JUNE 1957

ARROW 2

AIR CONDITIONING SYSTEM

REPORT No. 72/SYSTEMS 22/48

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

SECURITY WARNING

This document is classified "SECRET" and is intended solely for the use of the recipient and such persons as have been delegated to use it in the course of their duty and may only be used in connection with work performed for or on behalf of Her Majesty's Canadian Government.

The unauthorized retention or destruction of this document or disclosure of its contents to any unauthorized person is forbidden.

Failure to comply with any of the above instructions is an infraction of the Official Secrets Act.

Any unauthorized person obtaining possession of this document, by finding or otherwise, must forward it, together with his name and address, in a registered envelope, to the Engineering Division, AVRO Aircraft Ltd., Malton, Ontario, Canada.

Classification cancelled/~~changed to~~ UNCLAS
by authority of .... (date) 3 Mar 59
Signature Gott Gordon Rank F/L

This is copy number ....71....

Issued to ....

Date ....

SECRET

ARROW 2

AIR CONDITIONING SYSTEM

REPORT NO. 72/SYSTEMS 22/48

JUNE 1957

This brochure is intended to provide an accurate description of the system(s) or service(s) for purposes of the Arrow 2 Mock-up Conference, and is not to be considered binding with respect to changes which may occur subsequent to the date of publication.

COMPILED BY Geo Shaw **APPROVED BY** Alan R. Buley

ENGINEERING DIVISION

AVRO AIRCRAFT LIMITED

MALTON — ONTARIO

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

1. Introduction - Scope of Report

The air conditioning system is installed to maintain an acceptable cockpit environment and to cool equipment. The first two sections of this report covers the requirements and a detailed description of the system selected to meet these requirements.

The third section covers the system analysis and performance. The four appendices consist of lists of equipment, tests and reports and a tabulation of the system performance for various flight cases.

2. Loads and Requirements

2.1 Cockpit

The system is required to maintain an environment in the cockpit suitable for the crew. The factors considered here are pressure, temperature, humidity, noise and ventilating air velocity.

Limits are laid down for pressure and temperature. These are:-

(a) for cockpit pressure altitude a desirable maximum of 25,000 feet and a limit of 27,000 feet.

(b) for temperature, a range controlled by the pilot, of 40^{o} to 80^{o}F.

No definite limits are set for humidity, noise or air velocity except that the combined effect of all these factors must not cause undue discomfort. The pressure and temperature requirements can be met with a cockpit air flow of 27.5 lb./min. at inlet temperatures ranging from 16 to 100^{o}F. Acceptability of the cockpit environment will be proven by ground and flight test.

2.2 Equipment

The maximum speed of the aircraft can result in skin temperatures of 250^{o}F. Any equipment which cannot stand this temperature must be cooled. The approximate flow requirements are 5 lb./min. of cooling air at 70°F per kilowatt for all electronic and electrical equipment consuming power. The 70°F temperature is chosen to keep the free moisture in the air to a minimum. Non heat generating. equipment requires sufficient cooling air to keep the compartment temperature at an acceptable level. Where possible the cooling air is cascaded from one piece of equipment to another in order to reduce the required flow. Cockpit exhaust air is used to cool the armament bay. Fig. 2 shows the various loads and air requirements for each compartment. Fig. 3 shows the location and limiting temperatures of each compartment.

2.3 Total Air Conditioning Requirements

- cockpit 27.5 lb./min. at 16 to 100°F
- equipment 122.5 lb./min. at 70°F

Auxiliary Requirements

L.P. Pneumatics - neg. flow at 250°F max.

Fuel tank pressurization 1 to 15 lb./min. at 370°F max.

2.4 Auxiliary Requirements

Partially cooled air is required for auxiliary systems such as fuel tank pressurization, anti "g" valves, canopy seals etc.

3. Description of System

3.1 Basic System

The basic system selected to meet these requirements is a simple air cycle system using bleed air from the main engine compressors. Fig. 1 is a schematic diagram of the system.

3.1.1 Air to Air Heat Exchanger

Bleed air is first cooled by means of an air to air heat exchanger. Boundary layer air from under the main engine intakes is used as a source of cooling air. (Fig. 4).

3.1.2 Expansion Turbine

After passing through the heat exchanger air is expanded through an air turbine motor to the pressure required by the distribution system. The energy is absorbed by a centrifugal compressor which takes air from the main engine intakes and exhausts it through a nozzle in the dorsal. (No attempt is made to obtain useful work from the turbine due to the wide variation in output).

3.1.3 Ducting

3.1.3.1 Bleed Ducting

The ducting from the engines to the turbine inlet and temperature control valves is made of .016 to.020 inch thick stainless steel. Both bolted flanges and Janitrol "V" band clamps are used for duct connection. The ducts are insulated with 5/8 inch of fiber glass type insulation protected with a stainless steel foil sheath. The ducting is mounted on rollers to permit free movement. Flex sections are used where necessary to allow for thermal expansion and relative motion.

3.1.3.2 Distribution Ducting

The distribution ducting downstream of the turbine is of aluminum alloy construction with beaded ends. Both Marman Channel Band and Wiggins connections are used for duct joints. Fiberglass blankets wrapped around the ducts and taped into place are used for insulation.

An air to oil heat exchanger is fitted in the equipment branch just downstream of the junction between the cockpit and equipment branches. Oil from the magnetron cooling system, and the radar hydraulic system is cooled in this heat exchanger.

3.1.4 Water Evaporator

Above 30,000 feet, under maximum speed conditions, the bleed pressure is not adequate for cooling. As an additional heat sink, a water evaporator is installed between the heat exchanger and the expansion turbine. Bleed air passes through this unit continuously. Boiling coincides with the additional cooling requirements, therefore no controls are used.

3.1.5 Pressure Reducing Valve

Below approximately 30,000 feet, engine bleed pressure can reach values considerably higher than is required to produce adequate cooling. To reduce the maximum working pressure on ducting and equipment, a pressure reducing valve set to 60 psig, is installed as close to the engine bleed port as possible.

3.1.6 Temperature Controls

Temperature control is achieved by mixing hot air ducted from upstream of the heat exchanger with the cold air from the turbine discharge. The equipment cooling air is controlled to a constant 70°F. The control point is downstream of the air-oil heat exchanger (3.1.3.2). The cockpit temperature is controlled to give a temperature of from 40 to 80°F at the cockpit outlet as selected by the pilot. An additional control permits the pilot to select an air inlet temperature of 90°F as a method of preventing fog.

3.1.7 Cockpit Pressure Control

Cockpit pressure is regulated by means of a valve in the cockpit outlet duct. This valve is operated by a controller that maintains the cockpit pressure to a fixed schedule with altitude, independently of flow. The cockpit is unpressurized from sea level to 10,000 feet. Above 10,000 feet the pressure differential is increased from 0 to 4.25 ± 0.25 psi, which is reached at 50,000 feet aircraft altitude. Above 50,000 feet a fixed differential of 4.25 ± 0.25 psi is maintained. (see fig 6).

3.1.8 System Flow Control

Total air flow through the system is regulated by varying the inlet nozzle area of the refrigerating turbine. This area is regulated to give a constant flow of 27.5 ± 2.5 lb./min. through the cockpit. The pressure drop in the equipment branch has been selected so that, for a constant flow of 27.5 lb./min. through the cockpit, the equipment flow will be 122^{+20}_{-0} lb./min.

3.2 Auxiliary Equipment

The basic system is dependent upon engine air bleed and ram air pressure for its operation. For certain conditions, when these pressures are very low, the system performance will be deficient. When these conditions are not transient, but liable to be prolonged, some auxiliary equipment has been added to extend the operating range.

3.2.1 Reverse Flow Valve

To create a flow of cooling air through the heat exchangers during taxi conditions, the normal cooling air inlet is blanked off and the duct is connected to the main intakes by means of the reverse flow valve. (See Fig. 4). During taxi there is a pressure depression in the main engine intake, which will cause air to flow in reverse to the normal direction through the heat exchangers.

3.2.2 Cockpit Inlet Restriction

During taxi the total system flow is deficient. To insure adequate flow to the fire control system, the cockpit flow is restricted by means of a valve at the cockpit inlet. This valve reduces cockpit flow to approximately 10 lb./min.

3.2.3 Cockpit By-pass

At extreme altitudes and low speeds, the bleed pressure is insufficient to maintain cockpit pressure to the desired schedule. Under these conditions the cockpit pressure control valve will close, reducing the flow to zero. Although this case can not be considered a true transient, it should be of short duration as it is far from an optimum cruise condition, due to the very poor fuel economy. To insure cooling of the armament bay, a by-pass is fitted around the cockpit which will open under these conditions.

3.2.4 Compressor Inlet Relief

If the engines are operated at full power with zero forward speed there will be a large negative pressure in the engine intake. This will create a negative pressure differential across the turbine loading compressor which will cause it to surge. To prevent this surge, a relief valve is installed at the compressor inlet which will open whenever the compressor inlet pressure is below ambient pressure.

3.3 Safety Devices

The system contains various warnings and emergency devices to give it as complete protection as possible.

3.3.1 Turbine Outlet Temperature

If this temperature exceeds 80°F a warning light will come on indicating:-

(a) too low a bleed pressure (i.e. hot day taxi, Ref. Para. 3.2)

(b) boiler run dry

(c) seized turbine

The corrective action for (b) and (c) would be to reduce power. If this does not clear the fault the system should be shut down and emergency ram air used.

3.3.2 System Shut Off and Emergency Ram Air

A two position switch (Normal - Em) in the cockpit permits the pilot to select Em. Ram Air. When operated this switch will shut off the normal system at the turbine inlet and open the emergency ram air valve.

A thermostat set to 100°F prevents the ram air valve from operating unless the ram air is below this temperature. This selection also operates the reverse flow valve in the left hand cooling air duct blocking it off and thus increasing the ram pressure. (See Fig. 4). The fire control system is also shut down, and a valve cuts off the flow to the nose radar to reduce the ram air requirements.

3.3.3 Duct Relief Valve

The main pressure reducing valve, (3.1.5) due to its size and the large normal flow, will not control pressures with a flow of less than 10 lb./min. A duct relief valve is provided to guarantee a total flow of 20 lb./min. when the duct pressure rises to 75 psig. This situation can occur when the main system shut off valve is closed (3.3.2).

3.3.4 Cockpit Pressure Protection

The pressure cockpit is protected with a safety valve set to 5.3 ±.2 psig maximum differential. (See Fig. 6). An inward relief valve prevents the possibility of a negative differential pressure occurring.

A warning light operates when the cockpit altitude exceeds 31,000 feet. A switch permits the pilot to dump cockpit pressure at any time.

Non return valves in the main and emergency ram air cockpit inlets will retain the cockpit pressure in the event of loss of the normal air supply.

3.3.5 Engine Bleed Ducting Protection

Overpressure switches and thermal type leakage detectors fitted to the bleed ducts operate warning lights in the pilot's cockpit. A switch permits the pilot to shut off bleed air flow in either right hand or left hand duct by means of valves fitted to the bleed ports on the engine. Non return valves installed in the ducts, close to the heat exchanger, serve to isolate the duct that is shut down.

3.3.6 Temperature Control Protection

The temperature controls are protected with overheat thermostats. These thermostats will cycle the temperature control valves thus giving a crude form of control.

An additional overheat thermostat in the equipment branch will show an indication of a fault in the ground check annunciator box. (Ref. 72/Systems 11/27.)

3.4 Cockpit Controls

The following warning devices and controls are fitted in the pilot's compartment. (Ref. Fig. 5).

3.4.1 Warning Lights

(a) Cockpit Pressure - On for cockpit altitude above 31,000 feet.

(b) Turbine Outlet Temperature - on for outlet temperature above 80°F.

(c) Engine Bleed Ducts - On for pressures above 90 psig or compartment temperatures above 370°F. The light indicate right hand or left hand duct pressure.

3.4.2 Instruments

The only instrument provided is a cockpit altimeter.

3.4.3 Switches

The following controls are provided all of which are for emergency use with the exception of the cockpit temperature selector:-

(a) System Shut Off - Two positions, Normal and Emergency Ram.

(b) Emergency Shut Off - Three position, toggle L.H. closed - Normal and R.H. closed.

(c) Cockpit Pressure Dump - Two position, Normal and Dump.

(d) Defog - Two position, Off and Defog.

(e) Cockpit Temperature Selector - Rotary

The extremes are 40°F and 80°F.

3.4.4 General

The remainder of the controls and safety devices are automatic.

3.5 Servicing

3.5.1 Equipment

All equipment will require standard maintenance procedures with the exception of the following items:-

(a) Water Boiler - The method of checking and filling this unit is still under study.

(b) Refrigeration Turbine - This item requires lubrication.

(c) Engine Bleed Ducting - This ducting, since it carries air at high pressures and temperature, will require leakage checks at regular intervals.

(d) Cockpit Leakage - Due to the extreme altitude reached by the aircraft and also due to the fact that cockpit exhaust air is used to cool equipment a close check will have to be kept on the cockpit leak rate. The controllers for both the cockpit pressure regulator and the safety valve are provided with the means for closing them at sea level and for checking their max. differential pressure settings. (Ref Maintenance Report 105-22-4).

3.5.2 System

Pressure and temperature taps have been provided in the nose wheel well. These can be connected to a ground test panel so that on an engine run the following can be checked. (Ref. Maintenance Report 105-22-4).

(a) Pressure reducing valve.

(b) Refrigeration turbine performance.

(c) Temperature controls.

(d) Flow controls.

3.5.3 Ground Air Supply

Provision has been made for connecting a ground air supply to the main system downstream of the refrigeration turbine. This will permit equipment in the aircraft requiring cooling air, to be operated on the ground. The air requirements are 150 lb./min. at 60^{o}F and 4.5 psig. delivered to the aircraft. This includes 27.5 lb./min. for the cockpit.

4. System Analysis and Performance

To fully investigate the behaviour of this system, its performance for some 50 flight and ground cases must be analysed. Preliminary estimates must first be made for engine bleed condition, cooling air requirements, duct losses and equipment performance. With this data a first analysis of the system can be made. From this can be obtained duct sizes, limiting duct pressures and temperatures, requirements for bought out equipment and limitation to the system performance.

The variables which can alter the original analysis are

(a) Variations in engine bleed pressure and temperature.

(b) Variations in performance of bought out equipment.

(c) Variations in duct pressure loss characteristics (duct runs).

(d) Changes in system loads.

When any of these are changed the changes must be fed back into the original analysis to assess the effect.

In addition to this theoretical analysis a full scale system rig test will be run. This rig will contain all ducting and equipment which is used in the system mounted as it will be in the aircraft. The purpose of these tests is to check the theoretical analysis and the behaviour of the system as much as possible before the system flies in an aircraft. The final stage will be a flight test program to prove the system.

The system analysis is in a continuous state of change. At present this analysis is being programmed on a digital computer which will allow the effect of changes to be checked much faster than can be done by hand. Tabulated results of the system analysis are shown in appendix "B".

The system has been designed to operate as nearly as possible over the same flight envelope as the aircraft. Since the system is dependent on engine bleed pressures its performance will deteriorate when this pressure is low. Performance will be marginal during taxi on a hot day, during descent and at extreme altitudes particularly at low speeds.

There are a number of problems not mentioned previously which require calculation and testing. Some of these are: cockpit environment, insulation requirements, reverse flow cooling air data, emergency cooling, etc.

APPENDIX "A"

EQUIPMENT LIST

The following list covers all the bought out equipment used in the air conditioning system with the exception of Hardware and Ducting.

Item No.	Report Sec. Ref.	Description	Avro Dwg. No.	Spec. No.	Supplier	Remarks
1	3.1.1	Air to Air Heat Exchanger	7-2254-1001	E.483	AiResearch	
2	3.1.2	Turbine and Compressor	7-2254-1002	E.484	AiResearch	
3	3.1.4	Water Evaporator	7-2254-1003	E.486	Surface Combustion	
4	3.1.5	Pressure Reducing Valve	7-2256-15023	E.552	AiResearch	
5	3.1.6	Cockpit-Temperature Controller	7-2252-15327	E.265		Type 2 System
6	3.1.6	Cockpit-Temperature Sensing Element	7-2252-15323	E.265		
7	3.1.6	Cockpit-Temperature Rheostat	7-2252-15321	E.265		
8	3.1.6	Cockpit-Temperature Control Valve	7-2252-15325	E.265		
9	3.1.6	Equipment-Temperature Controller	7-2252-15329	E.264		Type 2 System
10	3.1.6	Equipment-Temperature Sensing Element	7-2252-15323	E.264		
11	3.1.6	Equipment-Temperature Control Valve	7-2252-15325	E.264		
12	3.1.7	Cockpit-Pressure Controller	7-2252-15205	E.298	Normalair	

Item No.	Report Sec. Ref.	Description	Avro Dwg. No.	Spec. No.	Supplier	Remarks
13	3.1.7	Cockpit-Pressure Relay Valve	7-2252-15195	E.298	Normalair	
14	3.1.7	Cockpit-Pressure Filter	7-2252-316	E.298	Normalair	MK 1 Item
15	3.1.7	Cockpit-Pressure Discharge Valve	7-2252-15093	E.298	Normalair	MK 1 Item
16	3.5.1	Shut Off Valve	7-2252-423	E.298		MK 1 Item
17	3.2.1	Reverse Flow Valve Actuator	7-2254-15612 15611	E.474		R.H. & L.H.
18	3.2.2	Cockpit Inlet and Non return Valve	7-2254-15193	E.239		Type 2
19	3.2.3	Cockpit By-Pass	7-2252-15101			
20	3.2.4	Compressor Inlet Relief Valve	7-2254-15617	E.550		
21	3.3.1	Thermostat-Turbine Outlet Warning	7-2250-131	E.515	United Controls	MK 1 Item
22	3.3.2	System Shut Off Valve	7-2254-16013	E.487		
23	3.3.2	Emergency Ram Air Valve	7-2252-15201	E.489		
24	3.3.2	Nose Radar Shut Off	7-2252-15203	E.492		
25	3.3.2	Emergency Non return Valve Cockpit	7-2252-15202	E.490		

Item No.	Report Sec. Ref.	Description	Avro Dwg. No.	Spec. No.	Supplier	Remarks
26	3.3.3	Duct Relief Valve	7-2254-15618	E.551		Type 2
27	3.3.4	Cockpit Safety Valve	7-2252-328	E.572	AiResearch	MK 1 Item
28	3.3.4	Cockpit Safety Valve Controller	7-2252-329	E.572	AiResearch	MK 1 Item
29	3.3.4	Cockpit Inward Relief Valve	7-2252-403	E.559	AiResearch	MK 1 Item
30	3.3.4	Cockpit Pressure-Warning Switch			Meletron	Mk 1 Item
31	3.3.5	Bleed Duct Overpressure Switch	7-2256-15021	E.513	Parmatic	Type 2
32	3.3.5	Leak Detection Thermostat	7-2250-126	E.515	United Controls	MK 1 Item
33	3.3.5	Engine Bleed Shut Off Valve	7-2295-15013 15014	E.374		Type 2 R.H. & L.H.
34	3.3.5	Non return Valve	7-2254-16005	E.488		
35	3.3.6	Cockpit Overheat Thermostat	7-2250-127	E.515	United Controls	MK 1 Item
36	3.3.6	Equipment Overheat Thermostats	7-2250-128 -129	E.515	United Controls	MK 1 Item
37	3.5.2	Ground Service - Press Pickup				MK 1 Item
38	3.5.2	Ground Service-Turbine Outlet Temperature Pickup				MK 1 Item

Item No.	Report Sec. Ref.	Description	Avro Dwg. No.	Spec. No.	Supplier	Remarks
39	3.5.2	Flow Pickup (Nose radar)				MK 1 Item
40	3.5.2	Temperature Pickup (Cockpit inlet)				MK 1 Item
41	3.5.2	Temperature Pickup (Nose radar)				MK 1 Item
42	3.5.3	Ground Connection (A/C part)	7-2255-15053	E.397	Normalair	Type 2
43	3.5.3	Ground Connection (Hose end)	7-2252-198	E.397	Normalair	MK 1 Item
44	3.1.3.2	Air-Oil Heat Exchanger	7-0122-207			R.C.A. Supply

AVRO AIRCRAFT LIMITED

AVRO ARROW

SECRET

APPENDIX "B"

SYSTEM ANALYSIS

Results of the system analysis are listed here in tabular form. As described in section 4. of this report this analysis is in a continuous state of change. For this reason only a few cases are shown at this time. These cases outline the flight envelope of the system and will serve to illustrate its behaviour, however, they do not include all the changes to the present date. These changes will not greatly alter the data.

Another point which must be born in mind while studying these cases, particularly the descent cases, is that they are based on steady state conditions.

APPENDIX "B" SYSTEM ANALYSI

Case No.		1a	1c	2c	2a	4a	14b
A/C Mach No.		0	0	0	.4	.4	.4
Pressure Altitude	Ft.	S.L.	S.L	S.L.	S.L.	S.L.	S.L.
Flight Condition		Taxi	Taxi	Taxi	Cruise	Cruise	Descent
Ambient Temperature	°R	563	540	520	563	400	563
Stagnation Temperature	°R	563	540	520	581	413	581
Engine Bleed - H.E. Inlet Temp	°R	645	621	601	780	555	732
Engine Bleed Pressure	Lb/In^2Abs	21.74	22.03	22.37	38.40	38.40	30.60
Total Bleed Flow	Lb/Min.	107.6	116.3	139.0	158.8	161.5	154.2
H.E. Outlet - Boiler Inlet Temp.	°R	581	551	531	595	414	592
Cooling Air Mass Flow	Lb/Min.	229.0	234.0	263.7	635.0	750.0	635.0
Fuel Pressurization Mass Flow	Lb/Min.	1.0	1.0	1.0	1.0	1.0	1.0
Boiling Temperature of Water	°R	672	672	672	672	672	672
Rate of Water Consumption	Lb/Min.	0	0	0	0	0	0
Boiler Outlet - Turbine Inlet Temp.	°R	581	551	531	595	414	592
Turbine Inlet Pressure	$Lb/In^2Abs.$	19.56	19.80	19.85	35.56	37.80	27.03
Bearing Cooling Mass Flow	Lb/Min.	5.6	5.8	5.7	7.8	1.6	8.0
Turbine Mass Flow	Lb/Min.	101.0	106.0	104.3	141.5	30.0	145.2
Turbine RPM		13,739	13,856	13,709	24,382	12,210	19,463
Turbine Nozzle Area	In^2	7.0	7.0	7.0	3.56	.55	5.24
Turbine Outlet Temperature	°R	554	524	507	500	366	522
Turbine Oútlet Pressure	$Lb/In^2Abs.$	15.30	15.36	15.61	15.65	15.63	15.65
Cockpit Total Flow	Lb/Min.	7.5	8.1	9.7	27.5	29.0	26.9
Cockpit Turbine Flow	Lb/Min.	7.5	8.1	9.7	27.5	6.0	26.9
Cockpit HE Bypass Flow	Lb/Min.	0	0	0	0	23.0	0
Cockpit Inlet Temp.	°R	554	524	507	500	516	522
Cockpit Outlet Temp.	°R	609	580	554	531	520	550
Cockpit Pressure	$Lb/In^2Abs.$	14.75	14.75	14.80	15.27	15.32	15.26
Cockpit Bypass Flow	Lb/Min.	0	0	0	0	0	0
Equipment Total Flow	Lb/Min.	93.5	101.2	122.6	122.4	129.9	118.3
Equipment Turbine Flow	Lb/Min.	93.5	97.9	94.6	114.0	24.0	118.3
Equipment HE Bypass Flow	Lb/Min.	0	3.3	28.0	8.4	105.9	0
Equipment Inlet Temp.	°R	556	530	530	530	530	533

APPENDIX "B" SYSTEM ANALYSIS

1a	1c	2c	2a	4a	14b	7a	5a	6a	11b	10b	8a	11a	10a	12a
0	0	0	.4	.4	.4	1.97	.92	.92	.92	.92	.92	1.916	1.5	1.90
S.L.	S.L	S.L.	S.L.	S.L.	S.L.	40,000	40,000	40,000	40,000	45,000	50,000	60,000	60,000	65,000
Taxi	Taxi	Taxi	Cruise	Cruise	Descent	Max. Speed	Cruise	Cruise	Descent	Cruise	Cruise	Max. Speed	Cruise	Max. Speed
563	540	520	563	400	563	416	416	375	416	418	421	426	426	393
563	540	520	581	413	581	739	486	438	486	489	493	740	617	676
645	621	601	780	555	732	1250	901	751	780	1024	936	1250	1155	1224
21.74	22.03	22.37	38.40	38.40	30.60	89.20	29.20	23.80	19.70	27.20	19.50	32.30	23.99	28.05
107.6	116.3	139.0	158.8	161.5	154.2	180.0	179.6	180.0	154.7	173.0	130.0	180.1	153.5	153.0
581	551	531	595	414	592	765	627	463	545	708	633	904	805	868
229.0	234.0	263.7	635.0	750.0	635.0	640.0	200.0	300.0	240.0	158.0	144.0	200.0	145.0	142.0
1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0	1.0	2.0	2.0	2.0
672	672	672	672	672	672	597	597	597	597	601	580	563	563	556
0	0	0	0	0	0	5.4	0.7	0	0	3.9	1.6	13.7	8.2	9.2
581	551	531	595	414	592	614	613	463	545	612	585	598	587	587
19.56	19.80	19.85	35.56	37.80	27.03	60.31	23.67	20.69	15.36	21.60	14.90	24.75	17.84	22.58
5.6	5.8	5.7	7.8	1.6	8.0	8.0	9.1	6.0	6.5	8.9	6.5	8.8	8.0	7.0
101.0	106.0	104.3	141.5	30.0	145.2	145.0	165.3	102.8	119.0	163.0	118.0	161.0	140.0	135.0
13,739	13,856	13,709	24,382	12,210	19,463	30,985	35,600	25,812	28,241	37,228	30,962	34,000	35,600	33,978
7.0	7.0	7.0	3.56	.55	5.24	1.93	6.13	3.76	7.0	6.82	7.00	5.50	7.00	4.96
554	524	507	500	366	522	382	511	368	471	528	499	480	508	461
15.30	15.36	15.61	15.65	15.63	15.65	7.08	7.32	7.04	6.76	6.99	5.52	6.85	6.10	5.97
7.5	8.1	9.7	27.5	29.0	26.9	28.2	27.3	27.8	10.2	28.0	15.4	34.0	26.0	27.5
7.5	8.1	9.7	27.5	6.0	26.9	24.8	27.3	16.1	9.0	28.0	15.4	34.0	26.0	26.6
0	0	0	0	23.0	0	3.4	0	11.0	1.2	0	0	0	0	.9
554	524	507	500	516	522	495	511	517	505	528	498	480	508	500
609	580	554	531	520	550	520	525	520	520	541	532	520	544	520
14.75	14.75	14.80	15.27	15.32	15.26	6.25	6.45	6.24	6.61	6.16	5.15	5.50	5.07	4.96
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93.5	101.2	122.6	122.4	129.9	118.3	142.0	140.0	144.0	130.0	136.0	107.3	135.3	116.0	116.0
93.5	97.9	94.6	114.0	24.0	118.3	12.00	138.0	86.0	110.0	136.0	102.6	127.0	114.0	108.0
0	3.3	28.0	8.4	105.9	0	22.0	2.0	58.0	20.0	0	4.7	8.3	2.0	8.0
556	530	530	530	530	533	530	530	530	530	543	530	530	530	530

APPENDIX "C"

TESTING

The following is a list of the tests to be carried out on the system.

Tests marked thus * have been completed.

Report Ref. No.	Description
RT 08 - 460 add 1	Duct Insulation Test
RT 08 - 532 add 1	* Janitrol Joint Test
RT 08 - 692	* Fatigue Test - Ducting at Sta. 485
RT 08 - 648 add 1	* Fatigue Test - Ducting at Sta. 485
RT 08 - 677	* Marman Channel Band Clamp Test
RT 08 - 695	* Compressor Outlet Test
RT 08 - 717	System Rig Test
RT 08 - 745	Cockpit Environment Test
RT 08 -	* Bleed Duct Mounting Test
RT 08 -	Pre - Flight Test

APPENDIX "D"

REPORTS

The following is a list of the reports covering the design of the MK 2 air conditioning system. Reports noted "not issued" mean they exist in draft form only.

Report No.	Description
P/Equip./67	Cockpit Leak Rate
74	Equipment Performance - Not issued - Section 16 sent to R.C.A.
75	System Analysis - Not issued Section 5 sent to R.C.A. and I.A.M. Section 6 sent to R.C.A.
76	Emergency Cooling System Issued to R.C.A.
77	Boiler Capacity - Not issued
78	Steam Outlet Size - Not issued
79	Temperature Control Valve Seized - Not issued
80	Duct Sizes - Not issued
81	System Pressure and Temperatures - Not issued
82	Emergency Bleed Condition - Not issued
83	Sparrow Missile Cooling - Not issued
85	T.R.U. Cooling - Not issued

Report No.	Description
86	Perlin, System Investigation - Not issued
88	Insulation Requirement - Not issued
89	Cockpit Environment - Not issued
90	Ground Air Conditioning - Not issued
92	System Analysis - Program for Computer
93	Bleed Duct Leakage Detection

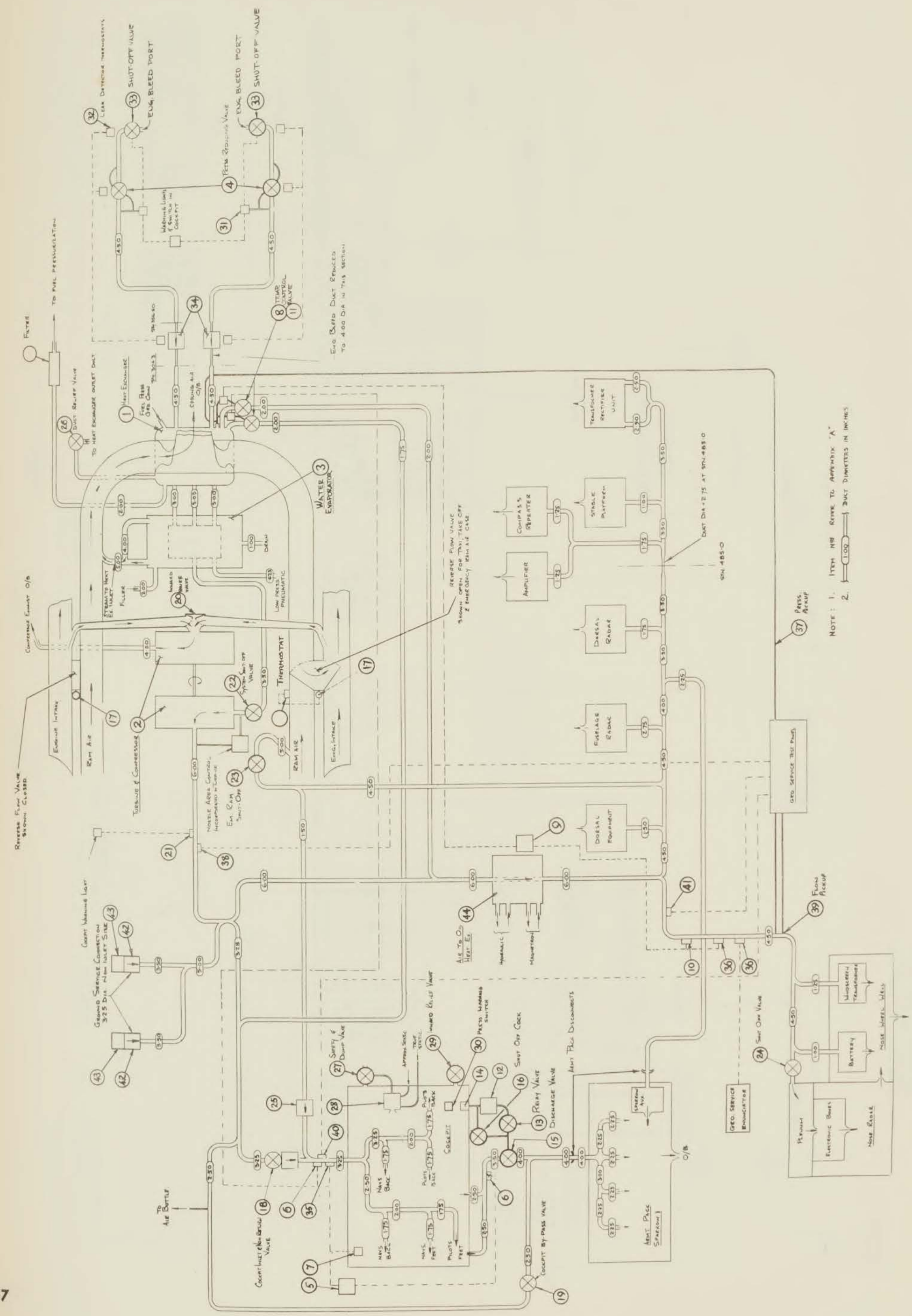


FIG. 1 SYSTEM SCHEMATIC

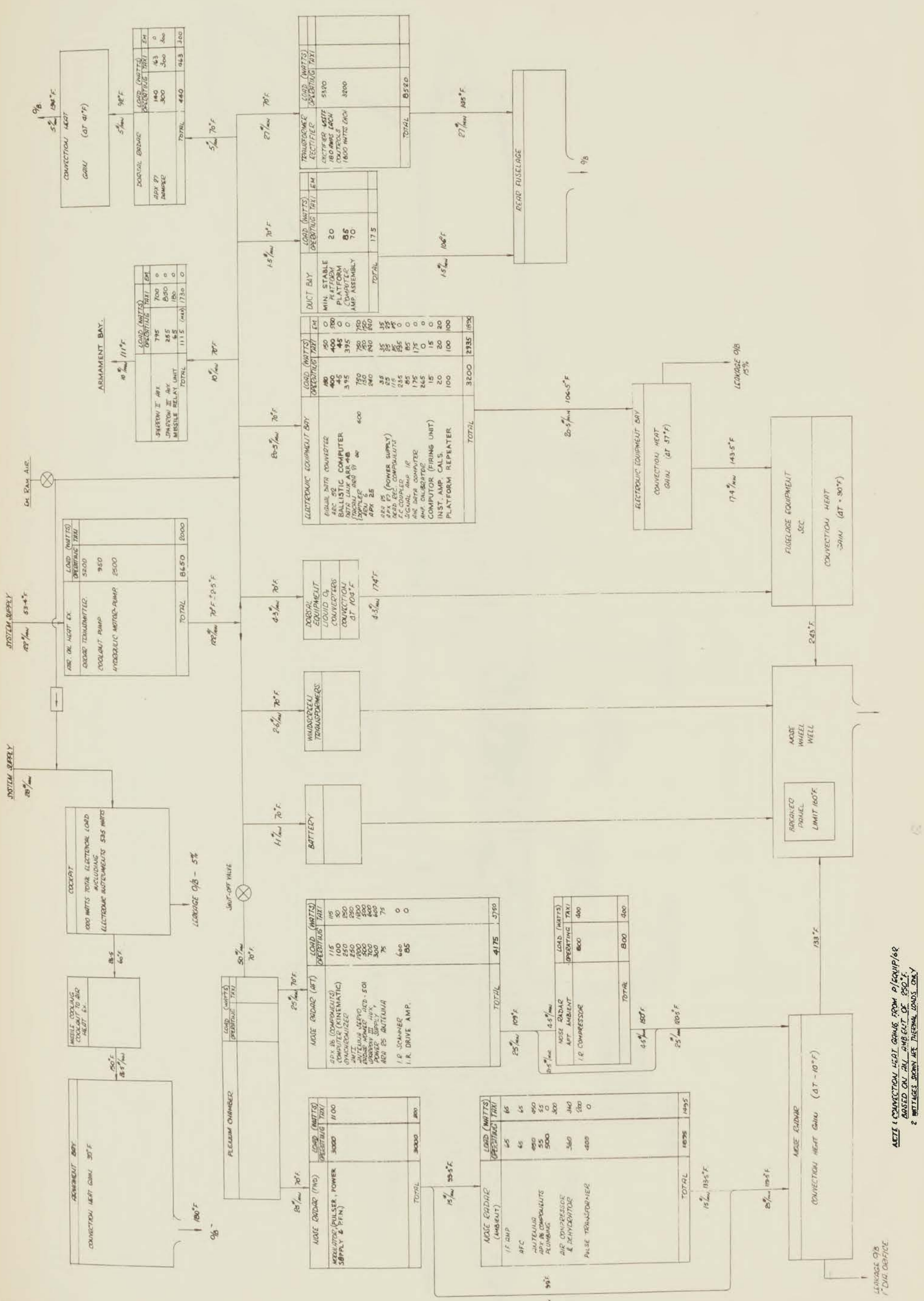


FIG. 2 SYSTEM LOADS

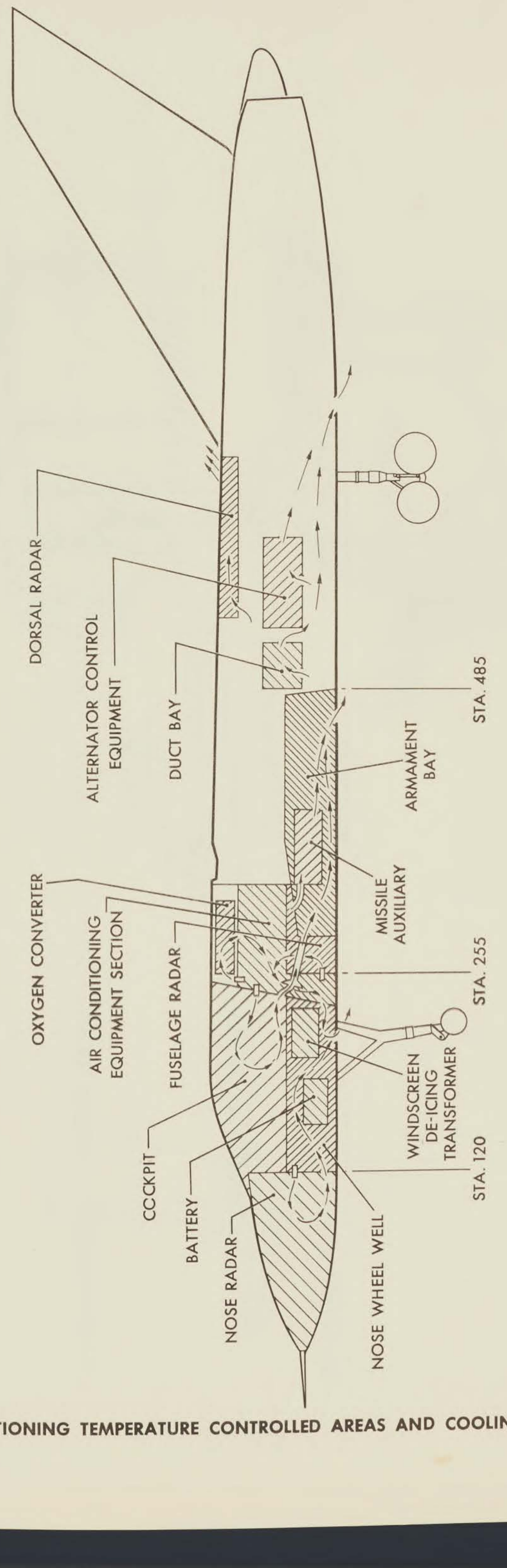


FIG. 3 AIR CONDITIONING TEMPERATURE CONTROLLED AREAS AND COOLING AIR CIRCULATION

2509-105-1

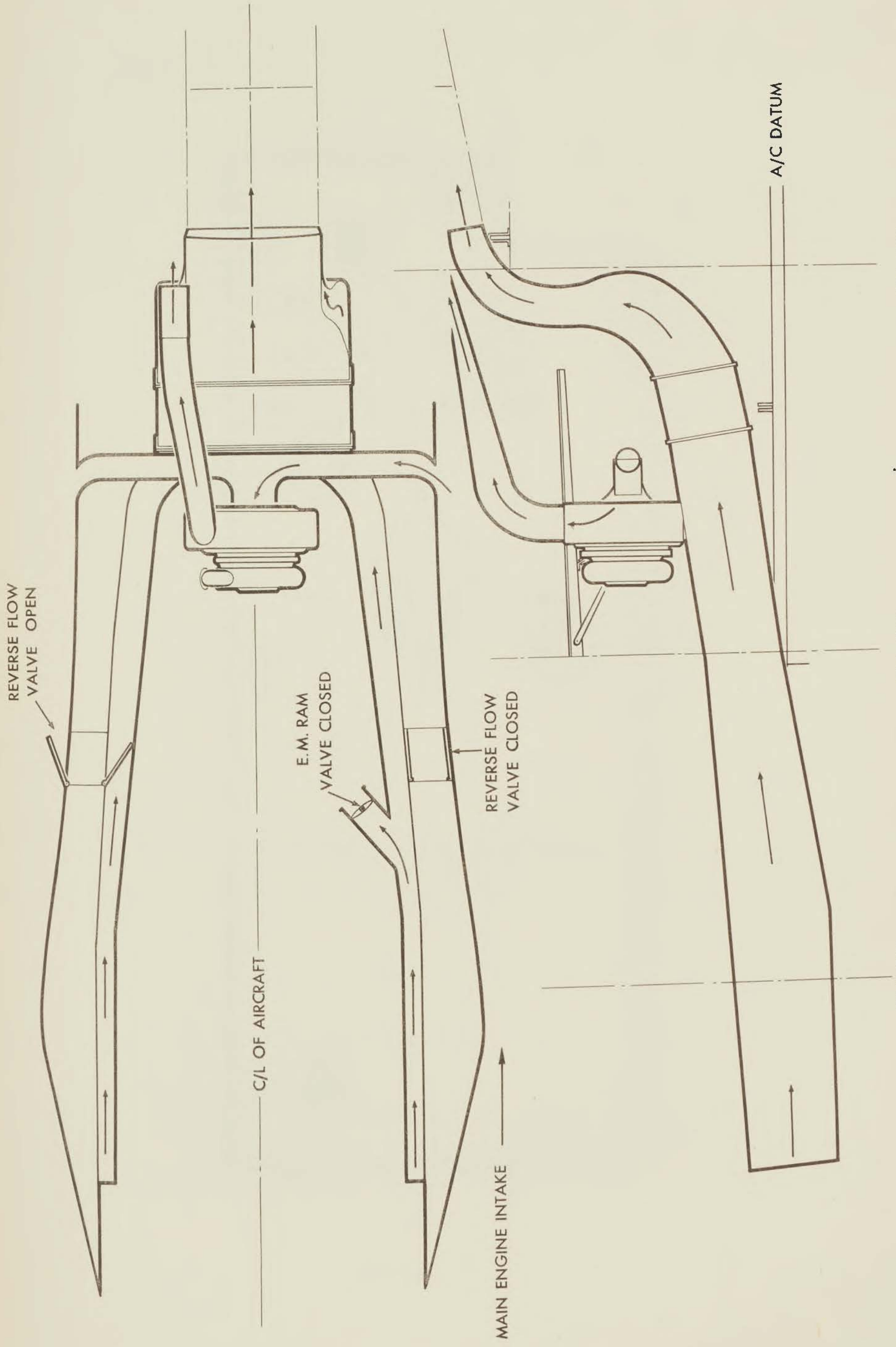


FIG. 4 COOLING AIR CIRCUIT

2508-105-1

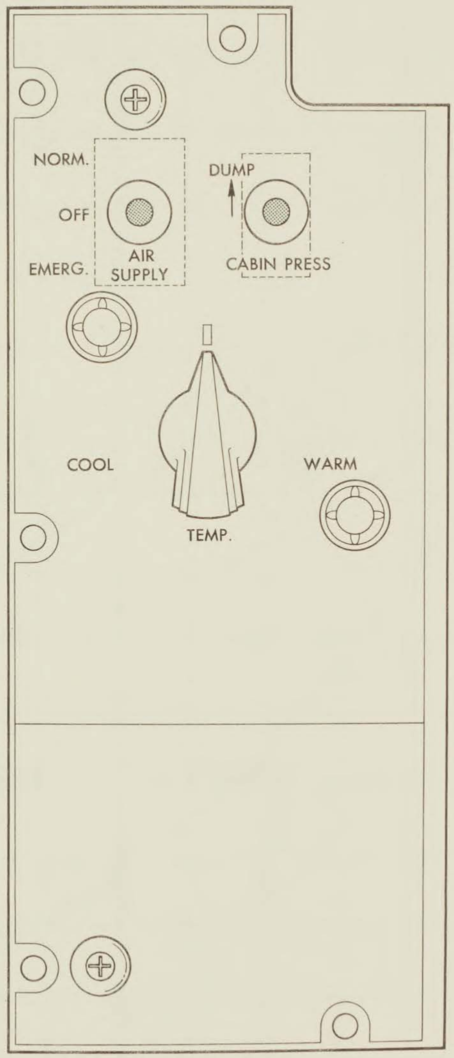
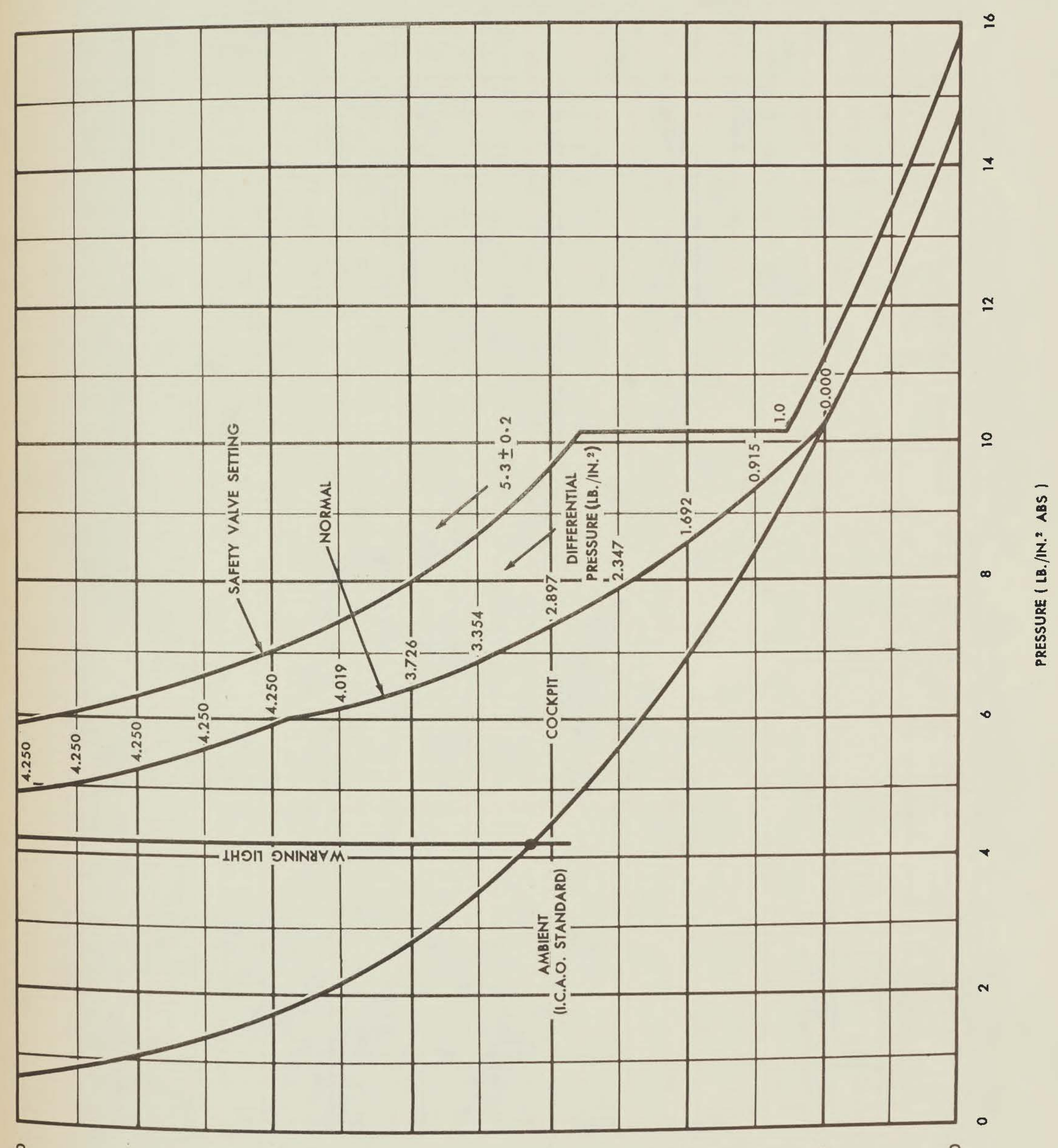


FIG. 5 COCKPIT CONTROLS



MAY/57 /48

FIG. 6 VARIATION OF COCKPIT PRESSURE WITH ALTITUDE