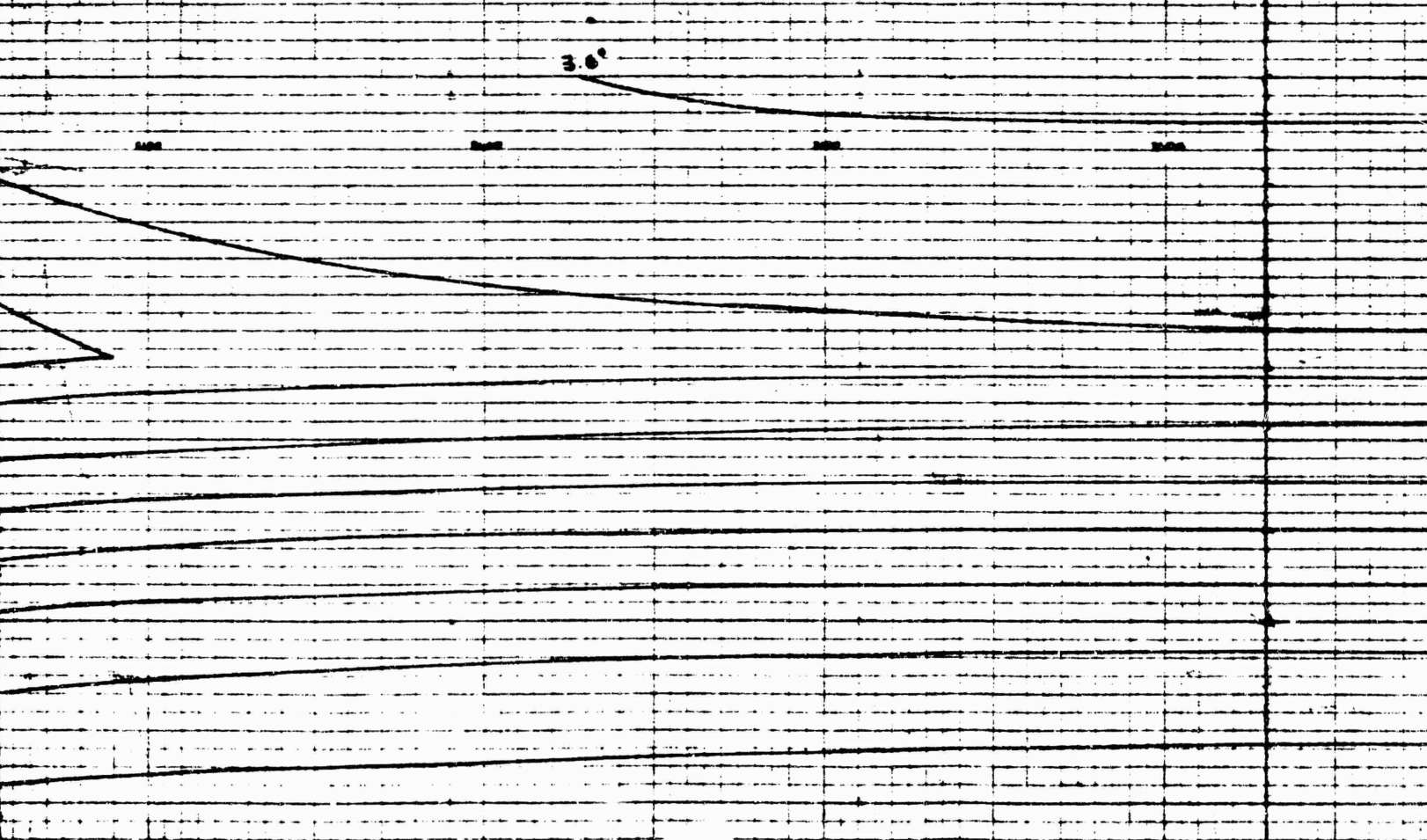
HORSERHOE VORTEX REFERENCE POINT C. X = 500, Z = 0, Y = 0

SAFEGE
CALC. PLANK 10-33-61

CHECK: B. SUTHERLAND
DATE: 11-1-61

A

LINE LINES OF CONSTANT DOWNWASH ANGLE



NOT REPRODUCIBLE

B

3.6°

4.0°

4.0°

3.6°

3.2°

2.8°

2.4°

2.0°

1.6°

DOWNWASH FIELD PLANE 1

FIGURE 11-16

B

<u>TANKER EQUIPMENT</u>	<u>RECEIVER EQUIPMENT</u>	<u>FREQUENCY</u>	<u>BEARING</u>	<u>DISTANCE</u>	<u>IDENT.</u>
1. UHF Communication AN/ARC-34 (dual)	UHF Direction Finder	225 to 400 mc	From Rec.	200 nmi max.	Voice
2. UHF Direction Finder AN/ARA-25	UHF Transmitter	225 to 400 mc	From Tanker	200 nmi max	Voice
3. HF Communication (SSB) AN/ARC-58 or AN/ARC-65	HF Direction Finder	2 to 30 mc	From Rec.	2000 nmi max.	Voice
4. Search Radar AN/APN-59	"X" Band Radar Beacon	9375/9310 mc	±120° from Tanker Hdq.	200 nmi max.	Visual Code at Tanker
5. Radar Beacon AN/APN-69 AN/APN-134 AN/APX-25	Search Radar "X" Band "K" Band "L" Band	- 9310/9375 mc Classified 1030/1090 mc	From Rec.	200 nmi unless limited by Receiver	Visual Pulse Code at Receiver

TANKER-RECEIVER RENDEZVOUS EQUIPMENT

FIGURE 1-17

III. FLYING BOOM RECEIVER INSTALLATIONS

A. Receiver Receptacle Location

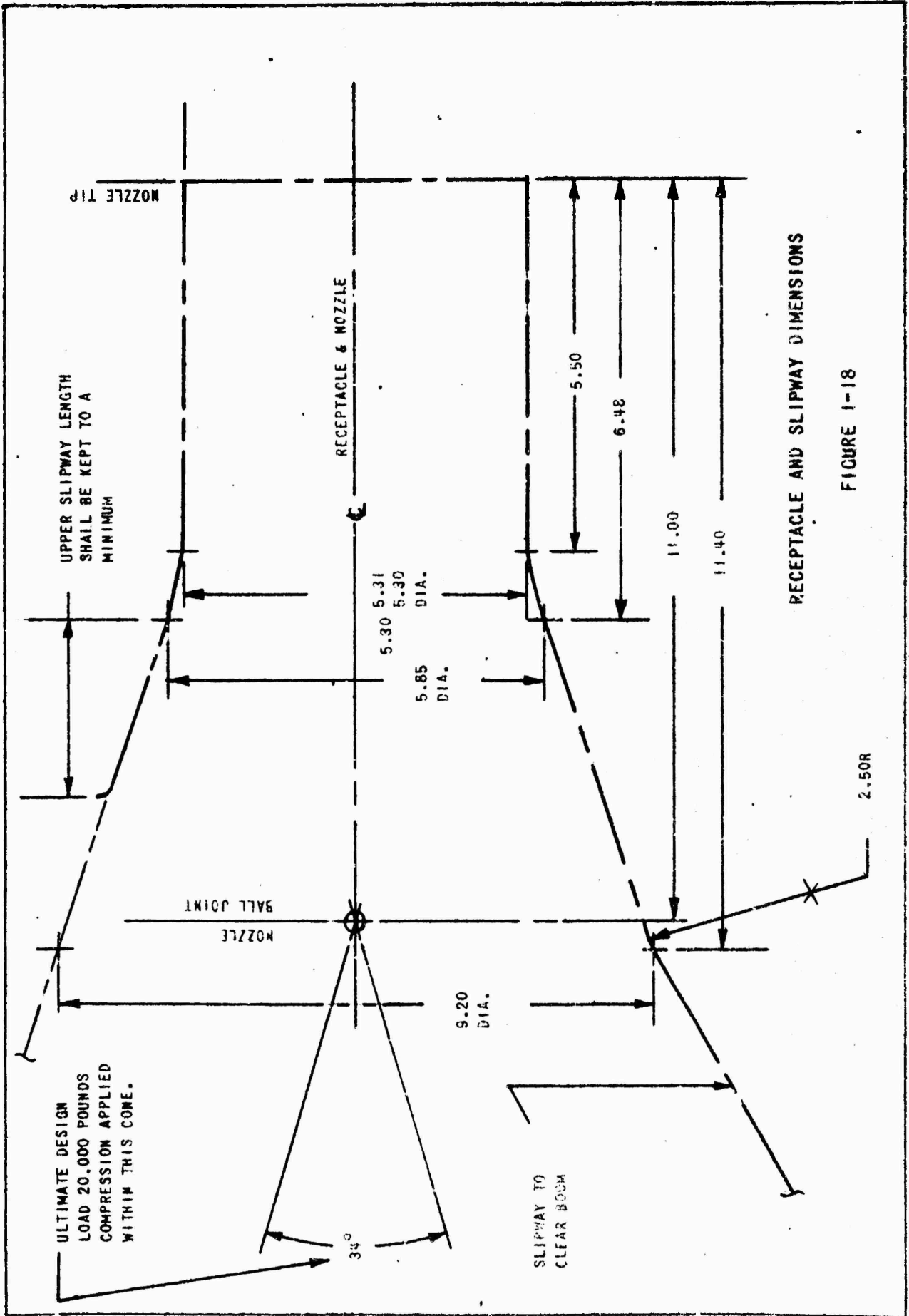
1. The air refueling receptacle in the Receiver must be located with due consideration of the problem of space, structure, other equipment and proximity to the Receiver fuel system. In addition, requirements relative to the forming condition and Boom limitations must also be considered.
2. Receptacles located in the nose of the Receiver ahead of the pilot seem to offer the optimum control. The second most desirable location is on the top of the body just aft of the pilot. Other locations such as leading edge of the wing and top of the body aft of the wing have been less desirable. Reinforcement of the skin adjacent to the slipway is recommended to minimize damage. Also, if the receptacle is close to and in line with the pilot's windshield, bullet proof glass should be considered.

B. Receiver Pilot Vision

1. The Receiver pilots should have the best possible vision of the Tanker while in the forming position; particularly of the pilot director lights or other means of holding the tight formation required. Structural members between windows should not blank out vision of Tanker. Windows which distort because they are not normal to the line of vision should not be used for any part of the forming envelope. For large Receiver Aircraft consideration should be given to pilot fatigue resulting from upward vision for extended periods of time. Any lights monitored during contact should be placed as close as possible to the line of vision.

C. Detail of Receptacle and Slipway

1. Clearance must be provided between the boom and the Receiver throughout the forming envelope as shown by figure 1-2. For clearance dimensions for Boom see figure 1-5. In addition sufficient width should be provided at the entrance of the slipway to assist the Boom operator in rough air. A width of 30 inches is considered desirable for large Receivers, while 20 inches is adequate for small maneuverable Receivers. The optimum slipway consists of two distinct areas: A forward area which must clear the boom under all operational conditions and a short transition area which positions the nozzle head under adverse conditions. The forward area should clear the boom by a minimum of 5 degrees for any angle within the contact envelope as shown by figure 1-2. This 5 degree minimum clearance should also include any movement of the Receiver relative to the Tanker - i.e. high angle of attack or trim from flaps being down. The dimensions for the transition area are shown by figure 1-18. The sides of the slipway should be smooth and high enough to guide the nozzle into the receptacle. Normally the slipway is covered with a door to reduce drag. If the



RECEPTACLE AND SLIPWAY DIMENSIONS

FIGURE 1-18

TD 1544 L-13

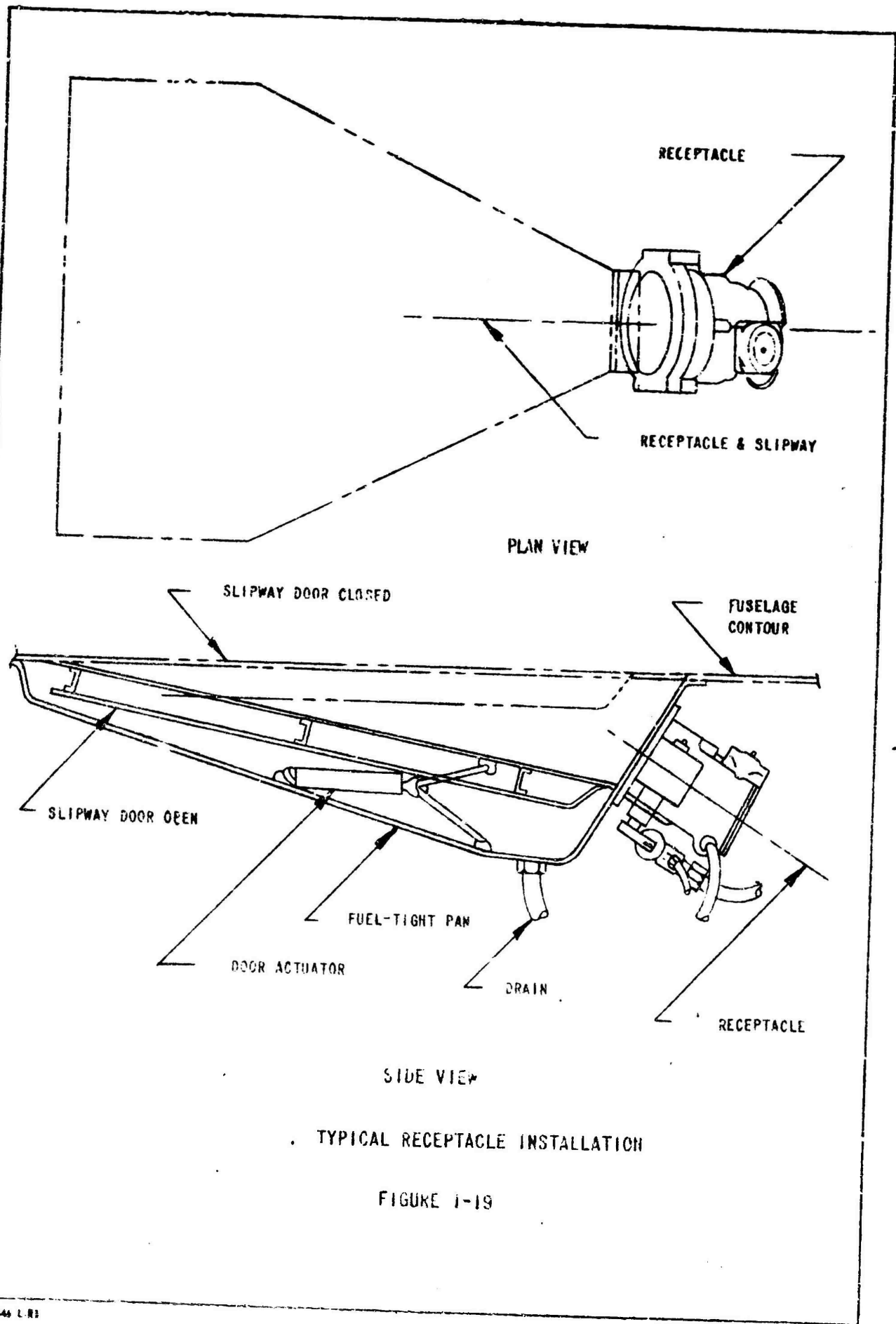


III. FLYING BOOM RECEIVER INSTALLATIONS

C. 1. (continued)

- doors are not visible to the crew some type of door indication should be provided for open, closed and locked.
2. Figures 1-19 and 1-20 show two typical types of slipway installations. The angle at which the receptacle is inclined on the Receiver is determined by referencing all normal changes in the Receiver angle of attack while in contact to the Tanker airplane center line in a composite layout. With smallest Receiver angle of attack at the Tanker lower, outer limit (40° and 551 inches figure 1-2) as one extreme and the largest Receiver angle of attack at the Tanker upper, inner limit (20° and 404 inches figure 1-2) including effect of downwash the optimum receptacle angle will be such that the boom nozzle is straight midway between these limits. The receptacle should be mounted in such a manner that a plane through its vertical centerline is parallel to the vertical plane of symmetry of the airplane. A check should be made to determine that the total motion does not exceed the nozzle allowables as shown by figure 1-5.
 3. In addition to air loads and other loads normally imposed on the aircraft structure, the slipway and its doors must be designed for impact loads imposed by contact with the nozzle. These requirements will vary with the type of installation and anticipated operating conditions; however, an ultimate design load of 2000 pounds laterally and 5000 pounds vertically is recommended.
 4. The receptacle transmits loads into the Receiver under the following conditions:
 - (a) At contact, compression due to the impact of the Boom nozzle.
 - (b) During contact, compression or tension, as the Boom is compressed or extended with relative motion of the two aircraft, plus a part of the air load reaction on the Boom.
 - (c) Under the following emergency conditions: Tension with a failure of the toggle release mechanism; compression with a failure of the release mechanism while the Receiver is in an overrunning condition and bottoming of the Boom.
 5. The receptacle attachment structure should be capable of withstanding the following design loads:
 - (a) A load of $\frac{7000}{\cos A}$ x 2 tension applied at the ball joint of the Boom nozzle where the angle A may vary from 0 to 30 degrees maximum.





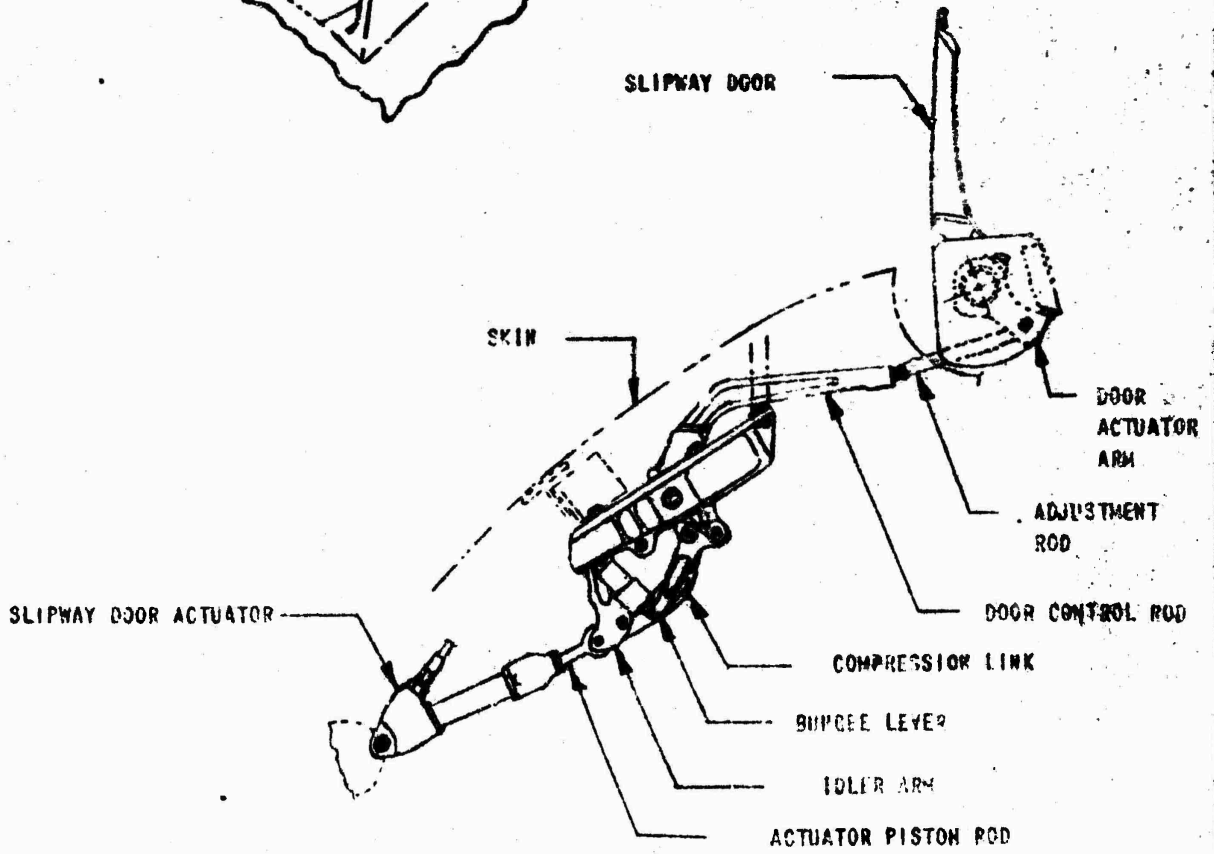
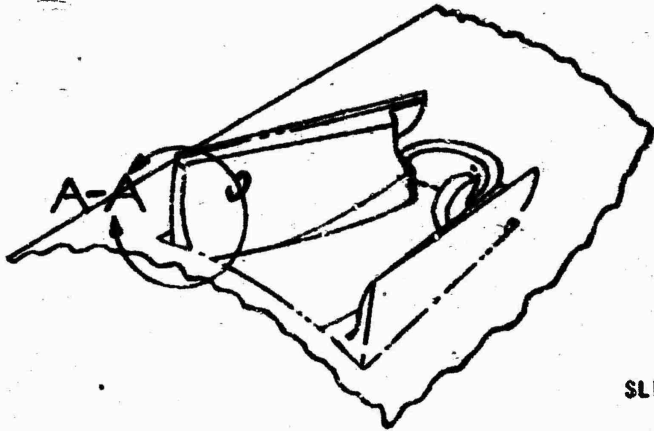
TYPICAL RECEPTACLE INSTALLATION

FIGURE 1-19

TD 1544 L R3



17000



A-A

TYPICAL RECEPTACLE INSTALLATION

FIGURE 1-20

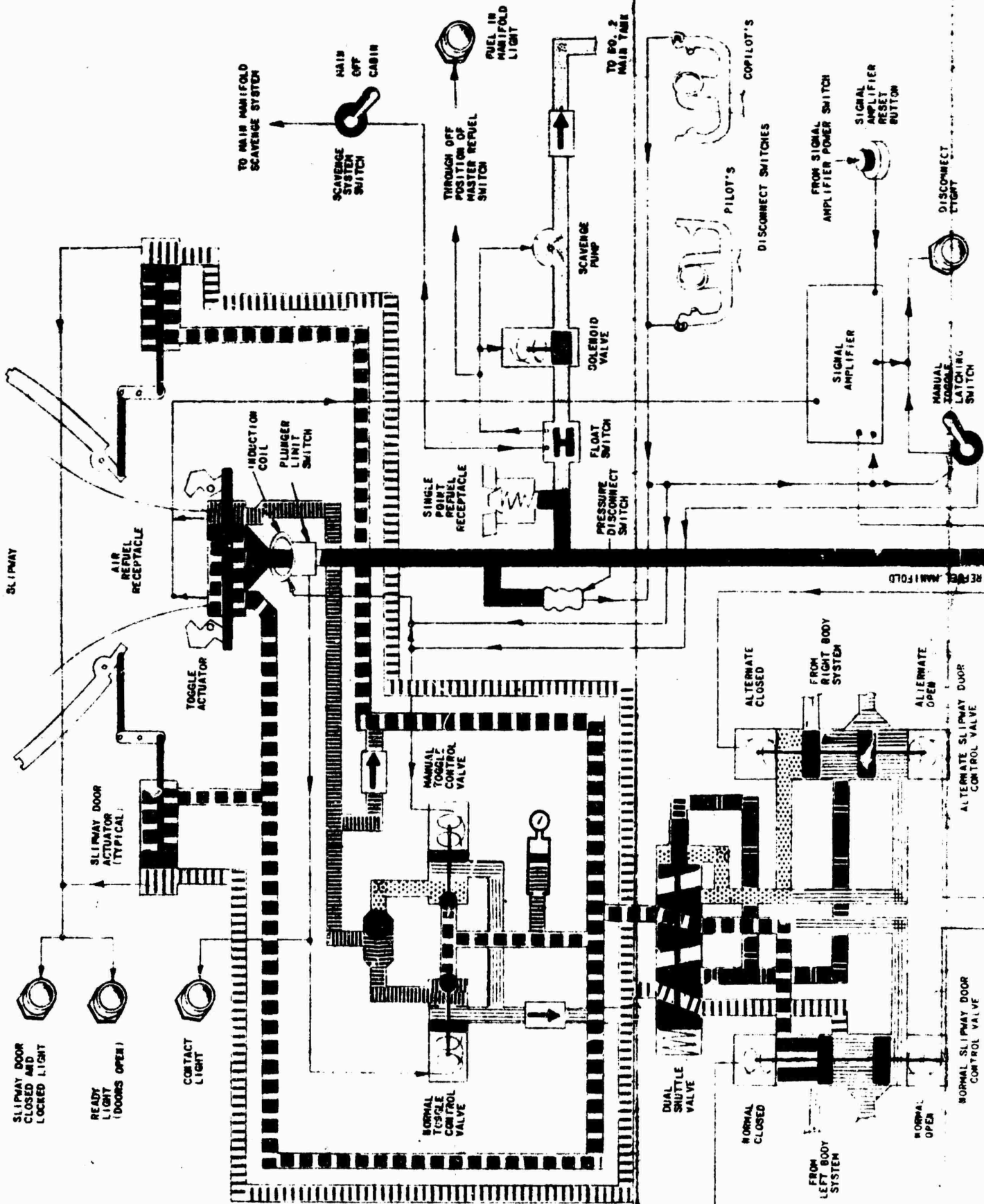
III. FLYING BOOM RECEIVER INSTALLATIONS

C. 5. (continued)

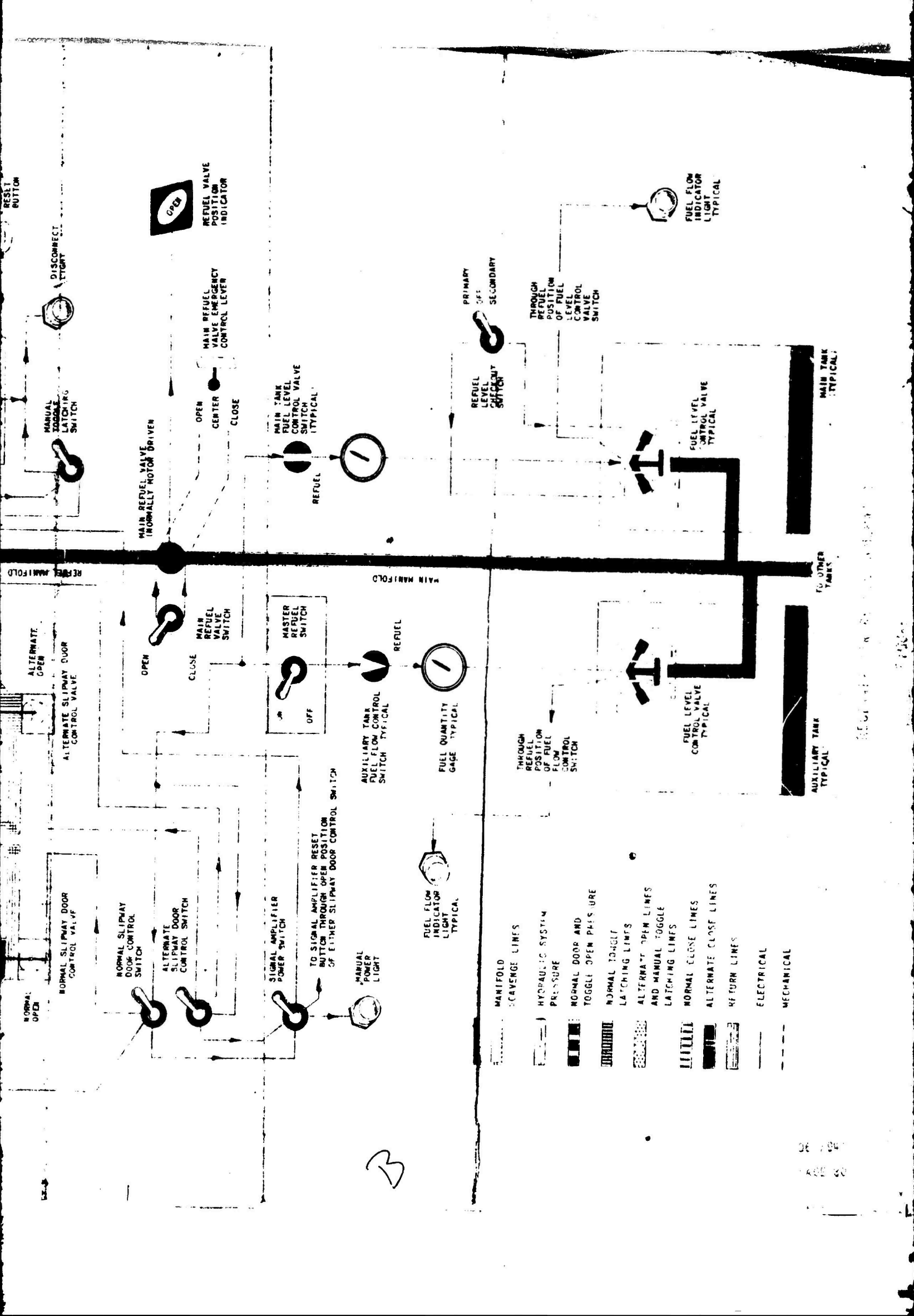
- (b) A load of 20,000 lbs. compression applied at the Boom nozzle ball joint, in a direction at an angle B with respect to the receptacle axis where angle B maximum = 17 degrees as shown by figure 1-18.
 - (c) A load of $\frac{3000}{\cos C}$ x 3 compression or tension applied at the Boom nozzle ball joint, in a direction at an angle C with respect to the receptacle axis, where maximum angle C = 17°, combined with a fuel pressure of 125 psi x 3.
6. The slipway and receptacle joint, must of course, be fuel tight. The use of "O" rings and suitable sealants are suggested. It is advisable not to use paint in the slipway to avoid contamination of the fuel from particles peeling or flaking off. The use of hard coat is suggested for aluminum because it is non reflective as well as a good surface treatment.

D. Receiver Refuel System

- 1. A typical air refuel system schematic including fuel, hydraulic, electrical and mechanical elements is shown by figure 1-21.
 - (a) The use of dual element level control valves to control the shutoff of flow to the tanks as they fill is shown. Additional manual or remote control valves monitored by the pilot or flight engineer may be desired.
 - (b) Means for protecting the Receiver fuel system from excessive pressures in the event of a malfunction. This is normally done by use of a pressure switch connected into the Receiver signal system which initiates a disconnect if a preset pressure value is exceeded.
 - (c) Line sizes, angles of bend, fitting configurations and other items which produce pressure losses should be controlled so that with the pressures available from the Tanker the Receiver manifold system will allow the desired flow rate. See figure 1-11 for plot of pressure vs flow for the Tanker.
 - (d) The use of 3000 psi hydraulic power from either one of two systems as the prime mover for doors and toggles is shown schematically by figure 1-21. Remote control of the valves on this system is accomplished electrically.
 - (e) The electrical circuitry necessary for the all important signal amplifier as well as remote operation of valves, switches and indicator lights is shown diagrammatically by figure 1-21 along with the hydraulic and fuel elements.



A



3

III. FLYING BOOM RECEIVER INSTALLATIONS

E. Slipway and Receptacle Drains

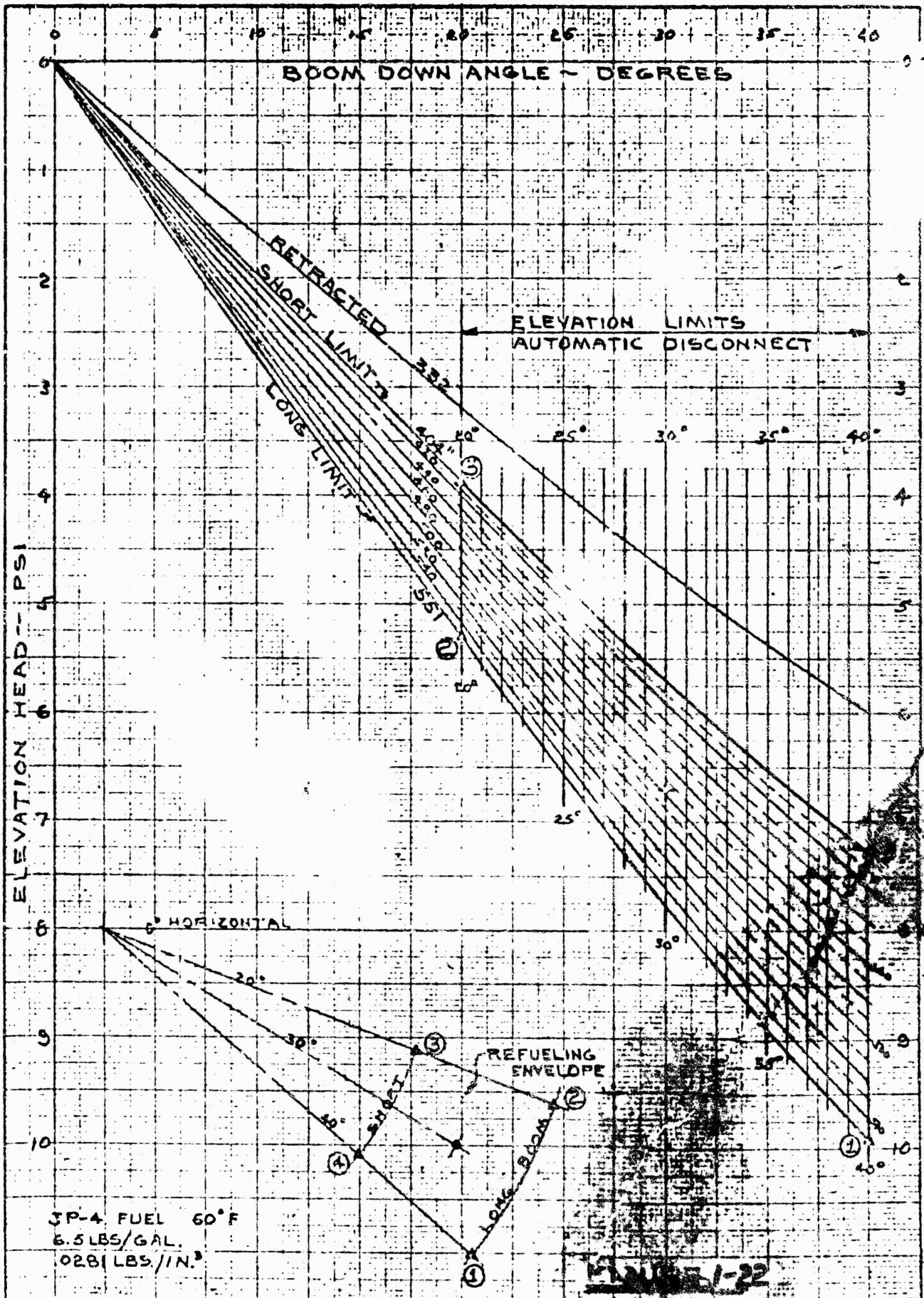
1. It is desirable to enclose the slipway and receptacle in a fluid tight structure. Drainage is routed from the low point or points in this structure to a suitable low, low pressure area so that it will spill into the slipstream without re-entering the aircraft.

F. Special Provisions for Air Refueling Receivers

1. All manifolds connections, fittings and equipment should be suitable for the flow rate required. If the fuel shut-off valving used is fast closing, suitable surge suppression should be provided since the total fuel column length from the Tanker pumps to the Receiver is long.
2. The path of fuel spilled in or near the slipway and the possibility of obscuring the pilot's vision, navigation windows or other equipment items should be considered.

G. Night Lighting Provisions

1. To enable satisfactory night refueling, provision should be made for the illumination of those areas of the Receiver aircraft which will enable the Boom operator to judge the position and alignment of the Receiver aircraft. The particular areas requiring illumination are:
 - (a) Slipway and receptacle.
 - (1) 2 slipway and one receptacle lights are recommended.
 - (b) Receiver upper body surface aft of slipway.
 - (c) Receiver wing leading edge and upper surface.
 - (d) The area immediately forward of the slipway, if practical.
2. Particular precaution should be taken to avoid any direct or reflected light which might shine into the Boom operator's eyes.
3. Suitable brightness control should be provided for all external Air refuel lighting to allow for the relatively wide variations in the amount of sky illumination on the Receiver, from partially overcast early dusk, to full black conditions.



CALC	E.O.	9-1-60	REVISED	DATE	ELEVATION HEAD TO BOOM POSITION - BOOM FINCH TO NOZZLE - JP-4 FUEL BOEING AIRPLANE COMPANY SEATTLE 24, WASHINGTON	KC-135 06-7941 PAGE 32
CHECK			NEW	12-23-60		
APR						
APR						