Classification cancelled / Changed to UNCLASS

EMERGENCY POWER BROCHURE

By authority of AVRS

Date [illegible] ARROW

~~SECRET~~ Unclassified

Signature [illegible]

Unit / Staff Appointment AVSS

SEPTEMBER 1957 D. Royston

A.V. ROE AIRCRAFT LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT

REPORT No.

SHEET No.

AIRCRAFT:		PREPARED BY	DATE
		CHECKED BY	DATE

SECRET

ANALYZED

This brochure presents the investigations carried out on the problem of emergency provision of electrical and hydraulic power after double engine flame-out.

1. Report 7/3200/1 and its Appendix

   This report covers the investigation into the best method of providing sufficient electrical A.C. power to bring the aircraft into the engine relight zone during double engine flame-out. In this case sufficient hydraulic power for limited flying control actuation is provided by the windmilling engine(s)

   The results show that a hydraulic driven alternator is preferred;

2. Report P/Systems/35 and its Appendix

   This report covers the investigation into the use of a ram air driven turbine to provide sufficient electrical A.C. and hydraulic power to land the aircraft after a double engine flame-out.

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FORM 1319A

A. V ROE CANADA LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

SECRET

AIRCRAFT: ARROW

REPORT No: 7/3200/1

FILE No:

No. OF SHEETS: 5

TITLE:

REPORT ON THE GENERAL PROBLEM OF EMERGENCY CONTROL, WITH PARTICULAR REFERENCE TO ITEM 3.8 (B) OF THE MINUTES OF THE 29th MEETING OF CF-105 DEVELOPMENT COORDINATING COMMITTEE.

PREPARED BY J.N. Moors DATE Sept. 1956

CHECKED BY DATE

SUPERVISED BY DATE

APPROVED BY SECRET DATE Aug/57

ISSUE No.	REVISION No.	REVISED BY	APPROVED BY	DATE	REMARKS
2		D.Royston		Aug'57	Re-issue

FORM 1316A

AIRCRAFT:		PREPARED BY	DATE
CF-105	Engines Windmilling A/C Performance	J.N. Moors	Sept./56
		CHECKED BY	DATE

Report on the general problem of emergency control, with particular reference to item 3.8 (B) of the minutes of the 29th meeting of CF-105 Development Coordinating Committee.

1. The attached graph sheets 12-52 and 12-105 of report 7-3200-1 show the flying control hydraulic system and the electrical system limitations during double engine flame-out conditions.

2. Flying Control Hydraulic System

The horizontal line near the bottom of graph 12-52 at the 3 GPM level defines the lower limit of what is considered to be adequate aircraft trim control for both engines windmilling. Below this line, control of the aircraft becomes marginal, and it is apparent that a landing procedure could not be expected during a case of double engine flame-out. Graph 12-105 shows the additional limitations due to one engine seized, one windmilling.

3. Electrical System

The solid curved line near the top of graph 12-52 defines the lower limit of output from the engine driven alternators. Below this line the alternator power source is cut out because of the under speed input to the constant speed drive.

To overcome the A/C power limitation it is proposed to install and emergency Power Pack which will supply the essential damping system and electronic loads during the event of twin engine flame-out.

4. Emergency Alternating Current Power Pack

(a) The emergency electrical power requirements are given in the appendix to this report.

(b) There are two alternative means of emergency power supply under consideration:

(a) Wind driven turbine alternator

(b) Hydraulic motor driven alternator.

(c) Wind-driven Turbine Alternator

Description

The wind driven turbine alternator is approximately 11" in length with 9" diam. turbine blades and has a weight of about 25 lbs. installed. (Ref. Airesearch Mfg. Co. Report No. PT-651-MR.)

The proposed location is on the floor in the forward part of the armament pack.

On A.C. power failure, this set would automatically thrust downwards into the airstream and would begin to generate A.C. power.

Advantages

1. Will operate independently of the other aircraft systems.

Disadvantages

1. Relatively heavy

2. Cannot be readily ground tested.

3. Inherently difficult installation with regards to the mechanism for thrusting the unit out into the airstream and providing necessary skin cut-outs.

(d) Hydraulic Motor Driven Alternator

Description

This unit is about 10" X 10", and weighs about 17 lbs., installed.

The proposed location is in the vicinity of the left hand speed brake actuator.

The unit consists of an alternator driven by a constant speed hydraulic motor, which will be powered from the utility hydraulic system. The hydraulic power supply from the two utility pumps will be driven by the windmilling engines during conditions of double engine flame-out. On A.C. electric power failure, a solenoid operated stop valve will open directing fluid from the pumps to the motor, and A.C. Power will be generated.

Advantages

1. Relatively light installation
2. Relatively simple installation
3. Easy to ground test.

Disadvantages

1. Depends on a serviceable hydraulic utility system
2. Will not operate with both engines seized.

(e) RECOMMENDATIONS

It is recommended that the hydraulic motor driven alternator be used. The advantages given are apparent and the disadvantages arise only when considering improbable circumstances.

1. While the system depends on a serviceable utility hydraulic system, there exists the two pump reliability feature.
2. The system operation is limited to a defined range, but this is compatible with the limitations of the aircraft power control supply.
3. The fact that it will not operate with both engines seized is not considered a serious disadvantage because of the improbability of this case arising.

A. V. Roe AIRCRAFT LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT

REPORT No. 7-3200/1 App 1
SHEET No. 1

AIRCRAFT:		PREPARED BY	DATE
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EMERGENCY POWER REQUIREMENTS

Ref: Appendix A to S1038CN-180 (AMTS/DA ENG) of 21 September 1956

Electrical Requirements

1. Under Partial Loss of Power or Single Engine Failure all requirements listed are supplied by the remaining Generator and Transformer - Rectifier Unit.

2. Under the Double Engine Failure condition, the requirements are supplied as noted in the following:-

(a) Receiver, Transmitter, Interphone (AIC-10) Interim A/C ARC-34 (Supplied from Battery) Production A/C ARC-52 (A.C. & D.C.)	Required - supplied
(b) IFF - Interim A/C APX-6 Production A/C APX-19	Required - Supplied
(c) Flight Instruments	Required - Supplied
(d) Radio Compass or Tacan	Required Heading reference supplied in accordance with S1038/105/5 (ACE) of 27 Mar./56
(e) Ejection	Required Supplied (Mechanical)
(f) Relight (D.C. Battery)	Required - Supplied
(g) Stores Jettison Capability (D.C. Battery)	Required - Supplied
(h) W/S Demisting	Required Not supplied - The W/S glass is heated and the temperature is thermostatically controlled to prevent W/S misting. On loss of electrical power the thermal lag will keep the glass warm enough to prevent misting during descent to the engine relight area.

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(i) Cockpit and Instrument lighting — Required Emergency spot lights supplied; operated off battery under these conditions.

(j) Override of AFCS — Required A.C. & D.C. Yaw Damping supplied.

(k) Auto Transmit of RT & I.F.F. A/C Abandoned — Required - Supplied

(l) Capability of firing missiles if in final stages — Not required.

3. In addition to the Electrical requirements listed in (2), Emergency power is supplied for the following:-

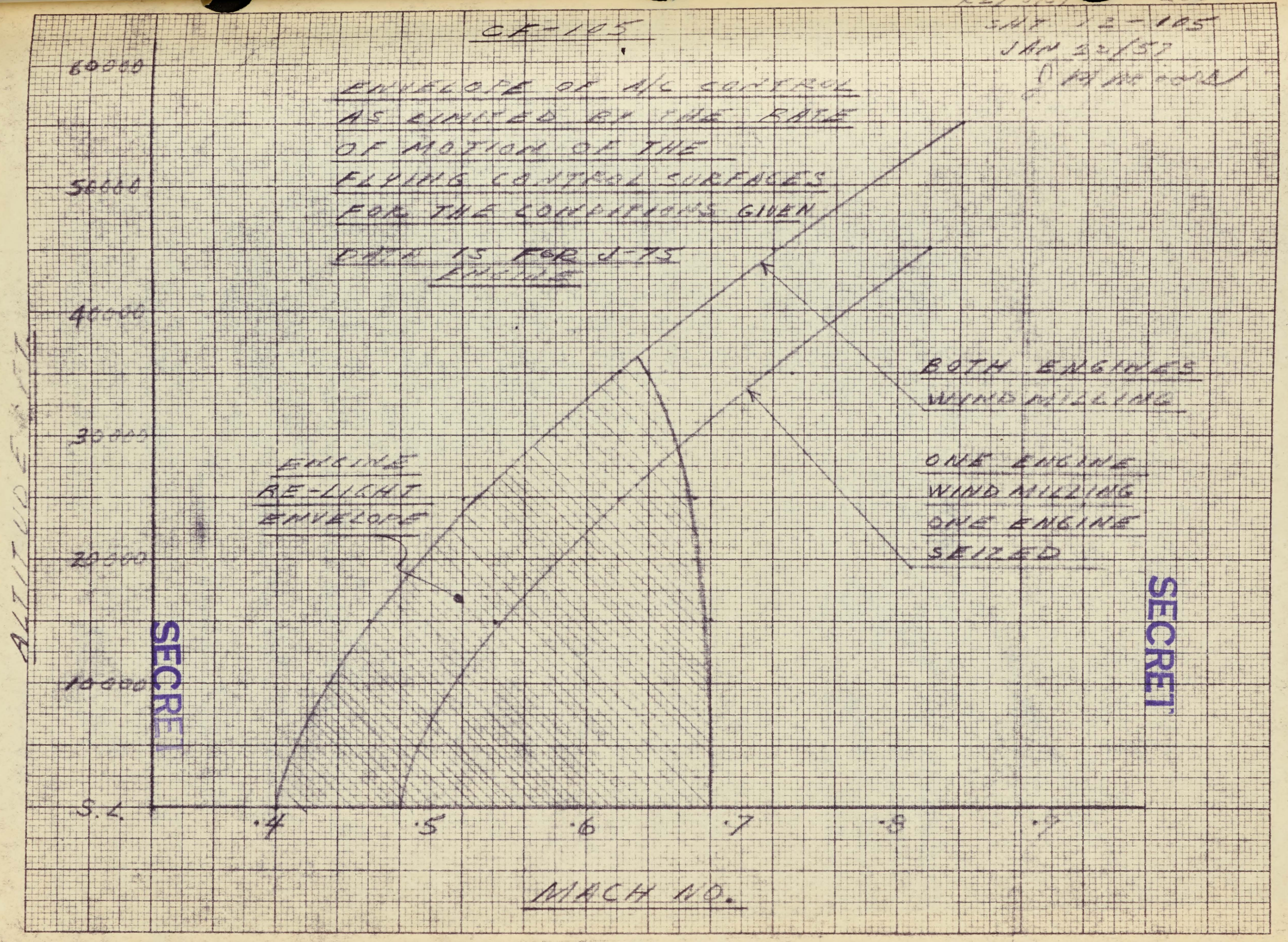
(a) Speed Brakes operation should not be operated unless absolutely essential; as they take hydraulic power from the A.C. emergency alternator.

(b) Engine Emergency Fuel Selection

(c) Canopy Seal Valve

(d) Fire Extinguishing

4. Under a single engine seized and the second engine windmilling - Emergency power is supplied in accordance with Par. (2) and (3).


CF-105
ENVELOPE OF A/C CONTROL
AS LIMITED BY THE RATE
OF MOTION OF THE
FLYING CONTROL SURFACES
FOR THE CONDITIONS GIVEN
DATA IS FOR J-75
ENGINE
BOTH ENGINES
WIND MILLING
ONE ENGINE
WIND MILLING
ONE ENGINE
SEIZED
ENGINE
RE-LIGHT
ENVELOPE
60000
50000
40000
30000
20000
10000
S.L.
ALTITUDE FT
·4
·5
·6
·7
·8
·9
MACH NO.
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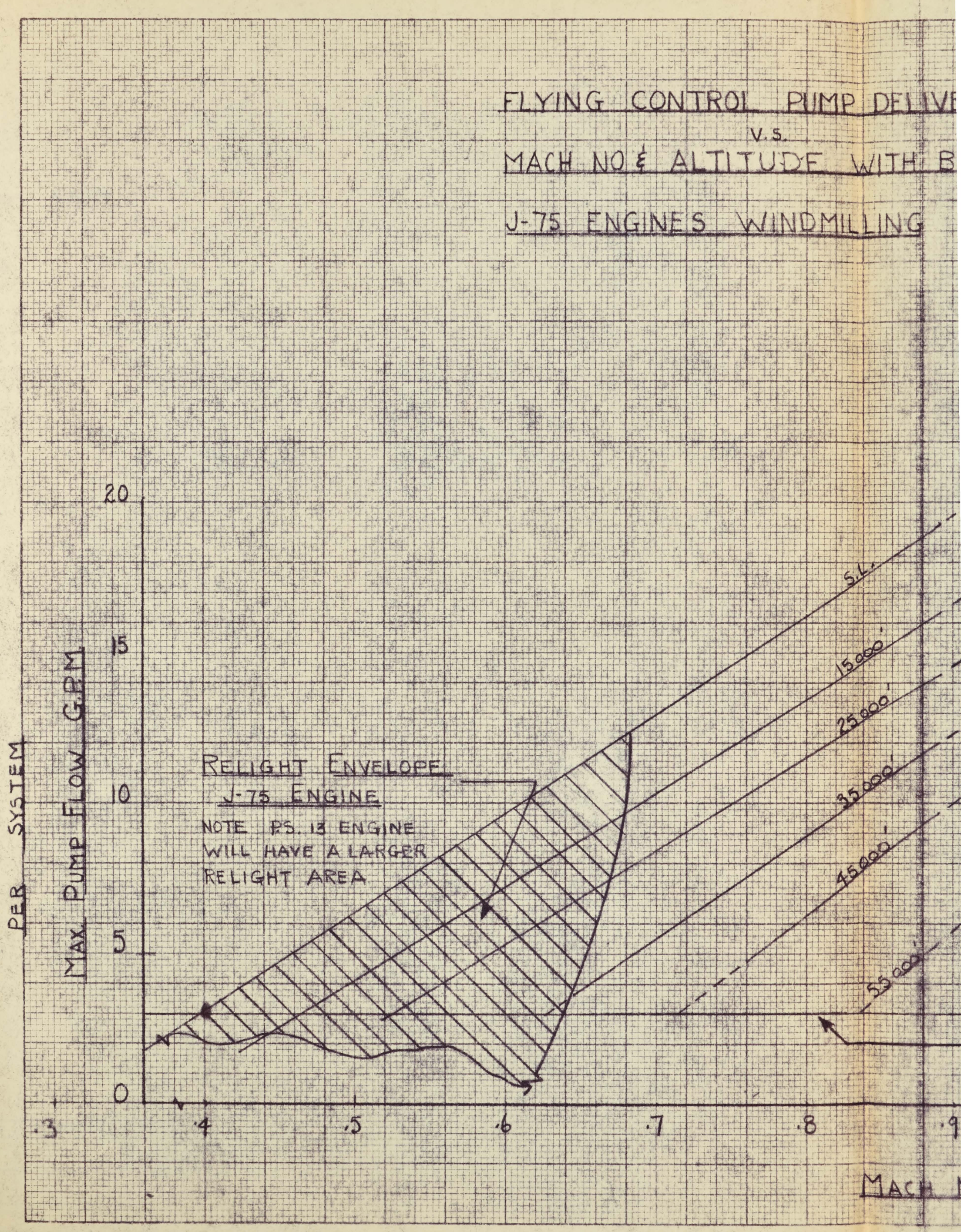
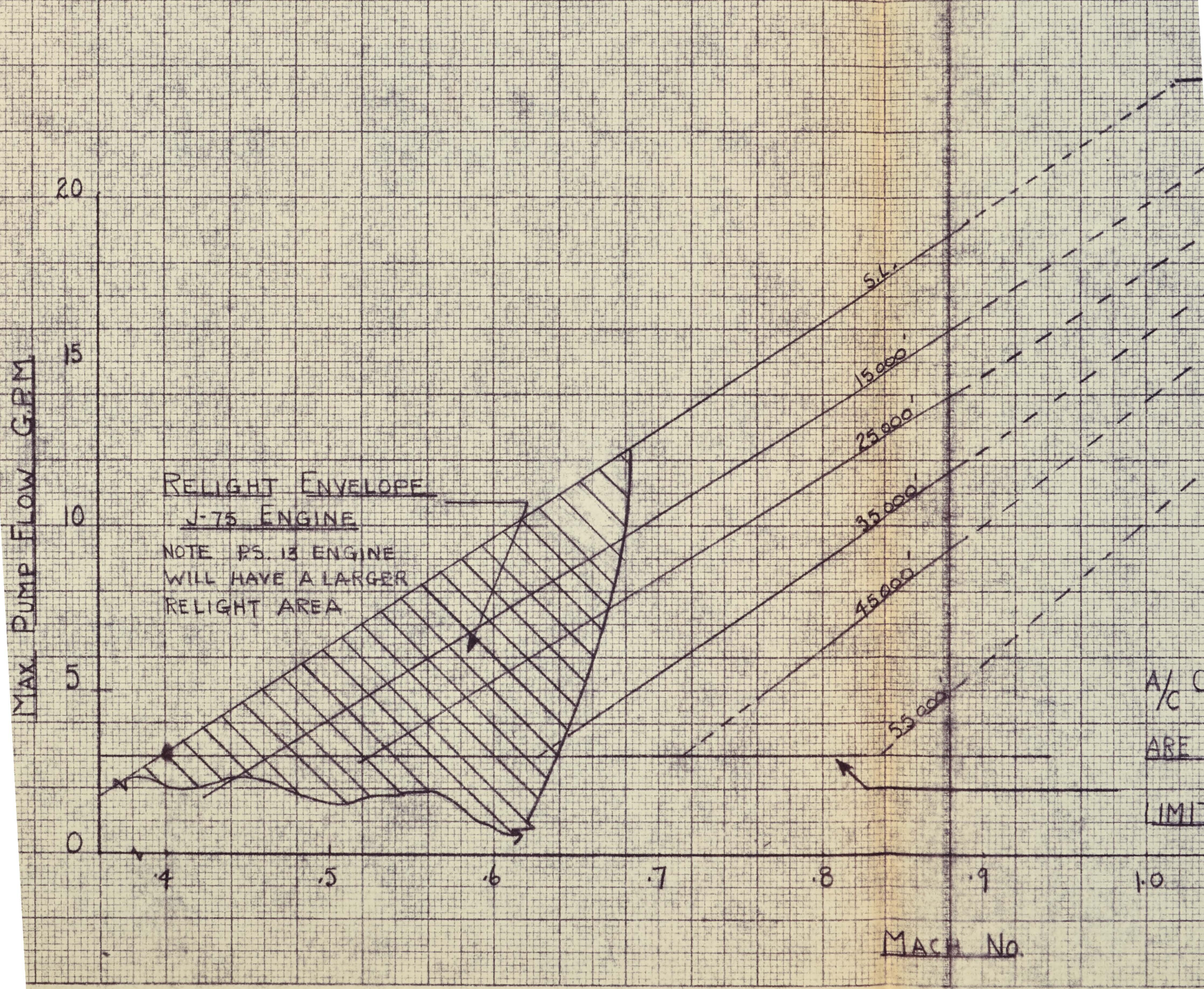
FLYING CONTROL PUMP DELIVE
V.S.
MACH NO & ALTITUDE WITH B
J-75 ENGINES WINDMILLING



FLYING CONTROL PUMP DELIVERY (4000 p.s.
V.S.
MACH NO & ALTITUDE WITH BOTH
J-75 ENGINES WINDMILLING



TROL PUMP DELIVERY (4000 p.s.i)
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LTITUDE WITH BOTH
S WINDMILLING

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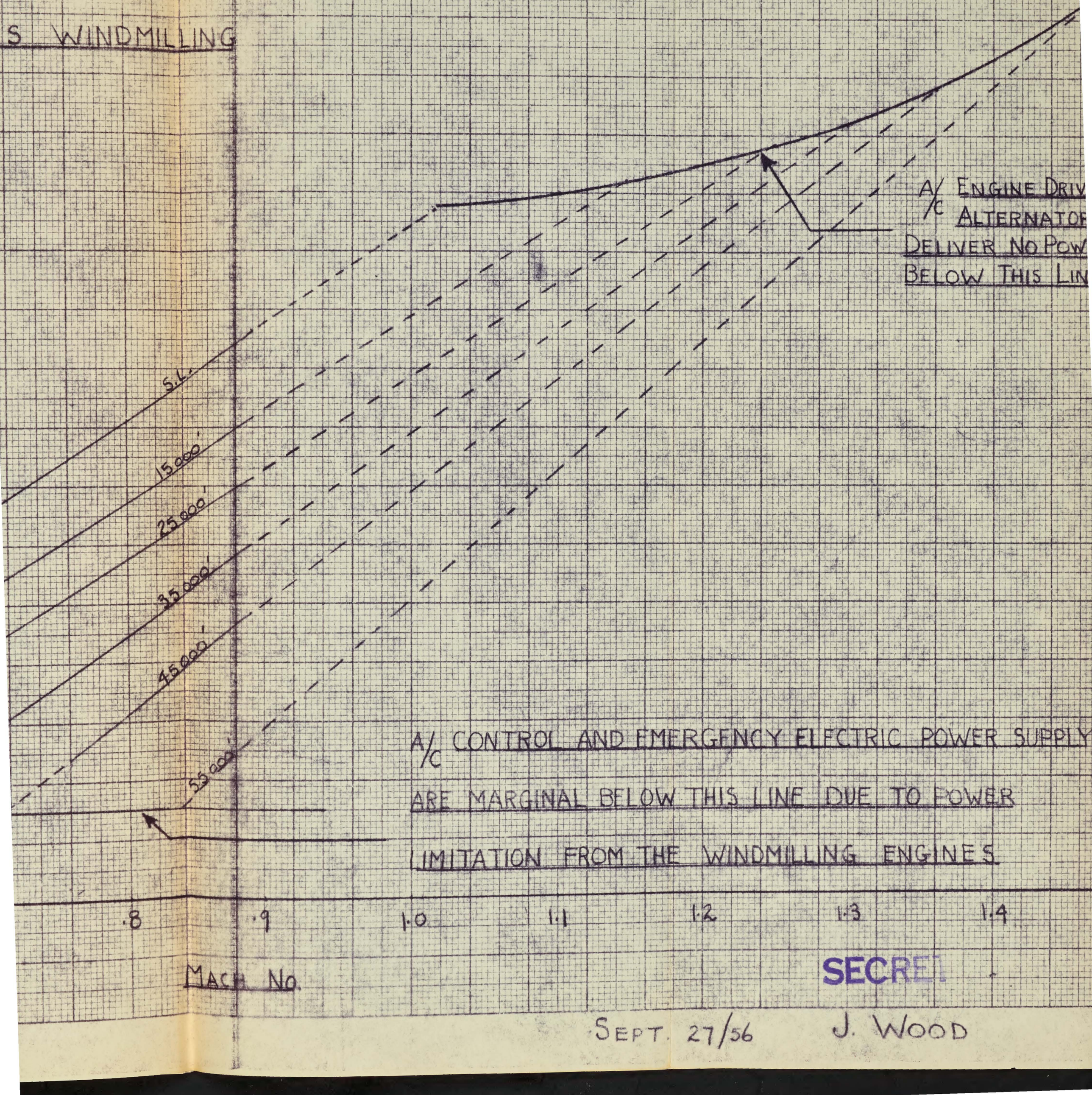

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SEPT. 27/56 J. WOOD

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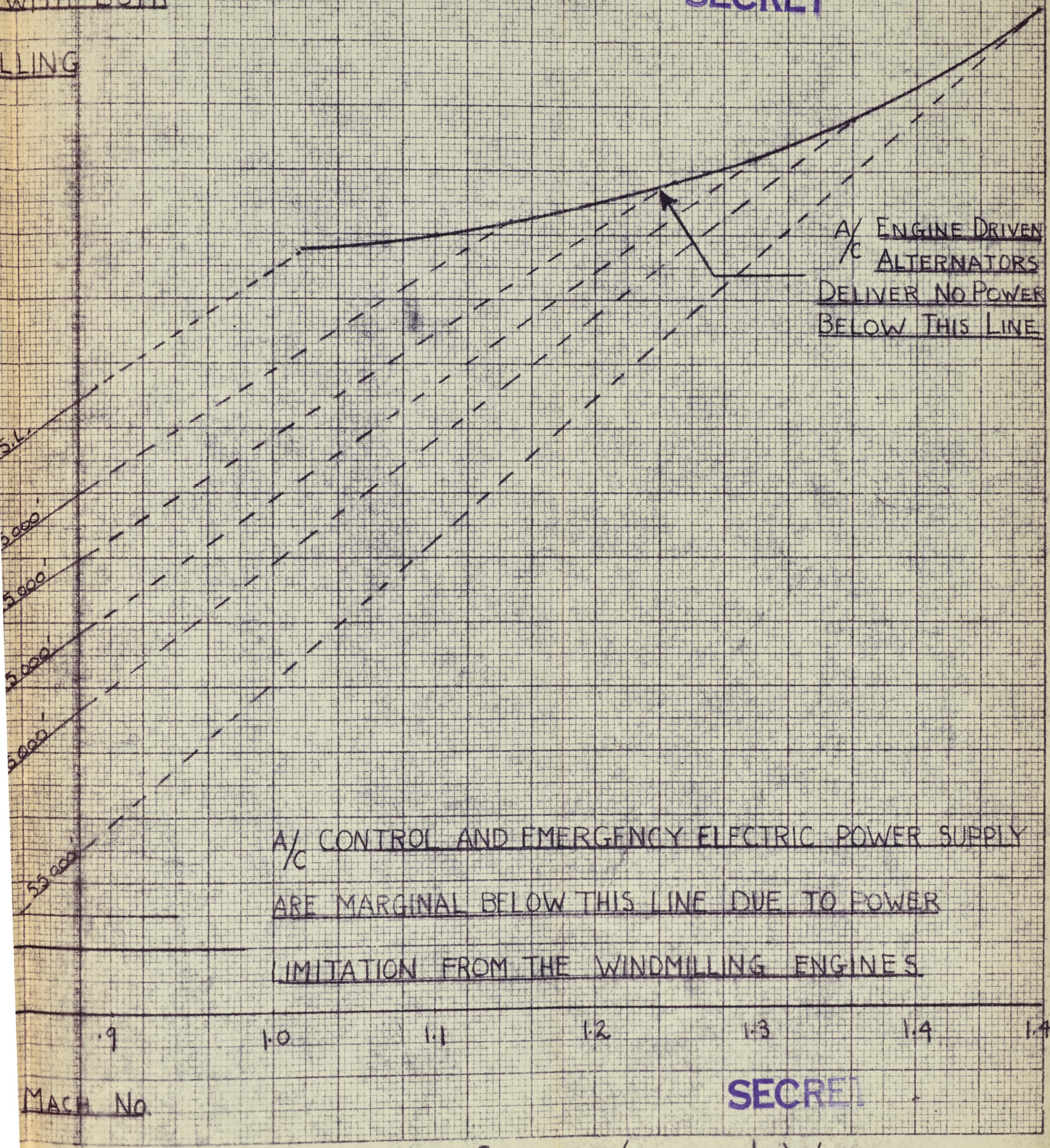
WITH BOTH

LLING



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A. V. ROE CANADA LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

SECRET

AIRCRAFT: ARROW

REPORT NO: P/Systems/35

FILE NO:

NO. OF SHEETS: 6

TITLE:

RAM AIR TURBINE INVESTIGATION

PREPARED BY D. Royston DATE

CHECKED BY DATE

SUPERVISED BY DATE Aug '57

APPROVED BY DATE

ISSUE No	REVISION No	REVISED BY	APPROVED BY	DATE	REMARKS
2		D. Royston		Aug'57	Re-written.

FORM 1316A

SECRET

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

REPORT NO. P/Systems/35
SHEET NO. 1

AIRCRAFT:		PREPARED BY	DATE
ARROW	RAM AIR TURBINE INVESTIGATION	D.L. Royston	Aug.'57
		CHECKED BY	DATE

SECRET

1. INTRODUCTION

The purpose of this report is to investigate the use of a ram air turbine to supply emergency A.C. electrical and hydraulic power in the event of double engine flame-out, including the single engine seized case.

The windmilling engines are capable of providing sufficient hydraulic power to control the aircraft down to .4 Mach No. at S/L or to about .85 Mach No. at 55,000 ft. (See graph 7-3200-1 sht. 12-52 attached). The windmilling engine rpm falls below the minimum required to supply 400 cps A.C. electrical power at about 1.0 Mach No. at S/L and 1.5 Mach No. at 55,000 ft; at speeds below these the engine driven alternators cut-out, and it is necessary to supply A.C. power from an emergency source. The relationship between these figures and the engine relight area is shown on graphs 7-3200-1 shts. 12-52 and 12-105 attached.

It is intended to install a ram air driven turbine on the first three aircraft of each mark (i.e. aircrafts 1,2,3 and 6,7,8). This will provide the power to land the aircraft and thereby give the necessary insurance on the early aircraft using relatively undeveloped engines. Beyond these aircraft serial nos. the reliability of the engines and associated systems will have been more adequately proven and it should then only be necessary to supply emergency electrical power.

2. DESCRIPTION OF INSTALLATION

2.1 A single ram air turbine is being used to power an electrical alternator and a hydraulic pump on a common drive shaft.

It is being installed on the left hand side of the aircraft between stations 255.0 and 292.0 and is to be extended horizontally out of the side of the fuselage.

The turbine is to be stored inside the aircraft until emergency power is required at which time it would be thrust into the slipstream.

2.2 The hydraulic schematics for unit extension and connection into the flying control hydraulic system are given in fig. 1 and 2 attached.

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2.2.1 The first problem is concerned with the electrical requirements of the aircraft. On a double engine flame-out the input speed to the constant speed drive drops off rapidly until the C.S.U. can no longer maintain the main aircraft alternators at their required operating speed. The main electrical supply is then cut-off. It is therefore essential

FORM 1319A

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2.2.1 for damping system requirements that at high Mach number the emergency power be available within 2 to 3 seconds after main supply failure.

The existing signal which indicates main A.C. supply failure is to be used to initiate the actuation of the turbine extension mechanism.

2.2.2 The aircraft speed at which the windmilling engines fail to provide enough power to operate the main A.C. supply is about Mach 1.0 at sea level and 1.5 at 55,000 ft. (These are Arrow I values but should be reasonably close to Arrow 2 figures). At this aircraft speed the ram air turbine will accelerate to operating RPM in about ½ second. This allows about 2 seconds maximum to get the unit out into the slipstream after the initiating signal is received.

The best power source for extension and retraction appears to be the utility hydraulic system. At the time the unit is needed, the hydraulic system pressure is being maintained by the windmilling engines.

The additional hydraulic equipment required to perform this function is:

1. A solenoid operated selector valve

2. A hydraulic actuator

3. POWER REQUIREMENTS

3.1 Flying Control Hydraulic Power Requirements

The windmilling engine(s) will supply sufficient power to the hydraulic pumps to bring the aircraft into the engine relight zone; but not sufficient to land the aircraft.

The hydraulic power required to land the aircraft based on stability and control requirements can be supplied by a 10 GPM, 500 psi pressure pump, supplying power to one flying control hydraulic system. This gives an input H.P. requirement of 3.25 assuming an overall pump efficiency of 90%.

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3.2 Electrical Power Requirements

The details of the electrical power requirements are given in appendix of this report.

For aircraft 1,2, and 3, the power required is 0.425KVA which is 0.64 H.P. assuming a power factor of 0.9 and an

3.2 Continued.

alternator efficiency of 80%.

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For aircrafts 6,7 and 8 the power required is 1.4 KVA, which is 2.11 H.P. at a power factor of 0.9 and an alternator efficiency of 80%.

3.3 Ram Air Turbine Power Requirements

The total power required is then for aircrafts 1,2, and 3 = 3.89 H.P. for aircrafts 6,7, and 8 = 5.36 H.P.

The landing speed of the aircraft at minimum weight is 120 knots. Due to the location of the unit when extended into the airstream, the effective forward speed of the turbine is 105 knots. This is due to the boundary layer effect on a 10° adverse yaw condition.

At this speed (i.e. 105 knots) the blade diameter of a unit to produce 5.63 H.P. is of the order of 18 to 19 inches.

The compromise on this requirement it is possible to lay down a landing speed of 140 knots minimum, under double engine out conditions. This is the minimum landing speed at maximum landing weight, and is obviously higher than the minimum landing speed at a lower weight. This gives an effective turbine forward speed of 123 knots. This reduces the blade diameter to about 15 inches to supply 5.63 H.P.

4. Attached also are two graphs (fig. 3 and 4) from report P/Performance/125 showing gliding time and distance from 60,000 ft. to sea level after double engine flame out.

5. UNIT WEIGHTS

The estimated weight of a unit to supply 5.63 H.P. @ 105 knots, plus the hydraulic equipment required to actuate it is about 40 lbs. Added to this will be the weight of structural strengthening required to absorb the air loads on the turbine, plus levers and locks.

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6. CONCLUSION

It is concluded that the use of a ram air turbine, to provide enough emergency electrical and hydraulic power to land the aircraft after double engine failure is a feasible proposition.

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MALTON - ONTARIO
TECHNICAL DEPARTMENT

REPORT No. P/Syst/35 App. 1
SHEET No. 1

AIRCRAFT:		PREPARED BY	DATE
ARROW	RAM AIR TURBINE INVESTIGATION		
		CHECKED BY	DATE

A/C 1,2,3 Arrow I

EMERGENCY ELECTRICAL LOADS

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A.C. Damping (Yaw)	29 VA	
Art. Horizon	67 VA	
J4 Comp.	99 VA	
IFF (APX-6A)	224 VA	
Hinge moment limiter	6 VA	
	425	
D.C. Damping (Yaw)	1.36 Amps	
Turn & Slip	.20	
Speed Brakes	.70	
Interphone (AIC-10)	2.55	(possibly high)
IFF (APX-6a)	1.45	
Canopy Seal	1.00	
Relight (10a for 20-30 sec.)	.20	average
Emerg. Flood lights	.60	(if used)
Misc. Relay Control	.80	
Hinge Moment Limiter	1.50	
U.H.F. (ARC 34)	18.00	
	28.36 Amps.	

Additional connected loads - normally not used
Fire Protection - Engine Emerg. fuel select - Bail out indication.

The 15 A.H. battery would supply the Arrow I loads for approximately 20 minutes considering the cut-off point at 14 volts. (battery discharged)

From the graph of descent vs. time for the Arrow I A/C (essentially the same for the Arrow II) the max. time from 60,000 ft. to S.L. is 15 minutes. The speed at 60,000 ft. was considered at M = .9 and therefore an additional minute would be required for battery use as the main power system would be lost at approximately M = 1.5.

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FORM 1719A

ARROW II A/C 6,7, & 8

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EMERGENCY ELECTRICAL LOADS

	Phase A (V.A.)	B (V.A.)	C (V.A.)
A.C. Damping (Yaw)	22	3.5	3.5
AN/APX-25A		245.0	
AN/ARC-52 (XN-4)	147	147	147
Roll Stabilized J4	69	15	15
GG-48 vert. gyro	18.3	18.3	18.3
Air Data Computer	165		
FD/A & Mach. Meter			72
I.D.I.			200
Hinge Moment Limiter		6.0	
Fuel & Oxygen Capacitance	32		
	453.3	434.8	455.8

Emergency Generator Rating 1.4 KVA P.F. .85 lagging to unity.

The fuel & oxygen capacitance gauges are connected to the A.C. emergency supply only to cater for a main bus fault condition.

Under this condition the ram air turbine will be extended into the slipstream even though both the engines are operating normally. The D.C. supply to these indicators is obtained from the main D.C. source in this case. This applies only to Arrow II aircraft, and the probability of it occuring is considered to be very remote.

D.C. Damping (Yaw)	1.36 amps		
Turn and Slip	.20		
I.D.I.	1.45		
U.H.F. (ARC-52(XN-4))	1.00	for 2 min	.6 for 30 min.
I.F.F.	1.80		
Speed brakes	.70		
Interphone AIC-10	2.55		
Canopy seal	1.00		
Misc. Relay control	.80		
Relight 12-14 amps/engine for 20-30 secs.	.70	average	
Engine services	4.00		
U/C indication (when down)	.50		
Emergency flood lights	.60	(if used)	
Pitch Trim (1A for 20 secs over 20 min period)	.02	average	
Hinge moment limiter continuous load	1.50		
	18.18		

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Additional connected loads (normally not used)

Fire Protection, Engine Emergency Fuel Selection, Stores Jettison Bail out Indication.

The 15 A.H. Battery would supply the Arrow II loads for approx. 40 - 45 minutes.

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RAFT ARROW COMPONENT

SHEET No. 6

REPORT No. P/SYSTEMS/35

DATE

PREP. BY D. POYSTON.

SECRET

ARROW 1
DESCENT AT (L/D) MAX BOTH ENGINES
W - 47,000 lb
WINDMILLING

DESCENT FROM 60,000 ft ALTITUDE

STANDARD ALTITUDE (1000 ft)

60 50 40 30 20 10 0

DISTANCE N.M.

90 80 70 60 50 40 30 20 10 0

DRIVEN
TORS
OWER
LINE

PLY

1.48

SECRET

FORM 1746

CRAFT ARROW COMPONENT

W:

SHEET No. 7 REPORT No. P1SYSTEMS/35

DATE PREP. BY D. ROYSTON

SECRET

ARROW 1
DESCENT AT (L/D)MAX. BOTH ENGINES
320 MILLS @ 47000 LB

TIME FROM 60000' TO ALTITUDE

TIME - MINS

STANDARD ALTITUDE (1000 ft)

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Fig 4

FORM 1746

REPORT F-3200-1

SHT 12-105

JAN 12/57

CF-105

ENVELOPE OF A/C CONTROL AS LIMITED BY THE RATE OF MOTION OF THE FLYING CONTROL SURFACES FOR THE CONDITIONS GIVEN

PATH 15 FOR J-75 ENGINE

ALTITUDE

60000

50000

40000

30000

20000

10000

S.L.

ENGINE RE-LIGHT ENVELOPE

BOTH ENGINES WINDMILLING

ONE ENGINE WINDMILLING ONE ENGINE SEIZED

.4 .5 .6 .7 .8 .9

MACH NO.

SECRET

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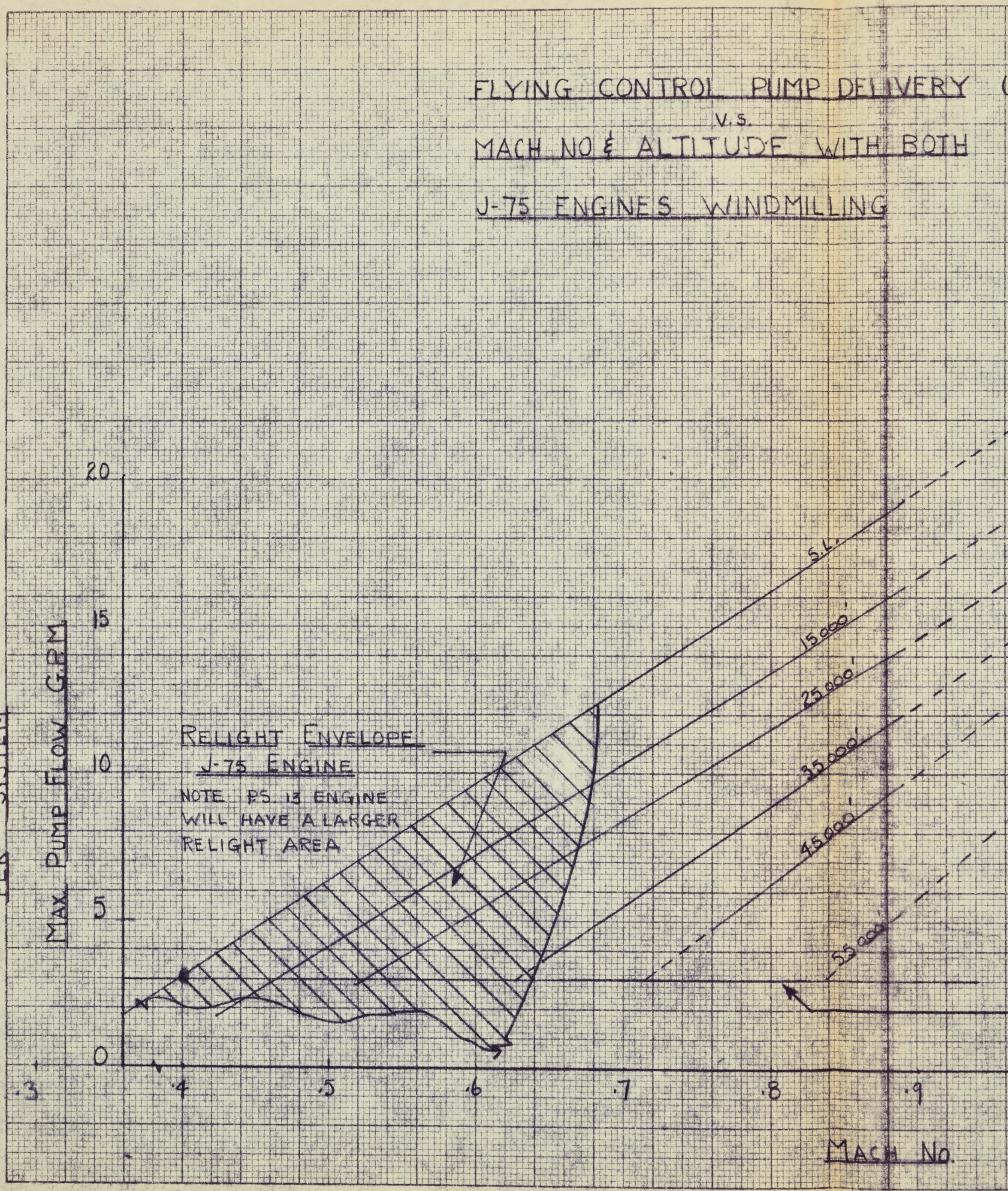
FLYING CONTROL PUMP DELIVERY (

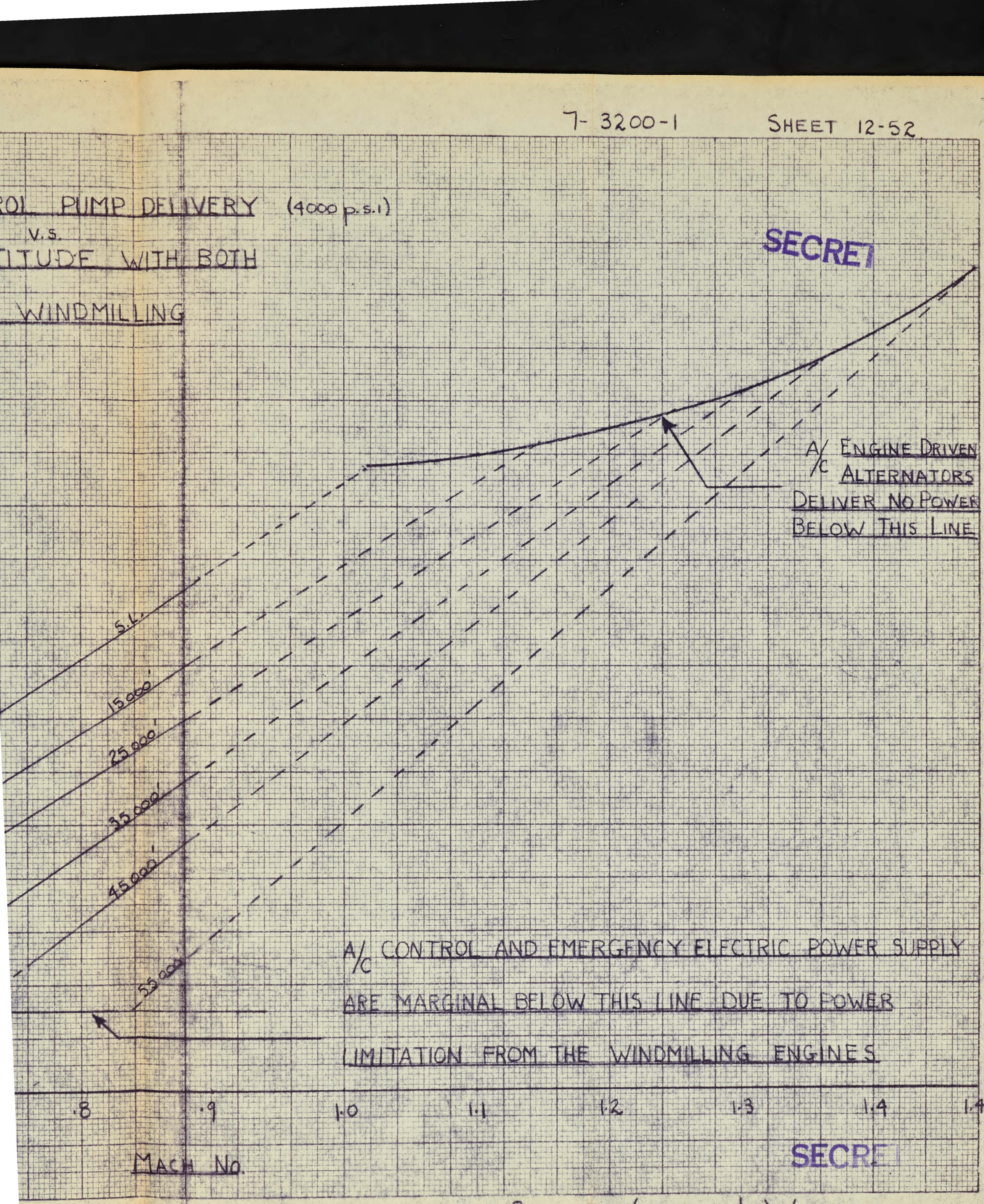
V.S.

MACH NO & ALTITUDE WITH BOTH

J-75 ENGINES WINDMILLING



ROL PUMP DELIVERY (4000 p.s.i)
V.S.
ITUDE WITH BOTH
WINDMILLING



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