CF-105

General Requirements

for

Mobile Ground Power Units

CONFIDENTIAL

LOG/105/8

March, 1955

Sand/ACA/F/L Cooke

ANALYZED

AVRO AIRCRAFT

LOG/105/8

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Note: Material differences between issues will be marked by marginal lines.

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AVRO Aircraft Limited

Mobile Ground Power Equipment - Report LOG/105/8

Amendment Issue No. 2 Date July 15, 1955

1. Remove and destroy the following pages:-

Table of Contents, 2, 6 and 8.
Figs. I & II.

2. Insert in correct numerical sequence the enclosed revised pages:

Table of Contents, 2, 6, 6A, 6B and 8.
Figs. I & II.

2.2 Services

The following services shall be supplied to the aircraft connections within the environmental conditions laid down in paragraph 3.8:

(a) Hot medium pressure air for starting the aircraft's turbo jet engines.

compression ratio	3.5 to 1
(Note: A pressure of 50 p.s.i.a. will, however, be acceptable at sea level conditions.)	
minimum flow	110 lb. p. min.
temperature	minimum 200°F at -65°F ambient atmosphere. Under no condition shall the maximum temperature exceed 650°F

(b) D.C. electric power, when using a separate "starter vehicle" only, to energize certain aircraft circuits during starting.

potential	28/24V
current	50 amp. max.

(c) A.C. electric power, 3 phase, to energize the aircraft's electrical system.

potential	208/120 V ± 2.5%
frequency	380-420 c.p.s.
power	35 KVA max.

(d) Hot medium pressure air for energizing the aircraft's electronic system, pressurizing fuel tanks and temperature control of aircraft's air conditioning system.

pressure	45 p.s.i.g.	OR	30 p.s.i.g.
minimum flow	0 - 45 lb. p. min.		0 - 51 lb. p. min.
temperature	minimum 150°F at -65°F ambient atmosphere. Under no condition shall the maximum temperature exceed 550°F		

(e) Cool low pressure air for air conditioning the aircraft's cockpit and equipment compartments.

pressure	3.5 p.s.i.g.
minimum flow	100 lb. p. min.
temperature	55°F to 80°F

(f) Voice intercom between air crew and ground crew on vehicle carrying "starting" equipment.

(g) Distilled water for topping up the aircraft's evaporative cooling unit in the air conditioning system.

If the vehicle is a self-propelled truck type, it shall be capable of towing trailers containing additional support equipment, within the towing capacity of the basic vehicle.

Materials used shall be of high quality, suitable for the purpose and shall, wherever possible, conform to Government Specifications and Standards. When materials are used that are subject to deterioration when exposed to climatic and environmental conditions likely to occur during service usage, they shall be adequately protested against such deterioration.

3.7 Maintenance

The ground power vehicles shall be designed to be easily maintained and repaired. Point of routine maintenance shall be easily accessible and individual items of equipment on the vehicles shall be readily replaceable. Overhaul life for components and equipment shall be at least 1000 hours operation; if gas turbines are proposed, these will be subject to special consideration.

3.8 Environment

The ground power vehicles shall be capable of being started and operated satisfactorily, by day and night, under all weather conditions encountered from extreme cold climates through to humid, tropical, salty, hot and sandy desert climates and also in any plane within 15 degrees of the horizontal.

The performance of the equipment will vary considerably with changes of climatic conditions; some of the services will have to meet the design requirements under extreme climatic conditions, whilst with other services some fall off in performance will be acceptable. Accordingly, the design requirements laid down in paragraph 2.2 will have to be satisfied, throughout the overhaul life of the equipment, within the classifications of temperature, pressure and humidity listed below:-

Class 1 - Extreme Climatic Conditions

This applies to the A.C. and D.C. electrical supplies and also to air for cooling the cockpit and equipment compartments, voice intercom and distilled water referred to in paragraph 2.2 (b), (c), (e), (f) and (g).

Altitude ft.	Temperature of free air (°F)		Barometric Pressure (in. Hg)		Dew Point (°F)	
	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere
0	130	-65	29.92	29.92	75	-70
1,000	124	-65	28.93	28.57	73	-70
2,000	118	-65	27.98	27.32	70	-70
3,000	112	-65	27.04	26.17	67	-70
4,000	106	-65	26.14	25.09	64	-70
5,000	100	-65	25.25	24.05	61	-70

Note: Provison must also be made for enclosed air temperatures, due to solar radiation, of up to 160°F.

Class 2 - Normal Operational Climatic Extremes

This applies to the medium pressure air supply for starting the engines and for energising the aircraft's electronic system, etc. referred to in para. 2.2 (a) and (d).

Altitude ft.	Temperature of free air (°F)		Barometric Pressure (in. Hg)		Dew Point (°F)	
	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere	Hot Atmosphere	Cold Atmosphere
0	110	-60	29.92	29.92	75	-65
1,000	108	-60	28.93	28.57	72	-65
2,000	104	-60	27.98	27.32	68	-65
3,000	100	-60	27.04	26.17	64	-65
4,000	97.5	-60	26.14	25.09	61	-65
5,000	95	-60	25.25	24.05	58	-65

Note: In the event of an ambient temperature of -65°F being experienced the delivery temperatures of the air supplies for engine starting and energising the electronic system shall not fall below 200°F and 150°F respectively.

From perusal of the foregoing, it will be seen that an increase in engine starting time would be acceptable in the extreme hot climatic conditions indicated in Class 1. The supply of air for the turbo-generator would, however, be maintained as, in the same circumstances, there would be no demand for hot air in the air conditioning system.

Due consideration must be given to:-

(a) The ingress of driving snow, moisture and sand on to switchgear, control panels and other items of equipment.
(b) The possibility of snow and freezing rain striking exhaust pipes and other hot spots, melting and subsequently freezing.
(c) That the fasteners on panels which have to be removed in service and the controls can be operated by personnel wearing heavy arctic clothing.
(d) Routing the fuel lines so as to avoid vapour locks in extremely hot weather.
(e) The effect of climatic extremes on lubrication and cooling systems.

3.9 Radio Interference

The entire power system shall be designed so as to minimize radio interference.

3.10 Instrumentation and Protection

Adequate instrumentation and protection for all the power supply equipment shall be incorporated.

Provision shall be made for the electrical grounding of all vehicles. A fire extinguisher must be installed in a readily accessible position on each vehicle.

4. TECHNICAL REQUIREMENTS

4.1 Services

The services which this mobile ground power equipment shall perform are as follows:

(a) Supply of hot medium pressure air, for starting the aircraft gas-turbine jet engines by means of an aircraft air-turbine geared to the high pressure compressor of each engine.

power to the control valve on the ground vehicle, which must then close and cut off the air supply to that engine starter turbine.

The required pressure, temperature and flow to start one engine is tabulated in Fig. I. The duration of the starting cycle for one engine, with this mobile ground equipment, shall be a maximum of 30 seconds at sea level; under the most adverse conditions at 5000 ft., however, a starting time of 40 seconds would be acceptable. This ground equipment need not be capable of starting the two aircraft engines simultaneously.

Should a heated and insulated air storage bottle be contemplated for supplying the starting air, then this bottle should be of sufficient capacity to permit a total of 4 engine starting cycles and means should be incorporated on the vehicle to re-charge the bottle in 15 minutes.

Unless it can be proven to be simpler and cheaper to use such an air bottle arrangement, a compressor supply of the required flow of hot pressure air is favoured. In order to meet Turn-around and Stand-by requirements it shall be possible to start the aircraft engines at a moments notice, i.e. the air supply shall be available immediately simply by pressing the aircraft starter button actuating the control valves in the ground unit.

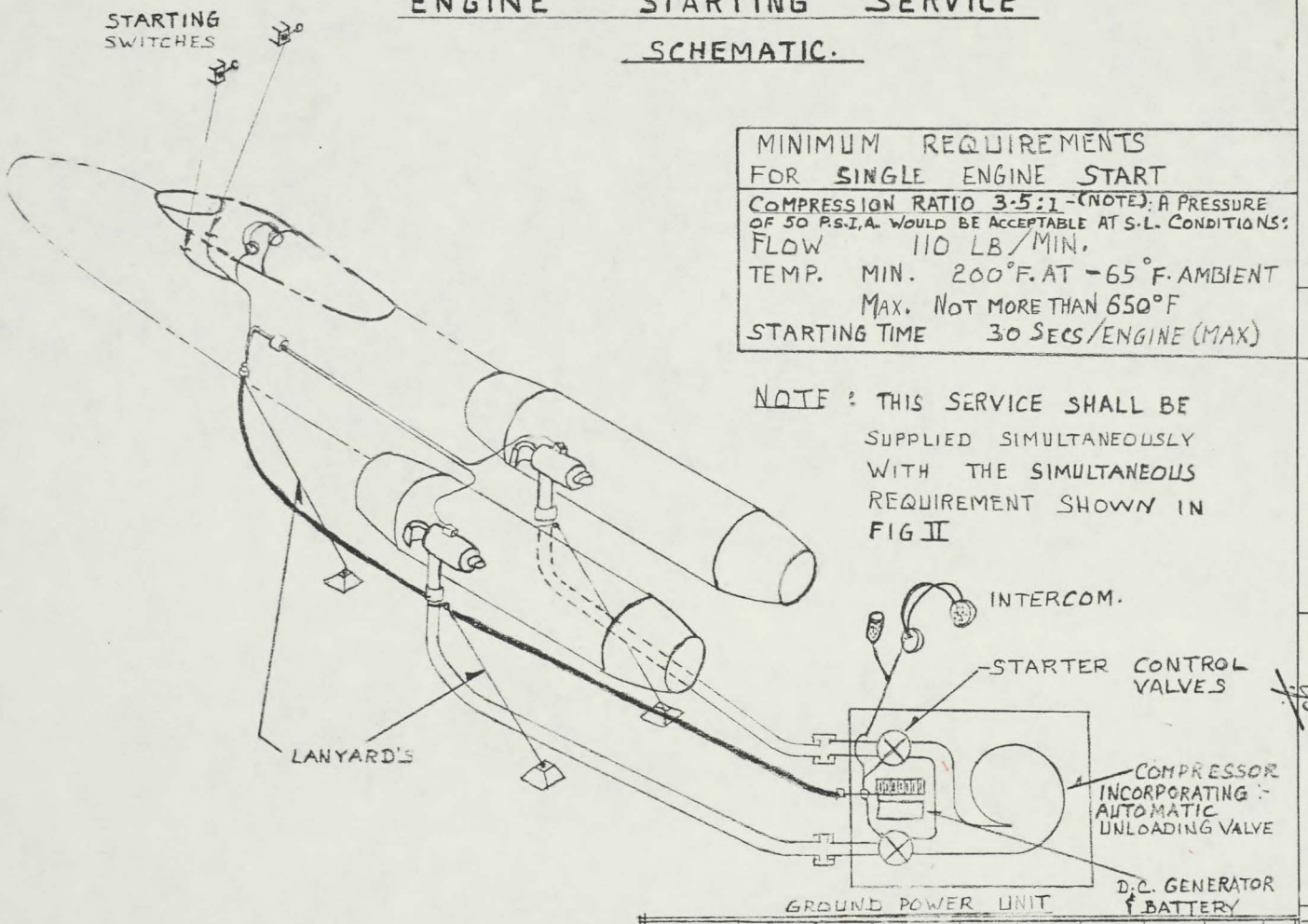
Before and during the starting operation, voice intercommunication is desired between the occupant of the aircraft cockpit and the ground crew. For this purpose the aircraft's AN-AIC10 intercom set will be used. The electric circuit wires for an amplifier on the ground unit must be coupled to the aircraft by means of the same automatic quick release coupling used for the starter control wires. Power for the amplifier shall be derived from a generator-battery set on the vehicle.

The electric wires required for these circuits are as follows:

2 starter valve control wires, size AN16
1 starter ground wire, size AN8
2 intercom wires, i.e. interphone, size audio common, AN20 SSCJ

The electric current for these circuits will be drived from the aircraft's electrical system which in turn must be energized from the ground power equipment as will be explained in the following paragraphs, 4.3 and 4.4.

ENGINE STARTING SERVICE SCHEMATIC.



MINIMUM REQUIREMENTS FOR SINGLE ENGINE START	
COMPRESSION RATIO 3.5:1 - (NOTE): A PRESSURE OF 50 P.S.I.A. WOULD BE ACCEPTABLE AT S.L. CONDITIONS:	
FLOW	110 LB/MIN.
TEMP.	MIN. 200°F. AT -65°F. AMBIENT
	MAX. NOT MORE THAN 650°F
STARTING TIME	30 SECS/ENGINE (MAX)

NOTE : THIS SERVICE SHALL BE SUPPLIED SIMULTANEOUSLY WITH THE SIMULTANEOUS REQUIREMENT SHOWN IN FIG II

ISSUE		2	3								
DATE		JUNE/55	JULY/55								
APPROVED		JPB	JPB								

FIG. 1

AIRCRAFT:

AVRO AIRCRAFT LIMITED
TECHNICAL DEPARTMENT (Aircraft)

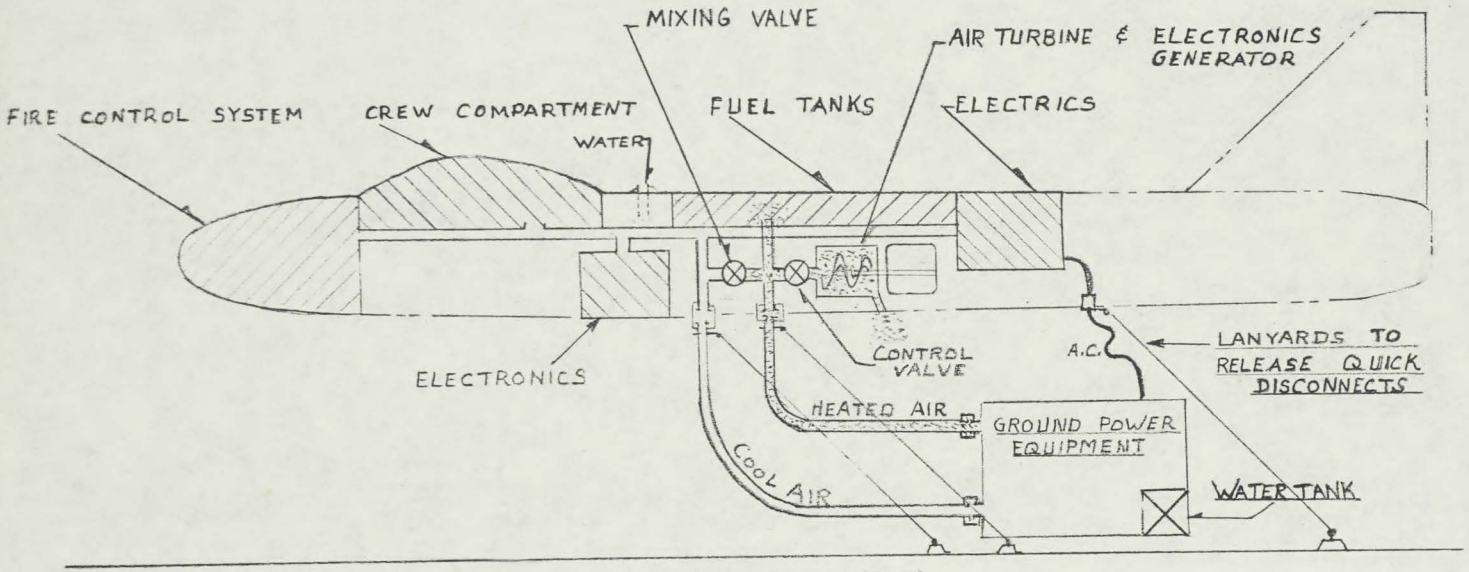
REPORT NO. LOG/105/8
SHEET NO

PREPARED BY DATE

CHECKED BY DATE MARCH-55

FORM 1319

AIR CONDITIONING / ELECTRICAL SERVICE SCHEMATIC



MINIMUM REQUIREMENTS		
HEATED AIR —	PRESS. 45 P.S.I.G. OR 30 P.S.I.G.	
	FLOW. 0-45 LB/MIN. OR 0-51 LB/MIN.	
	TEMP. MIN. 150 °F AT -65 °F AMBIENT MAX. NOT MORE THAN 550 °F	
COOL AIR —	PRESS. 3.5 P.S.I.G.	
	TEMP. 55° TO 80° F	
	FLOW 100 LB / MIN.	
ELECTRICAL	35 K.V.A. 208 V. 3 PH. 400 CYCLE	
	FREQUENCY RANGE 380-420 C.P.S.	
	VOLTAGE CONTROL ± 2.5%	

DUTY CYCLE
2 HOURS CONTINUOUS

ISSUE	2	3
DATE	JUNE/55	JULY/55
APPROVED	JPB	JPB

NOTE: 35 KVA IS NOT REQUIRED SIMULTANEOUSLY WITH FULL AIR FLOW
MAX. SIMULTANEOUS REQUIREMENT IS 10 KVA. 45 LB/MIN OR 51 LB/MIN. HOT AIR, 100 LB/MIN COOL AIR.

FIG. II

AVRO AIRCRAFT LIMITED
TECHNICAL DEPARTMENT (Aircraft)
AIRCRAFT:
REPORT NO. LOG/105/8
SHEET NO.
PREPARED BY
DATE
CHECKED BY
DATE MARCH-55

CF-105

GENERAL REQUIREMENTS

FOR

MOBILE GROUND POWER UNITS

Report No. LOG/105/8

C O N F I D E N T I A L

March, 1955

AVRO AIRCRAFT LIMITED, MALTON, ONTARIO

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1. INTRODUCTION

1.1 Purpose of Report

This report describes the general requirements for mobile ground power equipment to provide field support for a two engined interceptor aircraft designed by AVRO Aircraft Ltd. Its purpose is to provide sufficient information to submit engineering proposals for such equipment.

1.2 Engineering Proposals

Engineering proposals should contain sufficient information to enable AVRO Aircraft Ltd. to perform comparative evaluation studies. The following minimum information will be necessary on the proposed unit(s):

(1) Detailed technical description, data and preliminary general arrangement drawings showing main dimensions of equipment and vehicles.

(2) Estimated Costs, i.e. development cost, unit cost, operating cost, overhaul cost.

(3) Estimated rates of delivery.

(4) Proposed production facilities in Canada.

2. SUMMARY

2.1 Vehicles

Two basic configurations are possible:

(a) All services combined in one vehicle.

(b) A.C. electric/pneumatic/air-conditioning services in one vehicle and pneumatic engine starting/intercom services in another vehicle.

The choice will be determined after evaluation of the following parameters:

Flexibility of operations
size, weight and manoeuvreability of vehicles
reliability and overhaul life
costs.

The vehicles may be either trailers or self-propelled, depending upon their gross weight.

2.2 Services

The following services shall be supplied to the aircraft:

(a) Hot medium pressure air for starting the aircraft's turbo jet engines.

pressure	45 p.s.i.g.
flow	110 lb. p. min.
temperature	200°F at -65°F ambient atmosphere
	500°F at 100°F ambient atmosphere

(b) D.C. electric power, when using a separate "starter vehicle" only, to energize certain aircraft circuits during starting.

potential	28/24 V
current	50 amp. max.

(c) A.C. electric power, 3 phase, to energize the aircraft's electrical system.

potential	208/120 V ± 2.5%
frequency	380-420 c.p.s.
power	30 KVA max.

(d) Hot medium pressure air for energizing the aircraft's electronic system, pressurizing fuel tanks and temperature control of aircraft's air conditioning system.

pressure	45 p.s.i.g.
flow	45 lb. p. min.
temperature	200°F at -65°F ambient atmosphere
	500°F at 100°F ambient atmosphere

(e) Cool low pressure air for air conditioning the aircraft's cockpit and equipment compartments.

pressure	3.5 p.s.i.g.
flow	95 lb. p. min.
temperature	55°F to 80°F

(f) Voice intercom between air crew and ground crew on vehicle carrying "starting" equipment.

(g) Distilled water for topping up the aircraft's evaporative cooling unit in the air conditioning system.

If the vehicle is a self-propelled truck type, it shall be capable of towing trailers containing additional support equipment, within the towing capacity of the basic vehicle.

2.3 Configuration

AVRO Aircraft Ltd. does not intend, at this stage, to specify the configuration, type of prime mover, compressors and other related equipment or constructional details of the vehicles, but rather to describe the operational and technical requirements for this equipment and allow the optimum configuration etc. to be derived from this information by evaluation of technical suitability, procurability and cost. Engineering proposals should consider the two basic configurations referred to in para. 2.1, listing their advantages and disadvantages.

3. OPERATIONAL REQUIREMENTS

3.1 Scope

This mobile ground power equipment is intended to support those squadron airplanes which are considered serviceable and which are located on the tarmac apron or at the end of the runway. It is not intended to be normally used on those airplanes which are housed inside maintenance hangars or readiness shelters, ground power equipment for which will be stationary and driven from electric mains.

The purposes for which the mobile ground power equipment will be used are:

(a) Daily inspections and minor maintenance in the open.

(b) Turn-around of aircraft returning from a sortie followed by immediate take-off on an intercept mission.

(c) Engine starting for normal training flights.

(d) Stand-by condition prior to intercept mission; airplanes not in readiness shelters.

(e) To cater for special conditions when no electric mains power is available.

3.1.1 Daily Inspections and Minor Maintenance

This comprises check-outs and minor trouble shooting of the various aircraft systems requiring electric and pneumatic power and air conditioning and may occasionally require the starting or turning over of the aircraft engines.

3.1.2 Turn-arounds

During this operation, after the aircraft engines have been switched off, electric and pneumatic power and air conditioning are required in order to perform various servicing operations and in order to keep the electronic systems warmed up. Subsequently the aircraft engines must be started up, during which period the above services may not be interrupted.

3.1.3 Engine Starting

During normal peace time operations such as training flights where no urgent operational scramble is necessary, the only pre-flight support required is the ability to start the aircraft engines. This also applies when the airplane must take-off from an emergency landing strip for return to base.

3.1.4 Stand-by in the open

Under certain tactical conditions it may be necessary to have all serviceable airplanes standing-by, in addition to those in readiness shelters, for immediate take-off on intercept missions. In this condition the aircraft requires electric and pneumatic power and air conditioning and facilities to start its engines in sequence at a moments notice. It is important to note that it is not possible to interrupt the air conditioning and the electric and pneumatic power supply during the engine starting period. The ground equipment shall be capable of supporting the aircraft in this condition for a continuous period of at least 2 hours.

3.1.5 Special Conditions

These may arise when the airplane is temporarily located at an airfield which does not have the stationary support equipment of the home base, or when there occurs a serious breakdown of the stationary power facilities at the home base.

3.2 Handling and Operating

To facilitate ease of handling, this mobile ground power equipment shall be self contained and easily manoeuvreable around parked aircraft and it shall be required to service aircraft which may be dispersed over a fairly large area at the air base. Whether this equipment shall be self-propelled or not, depends on the gross weight of the vehicle; the following table gives an indication as to what may tentatively be considered satisfactory at the present time.

Vehicle gross weight

up to 1000 lb.	-	vehicle may be a trailer.
1000 to 1600 lb.	-	vehicle may be a trailer which shall incorporate self-propelling machinery to facilitate manoeuvring around parked aircraft while being steered by means of the tow bar.
1600 lb. and greater	-	vehicle shall be of the truck type self propelled by internal combusion engine with adequate transmission ratios to fulfill its purpose.

The vehicle shall be designed to make operating and servicing safe and convenient for personnel wearing arctic clothing. The noise level shall be kept down as much as possible and exhaust fumes shall be directed vertically upwards.

3.3 Roading

The ground power vehicle shall be capable of operating on paved runways or improved roads and on pierce plank under the environmental conditions stated in para. 3.8.

3.4 Towing

It is not a requirement that self propelled ground power vehicles are capable of towing the airplane. However, it is desirable that a standard pintle be installed on the rear of the vehicle so as to be able to tow trailers, containing additional support equipment, within the towing capacity of the basic vehicle. Trailer vehicles shall have a rear pintle so that the unit may be incorporated in a towing train.

3.5 Air Transportability

If a separate "starting" vehicle is used, this must be air transportable and the air conditioning/electric vehicle should be air transportable, if possible. If one self contained vehicle is used which includes facilities for starting, this must be air transportable. The maximum dimensions and weights of air transportable equipment shall be such that it can be carried by a C119F aircraft. For cargo loading instructions refer to EO 05-90A-8A issued by the RCAF.

3.6 Construction

The ground power vehicles shall be ruggedly constructed so as to withstand the strains, jars, vibrations and other conditions incident to shipping, storage, installations and service.

Materials used shall be of high quality, suitable for the purpose and shall, wherever possible, conform to Government Specifications and Standards. When materials are used that are subject to deterioration when exposed to climatic and environmental conditions likely to occur during service usage, they shall be adequately protected against such deterioration.

3.7 Maintenance

The ground power vehicles shall be designed to be easily maintained and repaired. Point of routine maintenance shall be easily accessible and individual items of equipment on the vehicles shall be readily replaceable. Overhaul life for components and equipment shall be at least 1000 hours operation; if gas turbines are proposed, these will be subject to special consideration.

3.8 Environment

The ground power vehicles shall be capable of being started and satisfactorily operated by day and night under all weather conditions encountered in extreme cold climates of -65°F to humid, tropical, salty and hot, sandy desert climates of 130°F free air temperature and 160°F enclosed air temperature and at altitudes from sea level to 5000 ft. and in any plane within 15 degrees of horizontal.

3.9 Radio Interference

The entire power system shall be designed so as to minimize radio interference.

3.10 Instrumentation and Protection

Adequate instrumentation and protection for all the power supply equipment shall be incorporated.

4. TECHNICAL REQUIREMENTS

4.1 Services

The services which this mobile ground power equipment shall perform are as follows:

(a) Supply of hot medium pressure air, for starting the aircraft gas-turbine jet engines by means of an aircraft air-turbine geared to the high pressure compressor of each engine.

(b) Supply of direct current electrical power to energize certain circuits in the aircraft during engine starting if the a.c. ground power supply is not available, when using a separate engine starting vehicle.

(c) Supply of alternating current, three phase, electrical power to energize the aircraft's electrical system.

(d) Supply of hot medium pressure air, for energizing the aircraft's electronic systems by means of an air-turbine driven generator in the aircraft and for pressurizing the aircraft's fuel tanks and for temperature control of the aircraft's air conditioning system by means of automatically controlled mixing with the:

(e) Supply of cool low pressure air, for keeping the aircraft's cockpit and equipment compartments within allowable temperature ranges.

(f) Voice intercom between air crew and ground crew.

(g) Supply of distilled water for topping up the aircraft's evaporative cooling unit in the air conditioning system.

(h) Towing of other support equipment trolleys.

For purpose of clarity, services (a), (b) and (f) and services (c), (d) and (e) are shown separately in Figures I and II respectively. On these sketches are also listed the minimum electric and pneumatic power requirements. Hydraulic and high pressure air services to the aircraft are not required from this equipment. A description of each service follows.

4.2 Engine Starting

Refer to Fig. I. It will be seen that the aircraft is fitted with air-turbine engine starters. Engine starting is required to be controlled by the occupant of the aircraft cockpit. There will be no starter control valves mounted in the aircraft and the starting cycle must therefore be controlled by means of electrically operated valves on the ground power vehicle. The electric control wires for these valves must be coupled to the aircraft by means of an automatic quick release coupling and the circuit must be so arranged that by pressing one of the starter buttons in the pilot's cockpit the appropriate control valve opens and permits the flow of air to the corresponding engine starter turbine. After engine "light-up" and when an appropriate engine speed is reached, a centrifugal switch, mounted in the starter turbine, opens and cuts off the electric

power to the control valve on the ground vehicle, which must then close and cut off the air supply to that engine starter turbine.

The required pressure, temperature and flow to start one engine is tabulated in Fig. I. The duration of the starting cycle for one engine, with this mobile ground equipment, shall be 30 seconds maximum. This ground equipment need not be capable of starting the two aircraft engines simultaneously.

Should a heated and insulated air storage bottle be contemplated for supplying the starting air, then this bottle should be of sufficient capacity to permit a total of 3 engine starting cycles and means should be incorporated on the vehicle to re-charge the bottle ih 15 minutes.

Unless it can be proven to be simpler and cheaper to use such an air bottle arrangement, a compressor supply of the required flow of hot pressure air is favoured. In order to meet Turn-around and Stand-by requirements it shall be possible to start the aircraft engines at a moments notice, i.e. the air supply shall be available immediately simply by pressing the aircraft starter button actuating the control valves in the ground unit.

Before and during the starting operation, voice intercommunication is desired between the occupant of the aircraft cockpit and the ground crew. For this purpose the aircraft's AN-AIC10 intercom set will be used. The electric circuit wires for an amplifier on the ground unit must be coupled to the aircraft by means of the same automatic quick release coupling used for the starter control wires. Power for the amplifier shall be derived from a generator-battery set on the vehicle.

The electric wires required for these circuits are as follows:

2 starter valve control wires, size AN16
1 starter ground wire, size AN8
4 intercom wires, i.e. interphone, size ANJ20 STPJ
audiocommon, size ANJ20 STPJ
UHF Sidetone, size ANJ20 SSCJ
Shield Ground, size AN20

The electric current for these circuits will be derived from the aircraft's electrical system which in turn must be energized from the ground power equipment as will be explained in the following paragraphs, 4.3 and 4.4.

From the foregoing it will be appreciated that there are a total of 3 couplings to the aircraft, namely:

Two air hoses from the control valve outlets on the ground unit to the lanyard operated automatic disconnect couplings on the aircraft, under each of the engines and one electrical cable also connected to the aircraft by means of a lanyard operated automatic disconnect coupling.

The 2 air hoses shall be flexible and in 2 lengths of 20 ft. for each; they shall be provided with "Wiggins" type 3 inch dia. coupling nozzles for connection to the aircraft, ground unit and between hoses. The make of quick disconnect aircraft coupling for the 40 ft. electrical cable has not been decided upon yet; it will be designed according to a specification to be issued by AVRO Aircraft Ltd. in the near future; refer also to next paragraph.

4.3 D.C. Electric Power Supply

If for reasons of economy and flexibility of usage a separate starter vehicle is decided upon, in order to cater for operational conditions where engine starting only is required (refer paras. 3.1.3 and 3.5), then it becomes necessary to supply a small amount of 24/28 volt D.C. current to the aircraft to prevent using the aircraft battery on the ground.

The circuits which this d.c. power might be required to energize are therefore as follows:

starter control valves
aircraft ignition system
aircraft engine fire detection
aircraft engine fire extinguishing
aircraft low pressure fuel cock shut-off
aircraft/ground intercom system
aircraft canopy actuation

The total load for all these services is of the order of 50 amperes. Hence, to cater for this particular division of ground power equipment, 1 extra electric power wire, size AN8 and a control wire, size AN16, shall be required, in order to connect a d.c. generator and battery on the starter-vehicle to the aircraft. A ground wire is already available, see para 4.3.2. A reverse current cut-out, amp. meter and voltage regulator is required on the ground vehicle. These d.c. power wires shall be coupled to the aircraft by means of the same automatic quick release coupling as used for starter control and intercom wires. Since, it is desired to allow for one spare contact in the plug of this coupling, we shall require a plug with 10 pins.

4.4 A.C. Electric Power Supply

Refer to Fig. II. The main electrical system of the aircraft derives its power from two 3-phase, 400 cps, 208/120 volt, 20 KVA alternators, one of which is driven from each engine. The d.c. power requirements derived from the source are obtained by means of the aircraft transformer-rectifier.

The ground power equipment shall be capable of supplying the following output power at the aircraft coupling:

10 KVA continuous during Stand-by condition
or 15 KVA during Turn-around condition
or 30 KVA peak load of short duration during Maintenance operations.

This power shall be supplied to the aircraft via a lanyard operated automatic quick disconnect coupling incorporating plug AN 3430 and in accordance with a specification to be issued by AVRO Aircraft Ltd. This plug shall mate with an AN 3114 receptacle on the aircraft. In order to prevent arcing during coupling or un-coupling, an a.c. power selector relay in the aircraft shall be energized by a 28 volt d.c. ground source through contact pin E of this receptacle. For this purpose, the ground power vehicle shall carry a 28/24 volt d.c. generator and battery capable of supplying 20 amperes to the aircraft via plug AN 3430.

A 30 KVA alternator shall be carried on the ground power vehicle, with switches and protection and 40 ft. cable.

It would be prudent to design for the possibility that in the future a 40 KVA alternator may be required, any such change should be possible to accomplish with the least amount of trouble.

The alternator shall be capable of delivering the rated output continuously at any frequency within the range of 380 to 420 c.p.s. and the alternator voltage shall be regulated within $\pm$ 2.5% when supplying any load from zero to 100% rated full load of any power factor or specified frequency and at all environmental conditions likely to be encountered. Radio interference shall be minimized.

The components of the aircraft electrical system are located in a number of enclosed compartments which must be held within certain temperature limits by means of air conditioning whilst operating from the ground power unit.

4.5 Hot Medium Pressure Air Supply

Refer to Fig. II. The electronic system in the aircraft requires very close regulation and is powered by generators energizing various circuits, which are driven by an air turbine motor. Motor and generators are a self contained package forming part of the aircraft electronic system; it is fed by hot air drawn from the high pressure leg of the aircraft's air conditioning system.

For ground operation of the electronic system, when the aircraft engines are switched off, a supply of hot medium pressure air is therefore required to take the place of the air normally supplied by the engines.

Although running the aircraft's turbo-generator when on the ground means that it will be using operational life time, it is nevertheless felt that, as the turbo-generator's life is comparable to or better than the life of the rest of the electronic system, there is no urgent reason for reducing the time that it is operating by providing a similar turbo-generator on the ground power vehicle. This argument is considerably reinforced when it is borne in mind that the additional switching relays which would be required in the aircraft for each of the circuits, together with an additional automatic quick disconnect coupling, would add a substantial weight penalty to the aircraft. In any case, some of this hot medium pressure air is required for controlling the temperature of the air used for conditioning cockpit etc. and also for pressurizing the aircraft's fuel tanks.

The air is divided between these three services as follows: 30 lb. p. min. to drive the electronics system turbo-generator, 10 lb. p. min. for mixing with the cool air supply, 5 lb. p. min. for pressurizing fuel tanks. The minimum total flow requirement is therefore 45 lb. p. min, but this demand may vary from zero upwards, depending upon the local ambient temperature and how many, if any, of the electronic system's components are switched on.

Hence the ground equipment shall be designed to provide continuous pressure and variable flow of hot medium pressure air. The unloading device shall be automatic and shall function with as little deviation in pressure and surging as possible.

Since some of this air is used in the air conditioning system, it shall be free of oil or any other form of contamination.

A flexible air hose made in 2 lengths of 20 ft. each shall be provided, to be fitted with 2.5 inch dia. coupling nozzles for connection to the aircraft, ground unit and between hoses. The automatic

quick disconnect coupling to the aircraft shall be in accordance with a specification to be issued by AVRO Aircraft Ltd. This automatic disconnect coupling will be lanyard operated.

4.6 Cool Low Pressure Air Supply

Refer to Fig. II. Components of the main electrical system and of the electronics systems are located in a number of enclosed compartments which are normally air conditioned in flight and which must be held within certain temperature limits whilst operating from a ground power unit. The aircraft cockpit must of course also be air conditioned during the Stand-by condition.

In order to do this, the ground power equipment shall supply low pressure cool air to the cold leg of the aircraft air conditioning system, down stream of the aircraft refrigeration unit. Before entering the cockpit and the various equipment bays, appropriate amounts of hot air (see para. 4.5) will be mixed with this cool air supply, the amounts depending of course on ambient temperature conditions. This is done by means of the normal temperature control valves in the aircraft's air conditioning system and is therefore entirely automatic.

The flow demand for this cool air is continuous and does not fluctuate. This air shall also be free of oil or any form of contamination.

A flexible air hose made in 2 lengths of 20 ft. each shall be provided, to be fitted with 3.5 inch dia. coupling nozzles for connection to the aircraft, ground unit and between hoses. The automatic quick disconnect coupling to the aircraft shall be in accordance with a specification to be issued by AVRO Aircraft Ltd. This automatic disconnect coupling, will be lanyard operated.

4.7 Intercommunication Cockpit/Ground

This has already been discussed in para. 4.2. Briefly, intercom equipment will be required on ground power vehicles containing starter equipment. This equipment shall consist of an audio amplifier powered from a source on the vehicle, head phone, microphone and jack and an optional PTT switch.

The 4 electric wires necessary, shall be incorporated in the same cable which houses the starter control wires and possibly the d.c. ground supply wires. This cable shall have a special automatic quick disconnect coupling for connection to the aircraft, in accordance with a specification to be issued by AVRO Aircraft Ltd.

4.8 Distilled Water Supply

The aircraft's air conditioning system incorporates by necessity a heat exchanger whereby heat is extracted from the supply air, in certain flight conditions, by means of the evaporation of water. This water is contained in a so-called "freezable boiler" in the aircraft. The capacity of the boiler is 125 lb. of water. This boiler will require topping up during Turn-arounds, Daily Inspections and prior to Stand-by conditions.

It is desired to carry a supply of distilled water in an insulated and heated tank on the ground power vehicle which carries the other air conditioning equipment.

The problem is how to get this water to the aircraft under arctic climatic conditions. The filling aperture on the aircraft is presently planned to be located on the top of the fuselage aft of the canopy and underneath the dorsal fairing. It is planned to have a dip-stick suitably calibrated to measure the amount of either water or ice remaining in the boiler, by means of insertion of this dip-stick into the filling aperture and pipe. When the dip-stick reads a "low" level of either water or ice, water must be poured into this 2" diameter pipe.

Water could of course be pumped from the ground supply tank to the filling aperture by means of a hand-pump and hose; however this raises the problem of freezing of this water in a 20 ft. long hose at temperatures of -65°F, unless a specially heated hose and nozzle is developed. A simpler way, which is also less likely to develop trouble, may be to have a man fill a 2 gallon insulated special can with hot water from the supply tank on the vehicle and have him carry this 20 lb. of water up the steps of the cockpit entry structure and then pour it into the aircraft.

It is suggested that the capacity of the heated and insulated water tank on the ground vehicle be 150 lb. of useable water.

4.9 Towing

Refer to paragraph 3.4.

4.10 Conclusion

From the foregoing it will be appreciated that the supply of electric-, and pneumatic/electronic-power and conditioned air are linked together, insomuch that it is not possible to supply one without the other. These services, plus the supply of distilled water, must therefore be combined on one ground power vehicle.

The services for engine starting and ground intercom are linked together but these are not directly related to the other services. As stated in paras. 3.1.2 and 3.1.4, during conditions of turn-around and stand-by, none of the other services shall be interrupted during the starting cycle. However, during normal peace time operations the only pre-flight support necessary to get aircraft into the air are facilities to start the aircraft engines.

It may be concluded therefore that there are two basic configurations possible:

(a) All services combined in one vehicle.

(b) Electric/pneumatic/conditioning services in one vehicle and starting/intercom services in another vehicle.

The choice will be determined after evaluation of the following parameters:

Flexibility of operations
size, weight and manoeuvreability of vehicles
reliability and overhaul life
costs.

Regarding the a.c. electric power supply (see para. 4.4), the following should be noted:

Peak load of 30 KVA will only occur for short durations during maintenance operations. During these operations it is not necessary to simultaneously supply the electronic system with pneumatic power. As stated in para. 4.4, the a.c. electrical power required simultaneously with full pneumatic power and air conditioning is 15 KVA, during Turn-around operations. In short, it is not absolutely necessary that the ground vehicle should be capable of providing both maximum air supply and peak a.c. electrical power at the same time.

When estimating the required sizes of prime-movers for the ground equipment, it should be borne in mind that the power requirements tabulated in Figs. I and II are minimum values, which shall be available at the aircraft couplings.

A. V. ROE CANADA LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT (Aircraft)

REPORT NO. LOG/105/8
SHEET NO.

AIRCRAFT:		PREPARED BY	DATE
		CHECKED BY	DATE
			MARCH '55

ENGINE STARTING SERVICE

SCHEMATIC.

MINIMUM REQUIREMENTS FOR SINGLE ENGINE START.	
PRESS.	45 P.S.I.-G. (4:1)
FLOW	110 LB./MIN
TEMP. MIN.	200°F AT -65°F AMBIENT & 500°F AT 100°F AMBIENT
STARTING TIME	30 SECS/ENGINE (MAX)

NOTE: THIS SERVICE SHALL BE SUPPLIED SIMULTANEOUSLY WITH THE SIMULTANEOUS REQUIREMENT SHEWN IN FIG II.

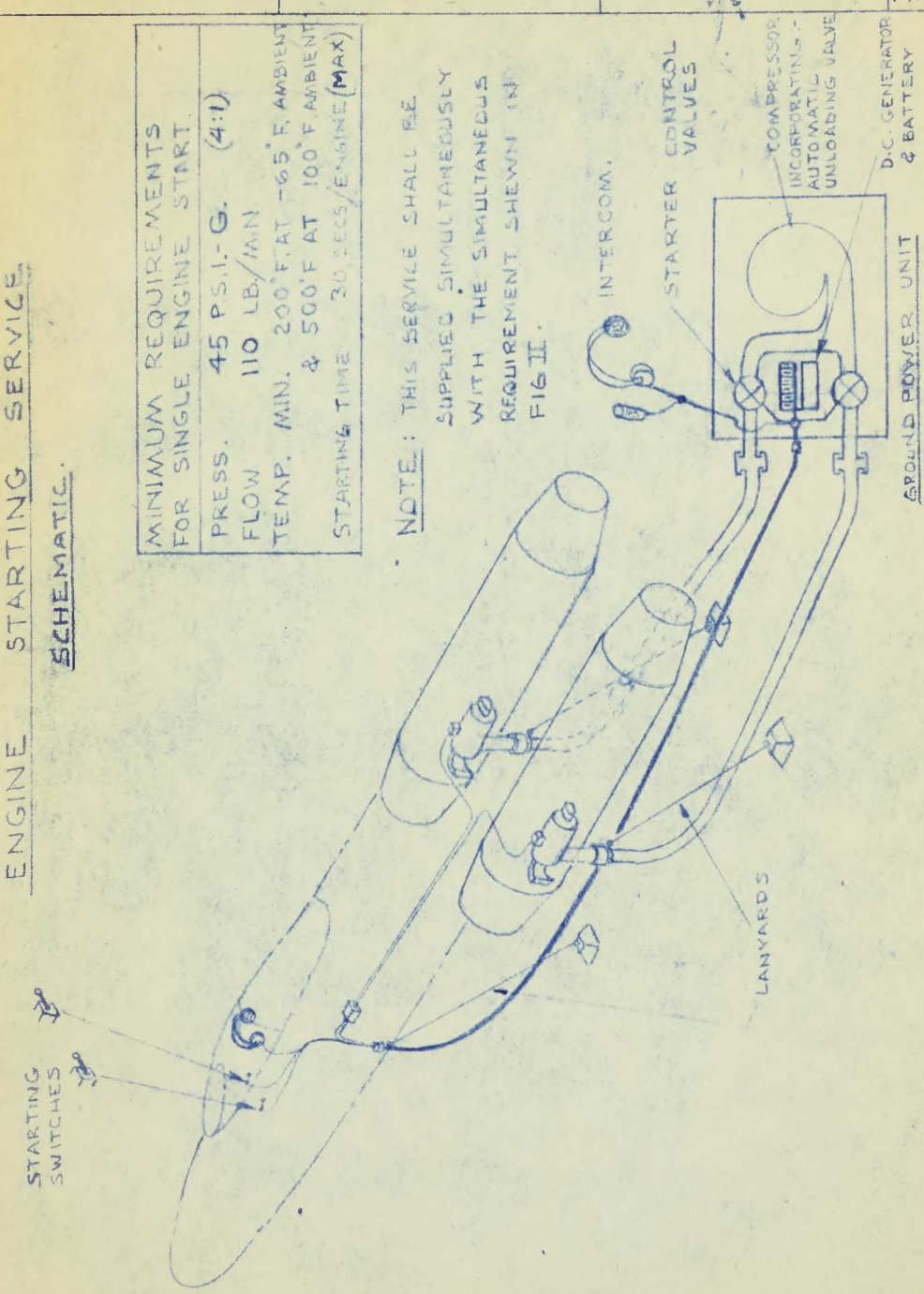


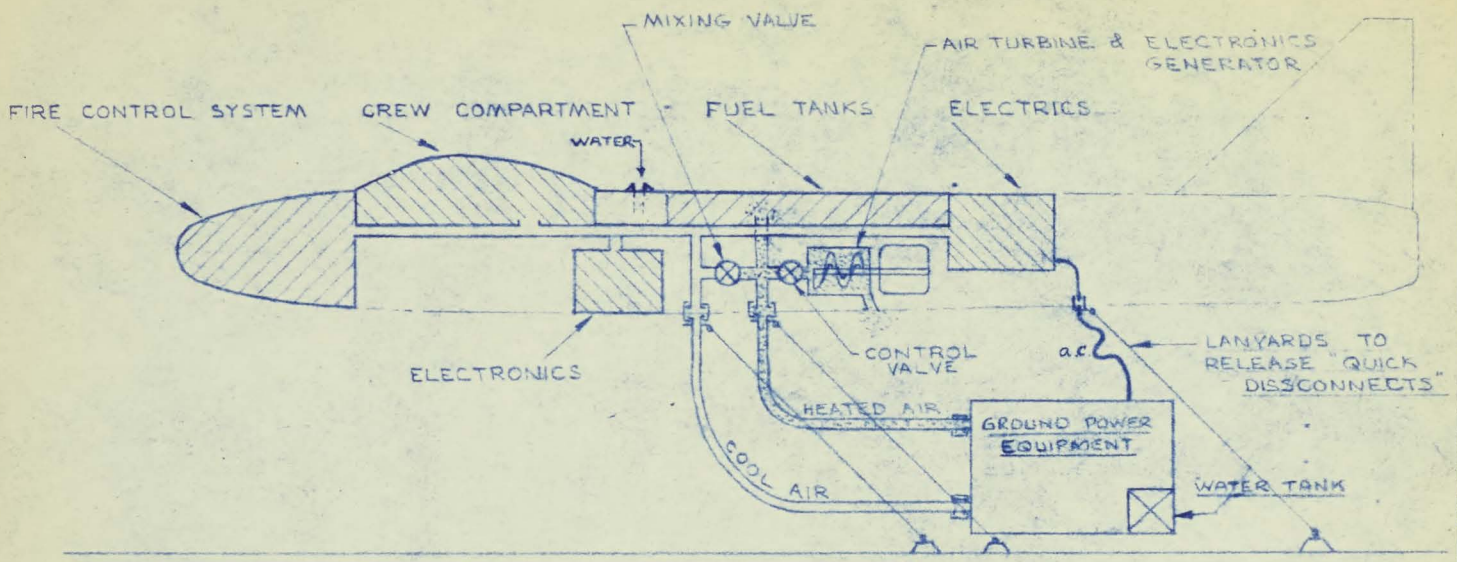
FIG. I

FORM 1319A

FORM 1319A

AIR CONDITIONING / ELECTRICAL SERVICE.

SCHEMATIC



MINIMUM REQUIREMENTS		
HEATED AIR —	PRESS. 45 P.S.I.G. TEMP. MIN. 200° F. AT -65° F. AMBIENT & 500° F. AT 100° F. AMBIENT FLOW 45 LB/MIN. TO ZERO (VARIABLE)	
COOL AIR —	PRESS. 3.5 P.S.I.G. TEMP. 55° to 80° F. FLOW 95 LB./MIN.	} INDEPENDANT OF AMBIENT TEMP.
ELECTRICAL —	30 K.V.A. 208 V. 3 PH. 400 CYCLE FREQUENCY RANGE 380-420 C.P.S. VOLTAGE CONTROL ± 2.5%	

DUTY CYCLE.
2 HOURS CONTINUOUS

NOTE: 30KVA IS NOT REQUIRED SIMULTANEOUSLY WITH FULL AIR FLOW.
MAX. SIMULTANEOUS REQUIREMENT IS 15KVA, 45LB/MIN HOT AIR, 95LB/MIN COOL AIR

FIG. II

A. V ROE CANADA LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT:

REPORT NO. 109/105/8
SHEET NO. 13.
CHECKED BY
PREPARED BY
DATE MARCH '55
DATE
DATE