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TECHNICAL REQUIREMENTS FOR ARROW 2 STARTING UNIT

Report No. 72/GEQ/12.

May, 1958.

CONFIDENTIAL

ANALYZED
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DRAWINGS

1. INTRODUCTION

The ground starting unit is to be a self contained, automatically controlled unit designed to provide compressed air for starting, and a small amount of electrical power to the ARROW 2 aircraft. It is intended that AVRO will suitably package this system and mount it on a four wheeled, two wheel steerable, towable chassis.

This report states the unit requirements in general terms, for the purpose of obtaining adequate preliminary engineering data on proposed components. This will enable AVRO Aircraft Limited to order the principal "off the shelf" components and to prepare an "Avrocan" Specification for subsequent detail engineering and procurement. Preliminary information on enclosures and on the vehicle chassis is included, to clarify the overall concept of the unit.

Reference should be made to schematic drawing No. 7-4427-134.

The starter unit shall supply sufficient air under all environmental conditions, to start the Iroquois engines of the ARROW aircraft within thirty seconds. In addition the unit shall supply 70 amps (maximum) of DC power, part of which will generate a small amount of AC power (500 VA 400 c.p.s. single phase) on the unit.

The primary power source of the unit will be an AiResearch GTCP 85 Series Gas Turbine engine. The gas turbine shall supply compressor bleed air for starting the Iroquois engine and drive a DC generator for the provision of the required power.

AC power will be provided by a DC driven inverter. Two flexible 45', 3½" i.d. ducts will be provided on the unit, each connected to a branch of a Y section in the delivery duct. Selector valves, to be controlled by either the pilot or the vehicle operator, will be fitted in the branches of the Y section, to direct flow to one hose or the other.

The unit is to be adaptable to both stationary and mobile applications. The stationary application is that of a starting unit installed in a hangar and operated remotely from a central control room. The chassis of the unit will be mounted on a four-wheel trailer running gear, which will be detachable for stationary applications. On the chassis frame the unit, consisting of three principal compartments, will be mounted:-

(a) The gas turbine compressor with electrical generating apparatus, instruments controls, and enclosure.

(b) The hose storage bin, with delivery hoses and electrical leads.

(c) The fuel tank.

1. INTRODUCTION (Continued)

These three compartments as an assembly will be easily detachable from the chassis. The vehicle, including running gear, is to be light and compact for air transportation.

It will be possible for one man to operate the vehicle. Starting the unit will be a one-switch operation. Further control and regulation of the unit is to be automatic. Normally, the pilot will make airflow selections, opening delivery valves on the unit by cockpit controls. Intercom will be fitted to the vehicle.

The vehicle shall perform its duty under conditions ranging from -65 to +120°F at sea level, and from -65 to 100°F at 3500 ft. altitude. The vehicle shall withstand the effects of sand, dust, ice, salt spray and fungus.

It shall also be possible to supply low pressure bleed air from the unit in conjunction with a small heat exchanger cart for use in aircraft defuelling.

Provision will be made for operation of the unit from a remote control panel.

2. METHOD OF OPERATION

The gas turbine will be started from a master switch. The starter sequence shall be automatic and engine acceleration must be controlled to ensure long engine life. When the turbine reaches operating speed a centrifugal switch shall energise the air and electrical loading circuits. A device will be fitted, if necessary, to prevent the operation of the AC inverter until the voltage regulator is ready for use. DC output to the aircraft will be controlled by a circuit breaker which would normally be "ON" during the starting sequence. AC output will be controlled in the same manner. Following the energising of the air loading circuit, the air flow to the Iroquois engine will be controlled by the pilot. Switches for operating the air delivery valves must also be provided on the unit. Additional controls for the auxiliary functions of the unit are required.

(a) Motoring switch.
(b) Low pressure bleed control switch which will control the bleed valve used in aircraft defuelling.

A receptacle for a remote control panel will be provided.

3. SPECIFIC CONSIDERATIONS

3.1 Powerplant

The powerplant is to be a gas turbine compressor with a power take off gear box. It will be a GTCP 85 series model manufactured by AiResearch. This engine is to drive a DC generator through its gear box.

The performance of this engine is to be such that it can start an Iroquois engine (equipped with an AiResearch ATS 100-39 air turbine starter) in 30 seconds or less under any of the prescribed ambient conditions.

The extremes of ambient conditions the design must cater to are:

-65°F. Sea Level
-65°F. 3500' Pressure Altitude
+120°F. Sea Level
+100°F. 3500' Pressure Altitude

To meet the objective of the 30 second maximum starting time, the powerplant shall meet or exceed the performance criteria quoted for model GTC 85-20 in AiResearch publication SC 5022, with respect to bleed air flow and pressure, and at the same time, provide sufficient shaft power to drive the DC generator under maximum electrical load.

3.2 Electric Power Production

A DC generator is to be driven through the power take off gear box. It will be either mounted on the gear box pad (conforming to AND 20006 type XVI B) or on an adapter mounting with the latter fitted to the gear box pad. The DC generator is to have a continuous output rating of not less than 75 amperes. Its regulated output is to conform to the requirements quoted for an external source of DC power in MIL-E-7894A (ASG) except that the steady state delivered voltage is to be 28 ± 1 volts, measured at the aircraft end of the delivery cable. Some of the DC power produced is to be used to drive an inverter. The inverter is to be rated for a continuous output of 500 VA of single phase, 400 c.p.s. 115 volt power. The output of the inverter is to be regulated as required by Specification MIL-I-7032. An external power receptacle for DC will be provided.

3.3 Controls, Instruments and Protective Devices.

It will be the object in designing the control system to make operation of the unit as simple, automatic, sure and safe as is possible. Controls and instruments are to be so grouped that one man may operate the vehicle from one position.

3.3.1 Engine Controls

Starting the gas turbine is to be accomplished by actuation of a "start" switch which will bring the compressor automatically to full governed speed without surge or over temperature. Starting will not be possible with a bleed air valve open or with the DC generator loaded. It shall be possible to re-initiate a start at any speed within the starter motor assist range.

There is no requirement for a throttle to control the fuel system or for the engine to run at idling RPM.

A device to prevent the gas turbine from starting or continuing to operate, when the oil pressure is too low, must be fitted.

A mechanically driven, centrifugal three-speed switch assembly shall sequence control operation to function at appropriate unit operating speeds. At the lowest speed the switch shall provide for the cutout of the starter and ignition circuits. At the second speed, the switch shall provide a signal to indicate that the unit has reached the minimum speed for application air bleed and shaft power load, and permitting the bleed air valve to be opened. At the highest speed, the switch shall automatically shut down the unit in the event of an overspeed condition. Resetting of this device shall not be required prior to restarting the unit.

The control system must hold the output drive speed of the gas turbine to its rated speed, within such limits that the DC power output from the generator does not result in deviations from the required performance. This speed control is to be maintained with any load up to and including full load (pneumatic or electric, or both).

In the event that bleed air demand plus shaft power demand exceeds the capacity of the unit, the control system shall function to decrease the bleed air output, rather than allow any reduction of the shaft power output.

Bleed air flow shall be limited so that the turbine exhaust temperature does not exceed its maximum allowable value.

Shutdown is to be accomplished by breaking the circuit of a solenoid operated fuel valve. This circuit shall be controlled by the engine master switch. Although the engine would normally be stopped under conditions of zero bleed flow, shut-down from conditions of full pneumatic and electric load shall be possible without damage to the unit. The compressor shall not surge when the bleed air line is closed by means of a valve in 0.40 seconds under any condition of output flow, starting or operation.

3.3.2 Electrical Controls

Protective devices will be fitted so that neither DC generator output nor AC inverter output may be used unless these components are rotating at their appropriate speeds.

It will be possible to operate all vehicle lights and intercom using only the unit's storage battery as a power source.

To obviate accidental starting of the unit or inadvertent operation of the lights or intercom during storage or transport, a means of isolating the unit's battery shall be provided.

3.3.3 Delivery Valves

The flow control valves will normally be operated from the aircraft starting circuit, and will also be operable by switches on the unit itself. The operating rate of the flow control valves will not exceed 0.5 seconds opening and 0.5 seconds closing.

3.3.4 Control Panel

The following instruments and controls will be mounted on a panel, which will form part of the gas turbine compressor enclosure.

(a) Master switch - supplying battery power to starter and ignition circuits and opening fuel valves for starting and operating.

(b) Press-to-start switch, or if starting has been made a function of the master switch (and this is desirable) a press-to-motor switch.

(c) Tachometer indicating engine percentage RPM.

(d) Exhaust gas temperature gauge - reading in 50°F. increments.

(e) Bleed air pressure gauge - 0-100 p.s.i. in 5 p.s.i. increments.

(f) Green press-to-test light indicating bleed airflow available.

(g) Panel light and switch, with dim control (pull and twist).

(h) A red oil pressure warning press-to-test light indicating when the oil pressure is low enough to cause automatic engine shutdown.

3.3.4 Control Panel (continued)

(i) Fuel tank contents gauge reading in quarter portions of full capacity.

(j) Two flow selector valve switches with safety guards, one for each branch of the Y section in the delivery duct.

(k) AC voltmeter 0-150 V - green marking at 115 V.

(l) AC ammeter 0-8 amps - green and red ranges as required.

(m) AC output circuit breaker.

(n) Inverter input circuit breaker.

(o) DC voltmeter 0-50 V - green marking on 28 V.

(p) DC ammeter - green and red ranges as required.

(q) DC output circuit breaker.

(r) Battery charge-discharge meter.

(s) Circuit breaker to isolate the intercommunication set electrical system.

(t) Circuit breaker to isolate the vehicle lighting system.

(u) Switch to isolate the battery during transport and storage.

(v) Obstruction light switch.

(w) Flood light switch.

(x) Low pressure bleed valve switch (for defuelling operations).

3.3.5 Other Controls & Instruments

The following controls and instruments are to be located inside the gas turbine enclosure, and will be easily accessible through hatches or panels.

(a) AC voltage regulator manual adjustment.

(b) DC voltage regulator manual adjustment.

(c) Startmeter.

3.3.5 Other Controls & Instruments (continued)

(d) Hourmeter.

(e) Oil Primer Button.

4. ARRANGEMENT OF COMPONENTS

The unit is to consist of 3 main compartments mounted on a platform, which in turn will be mounted on running gear. The three compartments are to be:

(a) The fuel tank.
(b) The hose bin.
(c) The gas turbine enclosure.

The fuel tank is to be large enough to contain 50 imp. gallons of fuel. It is to be held securely in place so that it cannot be dislodged or shifted by sloshing of the fuel. It will contain a fuel quantity sensing device which will be connected to the fuel gauge in the gas turbine enclosure by a quick-disconnect electrical connection. An air vent is to be provided at the top centre point of the tank, or near that point. The fuel supply line to the gas turbine is either to have a shut-off valve or a self sealing quick disconnect. The fuel tank is to be electrically grounded to the rest of the vehicle.

The hose bin is to be large enough to contain the two air delivery hoses coiled, with their aircraft couplings, and with both hoses connected to the Y-section of the delivery duct. This Y fitting is also to be located within the hose bin, and so the flow selector valve actuators will be in the bin. Because of this arrangement it will not be necessary to disconnect the hoses from the Y-section when they are coiled and stored in the bin. Other electrical equipment located in the bin will be the electrical delivery cable (coiled) which, when in use, is connected to the nose leg of the aircraft undercarriage; a floodlight retracted into hose bin when not in use, and covered by a hatch; and the intercom set, with storage space for a headset, in a compartment accessible from outside the bin through a hatch. All the required electrical connections between the hose bin and the gas turbine enclosure will be made through a single common plug.

The gas turbine enclosure is to contain everything else but the fire extinguisher. The control panel and the intercom enclosure are to be located close to each other. The arrangement of components within the gas turbine enclosure will be such that a maximum degree of accessibility is achieved, especially with those items requiring frequent servicing or attention. The design shall be such that removal of major components is facilitated.

A battery or batteries will be fitted within the gas turbine compartment.

4. ARRANGEMENT OF COMPONENTS (Cont'd)

They will be capable of supplying power to start the unit under the worst ambient conditions, and simultaneously provide power to the lighting and intercom systems. Battery combustion heating will be provided for low temperature operation.

If air cooling is to be required for any of the electrical equipment, this must be provided indirectly or directly by the gas turbine engine.

Two obstruction lights are to be mounted on top of the unit.

5. CHASSIS AND RUNNING GEAR

The unit is to be mounted on a simple, sturdy, lightweight frame, which will serve as a platform for the stationary unit and as a chassis when the unit is mounted on running gear. Running gear will be of the four wheel, two wheel steerable type. Probably either leaf springs or air suspension will be used. Steering will be effected by the towbar through an Ackermann steering gear, Pneumatic tires are to be fitted. Parking brakes capable of holding the vehicle on a 35% slope will be provided. A detachable pintle suitable for towing other items of ground support equipment will be fitted to the rear of the chassis.

Lifting and tie down points will be provided on the chassis frame.

A fire extinguisher suitable for extinguishing kerosene fires will be mounted on the side of the vehicle.

Both the electrical delivery cable, incorporating all AC, DC and intercom leads and the air delivery hoses will be 45' long.

6. EXTERNAL CONNECTIONS

In summary, the following external connections will be provided on the unit.

(a) Two 3½" internal diameter air hose couplings (with hoses attached) in the hose storage bin.

(b) One 1½" diameter low pressure air hose coupling (no hose attached) in the hose storage bin.

(c) Power delivery cable (including AC, DC, intercom, and control circuits) in the hose storage bin.

(d) DC output connection for use with defuelling heat exchanger vehicle.

(e) External power receptacle for DC in dead battery starts and for maintenance purposes.

(f) Connection for remote control panel incorporating all the normal instruments and controls.

Division of Engineering Work

Avro Aircraft Limited will design, manufacture and test the starter vehicle as defined in this report.

The Garrett Corporation of Canada, by sub-contract, shall provide technical assistance to Avro Aircraft as defined below:

1. The Garrett Corporation of Canada shall prepare and submit to Avro Aircraft Limited a complete system proposal for the system described hereafter. The system is defined as all components contained within the gas turbine enclosure, except the batteries, and control panel. It does not include the gas turbine enclosure itself, the hose bin, the fuel tank, the chassis, the running gear, the flow selector valves, the intercom sub-system, the delivery hoses and cable, nor the fire extinguisher.

   The system shall include:

   (a) The gas turbine compression sub-system.
   (b) The generator and inverter sub-system.
   (c) The integrated control sub-system, including instruments.

2. The Garrett Corporation of Canada shall at the earliest possible time submit to Avro Aircraft Limited a system proposal including:

   (a) System schematic drawings.
   (b) Wiring diagrams.
   (c) Installation drawings of "off the shelf" components made by the Garrett Corporation.
   (d) Parts list including manufacturer's name and part number.
   (e) A technical report describing the system and its components.

3. The Garrett Corporation shall assist Avro Aircraft Limited on the following points:

   (a) Recommendations and advice on the arrangement of components within the gas turbine enclosure.
   (b) Recommendations and advice on ventilation and required air circulation within the gas turbine compressor enclosure.
   (c) Recommendations and advice on the design of ducts within the unit.
   (d) Recommendations and advice on the installation of instruments.
   (e) Recommendations and advice concerning anti-vibration mounts.
   (f) Recommendations and advice concerning the location of pressure and temperature sensing devices.
   (g) Recommendations and advice on sound attenuation.

4. The Garrett Corporation shall prepare and submit to Avro Aircraft Limited maintenance and overhaul instructions for the system and its components.

F E

400 CY A.C FUEL CONTROL
START POWER RELAY
L.H AIR CONTROL
R.H AIR CONTROL
27·5V D·C STA
GROUND
AUDIO
INTE

SINE

NOSEWHEEL DISCONNECT ICS-C-142

AIRCRAFT

F H E C D A B K M J
F H E C D A B K M J

LOW PRESSURE BLEED CONNECTED FOR A/C DEFUELING ONLY

HEAT EXCHANGER

B A
B A

STARTING UNIT

RH

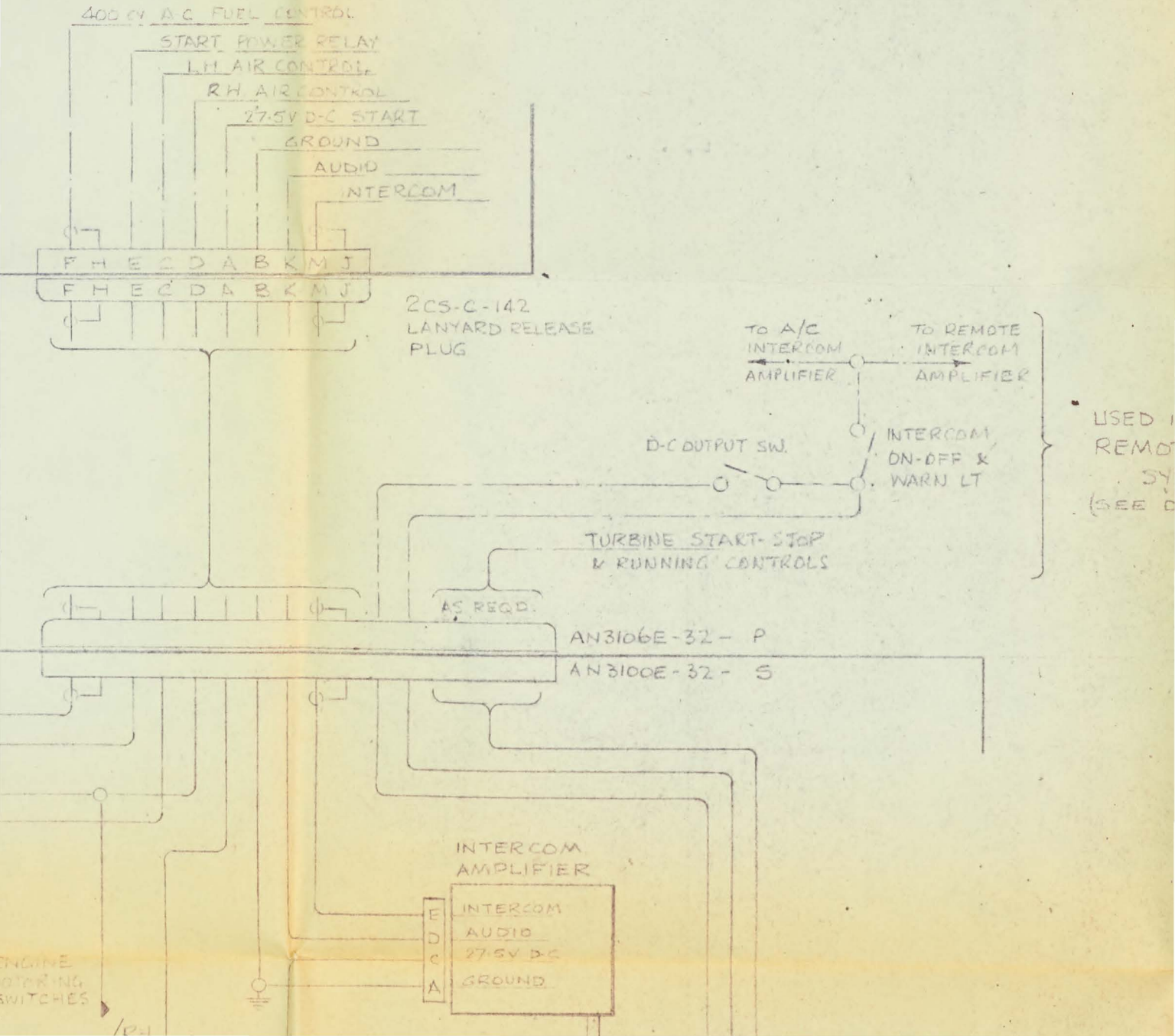
L.P. BLEED CONTROL VALVE

A.C OUTPUT

INVERTER 115V

VOLT REG

ENGINE MOTORING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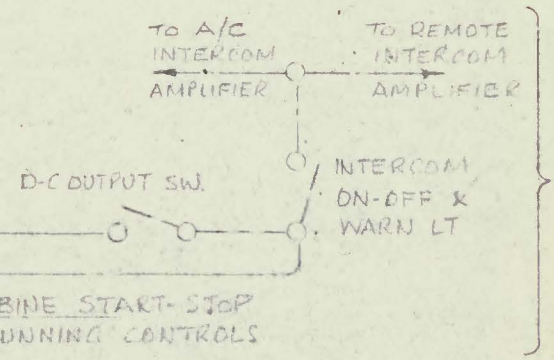

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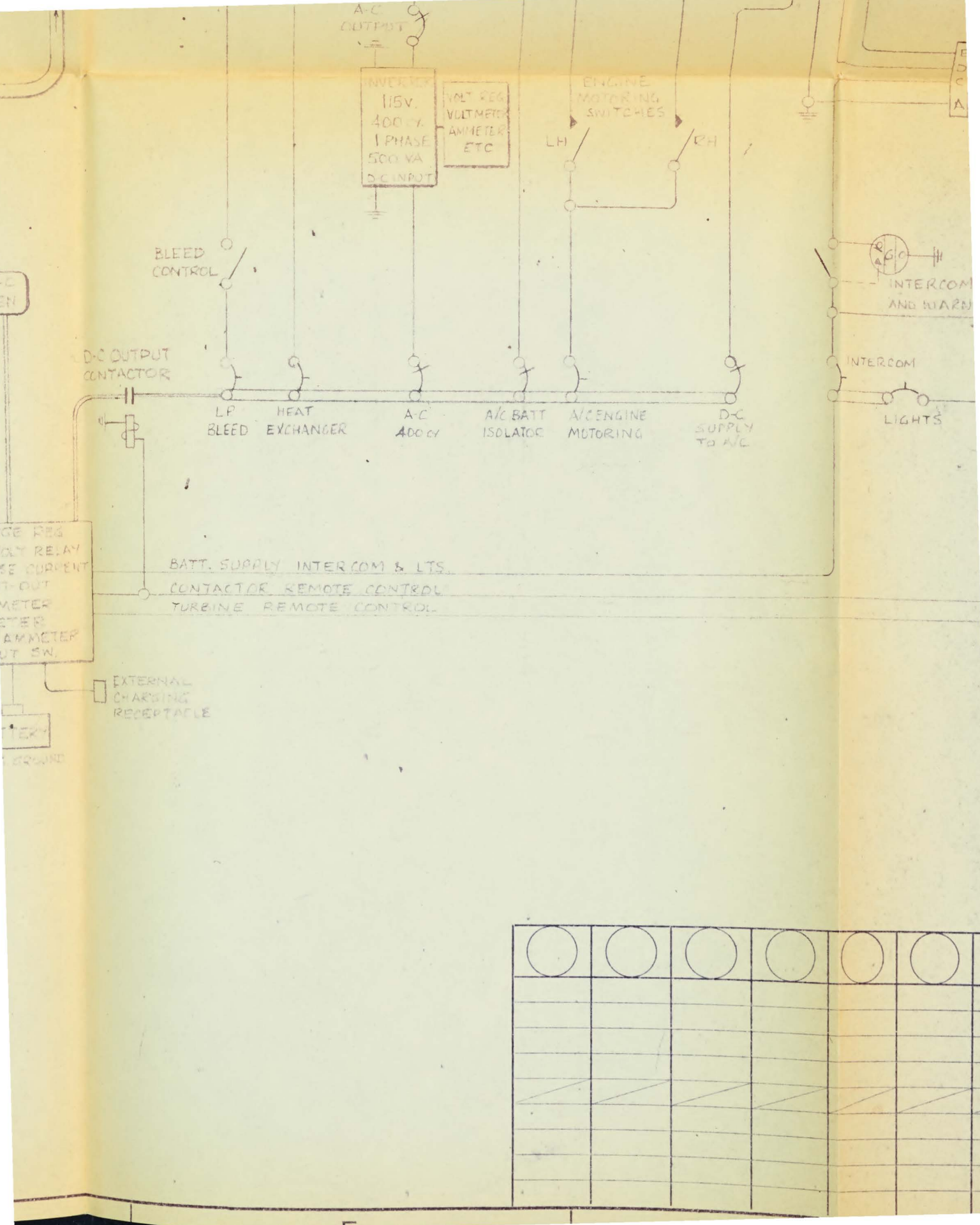
A-C OUTPUT
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115V. 400 CY. 1 PHASE 500 VA D.C INPUT
VOLT REG VOLTMETER AMMETER ETC
ENGINE MOTORING SWITCHES
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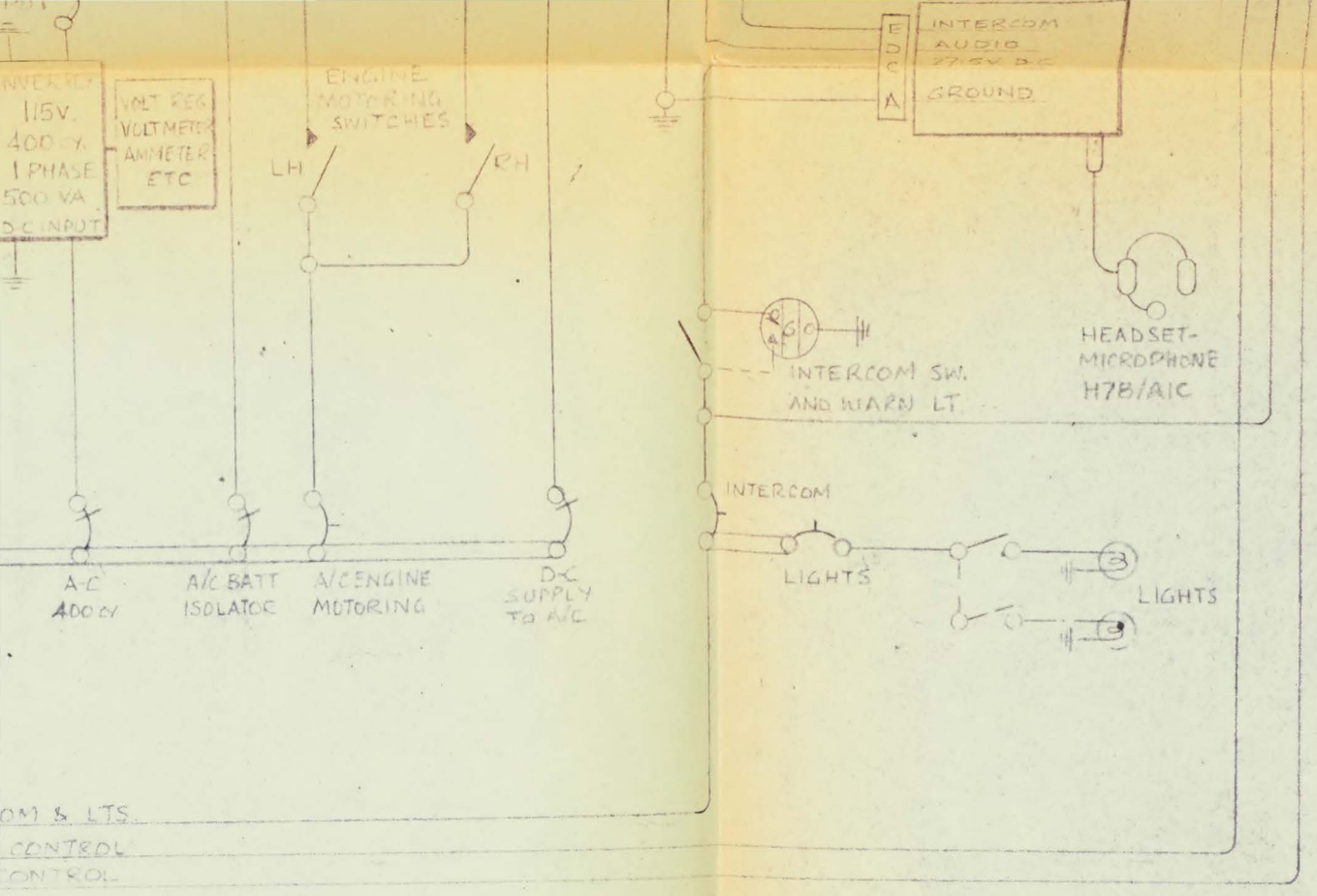
RH
BLEED CONTROL
INTERCOM AND WARN
D-C OUTPUT CONTACTOR
INTERCOM
LIGHTS
LP BLEED
HEAT EXCHANGER
A-C 400 CY
A/C BATT ISOLATOR
A/C ENGINE MOTORING
D-C SUPPLY TO A/C
BATT. SUPPLY INTERCOM & LTS.
CONTACTOR REMOTE CONTROL
TURBINE REMOTE CONTROL
EXTERNAL CHARGING RECEPTACLE



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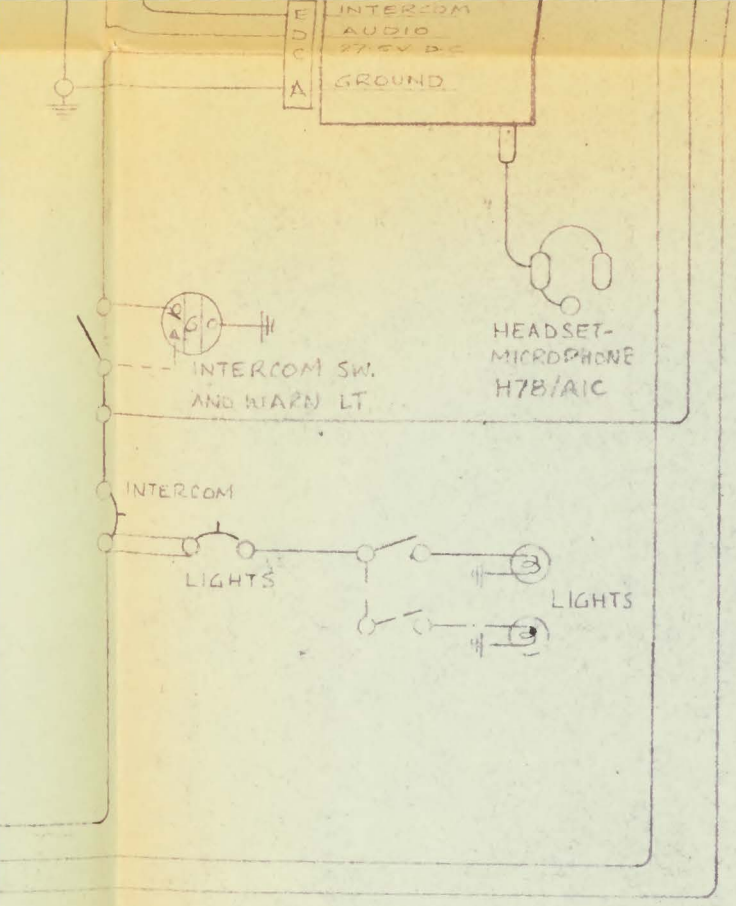

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REFERENCE DRAWINGS	
DWG. No.	DESCRIPTION
7-4427-61 SH 2	ENGINE STARTING ARR

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THIS DRAWING SHALL BE USED IN
CONJUNCTION WITH REPORT Nº 72/GEQ/12

REF.	PART No.	DESCRIPTION	L.H.	R.H.	DESCRIPTION
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REFERENCE DRAWINGS	
DWG. No.	DESCRIPTION
7-4427-61 SH 2	ENGINE STARTING ARROW I

DESCRIPTION

SCHEMATIC DIAGRAM
STARTING UNIT, PNEUMATIC,
TRAILER MOUNTED
GROUND EQUIPMENT

TYP

AVRO AIRCRAFT LIMITED
MALTON ONTARIO

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