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Report No. 72/Systems 22/170

ENVIRONMENTAL PROTECTION FOR CREW MEMBERS ARROW 2

UNCLASSIFIED

May 1958

G. Shaw

AVRO AIRCRAFT LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

SECRET

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TABLES

FIGS.

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   "Cockpit environment tests"
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1. INTRODUCTION

1.1 Requirements for the Arrow "cockpit environment" stipulate that the temperature shall be maintained between 40 and 80°F and the pressure maintained to a schedule as shown in Figure 1.

The system selected to meet these requirements is an air cycle system utilizing air bled from both main engine compressors.

The system performance is dependent on engine bleed pressures and therefore, during certain flight and ground conditions where low bleed pressures occur, there will be a deterioration in system performance. A system designed to satisfy all conditions would be unduly complex and heavy. The Arrow air conditioning system, as is any aircraft system, is a compromise between performance, complexity and weight. The problem areas resulting from this compromise are:

(a) Cockpit cooling during standby using the support vehicle.

(b) Cockpit cooling while taxiing.

(c) Cockpit cooling and pressure during descent (Normal Operation)

(d) Pressurization during zoom to high altitude.

(e) A final problem common to any system is system failure.

1.2 Since these problems occur with all present day military aircraft, considerable development work has been done on gear to protect the air crew from high temperature and low pressure. This gear, consisting of ventilated suits and pressure suits, does not in itself obviate the necessity of an air conditioning system for the cockpit, although it may somewhat reduce the problem. Also, the use of ventilated and/or pressurized suits in itself carries a penalty of added weight and complexity.

1.3 This report discusses the problem areas outlined above, the various types of protective gear to be considered, and the system requirements for them.

2. PROTECTIVE GEAR

2.1 The present equipment consists of

(a) the air conditioning system which controls the cockpit pressure and air temperature within the stipulated limits for normal flight.[2.1]

(b) A pressure vest worn by the crewman and interconnected with the anti "G" suit for emergency pressure protection.

With the Std. A13A mask this gear will give 5 min. protection @ 50,000 feet. With a pressure helmet this can be extended to 5 min. at 65,000 feet.

No special gear is worn by the crew members for protection against high temperature.

2.2 Two items are under development at I.A.M. which could be fitted to the Arrow.

2.2.1 The first of these is a vent suit for protection against high temperature. The requirements for this suit are given as 13 CFM of air per minute with a pressure of 10" W.G. at the suit inlet. Since this suit works primarily on the evaporation of sweat the actual air temperature can vary over wide limits providing it is dry enough.[3]. Figure 2 illustrates the flow and pressure drop characteristics of this suit. The suit is currently being developed and evaluated at I.A.M.

2.2.2 The second item which is presently under development at I.A.M. is a full pressure suit.

Since this suit covers the man in an impervious layer it must at all times be supplied with a ventilating air supply identical with that of the ventilated suit.

The pressure suit is normally deflated and acts as a ventilated suit. If the cabin pressure fails it will inflate and can give indefinite protection to any altitude. In this case the suit requires the same air flow as above but at a pressure equivalent to the

2.2.2 (Continued)
altitude desired in the suit.

3. PROBLEM AREAS

3.1 General Remarks

This section of the report covers in detail the problem areas outlined above and the limitations of the present system.

It is difficult to make a positive statement as to the severity of the problems, since we are dealing with human reactions to an environment. The physical characteristics of this environment such as time, temperature, humidity and pressure, all have to be taken into account.

In each case discussed, the following environmental data, when known, is presented:

(a) Duration of condition (min.)
(b) Cockpit pressure (psia)
(c) Cockpit mass flow (#/min.)
(d) Cockpit air temperature in and out (^{o}F)

This data is in the main based on a theoretical system analysis.[7]. There is therefore, the possibility of a small plus or minus error.

NOTE: (a) The outlet temperature should be considered the actual air temperature in the cockpit. The air temperatures quoted are actual air temperatures not environmental temperatures.

3.1 (Continued)

Such things as solar radiation, radiation from wall to man, air velocity, humidity and clothing worn by the man all effect the environmental temperature to some extent.

(b) The moisture content of the cockpit air will be the same as ambient since there is no moisture removal equipment in the system.

The study shows that the present equipment is marginal from a temperature aspect during taxi and standby on the ground and possibly following system failure during flight. From a pressure aspect the system is marginal during the zoom climb.

To evaluate the seriousness of ground conditions, the probability of the occurence of high temperatures should be considered. Figure 3 gives this data for South Western Ontario (Centralia.) Due to the high temperature and humidity, this is considered the worst area [5] in Canada.

In order to properly evaluate borderline cases it may be necessary to simulate conditions in a controlled test. Work is in progress at Avro to investigate air flow, noise and heat transfer in the cockpit [4]. There is also a program at I.A.M. to investigate ventilated suits.

3.2 Cockpit Cooling During Standby using Support Vehicle

The original ground supply requirement was for 150 lb. of air/min. This allowed for 27.5 lb./min. to the cockpit. The requirement has since been reduced to a total of 130 lb./min. with 7.5 lb./min. alloted to the cockpit.[6].

Figure 4 illustrates the cockpit temperature (canopy closed) vs. ambient temperature for flows of 27.5 and 7.5 lb./min.

During normal maintenance work it is assumed the canopy will be open. However, if there is an operational requirement to hold an A/C on standby with the mobile support equipment, particularly if the canopy must be closed, a serious temperature problem arises, as can be seen from the chart.

3.3 Cockpit Cooling While Taxiing

Figure 5 gives the estimated cockpit temperature vs. ambient temperature for taxi conditions, (canopy closed). Table 1 covers the experience to date on Aircraft 25201. The cockpit air flow on Aircraft 25201 is approximately 15 lb./min. The expected flow in the Arrow 2 is approximately 27.5 lb./min.

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If required to taxi with the canopy closed there is a temperature problem. However, there appears to be no reason why taxiing cannot be carried out with the canopy open.

A technique which can be used if the canopy must be closed is to stop the Aircraft and increase the engine RPM. The effect of this is shown in Figure 6.

This method may also be used to clear overheat warnings in the equipment cooling system.

3.4 Cockpit Cooling & Pressure During Descent (Normal Flight)

The air conditioning system has been designed to satisfy all conditions during normal flight.

Figures 7, 8 and 9 give the cockpit pressure, temperature and air flow plotted against time for an extreme mission. The conditions plotted are for steady state conditions which in many cases will not be reached in actual flight. This must be borne in mind when studying the curves.

The descent conditions do not fully meet the requirements, but are considered as transients of a short enough duration to be no problem. In any case a descent technique can be worked out to minimize the problem. One marginal condition not shown is the corner of the flight envelope covering subsonic flight @ 50,000.

This is not a realistic condition since at this point aircraft performance is very poor.

Not Point

The conditions here are:

Cockpit	Temperature in	- 47°F
	Temperature out	- 70°F
	Mass Flow	- 15.4 #/min.
	Pressure	- 5.93 psia 23,000'

These conditions are considered satisfactory.

3.5 Pressurization During Zoom to High Altitude

Using the kinetic energy of the aircraft it is possible to reach an altitude of 70,000' at M=1.65.

The steady state cockpit conditions here are:

Cockpit	T in	50°F
	T out	109°F
	Mass Flow	- 11 #/min.
	Pressure	- 4.89 psia - 27,500'

This flight condition can be maintained for approximately 10 sec.

The time to descend from 70,000' at M=1.65 to 65,000' is 26 sec. Minimum.

In case of cockpit pressure failure the present pressure protection is approximately 1 min. at 70,000' and 5 min. @ 65,000'. (Using pressure helmet).

3.6 System Failure

Any failure which necessitates shutting down the air conditioning system will result in aborting the mission

3.6 (Continued)

since the fire control system must also be shut down. The emergency procedure is to shut off air conditioning, reduce speed and descend to 40,000'.

An emergency ram air system is provided which will begin to operate when the stagnation temperature falls below ? 100°F.

The problem here is the temperature rise during deceleration from M=2.0 covering a period of approximately 3 min. It has been estimated that this temperature rise will peak at approximately 140°F. An attempt will be made to duplicate this in Avro's cockpit environment tests[4] to establish the max. temperature in the cockpit during this transient condition.

Figure 10 illustrates the limitation of the emergency ram air system from a temperature consideration. Cockpit flow would be approximately 5#/min. @ 40,000 - cockpit unpressurized (i.e. - Pressure dump switch "on") - and 10 #/min. @ S/L.

For general information - Figure 11 gives ram air temperature vs. M. No.

4. SYSTEMS

4.1 It is the purpose of this section to outline what sub-systems would have to be added to the airframe to cater for the vent suit and the full pressure suit.

4.1 (Continued)

These systems are discussed under the following headings:

(1) Supply for a vent suit for ground use only.

(2) Supply for a vent suit for use on the ground and in flight.

(3) As above with the addition of an emergency supply to cater for system failure and to assist during taxi.

(4) Supply for a pressure suit including an emergency supply.

Flow and pressure drop characteristics of these garments have been previously stated in sections 2.2.1 and 2.2.2. The effective cooling capacity is dependent on both temperature, humidity and flow. Data on this is scanty. For the purpose of system design a min. S/L flow of 13 CFM and a max. temperature of 80°F has been assumed.

4.2 <u>Ventilated Suit for Ground Use Only</u> System No. 1

4.2.1 This system is shown in Figure 12. Air is taken from the main system at the start of the equipment section and ducted to the suits via a shut-off valve operable by the crew members.

4.2.2 With the aircraft on standby, the ground servicing unit will supply air at from 55 to 66°F, this temperature being determined by the requirements for the equipment cooling air. Pressure available will be a function of the total equipment cooling flow (see Figure 13); if this is 122.5 lb/min (ref. paragraph 3.2) the available pressure is 30" w.g. and, making allowance for ducting losses and cockpit back pressure, suit flows of 20 CFM each could be obtained. (Ref. Figure 2.)

4.3 <u>Ventilated Suit for Ground and Flight Use (Fig. 14)</u>
<u>System No. 2</u>

4.3.1 This system is similar to the previous one, but a booster fan has been added to cater for a lack of pressure under some flight conditions which result in flows less than the assumed requirements; this deficiency arises because cockpit flows are normally larger in flight (27.5 lb/min.) than during standby (7.5 lb/min.) and the suit system therefore, works against a larger back pressure.

4.3.2 Performance for the standby case is identical with that of the previous system; the booster fan is not essential under these conditions.

4.3.3 Under flight conditions the temperature of the air supply to the suit will be approximately 55^{0}F for most cases. Should it be considered desirable to have a higher inlet temperature, an electrical heater would be provided, having a rating of 250 W. Adequate flow rates can be maintained by suitable choice of the booster fan. The suit supply temperatures from this system have been checked for a typical hot day combat mission and the results are shown in Table 2. It will be seen that temperatures exceed the assumed limit for sea-level cases at low forward speeds.

4.3.4 The system has no provision for meeting emergecny conditions such as system failure.

4.4 <u>Ventilated Suit Supply with Emergency Provisions (Fig.15) System No. 3</u>

4.4.1 The deficiencies of the previous system can be largely rectified by providing a storage system of liquid nitrogen to meet the cases of excessive temperature. A thermostat located in the equipment supply line will be used to actuate a change-over valve when this temperature exceeds, say, 80^{o}F; as soon as this temperature falls below 80^{o}F again the suit supply will be restored to the main system.

4.4.2 Performance for the standby case is unaffected by this change, and remains as for the previous systems.

4.4.3 Under flight or taxi conditions the gas supplied to the ventilated suit will never exceed 80°F and will usually be around 55°F. The capacity of the liquid storage is determined primarily by the requirements of the taxi condition and it is proposed to allow for 15 minutes taxi, plus 5 minutes use in flight to cover transient temperature peaks during deceleration. This gives a minimum requirement of 40 lb. of nitrogen.

4.4.4 This system will give protection during deceleration after system failure.

4.5 Air Supply for Pressure and Ventilated Suit (Fig.16) System No. 4

4.5.1 None of the system so far described could provide the pressure needed for a full pressure suit as they all draw air from the low pressure side of the expansion turbine. To ensure an adequate supply pressure the system now under discussion takes air from the high pressure side of the expansion turbine, between the turbine and water evaporator.

4.5.1 (Continued)

Air from this source is considerably hotter than it would be from downstream of the turbine, ranging up to 215°F and for this reason a cooler is included, using equipment air as a cooling fluid.

Also because of the higher supply pressures involved it is necessary to include a flow control unit; the booster fan, can, of course, be eliminated. As before liquid nitrogen storage is provided for emergency conditions, but a separate line from the ground service main system supply will be required; the heater can be provided if necessary.

4.5.2 Performance for the standby condition is essentially unaltered in comparison with any of the previous systems.

4.5.3 An estimate of the temperatures and pressures available at the inlet to the flow controller has been made for a typical hot day combat mission and the results are summarized in Table. 2. The nitrogen supply would be used for the sea-level low speed cases where temperatures are excessive.

4.5.4 This system provides crew protection for several emergency conditions.

In the event of the main system being shut down, pressure is still available for the suits since their air supply is taken from upstream of the shut off valve.

4.5.4 (Continued)

The equipment flow is not available for cooling, but, because of the greatly increased efficiency of the main system heat exchanger, which uses ram air, air temperatures to the suits will be very close to ram air temperatures. (See Table 2.) It is envisaged that in the event of the main system being shut down the aircraft will immediately head for base at subsonic speed and ram temperatures will then not exceed 30°F during this cruise. During deceleration prior to reaching the cruise condition the nitrogen system will be used.

Should there be a simultaneous flame out of both engines, as could occur at high altitude, cockpit pressure and system pressure would both be lost and the pressure suit would be supplied from the nitrogen system. For this purpose a pressure switch is incorporated in the system (Figure 16) so that the supply is automatically maintained. If cockpit pressure is lost due to excessive leakage the pressure suit supply will function essentially as for normal flight conditions, even though the cockpit flow is shut off.

5. CONCLUSION

From the study on problem areas it is seen that additional protection is required for standby with the ground vehicle. There are other areas where the system is marginal, i.e. taxi, deceleration after system failure and descentafter loss of cockpit pressure.

Table 3 is a comparison of systems studied to cover the ground standby case and the marginal cases. Table 4 gives the weight penalty involved in these systems.

If there is a requirement for holding the Aircraft on standby it is recommended that system No.2 be used since it will help the taxi case.

If a decision is made for more complete protection, system No. 4 is recommended since the weight and complaxity is very little greater than No. 3 and the protection offered much greater.

There are a number of technical points which should be cleared up before a decision is made.

(a) The limiting range of suit supply air temperature pressure and humidity. (Ref. Section 4.1)

(b) Peak temperatures that can be reached during deceleration from M=2.0 with main system failed (Ref. Section 2.6)

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Table 1 - Taxi times Aircraft 25201

Time from engine start to take off in min.

Flight No.		min.
1	-	43
2	-	29
3	-	20
4	-	16
5	-	7
x6	-	23
7	-	37
8	-	18
9	-	8
		22.3 min. Average

Notes:

(a) x Pilot commented on high temperature in cockpit

Date April 18, 1958
Time 1 P.M.
Conditions Clear, Ambient temperature approximately 70°F.

A decision was made after flight No. 6 to taxi with canopy open if temperatures were high. Previous to this the canopy had been closed before engine starting.

(b) This flying involved operation from a commercial airport with a prototype aircraft. Service flying should involve shorter taxi times.

ARROW 2 - AIR-CONDITIONING.

PERFORMANCE OF AIR SUPPLY SYSTEMS FOR PRESSURE

TYPICAL COMBAT MISSION. U.S.A.F. STAND

FLIGHT CONDITION	TAXI	START OF TAKE-OFF	START OF CLIMB	CLIMB	CLIMB	SUPER-SONIC CRUISE	CO
HEIGHT (FT.)	S.L.	S.L.	S.L.	30,000	30,000	50,000	6C
MACH Nº.	0	0	0.92	0.92	1.50	1.50	1
AMBIENT TEMP. (°F)	103	103	103	-16	-16	-39	-
	SYSTEM #2 : VENTILATED SUIT						
COCKPIT ALTITUDE (FT)	S.L	S.L.	S.L.	18,300	18,300	23,000	2
FLOW AVAILABLE WITHOUT BOOSTER FAN (C.F.M. /SUIT)	9.1	10.9	11.4	16.6	16.6	19.8	2
MINIMUM TEMPERATURE AVAILABLE FOR SUIT (°F)	94	66	54	56	56	56	
	SYSTEM #4 : PRESSURE x VEN						
TEMP. AVAILABLE FROM MAIN SYSTEM (°F)	99	76	83	70	82	76	
PRESSURE AVAILABLE FROM MAIN SYSTEM (psig.)	4.2	58.5	58.0	43.4	55.1	28.3	2
	SYSTEM #4 : MAIN SYSTEM SHUT						
TEMPERATURE AVAILABLE FROM MAIN SYSTEM (°F)	103	103	194	57	183	151	

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TABLE 2

...PRESSURE x VENTILATED SUITS.

...T STANDARD HOT DAY

	SUPER-SONIC CRUISE	COMBAT	START OF DESCENT	SUB-SONIC CRUISE	DESCENT	END OF DESCENT	CIRCUIT.	TOUCH-DOWN.
	50,000	60,000	60,000	40,000	40,000	S.L.	S.L.	S.L.
	1·50	1·92	1·92	0·92	0·92	0·40	0·40	0·17
	-39	-24	-24	-44	-44	103	103	103

...TED SUIT WITHOUT EMERGENCY PROVISION

	23,000	25,700	25,700	21,100	23,100	S.L.	S.L.	S.L.
	19·8	24·8	0	20·7	0	11·6	11·4	9·5
	56	54	56	52	56	73	53	90

...URE x VENTILATED SUIT. — NORMAL FLIGHT

	76	74	76	73	53	86	69	95
	28·3	21·7	8·5	19·0	5·6	12·4	20·7	4·6

...STEM SHUT-OFF VALVE CLOSED

	151	152	152	26	26	121	121	106

ARROW 2. AIR- CONDITIONI

AIR SUPPLY FOR PRESSURE x VE

. COMPARISON OF SUB- SYST

AIRCRAFT OPERATING CONDITION	STANDBY. USING GROUND SUPPORT VEHICLE. CANOPY CLOSED.	TAXI
PRESENT SYSTEM.	NOT SATISFACTORY FOR HIGH AMBIENT TEMPS.	NOT SATISFACTORY FOR AMBIENT TEMP. ABOVE 65°F WITH CANOPY CLOSED.
SYSTEM #1 VENT. SUIT FOR GROUND USE ONLY	COMPLETE PROTECTION.	AS ABOVE
SYSTEM #2. VENT SUIT FOR GROUND x FLIGHT USE	COMPLETE PROTECTION.	MARGINAL.
SYSTEM #3. AS FOR #2, WITH AN EMERGENCY GAS SUPPLY	COMPLETE PROTECTION	COMPLETE PROTECTION. EMERGENCY SUPPLY USED.
SYSTEM #4. FULL PRESSURE x VENT. SUIT.	COMPLETE PROTECTION.	COMPLETE PROTECTION. EMERGENCY SUPPLY USED.

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...URE × VENTILATED SUITS.

TABLE 3.

SUB- SYSTEMS.

AXI	SYSTEM FAILURE × SHUT-OFF. DECELERATION FROM $M_N = 2.0$	LOSS OF COCKPIT PRESSURE	
SATISFACTORY AMBIENT TEMP. F 65°F WITH Y CLOSED.	MARGINAL	PROTECTION FOR 1 MIN. AT 70,000' 5 MIN. AT 65,000'	
ABOVE	AS ABOVE	AS ABOVE	
RGINAL.	AS ABOVE	AS ABOVE.	
PLETE TECTION. RGENCY PLY USED.	COMPLETE PROTECTION. EMERGENCY SUPPLY USED.	AS ABOVE	
MPLETE TECTION. RGENCY LY USED.	COMPLETE PROTECTION. EM. SUPPLY USED DURING DECELERATION. A/C. SYSTEM FOR CRUISE HOME.	COMPLETE PROTECTION. EM. SUPPLY FOR DESCENT FROM 70,000'. A/C SYSTEM FOR CRUISE HOME.	

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TABLE 4

SYSTEM WEIGHT ANALYSIS

SYSTEM	1	2	3	4
Ducting	3.0	3.0	3.0	5.0
Mtg. brackets	2.0	2.0	2.0	2.0
Shut-off valve	0.5	0.5	0.5	0.5
Booster fan	-	3.0	3.0	-
Heater	-	1.5	1.5	1.5
Heater Controls	-	2.0	2.0	2.0
Liquid Nitrogen	-	-	40.0	40.0
Nitrogen storage	-	-	40.0	40.0
Change-over valve	-	-	1.0	1.0
Emerg. Controls	-	-	1.0	1.0
Flow controller	-	-	-	2.5
Heat exchanger	-	-	-	4.0
Check valve	-	-	-	0.5
Totals (lb.)	5.5	12.0	94.0	100.0

Note: The weights of the suits themselves are not included in these totals.

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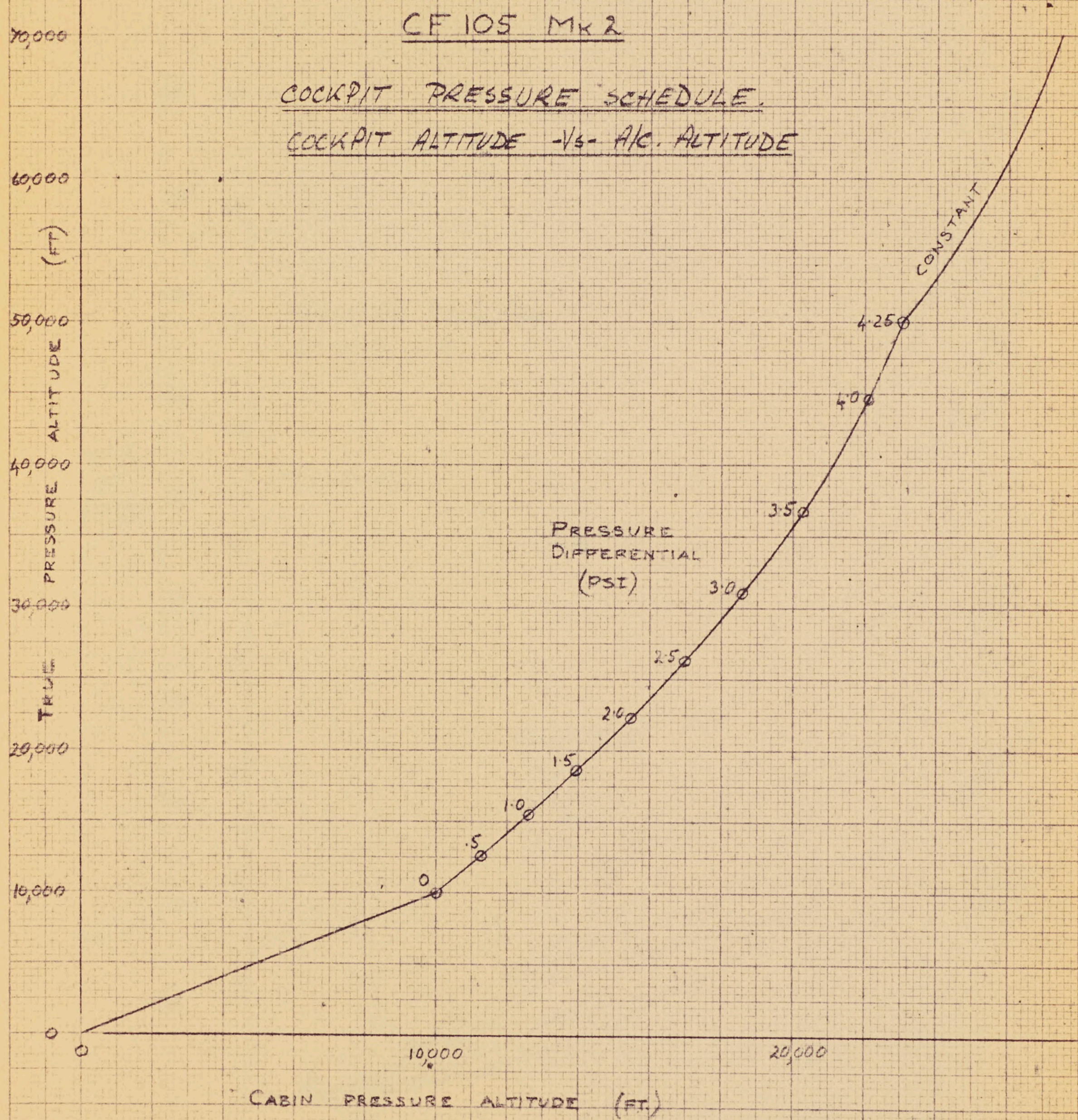
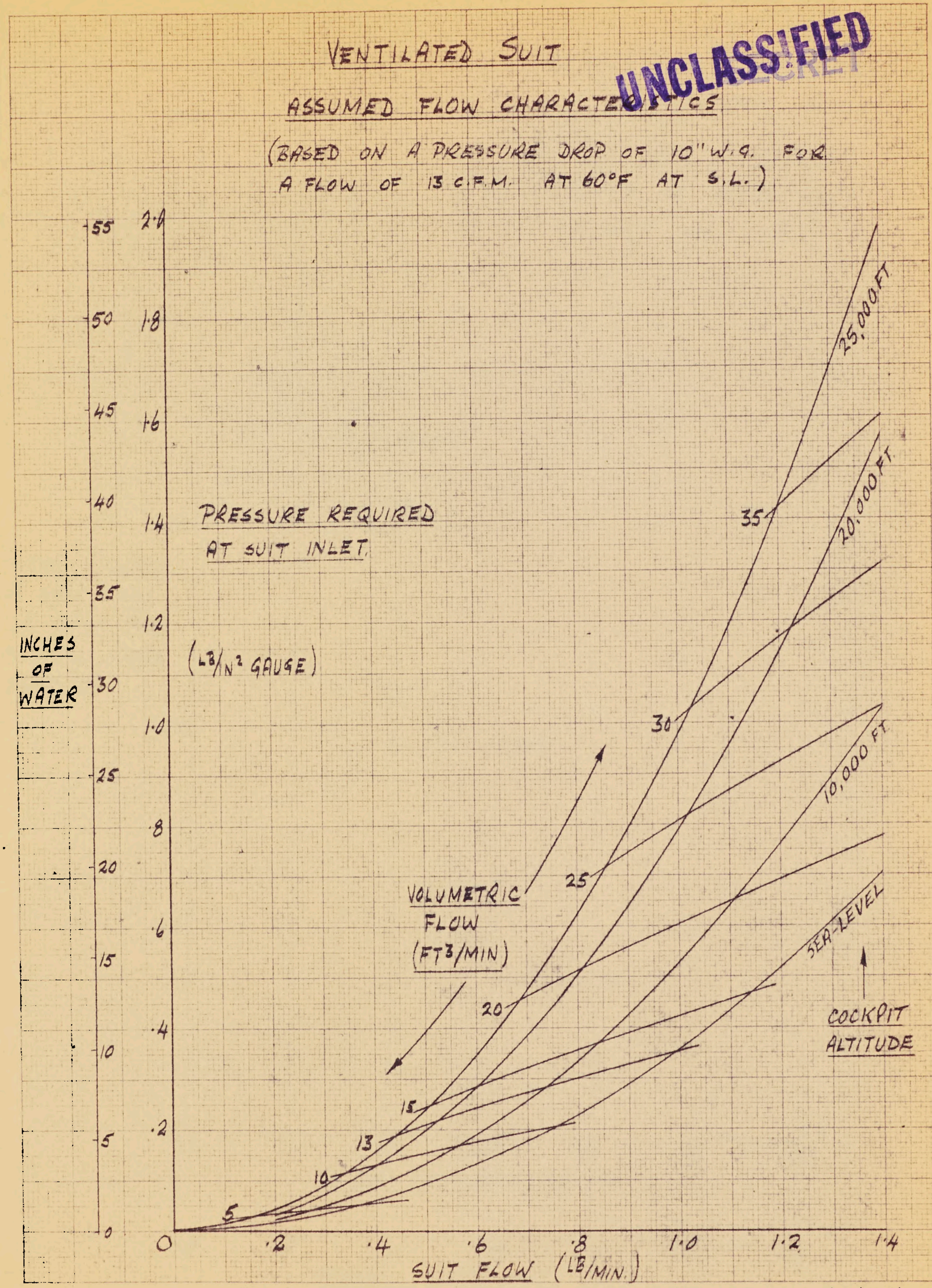


K+E 10 X 10 TO THE ½ INCH 359-12
KEUFFEL & ESSER CO. MADE IN U.S.A.

J. DUBBURY. APRIL '58.



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REPORT N° 72/SYSTEMS 22/170 FIG. 3

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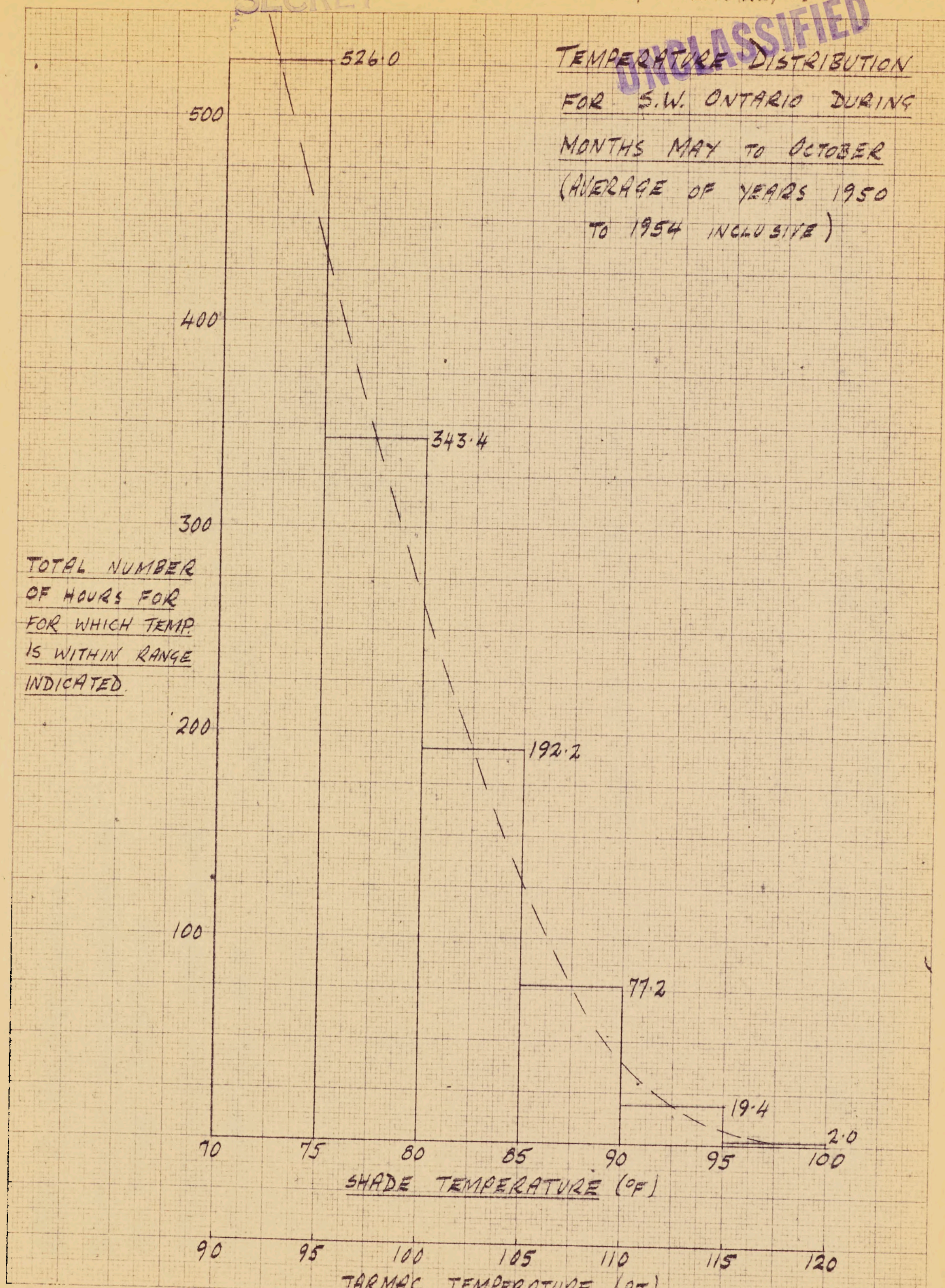

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REPORT No 72/SYSTEMS 22/170 FIG. 4

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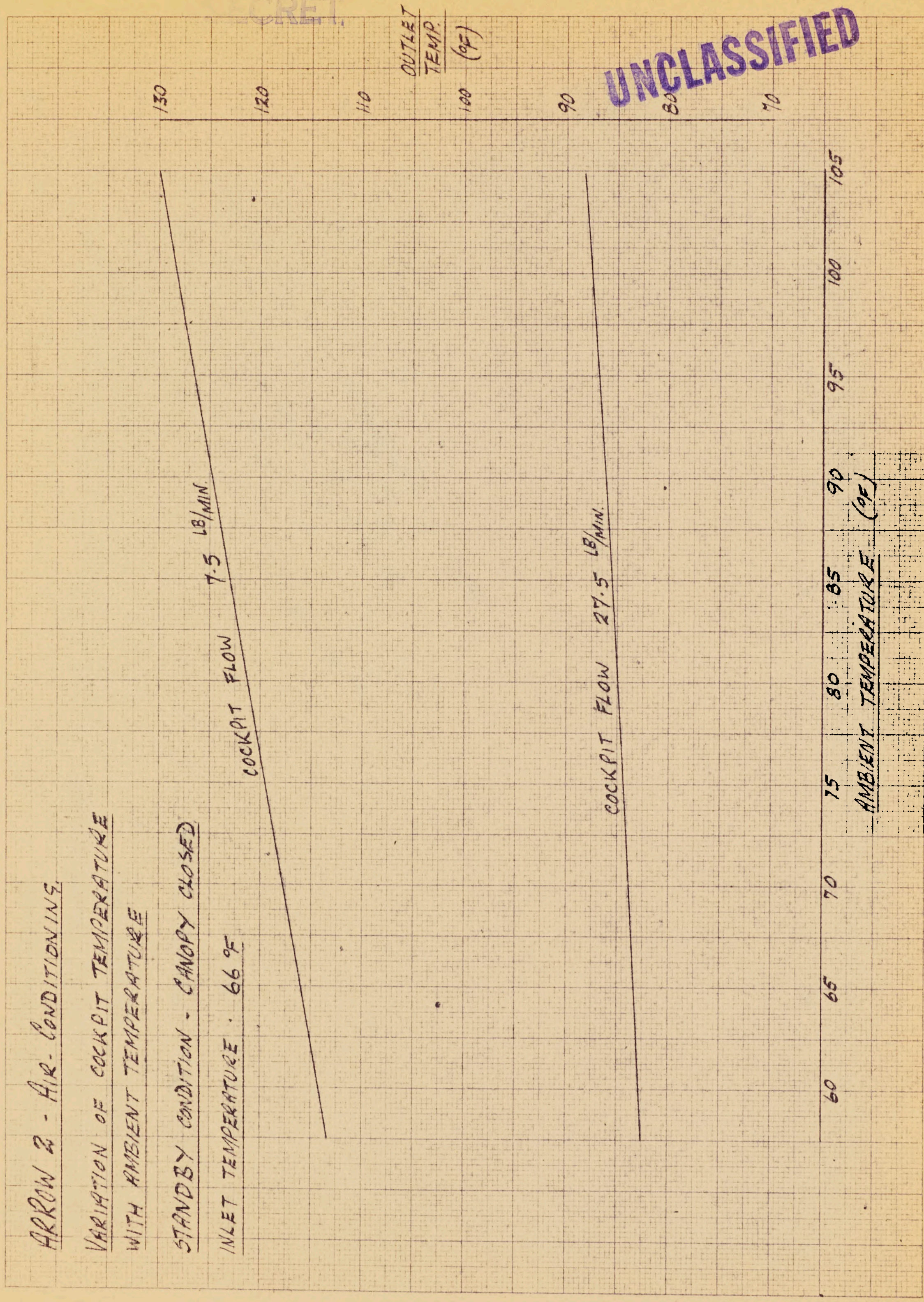

K&E 10 X 10 TO THE CM. 359-14 KEUFFEL & ESSER CO.

REPORT No 72/SYSTEMS 22/170 FIG. 5

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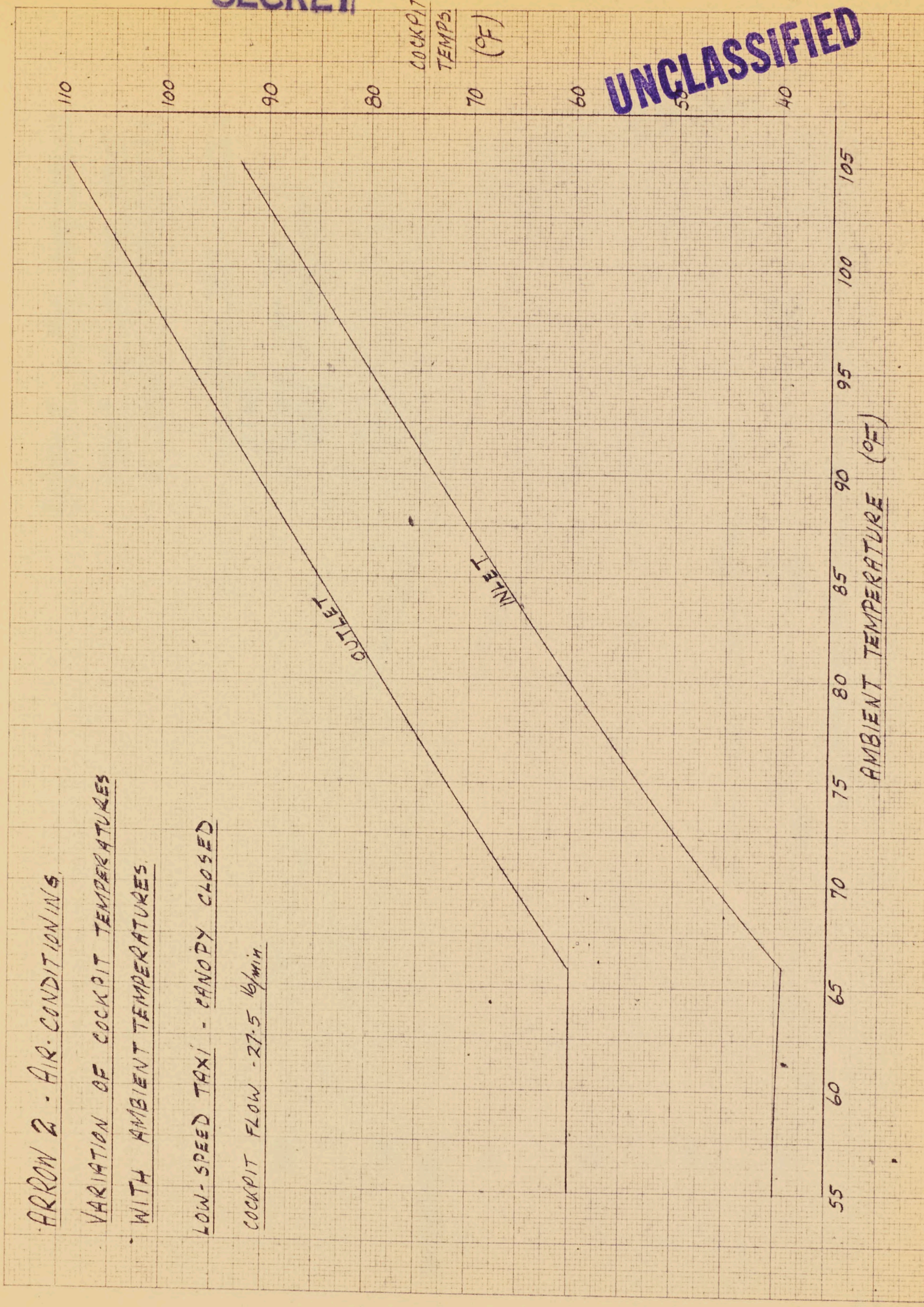

ARROW 2 - AIR CONDITIONING.

VARIATION OF COCKPIT TEMPERATURES WITH AMBIENT TEMPERATURES.

LOW-SPEED TAXI - CANOPY CLOSED

COCKPIT FLOW - 27.5 lb/min.

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REPORT No 72/SYSTEMS 22/170 FIG. 6

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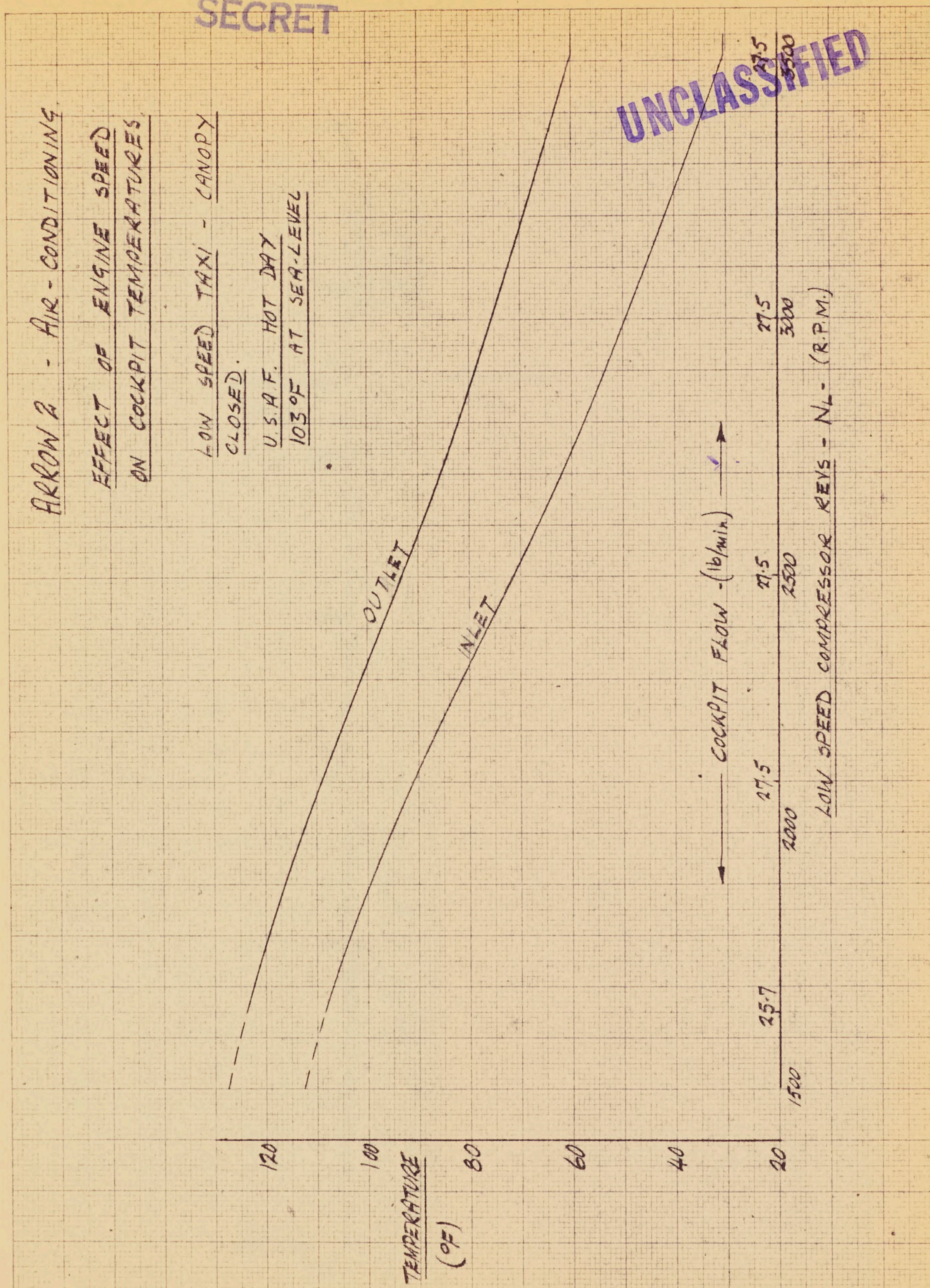

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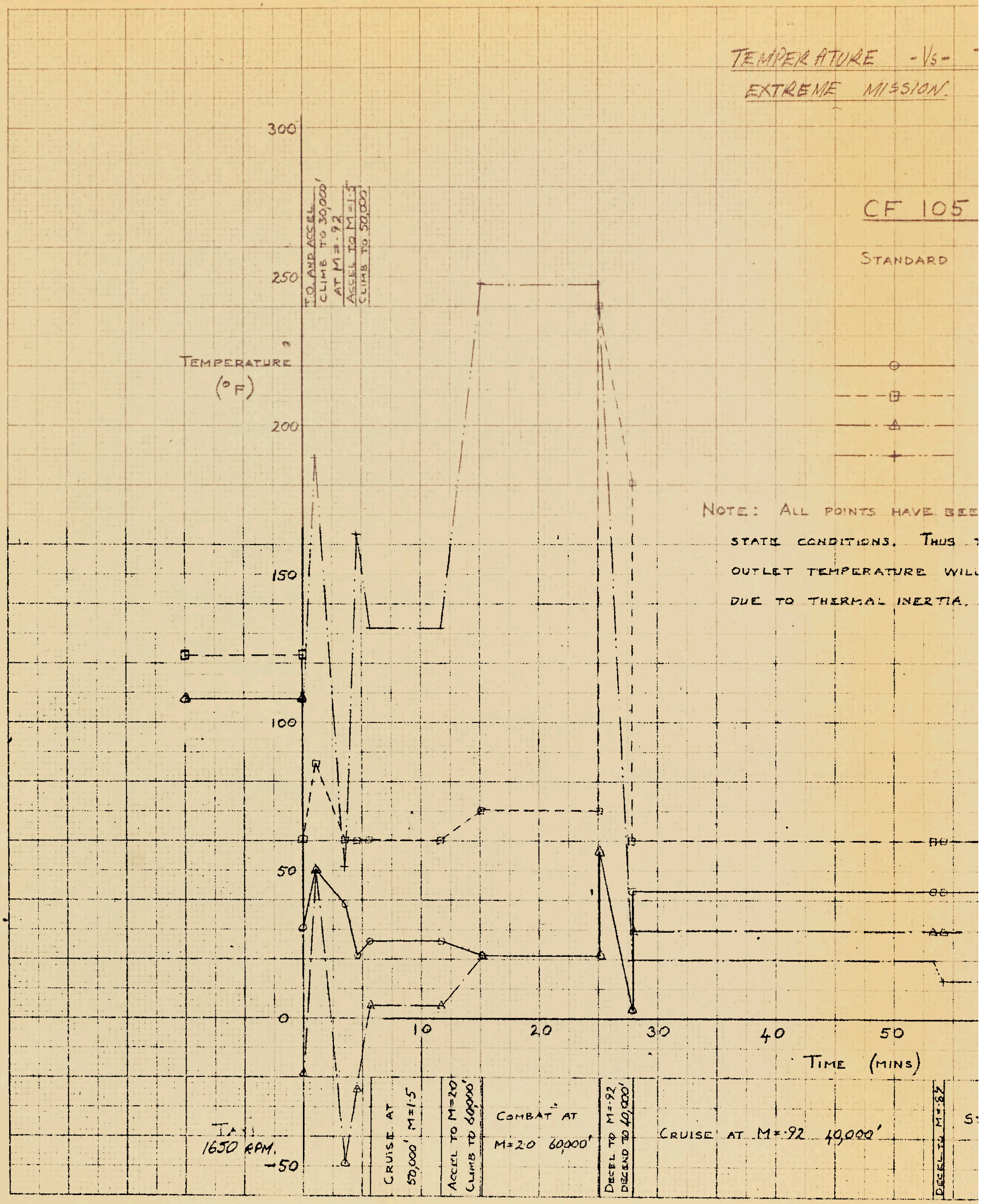
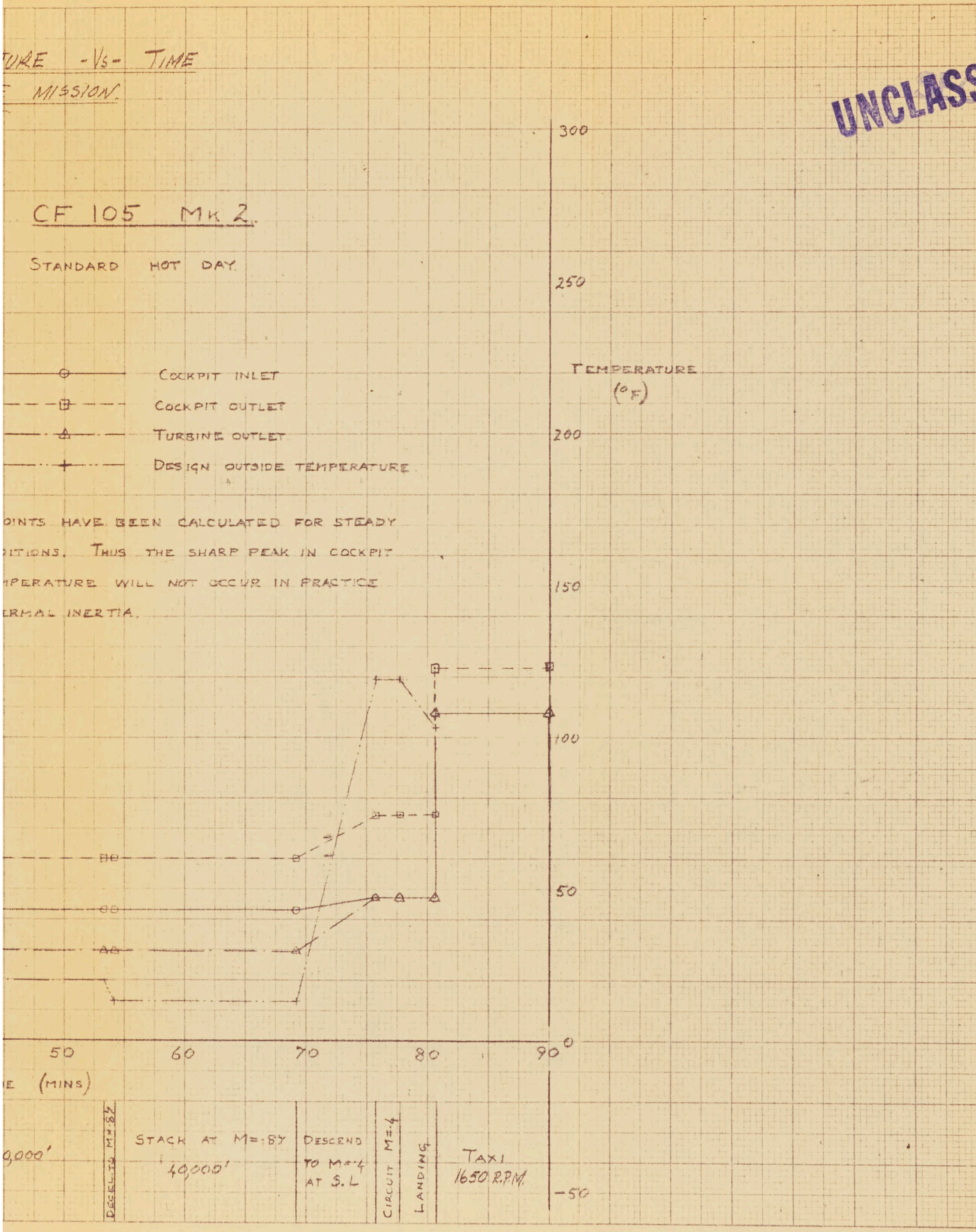
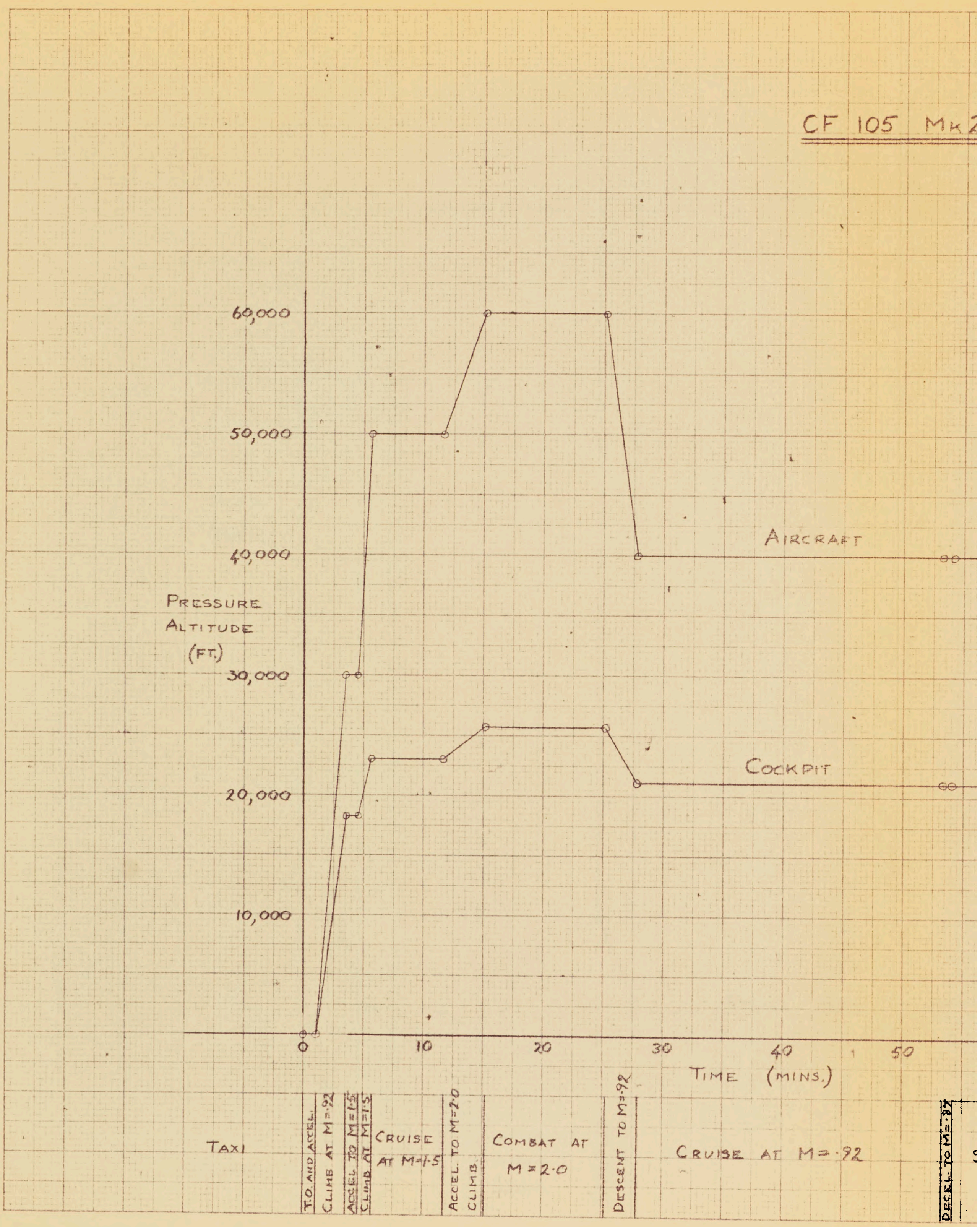


10 X 10 TO THE 1/2 INCH 359-11L

REPORT No 72/SYSTEMS 22/170 FIG. 7

UNCLASSIFIED

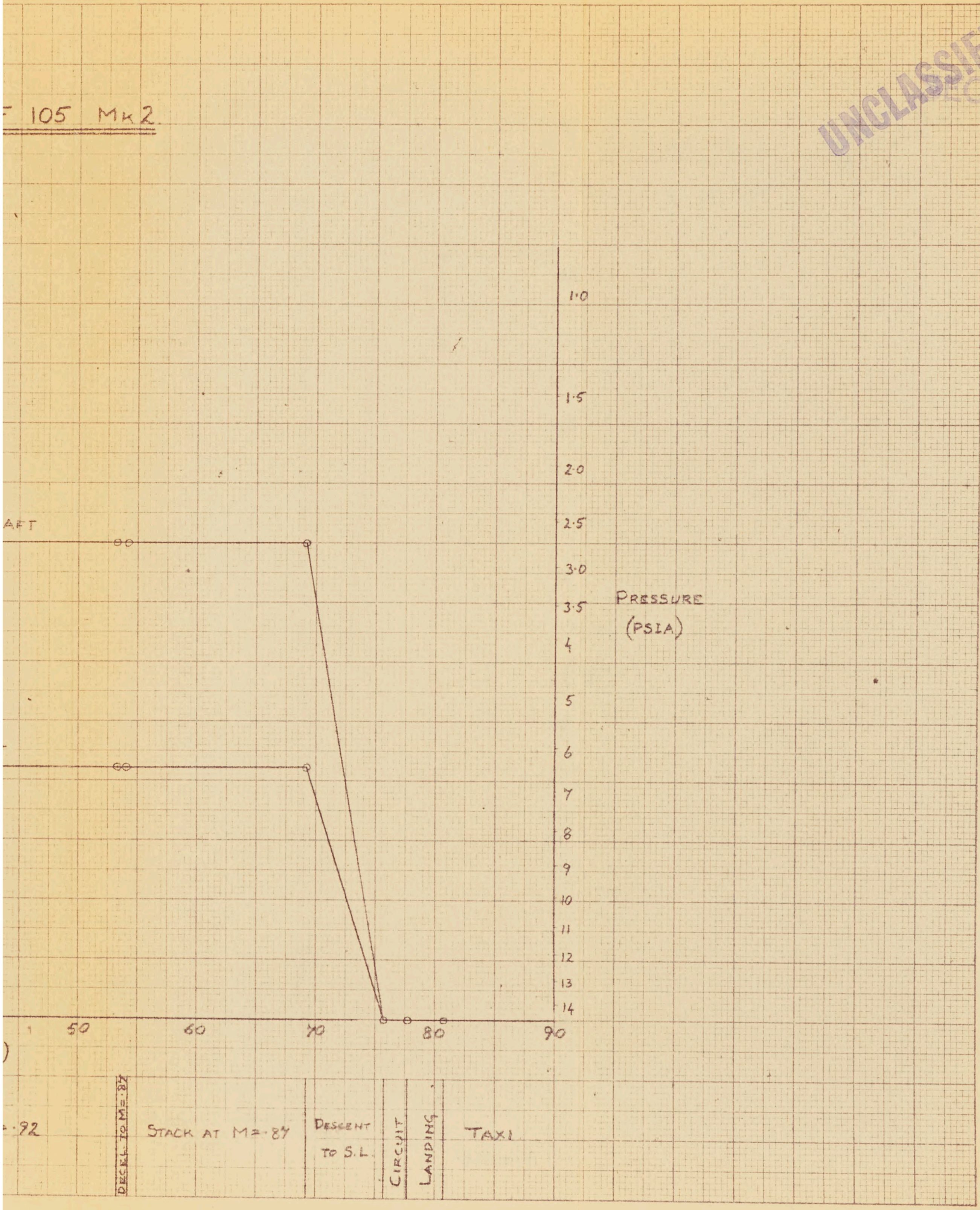


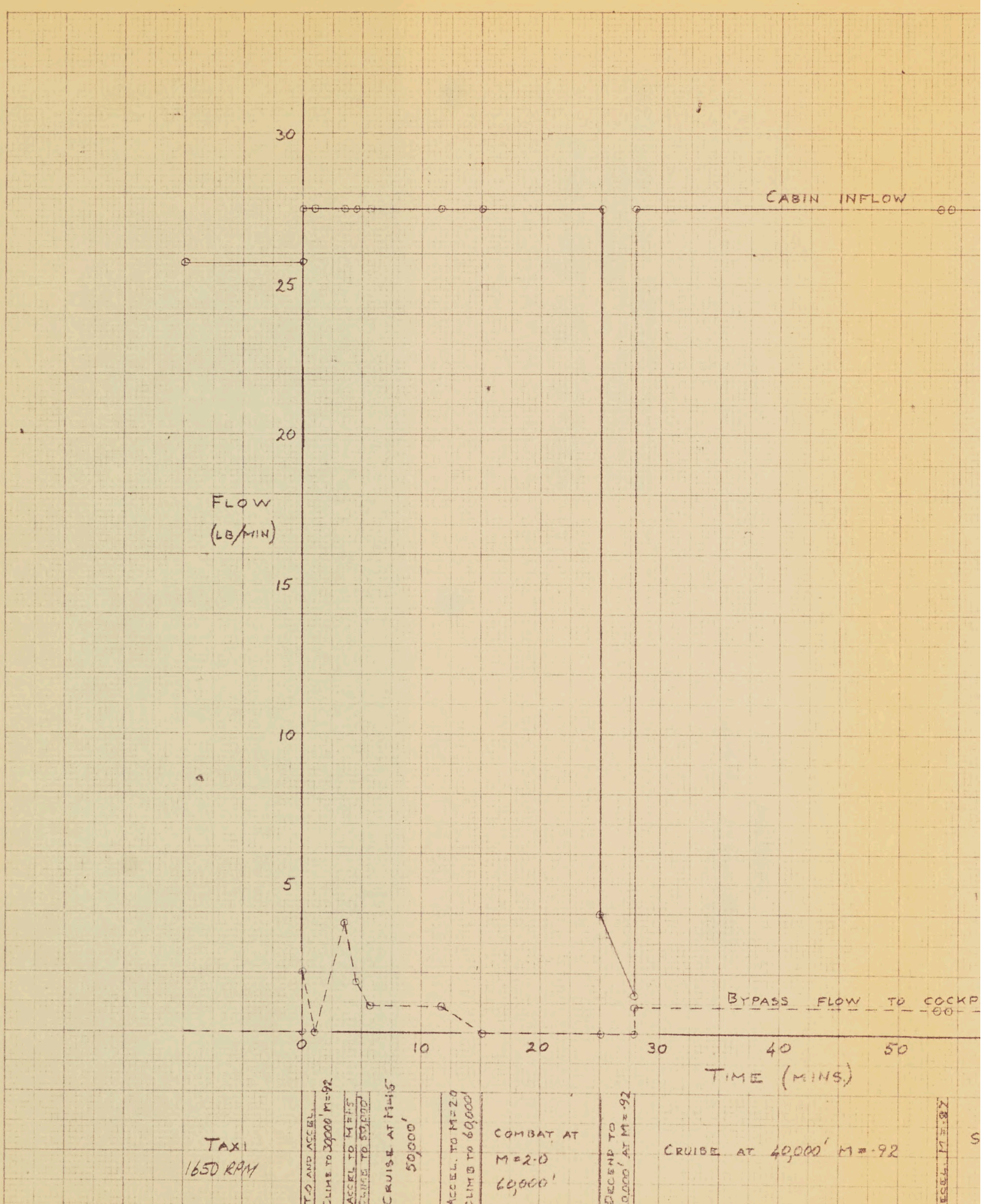


10 X 10 TO THE ½ INCH 359-11L
KEUFFEL & ESSER CO. MADE IN U.S.A.

REPORT Nº 72/SYSTEMS 22/170 FIG. 8.

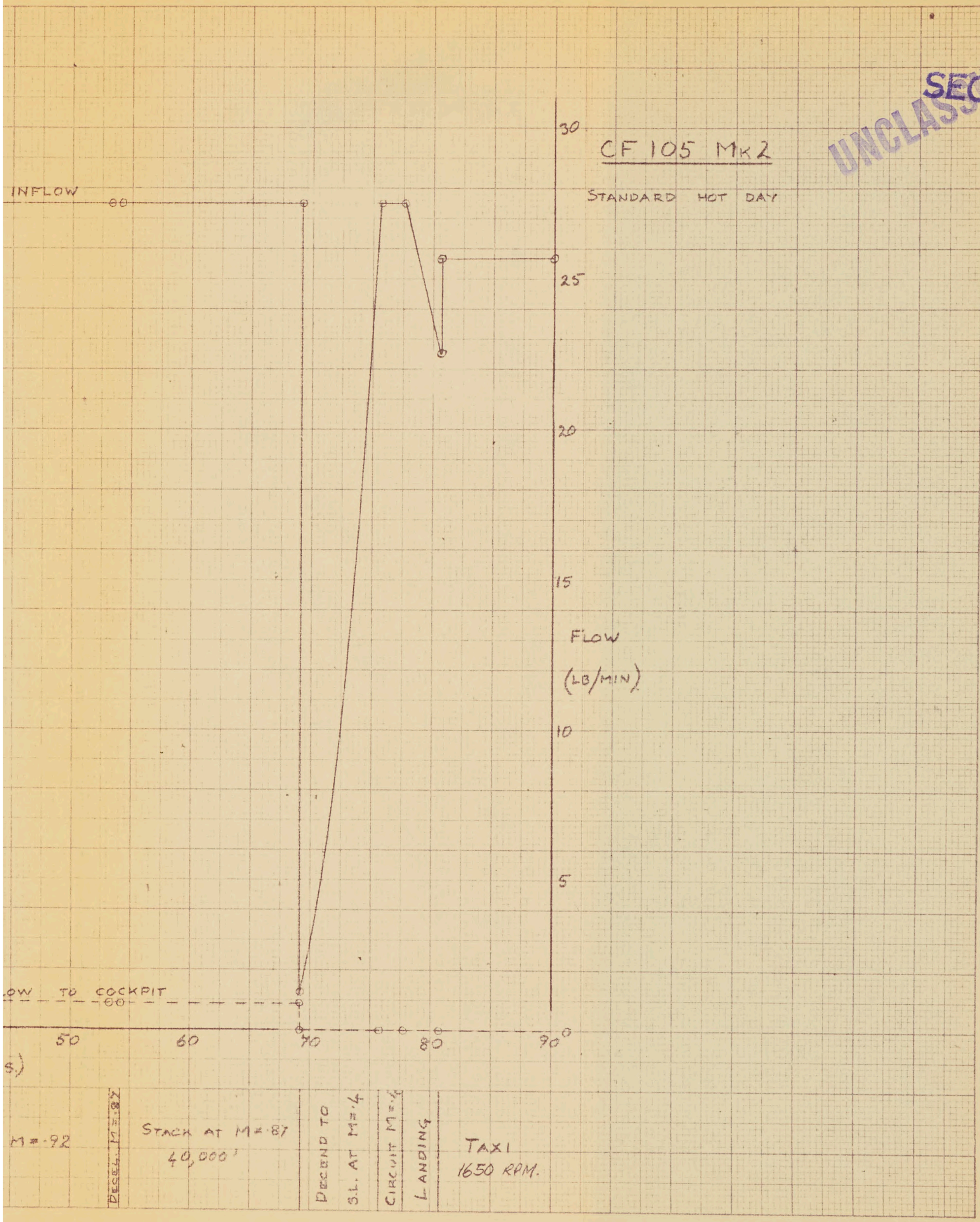
UNCLASSIFIED SECRET





10 X 10 TO THE 1/2 INCH 359 11L
KEUFFEL & ESSER CO.

SECRET
UNCLASSIFIED



REPORT No 72/SYSTEMS 22/170 FIG. 10

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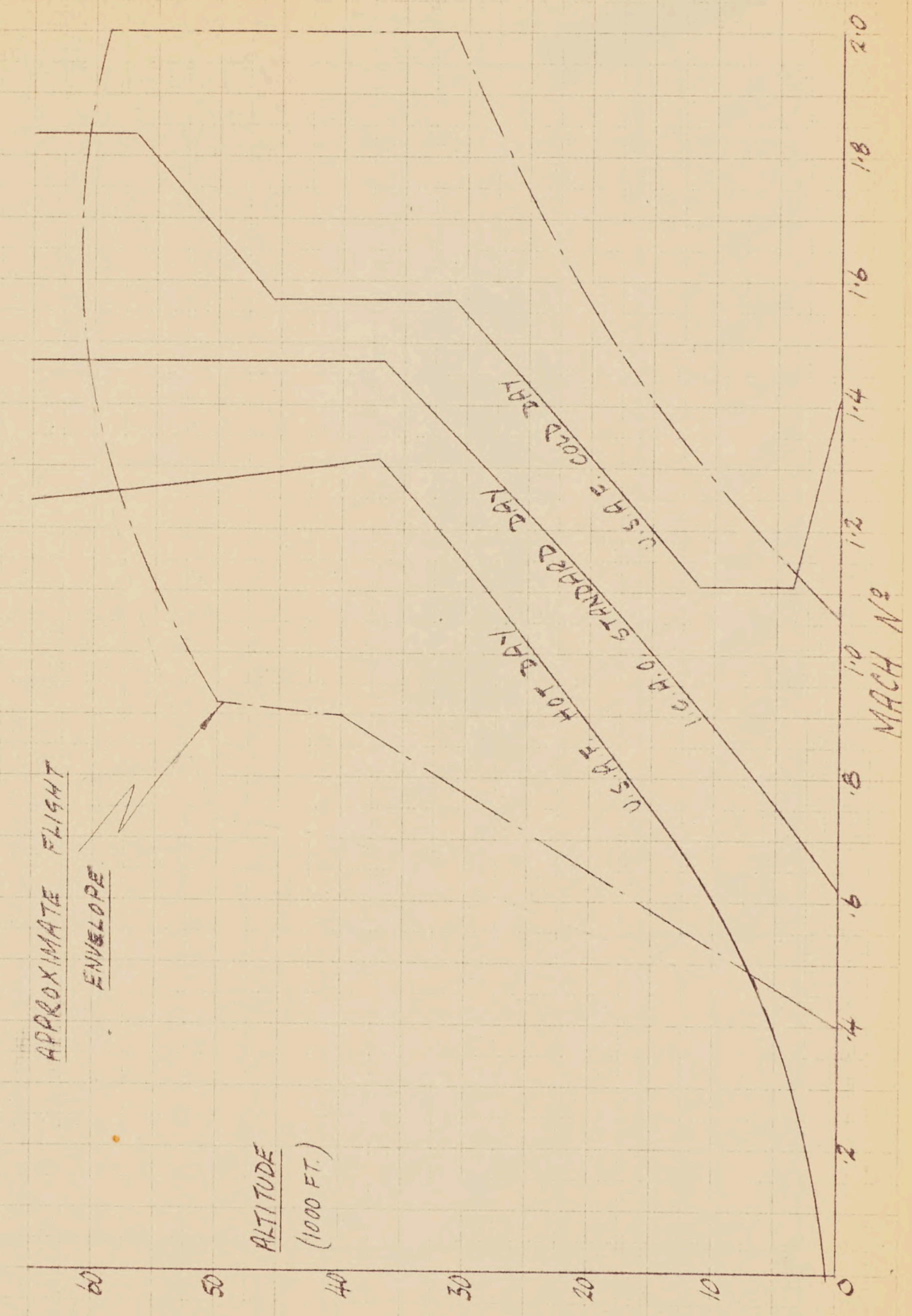
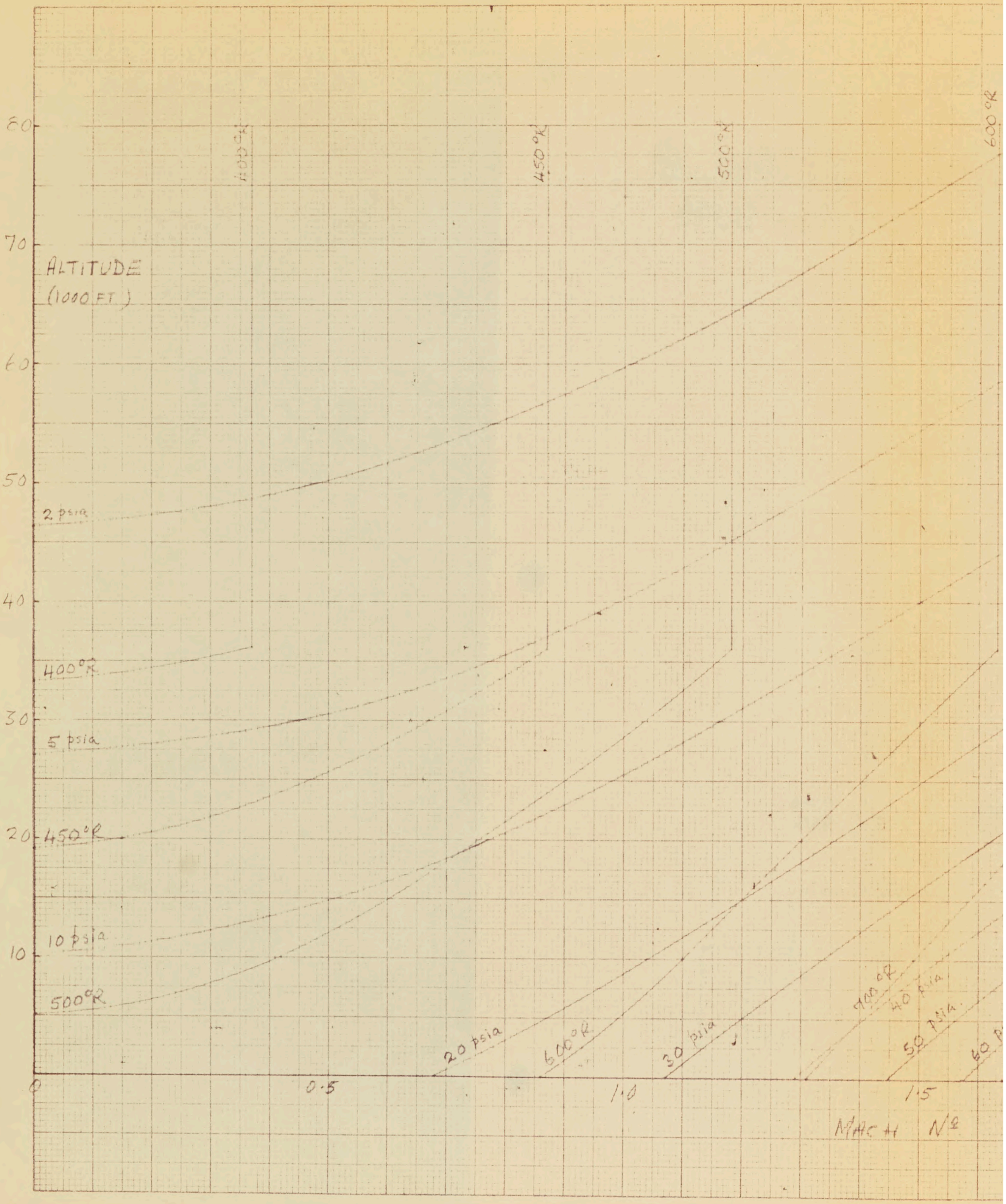
SECRET



ARROW 2 - AIR-CONDITIONING
LIMITATIONS OF EMERGENCY RAM-AIR SYSTEM (100°F RAM TEMP.)

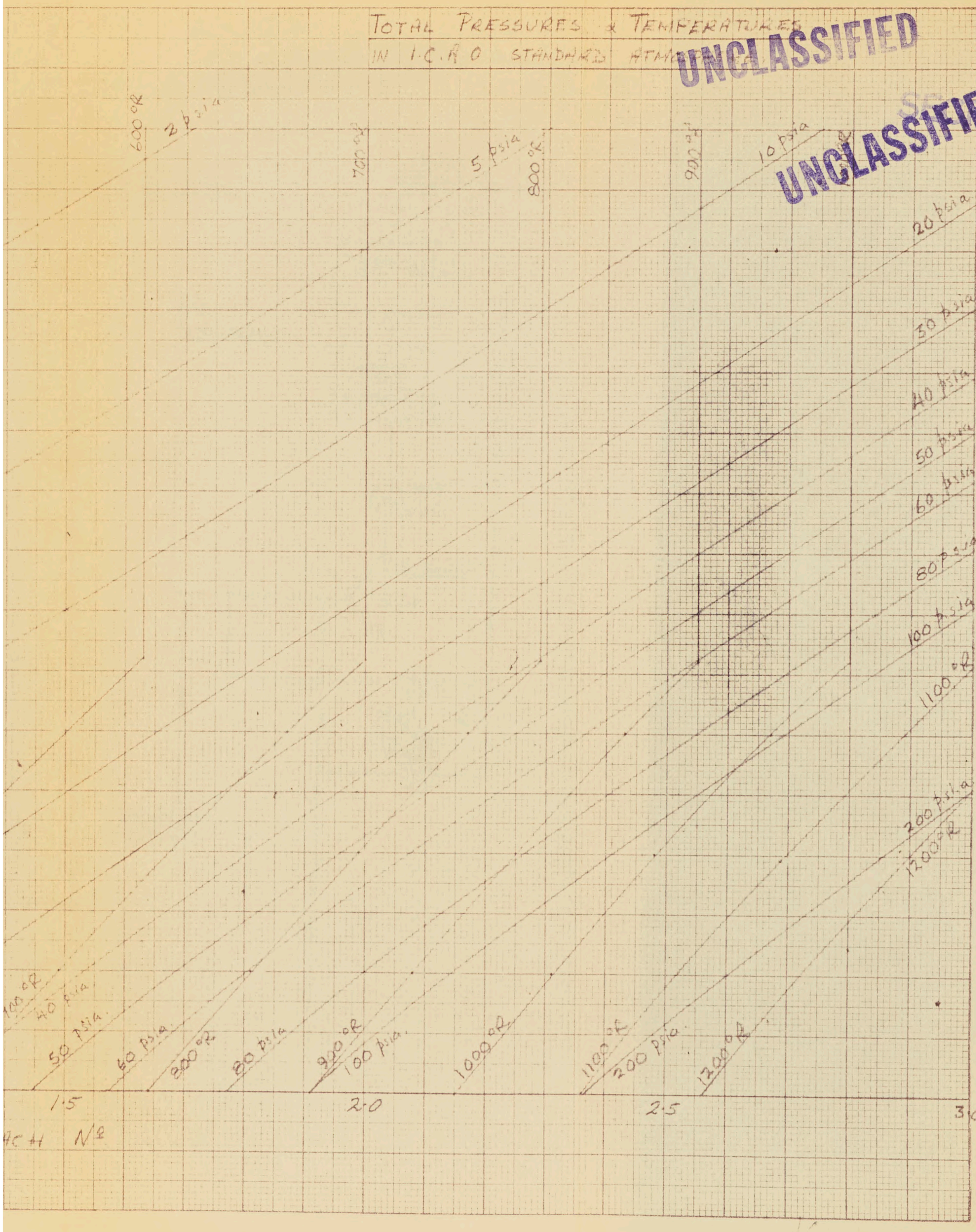
A G LOWE.
APRIL '58.



ALTITUDE (1000 FT)
80
70
60
50
40
30
20
10
0
0.5
1.0
1.5
MACH Nº
400°R
450°R
500°R
600°R
2 psia
400°R
5 psia
450°R
10 psia
500°R
20 psia
600°R
30 psia
400°R
40 psia
50 psia

UNCLASSIFIED

UNCLASSIFIED



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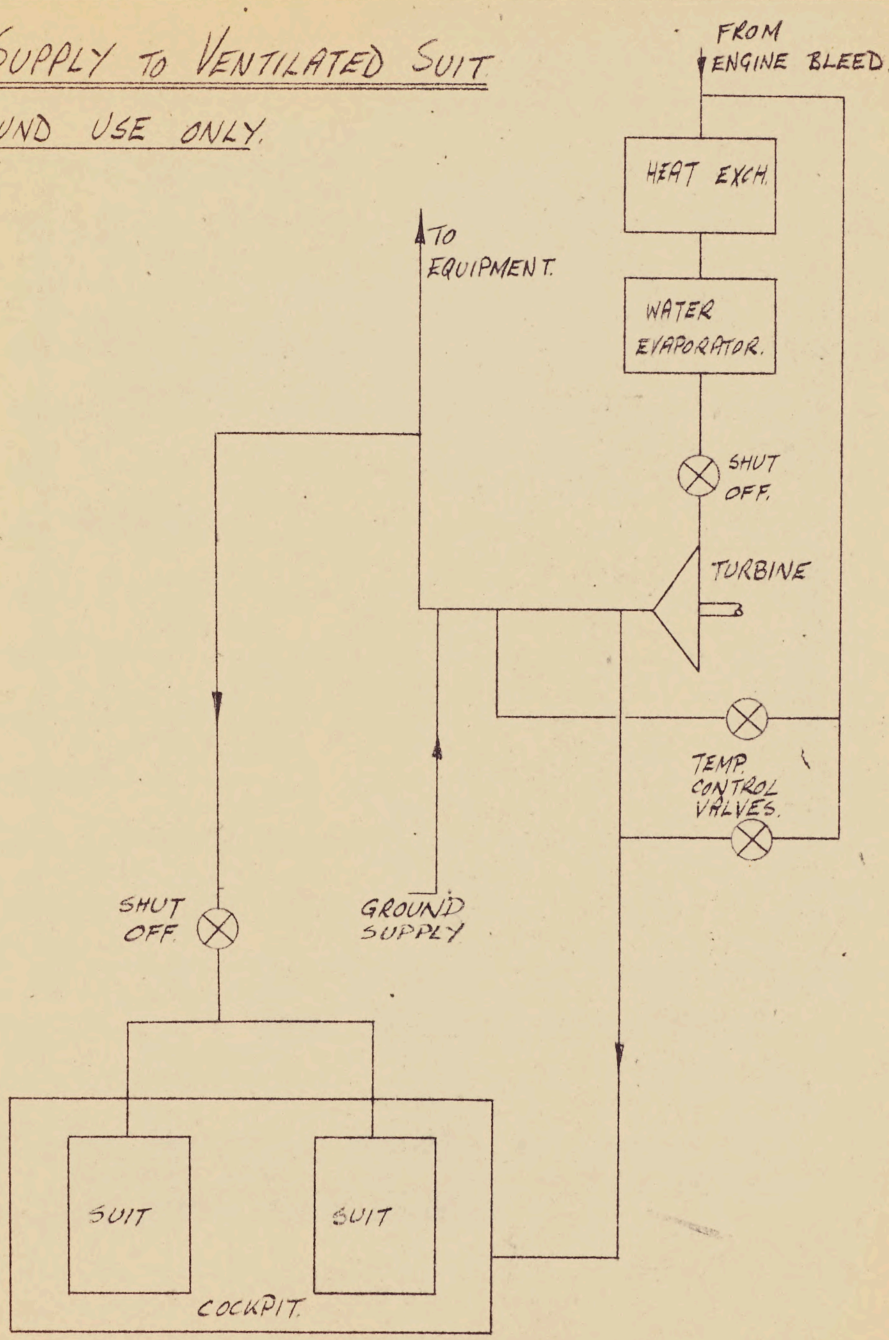
REPORT NO.	72/SYSTEMS 22/170
SHEET NO.	FIG. 12.

AIRCRAFT:		PREPARED BY	DATE
ARROW 2	AIR-CONDITIONING		APRIL '58
		CHECKED BY	DATE

AIR SUPPLY TO VENTILATED SUIT

GROUND USE ONLY.



FORM 1319A

SECRET

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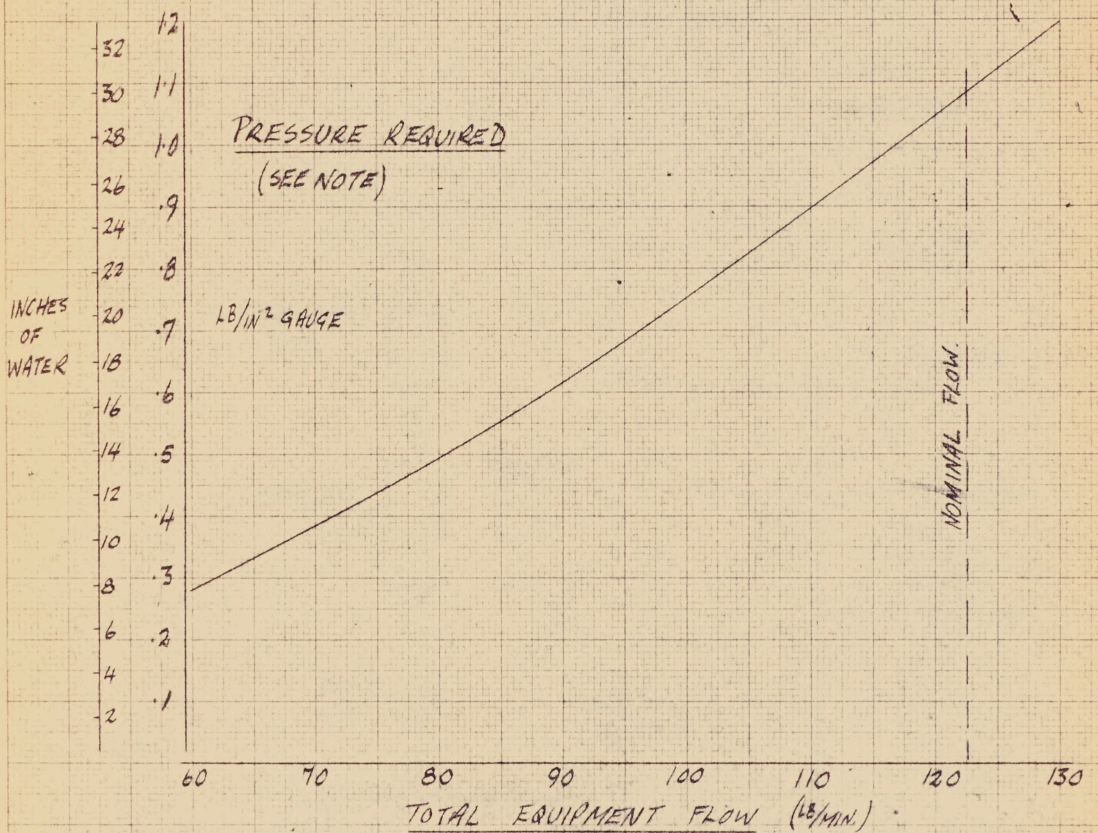
ARROW 2 - AIR-CONDITIONING

PRESSURES REQUIRED FOR EQUIPMENT COOLING AIR SUPPLY, AT SEA-LEVEL



NOTE: THIS PRESSURE IS MEASURED AT A POINT IN THE EQUIPMENT SUPPLY LINE FROM WHICH A VENTILATED SUIT SUPPLY COULD BE TAKEN

A G LOWE.
APRIL '58.

K+E 10 X 10 TO THE CM. 359-14 KEUFFEL & ESSER CO.

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TECHNICAL DEPARTMENT

SECRET

REPORT NO. 72/SYSTEMS 22/170			
SHEET NO. FIG. 14			
AIRCRAFT: ARROW 2	AIR. CONDITIONING.	PREPARED BY: A.G. LOWE.	DATE: APRIL '58
		CHECKED BY	DATE

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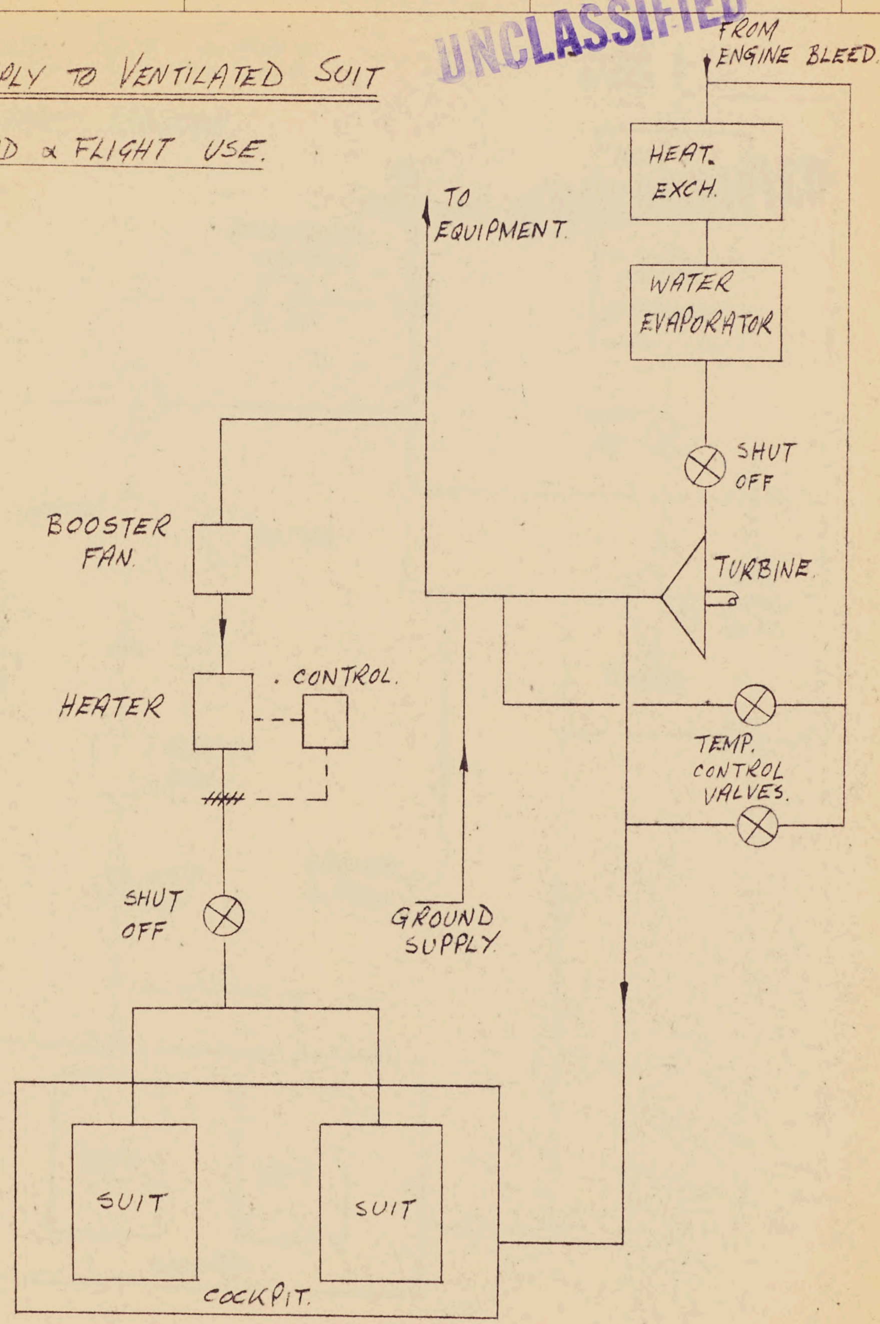
AIR SUPPLY TO VENTILATED SUIT

GROUND & FLIGHT USE.



FORM 1319A

AVRO AIRCRAFT LIMITED
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TECHNICAL DEPARTMENT

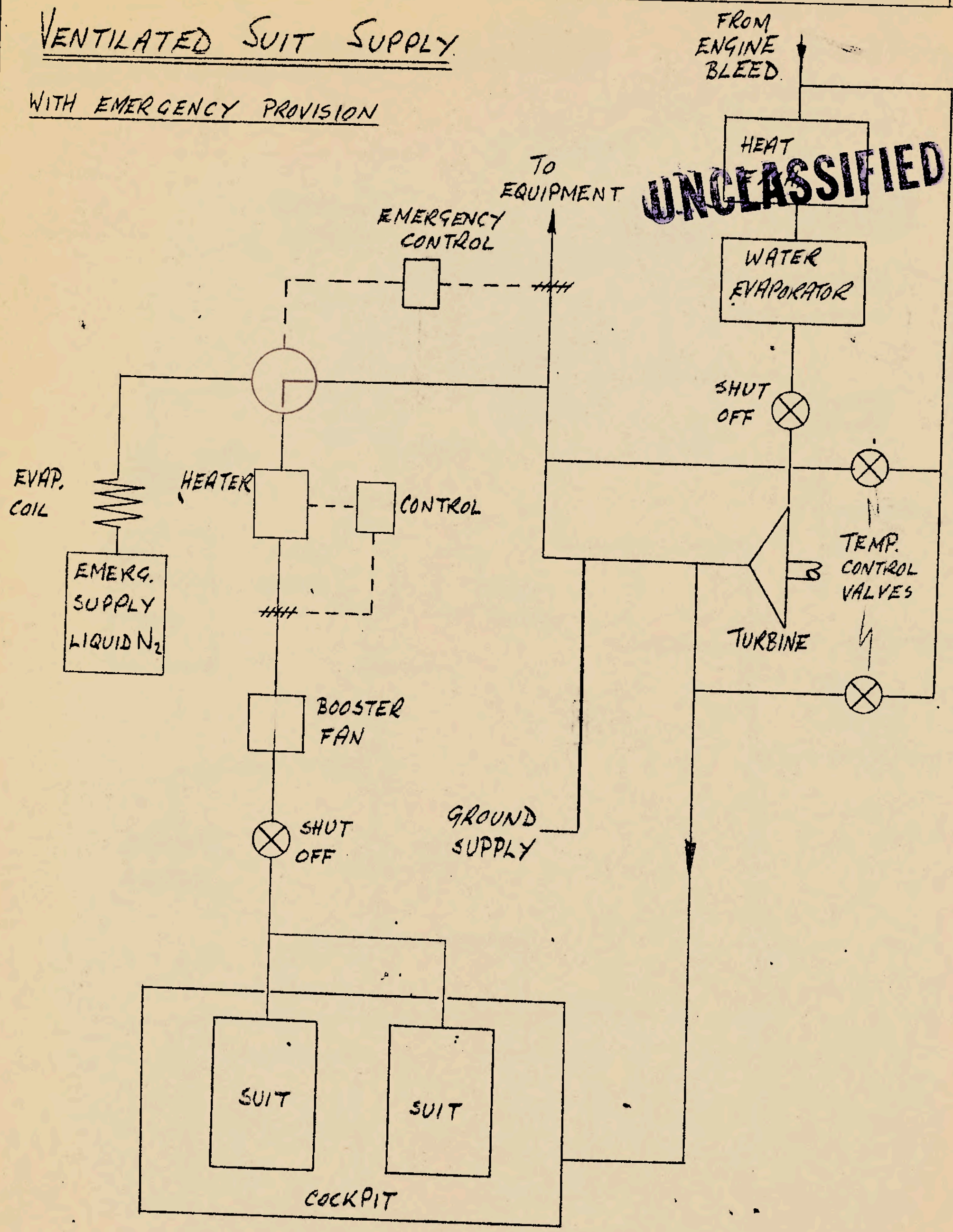
REPORT NO.	72/SYSTEMS 22/170
SHEET NO	FIG. 15

AIRCRAFT		PREPARED BY	DATE
ARROW 2	AIR-CONDITIONING.	A.G. LOWE.	16 APR. 58.
		CHECKED BY	DATE

UNCLASSIFIED

VENTILATED SUIT SUPPLY

WITH EMERGENCY PROVISION



FORM 1318A

AVRO AIRCRAFT LIMITED
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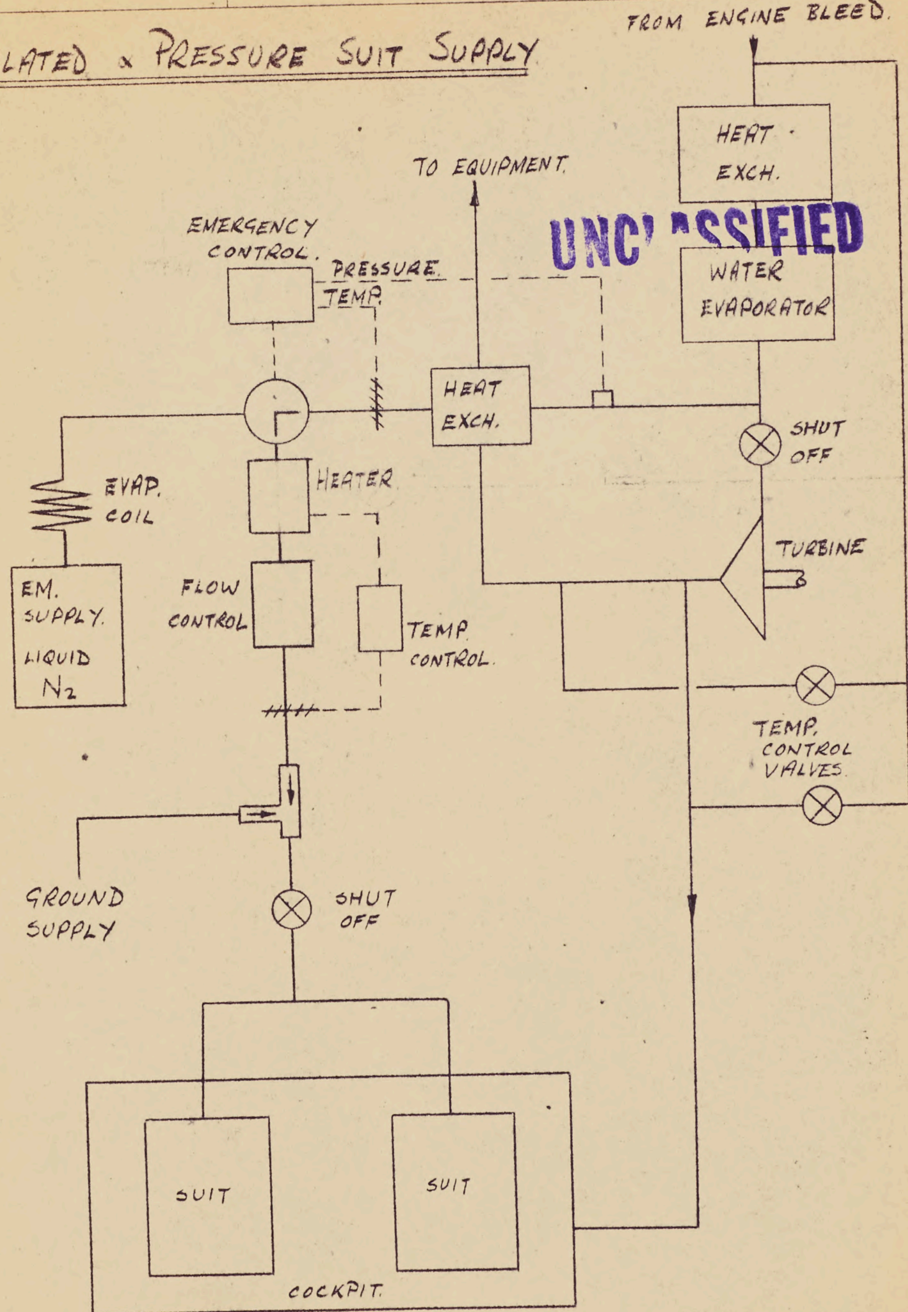
TECHNICAL DEPARTMENT

REPORT NO. 72/SYSTEMS 22/170		
SHEET NO. FIG. 16		
AIRCRAFT: ARROW 2	AIR- CONDITIONING.	PREPARED BY: A. G. LOWE. — DATE: 14 APR. 58
		CHECKED BY — DATE

VENTILATED & PRESSURE SUIT SUPPLY



FORM 1319A

DUO TANG
No. 3558
MADE IN U.S.A.