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ARROW 2

A STUDY OF FIRST LINE MAINTENANCE AND TURNAROUND FACILITIES

REPORT NO. 72/GEQ/3

MARCH 1958

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1.0 ABSTRACT

1.1 INTRODUCTION

In October 1955 the RCAF requested AVRO to conduct certain engineering studies in order to ensure that the RCAF would be adequately prepared to support and maintain the ARROW 2 in squadron use.

One of these studies was to cover the accommodation, procedures and equipment best suited for rapid turnaround and efficient 1st line maintenance of the weapon system.

1.2 PURPOSE OF THIS REPORT

The purpose of this report is:

(a) To outline the turnaround and 1st line maintenance hangar requirements.

(b) To review the ground support equipment for main and forward base activities.

(c) To state the procedures and personnel requirements for turnaround and 1st line maintenance.

(d) To make recommendations on the facilities and equipment for turnaround and 1st line maintenance.

1.3 DISCUSSION

This report is based on a squadron strength of 12 aircraft. Of these, there are six in 1st line maintenance, operating at nine sorties per day. This is the peace time training program requirement and is derived from proposed specification AIR 7-4 issue 4, which requires an aircraft utilization of 20 hours per aircraft per month:

Squadron hours per month	=	12 aircraft x 20 = 240 hours
Assume effective flying days	=	20
Squadron hours/day	=	$\frac{240}{20} = 12$
Average sortie	=	1 hour
Number of sorties per squadron per day	=	12

Operational capabilities in excess of this will be achieved in wartime, but cannot be realistically estimated until some operating experience is gained. However, provision should be made for realizing the highest potential at all times.

The report reviews the operational concept and outlines the main technical features of the ARROW 2 weapon system. This has been done in order to determine the type of hangar and equipment best suited for conducting turn-arounds and 1st line maintenance.

Recommendations are made for all the necessary facilities and equipment except that required for hydrant refuelling. A preliminary study has been made in this area with the intention of establishing the advantages of hydrant refuelling (if any), and to outline the requirements for a preliminary cost estimate.

The advantages of hydrant refuelling appear to be marginal in respect of actual pumping time, but this method of refuelling may be necessary in order to obtain a supply of cool fuel, if flights above Mach 1.5 are contemplated.

1.4 CONCLUSIONS AND RECOMMENDATIONS

1.4.1 HANGARS

(a) AIR 7-4 requires that for one squadron a hangar consisting of four separate bays is required in which turnarounds or 1st line maintenance can be performed.

The turnaround facility is a new concept which requires new hangars. The separate bays are necessary, as taxiing in and out is an essential feature if the turnaround time is to be met.

A hangar which meets the requirements is shown in Figure 18. The size has been dictated by the 1st line maintenance requirements which include an allowance of 30 feet for engine changing. An economy in size could be effected by either performing engine changes with the hangar doors open, or transferring this function to 2nd line servicing. If this is considered, then it would be feasible to adapt the readiness type of hangar for erection as separate modules, with additional space between them for equipment installation and storage.

No information has been released on the ultimate armament to be carried by the ARROW. Any complication arising from handling armament other than Sparrow missiles should be considered before finalizing the hangar design.

(b) It is recommended that the turnaround hangar be zoned near the readiness hangars to isolate the noise nuisance factor and for convenience as a secondary readiness facility.

From the theoretical considerations of noise attenuation in chapter 7.3, it appears desirable that the hangar should be 2000 feet from the main-runway and 2000 feet from the 2nd line maintenance and administrative areas.

(c) Heating in the combined turnaround and maintenance hangar should be at least 50°F. This will provide a comfortable working temperature and prevent freezing of the water supply lines for replenishing the aircraft's water boiler.

(d) Power requirements for the equipment in the 4-bay turnaround hangar will amount to 1108 KVA, which includes an estimated 240 KVA for hydrant refuelling pumps.

(e) In view of the aircraft's high wing construction, under wing flameproof lighting is recommended for maintenance work.

1.4.2 EQUIPMENT

(a) Static industrial type equipment is recommended for use in the turn-around hangar for providing cooling air and a-c power to the aircraft. This can be obtained at a lower initial capital cost, is more economical to maintain, and will reduce the quantity of expensive mobile equipment required.

(b) The equipment for field use is entirely mobile and air transportable in a C119 aircraft. A demonstration is desirable to establish the number of C119 aircraft necessary to support a forward base detachment.

(c) No provision has been made in the turnaround hangars for handling weapons other than by means of a complete weapon pack which has been serviced and loaded in the weapon storage and test facility. This will meet the turnaround time and eliminate the risk involved in handling missiles in the hangar.

1.4.3 OTHER FACILITIES REQUIRED

(a) A weapon storage and test facility will be required. This will include a missile test and assembly building, a missile fusing building and a weapon pack servicing and loading area. A preliminary report has been issued on this subject (AVRO LOG/105/36). A final report will be issued at a later date.

(b) An engine and aircraft run-up will be required to accommodate noise suppressors. This will be the subject of a separate report.

(c) Covered space will be required for storage and maintenance of ground equipment such as engine starting units, power and cooling air trucks, 4000 psi hydraulic rigs, nitrogen compressors, engine change equipment and access platforms. This requirement will be reviewed in the 2nd line maintenance study.

(d) A facility will be required for handling, storing and charging the liquid oxygen convertors. A building layout to meet this requirement is shown in Figure 21.

(e) Water softening equipment is required at the turnaround hangar to purify the water for use in the aircraft's heat exchanger boiler. The water should be purified and softened to contain not more than 5 parts per million of scale-forming substances. Two stage ionization of the type commercially available is recommended.

1.4.4 TIME STUDY - TURNAROUNDS AND PRIMARY INSPECTIONS - AND PERSONNEL REQUIRED

It appears from a theoretical time study of the turnaround functions that 14 men will be required to complet an aircraft within 15 minutes, using the proposed refuelling tender of 3200 gallon capacity, pumping at the initial rate of 250 gallons per minute,through each of two hoses. This time may be achieved in the proposed hangar irrespective of weather conditions. The time study is illustrated in Figure 17.

The number of men required to complete a primary inspection within three hours cannot be realistically established without a demonstration using RCAF skill levels under normal environment. However, it appears from a theoretical time study that a team of 12 tradesmen plus 2 technicians occupying the cockpits will be necessary. This team can complete the airframe inspection in approximately 1 hour 5 minutes, and the ASTRA I inspection in about 2 hours 40 minutes. It should be noted that these figures are preliminary only, and subject to confirmation by a Personnel Requirements Data Study now being made at AVRO.

The number of teams necessary to perform primary inspections will be related to the frequency of these inspections. It is understood that in the initial stages,the period between inspections will be 24 hours.

1.4.5 FUEL TEMPERATURES

If Mach 2 flight missions are contemplated, it will be necessary to establish the fuel temperatures attainable in the fuel tanks while the aircraft is standing in the open and in hangars in tropical summers. It will also be necessary to establish refuelling tender and hydrant delivery temperatures under similar circumstances to determine if hangar and tender cooling is necessary. A method of keeping the fuel cool by covering the aircraft wings with insulating material, while on the ground, should also be investigated.

1.4.6 MISCELLANEOUS RECOMMENDATIONS

(a) A suitably adapted vehicle is recommended for use in collecting drag chutes from a central parachute packing facility, and delivering them to the turnaround hangar. A requirement of 25 drag chutes per day for two squadrons is envisaged. Radio contact with the control tower would enable this vehicle to retrieve drag chutes released on the runway.

(b) Special work platforms, to be placed around the nose of the aircraft, will be required for 1st and 2nd line servicing. These will be mobile, of light structure, and house the ASTRA I portable test equipment, plus a hoist for radome and radar removal.

(c) The "UNITOW" D-8 tractor is suitable for towing the ARROW at the flight line, but it is recommended that each base be equipped with some tractors of 10,000 lb draw-bar pull for winter use.

(d) The tractor for towing the weapon pack hoist trolley should not exceed five feet in height. This will permit the tractor to pass under the fuselage when towing a trolley into position for unloading.

2.0 INTRODUCTION

2.1 AUTHORITY FOR STUDY

RCAF letter AMC 1038 CN-100 (Act 2-1) dated 27 September 1955, detailed certain engineering studies to be prepared by AVRO to ensure that the RCAF would be adequately prepared to support and maintain ARROW aircraft in the field.

RCAF letter S1038-105-11 (ACE-1) dated 4 October 1955, from TSD's/ A. V. Roe Canada Limited to AVRO set out in detail AVRO's development responsibility regarding ARROW ground support equipment. List 2, appended to that letter, called up specific engineering studies to cover the accommodation procedures and equipment needed for the ARROW 2 aircraft for 1st line maintenance and for turnarounds.

2.2 SCOPE OF STUDY

In accordance with the RCAF request for engineering studies of facilities for the ARROW 2 Weapon System, the scope of this report is:

(1) To review the operational concept.

(2) To outline the engineering aspects of the ARROW 2 weapon system which will influence the equipment, procedures and accommodation required for turnarounds and 1st line maintenance.

(3) To review the 1st line ground support equipment requirements.

(4) To outline the procedures, equipment and personnel required for:

- (a) Turnarounds
- (b) 1st line maintenance

(5) To outline the 1st line maintenance hangar requirements.

(6) To recommend accommodation, equipment and procedures to be adopted to discharge the 1st line maintenance requirements rapidly and efficiently.

3.0 THE OPERATIONAL CONCEPT

This review of the operational concept is based on proposed Specification AIR 7-4 Issue 4, as amended by RCAF letter S36-38-105 (APO) of 17 Feb. 1958 in respect of squadron strength and turnaround time. Although the specification is not yet officially amended or accepted contractually, it is taken to represent current RCAF requirements.

The pertinent points which relate to turnaround and 1st line maintenance are as follows:

AIR 7-4 Issue 4, Para. 3.1.1

Object

"The object in the operation of the ARROW weapon system in time of war will be the attainment of the highest possible operational potential at all times. In time of peace the operation of the weapon system will be concerned primarily with attaining and maintaining a high degree of proficiency in the all weather role. It will consist of a limited operational program superimposed on a training program.

The object of the operational sorties will be considered as training. The main penalty will be that they cannot be scheduled. The object is to have a satisfactory potential available at all times and associate contractors are to keep these factors in mind throughout the development of their design."

AIR 7-4 Issue 4, Para. 3.1.2

Battle State

"The concept is based on one or more squadrons of 12 operational aircraft, each, at a prepared all weather base. With 50% of the aircraft undergoing minor maintenance, each squadron will be required to maintain two aircraft at the state of readiness or standby at all times and as many of the remainder as possible in a state that can be changed to available within three hours."

AIR 7-4 Issue 4, Para. 3.1.3

Forward Base

"In exceptional circumstances, the squadron may be required to operate from a forward base to which the aircraft will be flown in a fully operational state. They will be serviced and brought up to available or readiness on arrival, but normally will return to the main base when scrambled. Should they be required to land back at the forward base, only sufficient facility to prepare them for return to main base is required. This is a detached operation which the main base must be capable of supporting up to a maximum of 50% of unit establishment. Individual aircraft will not normally remain on the forward base longer than the time between primary inspections. The servicing equipment required to prepare aircraft at a forward base for return to the main base must be air transportable, with trained personnel to carry out the operation, in a C119 or similar transport airplane."

AIR 7-4 Issue 4, Para. 3.1.4

Building Facilities

"For each squadron, the airfield shall include the following structures:

(a) Hangar(s) to house two aircraft at readiness or standby.

(b) Hangar(s) to house four aircraft undergoing 'turnaround' or first line maintenance.

(c) Hangars to house six aircraft undergoing second or third line maintenance.

(d) A missile preparation and storage facility.

(e) An engine run-up structure capable of housing one aircraft.

(f) An engine run-up structure capable of housing one engine.

NOTE: It is noted that a building for liquid oxygen storage and convertor charging has been omitted from AIR 7-4.

AIR 7-4 Issue 4, Para. 3.2

Time Limits

3.2.1 TURNAROUNDS

The maintenance organization of the weapons system shall be able to receive and turnaround operational aircraft at a rate of 4 every 15 minutes, provided the aircraft involved have no major unserviceabilities. The aircraft and ground support equipment shall be designed to meet this requirement, due regard being given to the reliability and maintainability of the aircraft and ground support equipment."

NOTE: It should be noted that the ARROW 2 has been designed with the original RCAF concept of a five minute turnaround in mind. To meet the wartime objective of the highest possible operational potential at all times, it is recommended that this minimum turnaround time be fully utilized, by providing hangars and ground support equipment of equal capability.

AIR 7-4 Issue 4, Para. 3.2.3

Replacement

"An aircraft scrambled from or becoming unserviceable in a readiness hangar is to be replaced by a serviceable aircraft, or returned to the readiness state in a maximum of 15 minutes "

Utilization Para. 3.2.4

"The aircraft together with the support of the ground support equipment and the RCAF shall be capable of a utilization of not less than 20 hours per month."

AIR 7-4 Issue 4, Para. 2.1.4

"1st line maintenance is defined as the series of maintenance operations which will be carried out on the aircraft that can be raised to the available state within three hours. These operations will consist of:

(a) Primary inspections.

(b) Fault isolation.

(c) Fault rectification.

(d) Special inspections.

(e) Alignment of relevant systems."

AIR 7-4 Issue 4, Para. 2.2.5

"Turnaround is defined as a series of maintenance operations which will be done on the aircraft that land in at least a near serviceable state, and shall include the replenishment of all consumable stores, (including missiles) and minor rectification to enable the aircraft to perform the combat mission."

4. REVIEW OF ARROW 2 MAIN TECHNICAL FEATURES

4.1 AIRFRAME

4.1.1 GENERAL

The ARROW 2 is a twin-engine, all weather, supersonic interceptor, armed with four Sparrow 2D air-to-air guided missiles and powered by two Orenda "Iroquois" engines with afterburners. The general arrangement of the aircraft is shown in Figure 1, and leading particulars are:

Wing span	50 ft 0 in.
Length	83 ft 9 in.
Height	21 ft 3 in.
Main landing gear	25 ft 8 in.
Wheel base	30 ft 1 in.
Weight - basic	43,000 lb.
- normal take-off	60,000 lb.
- maximum take-off	68,000 lb.
- maximum for jacking	55,000 lb.
Tire pressures	
- main	260 psig
- nose	170 psig

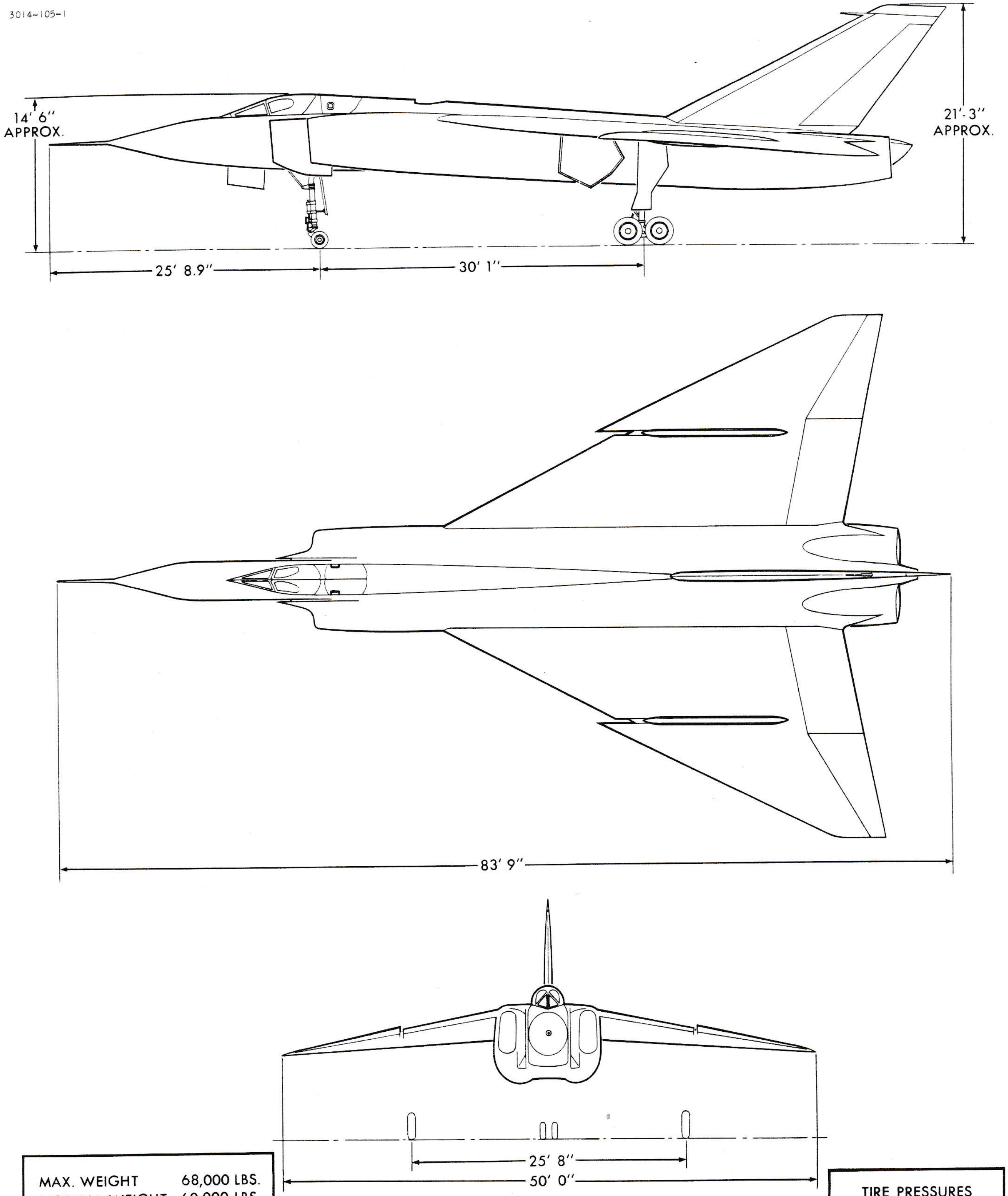
4.1.2 TURNAROUND

The airframe maintenance functions which must be accomplished during turn-around consist of the following:

(a) Inspect visually for structural damage or distortion.

(b) Check that all access doors and panels are secure.

(c) Check for signs of leaks from hydraulic, fuel, and lubricating oil systems.



MAX. WEIGHT	68,000 LBS.
NORMAL WEIGHT	60,000 LBS.
MAX. LANDING WEIGHT	55,000 LBS.

TIRE PRESSURES
MAIN - 260 P.S.I.g
NOSE - 170 P.S.I.g

FIG. 1 LEADING DIMENSIONS

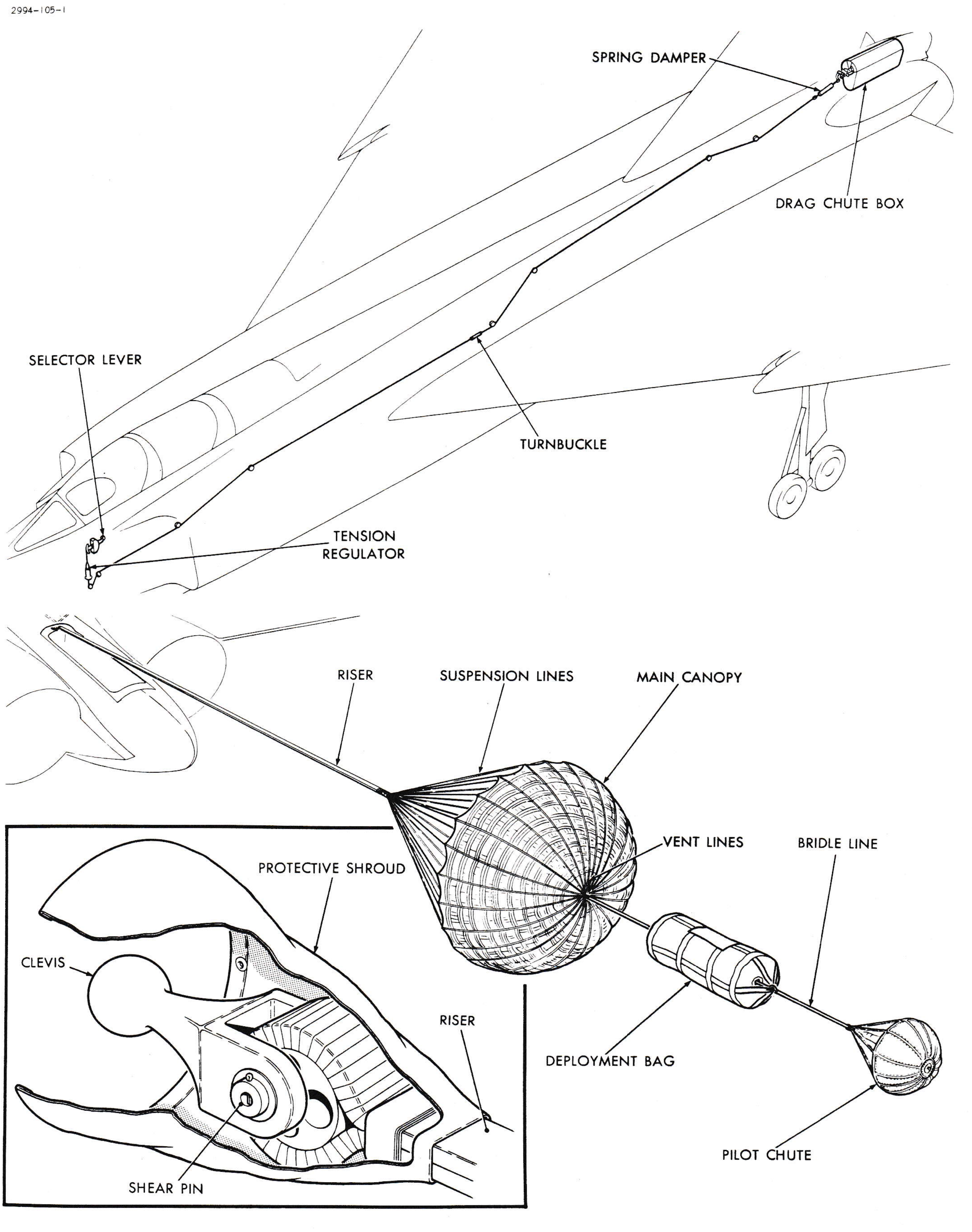


FIG. 2 DRAG CHUTE INSTALLATION

(d) Inspect wheels, brakes and tires.

(e) Inspect the cockpits and clean the windshields.

(f) Replace the dragchute. This is stowed in a compartment in the top of the fuselage between the two jet pipe fairings as shown in Figure 2. A new dragchute can be installed by two men in approximately five minutes, when the control lever in the pilot's cockpit has been reset. Access to the dragchute compartment will require a workstand approximately 7 ft. - 6 in high. Asbestos mats will be required to protect the upper surface of the airframe, while the dragchute is being installed. The dragchute attachment fittings are approximately 8 ft. - 6 in above the ground and about 4 ft ahead of the jet pipe fairings trailing edge.

4.1.3 1st LINE MAINTENANCE

It is anticipated that 1st line maintenance work on the airframe will consist mainly of the following functions:

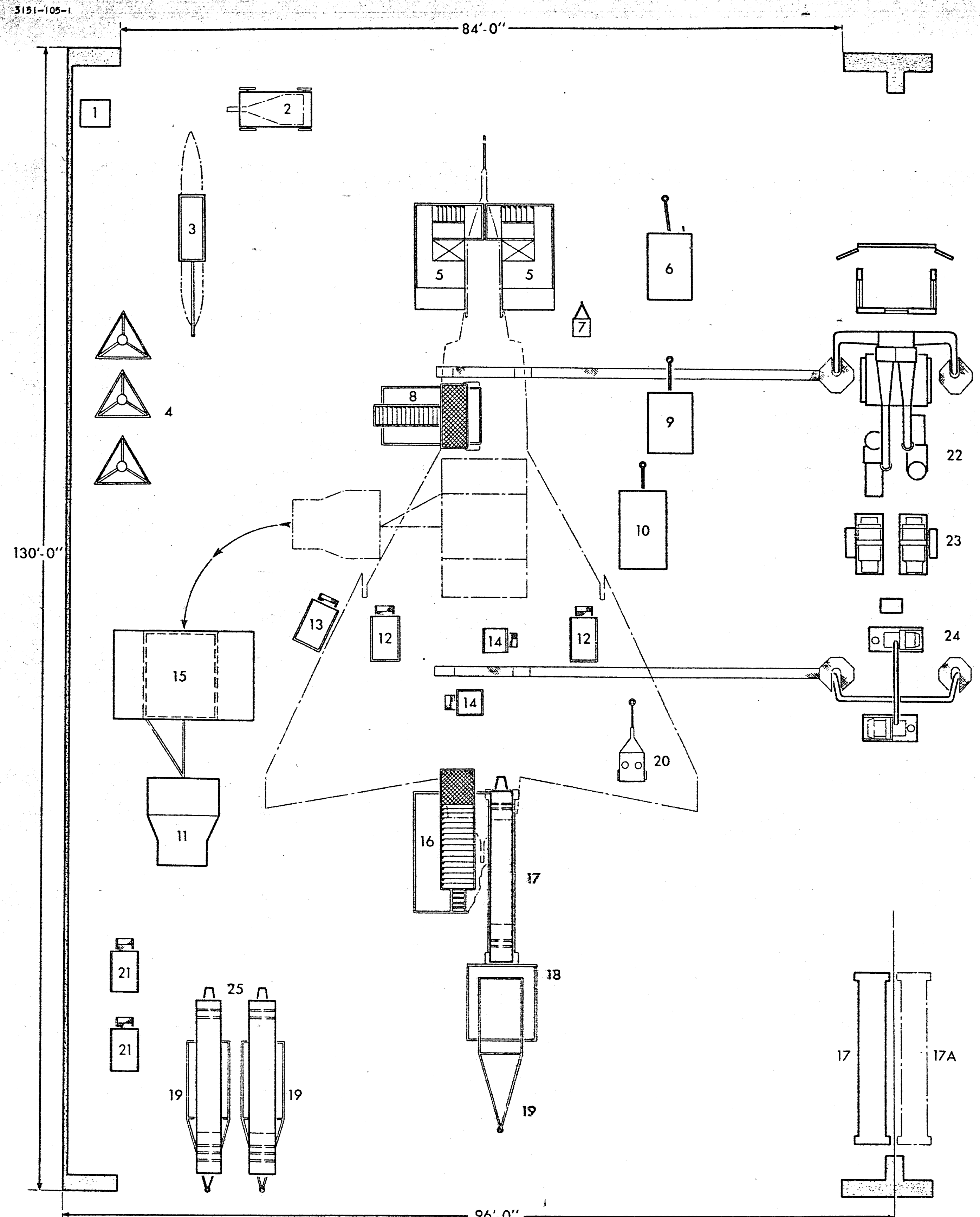
(a) Pre-flight, turnaround, post-flight and primary inspections.

(b) Washing and cleaning the aircraft.

(c) Functional tests of all sub-systems.

(d) Minor repairs, including fault analysis and replacement of components when the work is not likely to require more than three hours for completion.

The first line maintenance work will therefore require suitable workstands, platforms, jacks and test rigs, and the hangars must have adequate space for storing this equipment when it is not in use. The GSE's required for 1st line maintenance is shown in Figure 3.



ITEM	DESCRIPTION	AVRO REFERENCE NO.	REMARKS
1	STAND - SHORT TERM STORAGE LIQUID-OXYGEN CONVERTER		
2	TRAILER RADOME	208	
3	TRAILER HOIST. OVERLOAD FUEL TANK	167	
4	JACK - WING & NOSE FUSELAGE	128	
5	STAND - RADAR MAINTENANCE	250	TOTAL HT. 17'
6	TRAILER ELECTRONIC SPARES	106	
7	RIG-HYDRAULIC SUPPLY	246	TO FUNCTION RADAR ANTENNA FOR TEST
8	STAIRS. COCKPIT ENTRY	107	
9	COMPRESSOR	103A	
10	STAND-TEST-HYDRAULIC SYSTEM	168	
11	TRACTOR-TOWING	189	10' TURNING RAD.
12	MAINTENANCE PLATFORM	146	RCAF. DWG. 43078 - ADJUSTABLE
13	MAINTENANCE PLATFORM	147	RCAF. DWG. 43042 ADJUSTABLE
14	STAND-FUSELAGE MAINTENANCE	187	
15	HOIST - MISSILE PACK	112	FULLY CASTORING WHEELS
16	MAINTENANCE PLATFORM	148	HEIGHT RANGE - 13' TO 20'
17	STAND-ENGINE MAINTENANCE	134	MK. 2
17A	STOWAGE SPACE	-	
18	MOBILE GANTRY-ENGINE	190	
19	TRAILER-ENGINE	138	MK. 2
20	TRAILER-OIL DISPENSING	143	20 GALL. CAPACITY
21	MAINTENANCE PLATFORM	146	DRAG CHUTE REPLACEMENT
22	AIR CONDITIONING EQUIPMENT		STATIC EQUIPMENT
23	GENERATORS		"
24	ENGINE STARTERS		"
25	SPARE ENGINES		

FIG. 3 LAYOUT OF GROUND SUPPORT EQUIPMENT FOR 1st. LINE MAINTENANCE

3017-105-1

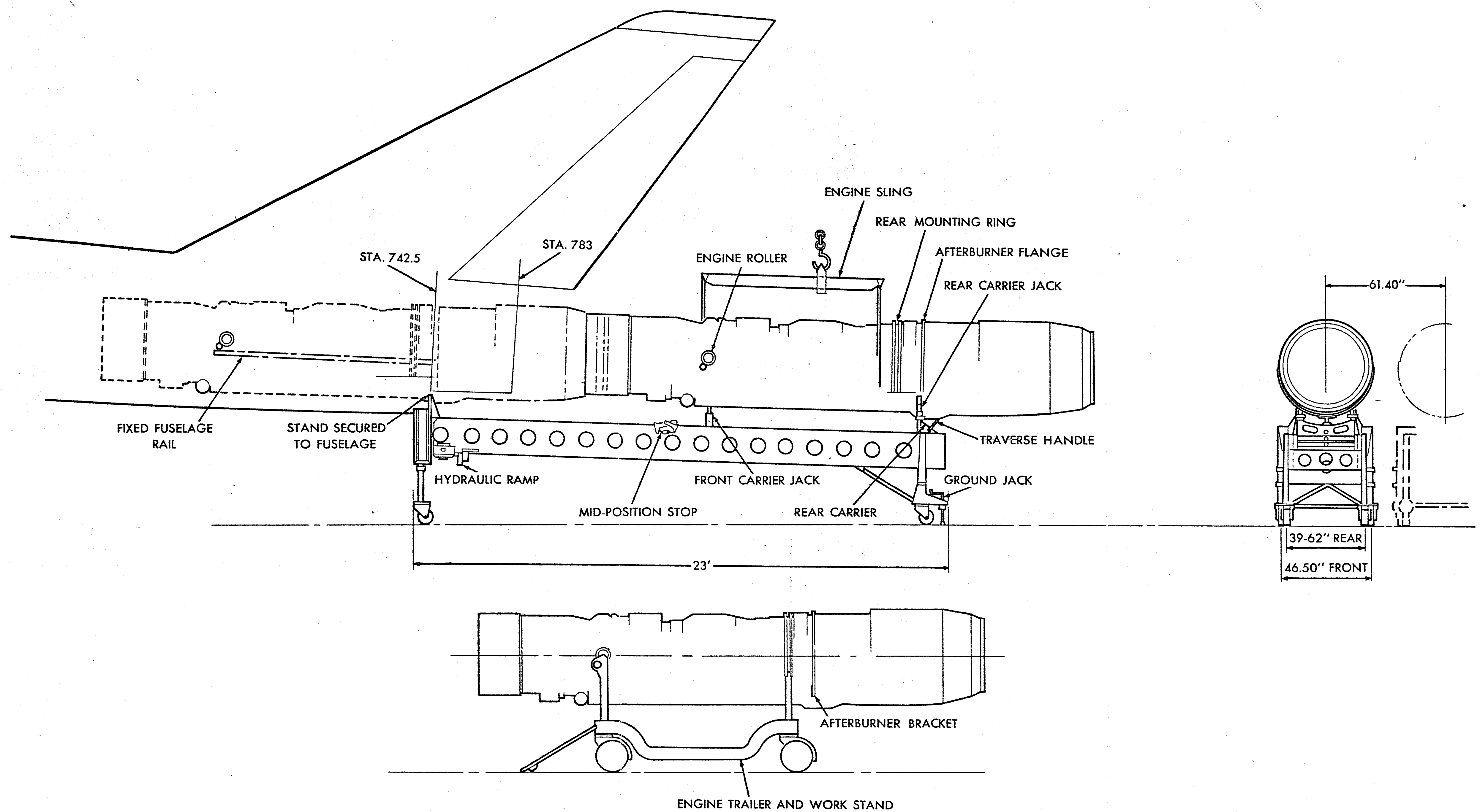


FIG. 4 ENGINE CHANGE EQUIPMENT

4.2 ENGINES

4.2.1 GENERAL

The ARROW 2 aircraft is fitted with two Orenda Iroquois engines, each capable of delivering 18,400 lb. thrust without afterburner, and 25,000 lb, with afterburner, under sea level static conditions. In addition, each engine drives a 40 KVA oil-cooled generator through a constant speed drive unit, and hydraulic and fuel pumps through an aircraft accessories gear box. Separate lubricating systems are installed for each generator and its drive unit, and each aircraft accessories gear box. All of these systems use oil to Specification MIL-L-7808, Grade 1010, so that only one lubricating oil dispenser is required for servicing the aircraft.

The engines are mounted inside the rear fuselage, and are installed and removed from the rear of the aircraft, using a special stand as shown in Figure 4. With the engines installed, the oil level cannot be measured directly. The oil tanks are filled after each flight, through combined fill/overflow valves so that an adequate supply of oil is assured, and the oil consumption can be ascertained. The filling and overflow connections will be accessible through service doors in the fuselage.

An oxygen system is installed on the Iroquois engine to assist combustion during relights at high altitude. The supply is stored in gaseous form in a bottle charged to 1800 psi and is adequate for approximately 20 relights. The bottle would not normally be checked during turnaround. When it is necessary to replenish the system,the used bottle is removed and replaced by a full one. The used bottle is then recharged, away from the aircraft.

The engines are started by air turbine systems. This method of starting was selected because of its reliability and low installed weight. As outlined in AVRO report LOG/105/9, "ARROW 2 Readiness Facility", (May 1957) these starters require a supply of hot, medium pressure air, as detailed below in, order to meet the scramble requirements:

Altitude	Sea Level	Sea Level	Sea Level
Ambient Temperature	-65°F	+59°F	+100°F
Flow (lb/min/engine	145 (minimum)	112 (minimum)	101 (minimum)
Pressure (psi absolute	60 (minimum)	50	47
Temperature	240 to 500°F.	360 to 500°F	390 to 500°F

It is recommended that gas turbine compressors be used to supply the air for engine starting, and that provision be made in the turnaround hangars for ducting the air under the floor to the aircraft location. Access to the starting air couplings on the ARROW 2 is shown in Figure 5.

4.2.2 TURNAROUND

During turnaround, the following maintenance operations will be required on the Iroquois engines:

(1) During shut-down, observe that both engines run down smoothly within the specified time limit.

(2) Replenish engine oil supplies. The gear box and generator drive systems will not require checking during turnaround.

(3) Inspect for signs of fuel, oil and hydraulic fluid leaks, and damage to the jet pipe, nozzles and turbines.

(4) Connect hoses from the starting air supplies.

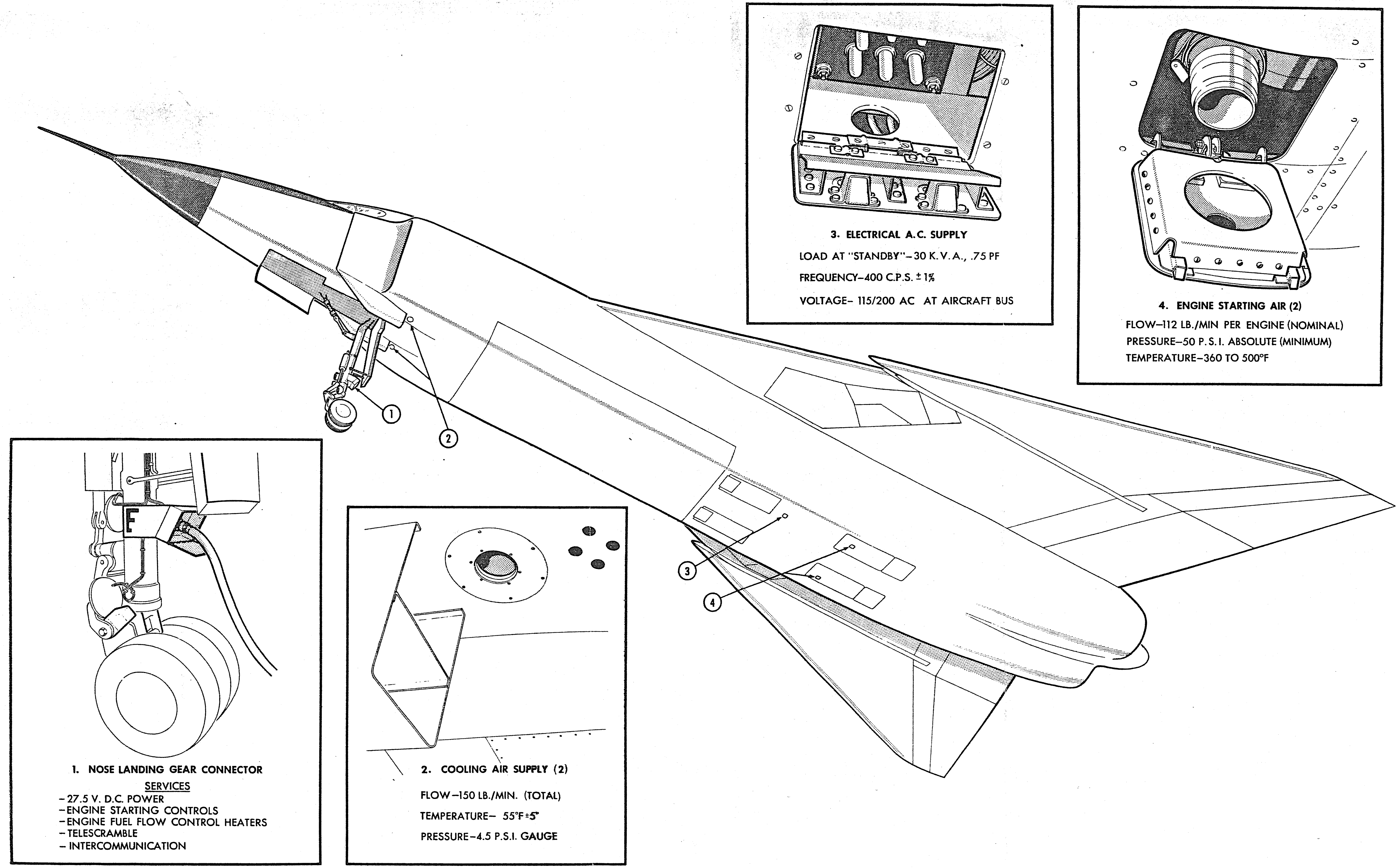


FIG. 5 ARROW 2 GROUND SUPPORT SERVICES

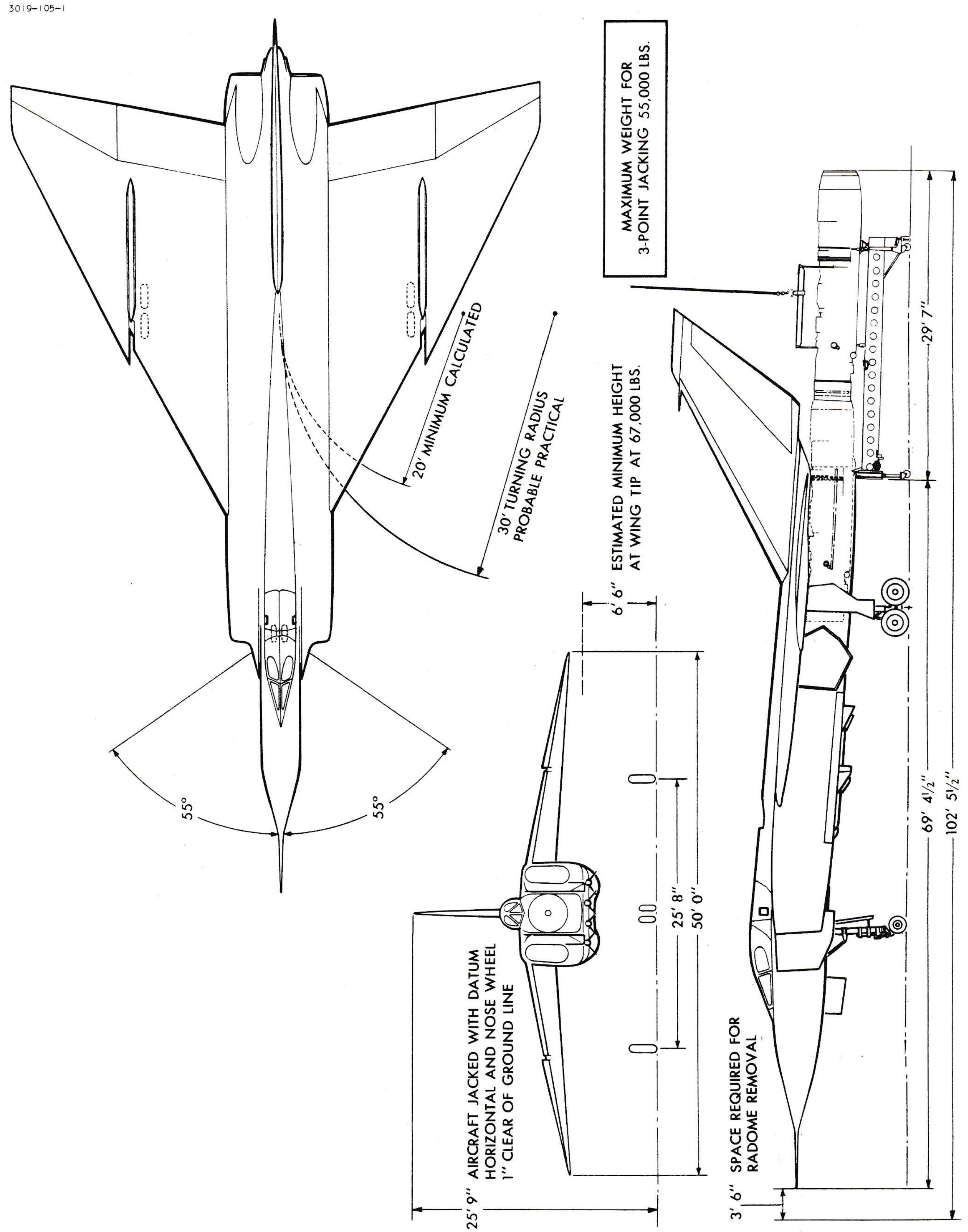


FIG. 6 SERVICING DIMENSIONS

4.2.3 1st LINE MAINTENANCE

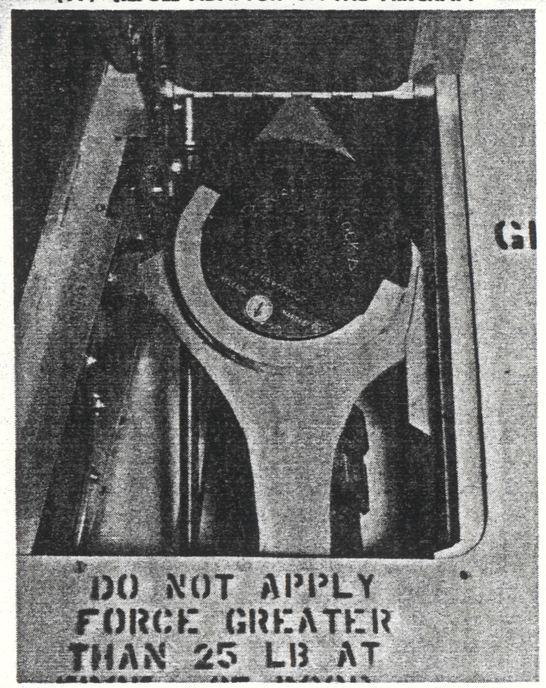
1st line maintenance work on the engine installation will include primary inspections, replacement of oxygen bottles, checking and replenishing the oil supply for the gear box and generator drive systems, and also removal and installation of the engines. Engine installation and removal is discussed fully in Avro Aircraft report LOG/105/43, "CF-105 Power Plant Ground Support Equipment" (October 1956). The engine must be moved aft 19 ft - 6.2 in. on an engine change stand before it can be lifted clear of the airframe and placed on a transportation dolly. As shown in Figure 6 space should be available in the 1st line maintenace hangars for engine installation and removal, and for storing the engine installation stands when they are not in use.

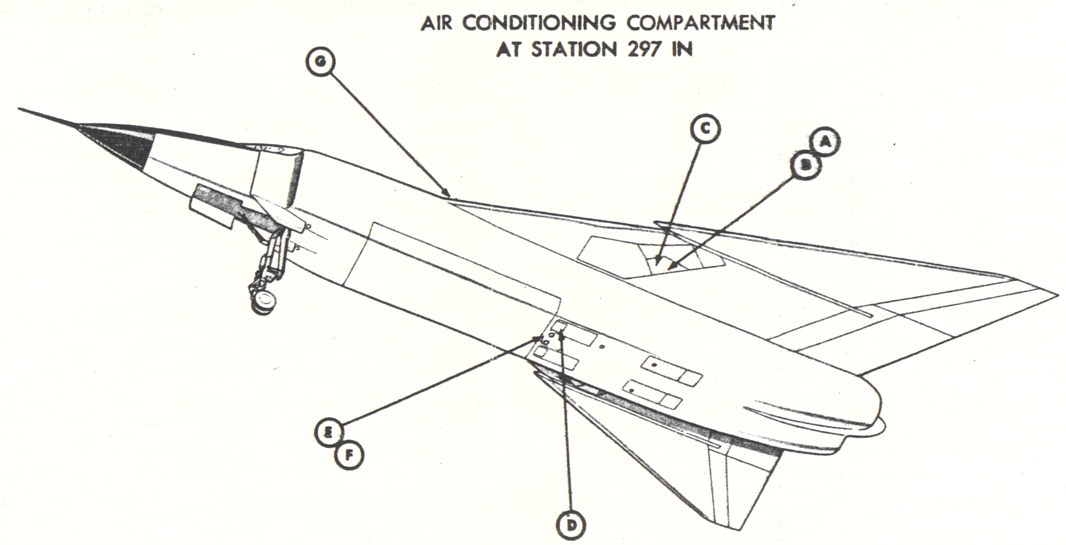
A mobile gantry is being designed by AVRO for lifting the engine off the engine change stand to the transportation dolly when an overhead crane is not available. The estimated weight of the power plant is 4,916 lb., and an overhead crane system of 6,000 lb. capacity is recommended for main base use, wherever installation is possible.

The alternative equipment for engine changing utilizes the engine transportation stand as part of the engine installation equipment. The transportation stand is manufactured by the Air Logistics Corporation, and is described fully in AVRO report LOG/105/43 "CF-105 - Power Plant Ground Support Equipment". While the overall length of this equipment is not as great as the AVRO engine changing equipment, equivalent space is required at the rear of the aircraft in order to manoeuvre the transportation trolley (See Figure 6).

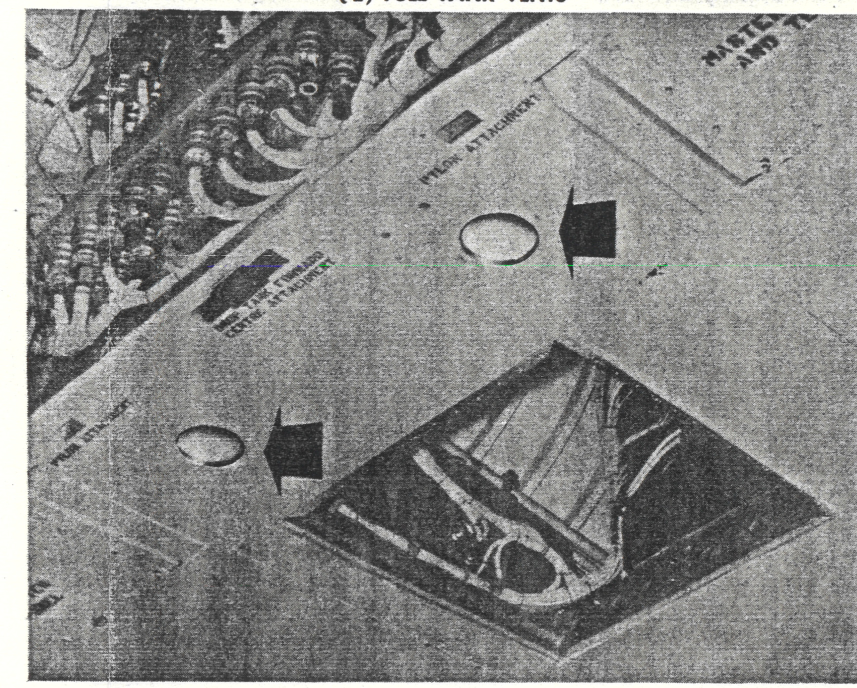
2990-105p1

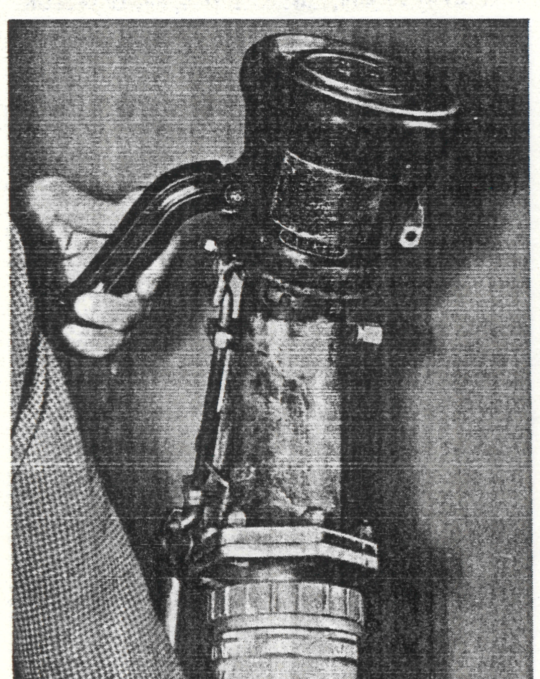
(A) REFUEL ADAPTOR ON THE AIRCRAFT





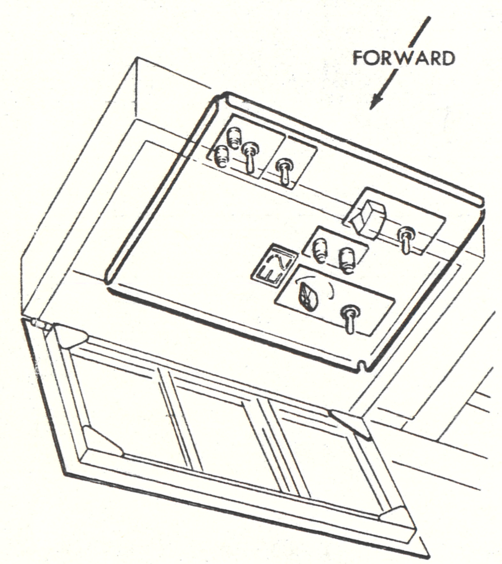
(E) FUEL TANK VENTS



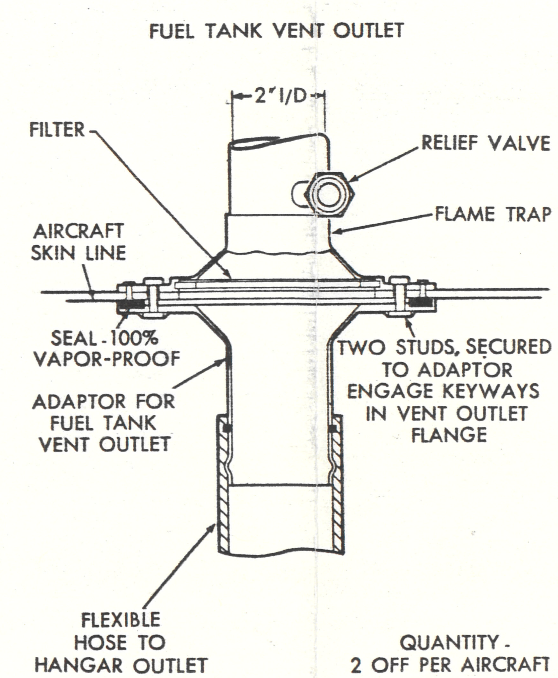


(B) REFUEL CONNECTOR ON THE TENDER

(C) REFUEL SELECTOR PANEL



(D) MAIN REFUEL CONTROL PANEL



(F) PROPOSAL FOR COUPLING

NOT AVAILABLE

(G) CONNECTION FOR AIR SUPPLY FOR DEFUELING

FIG. 9 CONNECTIONS FOR FUELING AND DEFUELING be extinguished, and illuminate again if all the fuel level sensing valves and shut-off valves are operating satisfactorily.

(f) Select the refuel switches to the ON position.

(g) When refuelling has been completed, select the refuel switches OFF, remove the refuelling nozzles, replace the dust covers on the refuelling adaptors, and close all access panels.

During refuelling, air and fuel vapour from the tanks will be ducted through the tank pressurization system and overboard through two ports on the bottom of the fuselage as shown in Figure 9. In order to permit aircraft refuelling inside a hangar, these ports have been designed so that exhaust ducts may be attached to the aircraft. The fumes would then be ducted outside the hangar by exhaust fans.

4.3.3 DEFUELLING

Aircraft defuelling will be required when any of the following first line maintenance work is performed.

(1) Engine removal and installation, landing gear retraction tests, fire control and navigation equipment alignment, etc. of all of which require jacking the aircraft. The weight must not exceed 55,000 lb. when lifting the aircraft at the wing and fuselage jacking points.

(2) Tasks which require access to fuel system components mounted within the fuel tanks.

(3) Off-loading fuel for training or test flights.

The fuel is removed through the two defuelling points by either of two methods:

(a) Using an external air supply and refuelling tender suction.

(b) By refuelling tender suction along without an air supply.

The former method is recommended for general use, as this requires less suction from the defuelling pumps, and air must be available for fuel transfer tests.

Method (a) Using an external air supply and tender suction

(a) Ground the aircraft.

(b) Switch master refuel switch to OFF AND DEFUEL

(c) Pressurize the fuel system. Allow 30 seconds for the tank pressure to build up. Provision has been made for supplying air through a ground connection at station 297 in the air conditioning equipment bay. A two inch diameter flexible pipe terminating in a Janitrol coupling (part number A40C60) is required. The ground connection is illustrated in AVRO drawing No. 7-2254-15677.

(d) Start the defuelling pumps. The nozzle suction should not exceed 1.0 psig to ensure that the collector tanks are not emptied first. If the collector tanks are emptied first, air will be admitted and will prevent further defuelling.

(e) The defuelling rate will depend on the amount of fuel in the fuel tanks. If the tanks are full, the rate will be high and if most of the tanks are empty the rate will be as low as 32 IGPM.

(f) When the defuelling rate falls below 20 IGPM, with nozzle suction 1.0 psig, it may be assumed that the transfer tanks are empty.

(g) The collector tanks are then defuelled with the air supply shut off.

With an air supply of 25 psia the defuelling characteristics are as follows:

ARROW 2 - DEFUELLING WITH AIR PRESSURE AND TENDER SUCTION

Defuel Condition	Defuel Rate Per Sub-System IGPM	Nozzle Pressure Required PSIG	Air Supply Req'd Per A/C at 25 psia.
(a) All transfer tanks full and defuelling together (1100 gallons per sub-system)	20	2.7	3.3 lbs/min
	40	2.2	4.4 lbs/min
	60	1.6	5.4 lbs/min
	80	.9	6.5 lbs/min
	100	- .1	6.9 lbs/min
	117	- 1.0	8.5 lbs/min
(b) Collector tank, altitudes below 8000 ft. (146 gallons per sub-system).	10	- .7	No air required
	15	- 1.0	Air shut off
	20	- 1.5	
	40	- 5.5	

Method (b) Using tender or hydrant suction only, with no air supply

(a) Disconnect the air release line at the air ejector, and blank the line.

(b) With the master switch in the OFF AND DEFUEL position, defuel the tributary tanks by applying suction at the nozzle. When the flow ceases, remove and blank the air release line and defuel the collector tanks. No nozzle pressure restrictions need be observed.

(c) Disconnect the release line.

The defuelling characteristics are shown in the following table:

ARROW 2 - DEFUELLING WITH TENDER SUCTION ONLY

Defuel Condition	Defuel Rate Per Sub-System IGPM	Nozzle Pressure Required PSIG	
(a) All transfer tanks full and defuelling together (1100 gallons per sub-system)	20	- 1.6	Air release line from collector tank has to be disconnected and blanked, or flame trap to be sealed off.
	40	- 1.7	
	60	- 2.0	
	80	- 3.4	
	100	- 6.0	
	120	- 8.0	
	140	-10.5	
(b) Collector tank (146 gallons per sub-system).	10	- 0.7	
	15	- 1.0	
	20	- 1.5	
	30	- 3.2	
	40	- 5.5	

4.3.4 PRESSURIZATION AND FUEL TRANSFER TESTS

The defuelling air ground connection is also used for supplying air for fuel tank pressurization and fuel transfer tests, for which the following air supply is necessary:

Pressure	50 - 60 psia	desirable
	85 psia	maximum
Flow:	9 lbs/min at 50 psia	
	11.2 lbs/min at 60 psia	
Temperature	Not to exceed 350°F (max).	

The variation in flow at different pressure is due to increased spillage through an air ejector used in the system.

The defuelling may also be conducted using 50-60 psia air pressure, but an increased air flow will be required as follows:

AIR SUPPLY FOR DEFUELLING, USING 50 - 60 psia	
Pressure	Flow
at 50 psia	10 lbs/min.
at 60 psia	10.6 lbs/min.

4.3.5 AIR SUPPLY

The air supply for fuel system pressurization, transfer tests and defuelling may be obtained from the main hangar supply or from a mobile rig. The air supply required will be 12 lbs/min. at 60 psia with temperature not to exceed 350°F.

There is no suitable mobile rig in use with the RCAF at present but the Iroquois engine starting unit is capable of meeting the pressure and flow requirements. This unit, however, delivers air at temperatues up to 500°F depending on ambient conditions, and a heat exchanger will be necessary to reduce this temperature to below the maximum of 350°F, acceptable for fuel tank tests. A small portable air-to-air heat exchanger is at present being designed for this purpose by AVRO.

4.3.6 1st LINE MAINTENANCE

1st line maintenance on the fuel system will consist of visual checks for leaks and for venting from the tank vent system at the flame trap outlets. In addition, functioning checks on the low pressure cocks, cross feed cocks and low pressure warning lights will be required. No routine engine run will be made during primary inspections. However, an engine run will be necessary to completely function the fuel system after rectification of defects.

Test sets will be provided to check the functioning and serviceability of the fuel contents gauges and fuel system centre of gravity control sequence units. The latter equipment is still in the design stage.

4.4 HYDRAULIC SYSTEM

4.4.1 GENERAL

The ARROW 2 is equipped with three separate 4000 psi hydraulic systems:

(a) Utility services hydraulic system

(b) Flying controls hydraulic system A

(c) Flying controls hydraulic system B.

The flying controls hydraulic system is duplicated, and identified A and B. The utility system operates the armament system, speed brakes, landing gear, wheel brakes and nose wheel steering sub-system. Each system uses hydraulic fluid to Specification MIL-O-5606 and is powered by two pumps, one driven from each engine through an aircraft accessories gear box. Each pump delivers 20 US GPM of fluid at 4000 psi, and accumulators are fitted to reduce pressure fluctuations, and to permit lowering of the landing gear, and braking under emergency conditions. A hydraulically pressurized compensator is installed in the return side of each system to provide reserve fluid, and to pressurize the pump inlets. In addition, a 1000 psi sub-system is used to operate the radar antenna drive. This is powered from one of the 4000 psi flying control systems. The 4000 psi hydraulic systems may be

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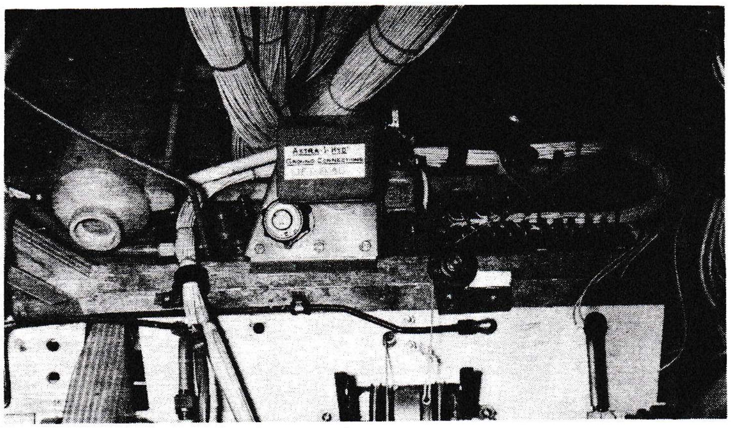
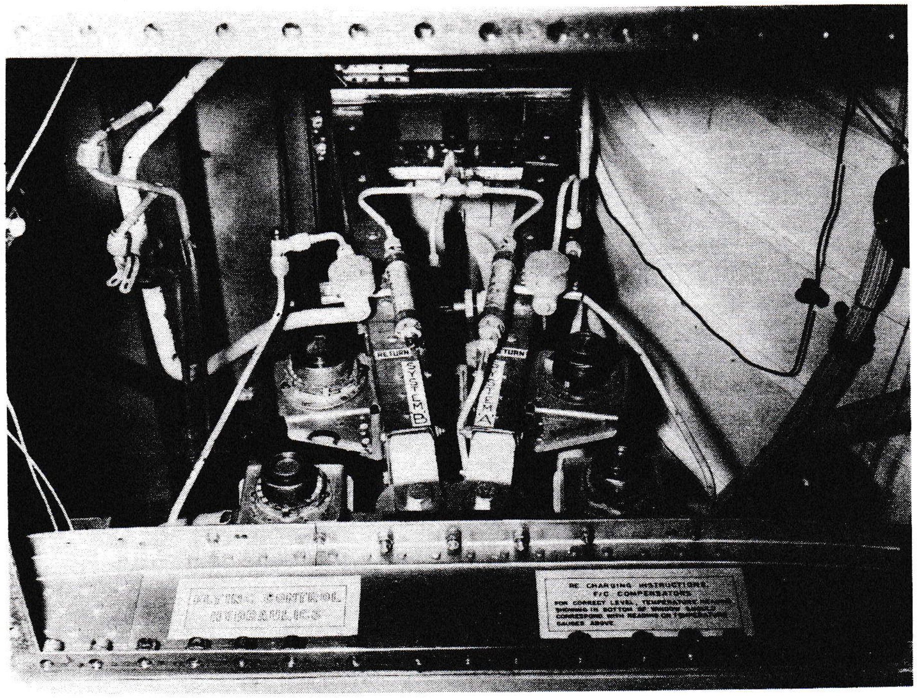
ASTRA I - HYDRAULIC
GROUND CONNECTIONS
IN NOSE WHEEL WELL



STATION 644
FLYING CONTROL HYDRAULICS
LOWER FUSELAGE



STATION 572
GROUND CHARGING CONNECTIONS
UTILITY HYDRAULICS
LOWER FUSELAGE

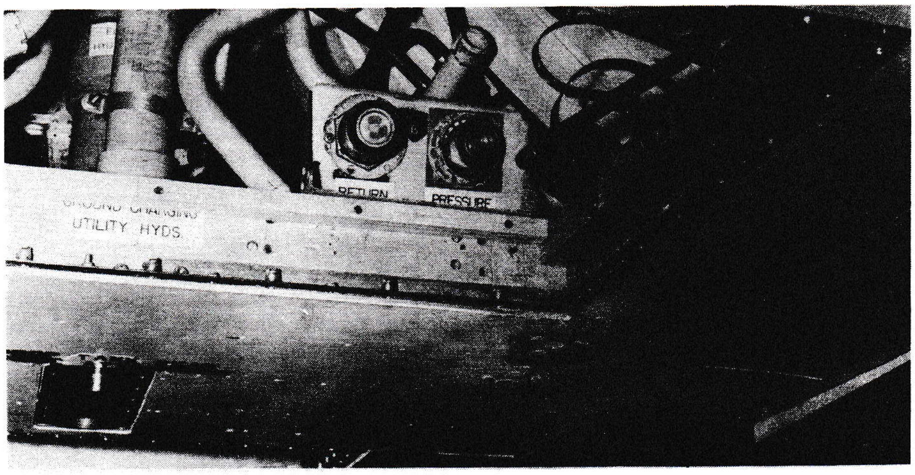


FIG.10 HYDRAULIC SERVICE COUPLINGS

operated on the ground by supplying fluid from a ground rig through self-sealing, quick-disconnect couplings as shown in Figure 10. A hydraulic test rig for this purpose has been designed to AVROCAN Specification E-466. This rig is capable of supplying a flow of 40 US GPM at 4000 psi to one aircraft system or 20 US GPM at 4000 psi to both flying control systems simultaneously. Fluid may be added to the systems through the return line couplings. The radar antenna drive system may be operated on the ground either by energizing the 4000 psi flying control system or directly from a 1000 psi external supply.

4.4.2 TURNAROUND

Normally, the hydraulic systems will not require inspection or servicing during turnaround.

4.4.3 1st LINE MAINTENANCE

First line maintenance on the hydraulic systems will consist of the following:

(a) Checking and adjusting compensator fluid levels.

(b) Checking and adjusting accumulator pressures.

(c) Filling and bleeding the systems.

(d) Systems functional tests.

The access points for these servicing functions are shown in Figure 10, and the following support equipment is required:

(1) Hydraulic test rig - 40 US GPM at 4000 psi.

(2) Hydraulic test rig - 9 US GPM at 1000 psi.

(3) Hydraulic fluid dispenser with five micron filtration.

(4) 5000 psi nitrogen supply for charging accumulators.

4.5 OXYGEN SYSTEM

Two oxygen supply systems for crew breathing are installed on the aircraft, one for normal use and one for emergency use. For the normal supply liquid oxygen is carried in a 5.0 litre converter and is converted to gaseous oxygen at 70 psi. From the converter, the oxygen flows to a pressure regulator on each ejection seat and thence to the crew's oxygen masks and partial pressure suits. The supply is adequate for the aircraft's longest ferry mission or for three high-speed combat missions (1-1/2 hours), provided that no more than 24 hours have elapsed since the converter was filled. The converter weighs 23.5 lb. when filled and is mounted on a tray in the dorsal fairing immediately behind the rear cockpit. Access to the converter is gained through a door in the fairing and all connections are of the quick-disconnect type, so that a converter can be replaced in approximately 3 minutes. The installation is shown in Figure 11.

In the emergency oxygen system, gaseous oxygen is stored at 1800 psi in a 50 cubic inch capacity cylinder mounted on each ejection seat. The supply is adequate for 20 minutes of crew breathing.

4.5.1 TURNAROUNDS

Replenishment is made at turnarounds by removing the convertor and replacing it with a full one.

No servicing is required in the emergency oxygen system other than a visual check of the contents gauge.

4.5.2 1st LINE MAINTENANCE

This will consist of a visual inspection and functional check of the oxygen regulator and convertor quantity indicator.

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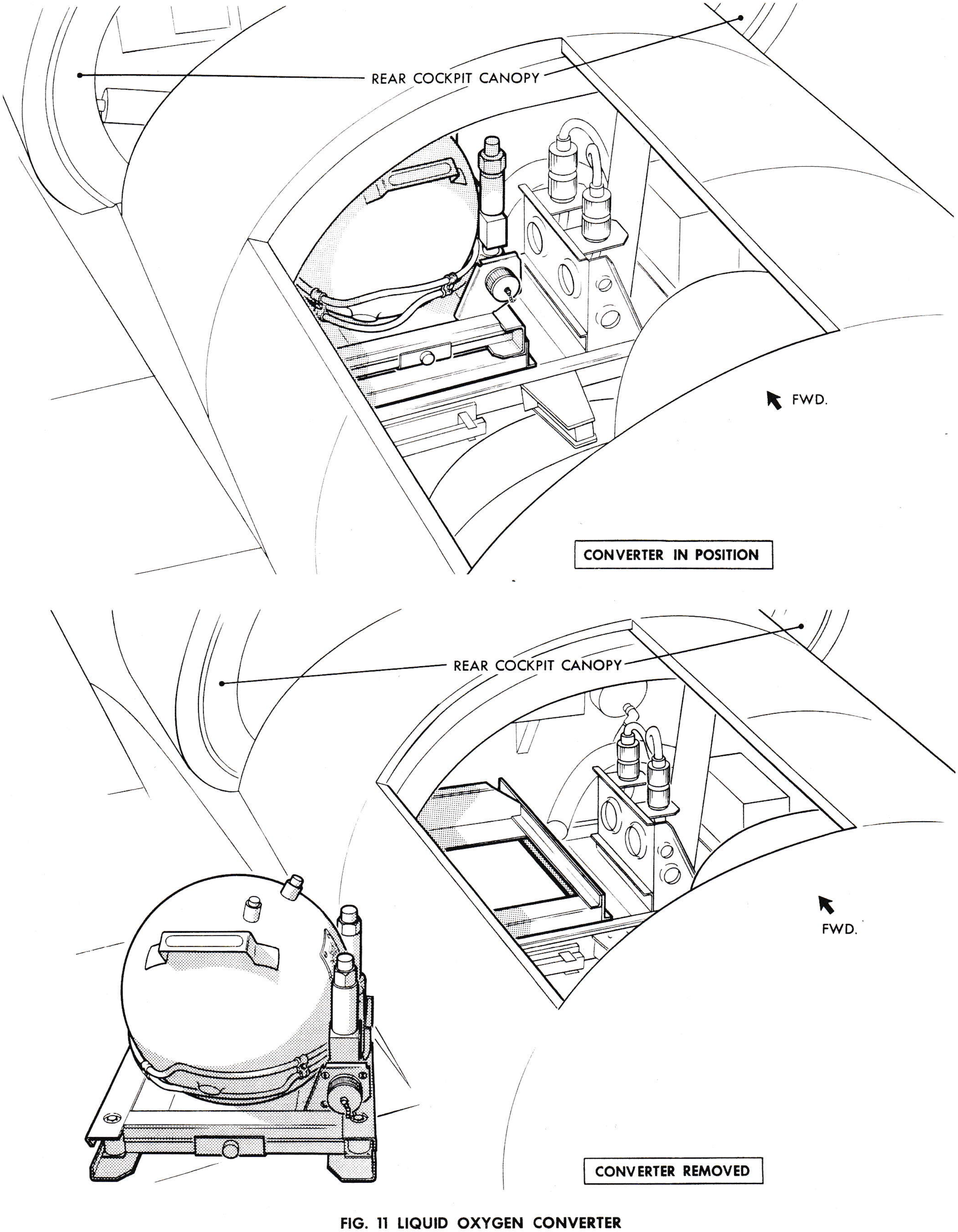

FIG. 11 LIQUID OXYGEN CONVERTER

4.6 THE PNEUMATIC SYSTEMS

Two basic pneumatic systems are used in the ARROW 2; a high pressure storage system and a low pressure system.

4.6.1 THE HIGH PRESSURE SYSTEM

Power for landing gear emergency operation is obtained from a 5000 psi nitrogen storage bottle mounted in the fuselage below the air conditioning equipment bay. A pressure gauge and charging point are located in the nose wheel well. Nitrogen is used to eliminate the possibility of a diesel explosion when the high pressure gas comes into contact with the hydraulic oil in the landing gear actuator.

Air or nitrogen, stored at 3000 psi is used for transferring fuel from the overload tank to the main tanks. This will only be required for ferry missions.

A mobile compressor manufactured to AVROCAN Specification E-333 will provide either compressed nitrogen or air to replenish these storage systems.

4.6.2 THE LOW PRESSURE SYSTEM

The low pressure system is sub-divided into three sub-systems:

(a) Fuel tank pressurization system

(b) Equipment pressurization system

(c) The pitot-static system.

4.6.2.1 Fuel Tank Pressurization

The fuel tank pressurization system draws air at 65 psia from the air conditioning system to pressurize the fuselage tanks to 22 1/2 psia and the wing tanks to 19 psia, to prevent boiling and to effect transfer of fuel.

4.6.2.2 Equipment Pressurization

The equipment pressurization system draws its air from the water evaporator in the air conditioning system at 65 psia. The air passes through a 200 mesh screen and water trap which may be drained periodically. This air is used to pressurize the cockpit canopy seals at 20 psig (with relief valve setting at 25 psig), the armament pack seals at 20 psig, the crew members anti-g suit at up to 10 psig and the electronic system wave guides.

4.6.2.3 The Pitot-static System

A boom mounted on the nose, and a probe mounted on the fin sense ambient pressure conditions for operating flight instruments and cabin pressure control valves.

Turnarounds

No maintenance is required at turnarounds other than a visual check of the pressure gauges on the emergency nitrogen high pressure bottle, and a visual check of the nose boom and fin probes.

First Line Maintenance

This will consist of a visual check as at turnarounds, plus a leak test of the pitot-static system.

Satisfactory operation of the canopy seal and crews anti-g suit will be apparent to the aircrew and no maintenance is required unless an unserviceable report is received. Should a cockpit pressurization system check be necessary, a test rig will be required. This should be capable of supplying 20 psig for canopy seal inflation, and at least 50 CFM at 6 psig to cover cockpit pressure regulation and relief valve tests.

A Godfrey cabin pressure test rig Type IF/CAN (RCAF 4G/2374) or Type IE/CAN (RCAF 4G/1815) should be suitable for this purpose. The Type 4G/2374 is being evaluated on the ARROW 1.

4.7 ANTI-ICING AND DE-ICING

4.7.1 ANTI-ICING

Anti-icing protection is provided as follows:

(a) Electro-thermal panels for the canopy windows

(b) Electro-thermal elements for air data sensing heads.

(c) Hot air bleed for the struts in the engine front frame section and engine nose bullet.

4.7.2 DE-ICING PROTECTION

De-icing protection is provided for the complete surface of the air intake ramp and the inside surface of the ramp lips by an electro-thermal cyclic de-icing system. The system, which is completely automatic, sheds ice in small pieces to prevent damage to the engine or airframe

4.7.3 TURNAROUNDS AND 1ST LINE MAINTENANCE

No servicing is required at turnarounds and only functional checks are required at primary inspections.

4.8 AIR CONDITIONING

Because of the operational role of the ARROW 2, many items of electrical and electronic equipment have been designed for forced air cooling. These items rely on a continuous flow of air to maintain the temperatures at an acceptable level. In flight, the cooling air is obtained from the aircraft air conditioning system. The system uses air bled from the engine compressors and cooled through an air-to-air heat exchanger, a water boiler and an expansion turbine. The cool air is then ducted to the cockpits and equipment bays and is finally exhausted overboard.

For ground operation, cooling air can be supplied to the aircraft through two automatic quick release couplings, which are located in the bottom of the fuselage, forward of the armament bay, as shown in Figure 3. A minimum air flow of 150 lb/minute, at a temperature not higher than 55°F, and at a pressure of 4.5 psig is required at the aircraft to maintain adequate cooling throughout the aircraft. This air supply should contain no free moisture. Since there is no provision for adjusting the distribution of air within the aircraft, as various loads are switched on and off, this quantity of air must be supplied to the aircraft whenever external a-c electrical power is used.

4.8.1 TURNAROUNDS

During turnaround, no inspection or maintenance work is required on the air-conditioning system, but cooling air must be supplied from an external source and the boiler must be filled with pure water. Water has been chosen as a cooling medium because of its high latent heat of evaporation. Pure water is required in order to prevent deposits from forming within the boiler, thereby reducing its efficiency.

Three acceptable sources of water have been considered:

1. Filtered rain water or melted snow, to which sodium sulphite has been added to inhibit corrosion.
2. Main drinking water supply which has been softened by two-stage ionization to leave not more than 5 parts per million of scale forming substances.

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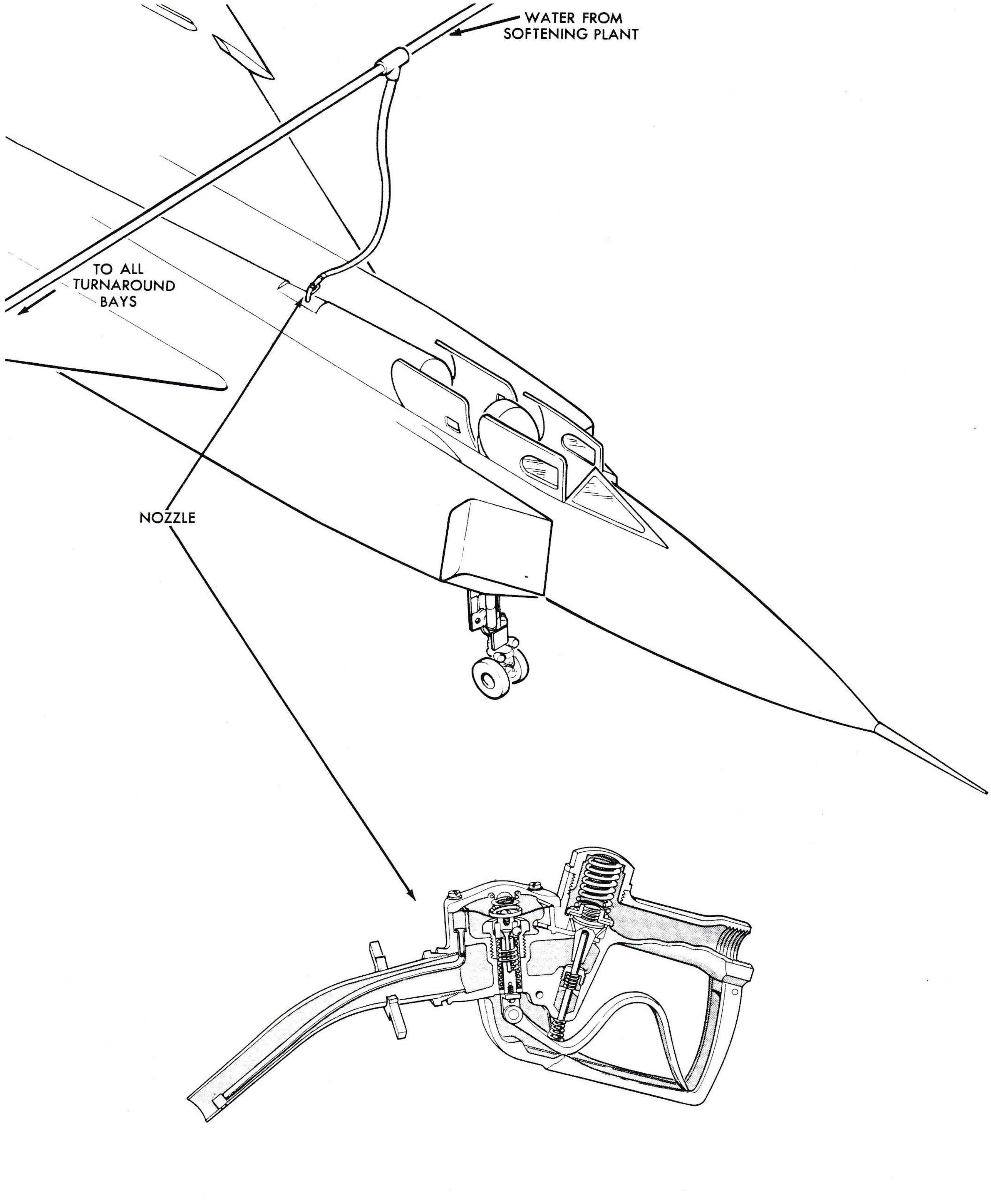

FIG. 12 PROPOSED METHOD OF FILLING WATER BOILER

3. **Distilled water.**

In view of the large quantities of water involved, the softened main drinking water supply appears to be the most reliable source. The capacity of the boiler in the ARROW 2 is 26 gallons, and it is estimated that a replenishment of 24 gallons will be required after a combat mission in which speeds of Mach 2 have been attained. The boiler is designed to withstand freezing, but a supply of hot water (160°F) will be required for replenishment at forward bases, in sub-zero weather. The filling point for the boiler is illustrated in Figure 12.

4.8.2 1ST LINE MAINTENANCE

Should a defect be reported in the air conditioning system, a quick check may be made of the temperatures and pressures in the system by connecting a test box to a receptacle in the nose wheel well. This test unit uses thermocouples and pitots permanently installed in the air conditioning system. It will be necessary to run the engines to perform this test,so that the complete system is functioned.

4.9 <u>ELECTRICAL SYSTEM</u>

4.9.1 ALTERNATING CURRENT POWER REQUIREMENTS

The ARROW 2 aircraft is equipped with two completely independent and self-contained electrical systems, one being powered from each aircraft engine. Each system obtains its power from a 40 KVA, 120/208V, 3 phase, 400 cps a-c generator which is driven by its aircraft engine through a constant-speed drive unit. Direct current at 27.5V is obtained from two 4.5 KW transformer-rectifier units, each supplied from one of the a-c systems. These d-c outputs are parallelled to feed all the aircraft d-c services.

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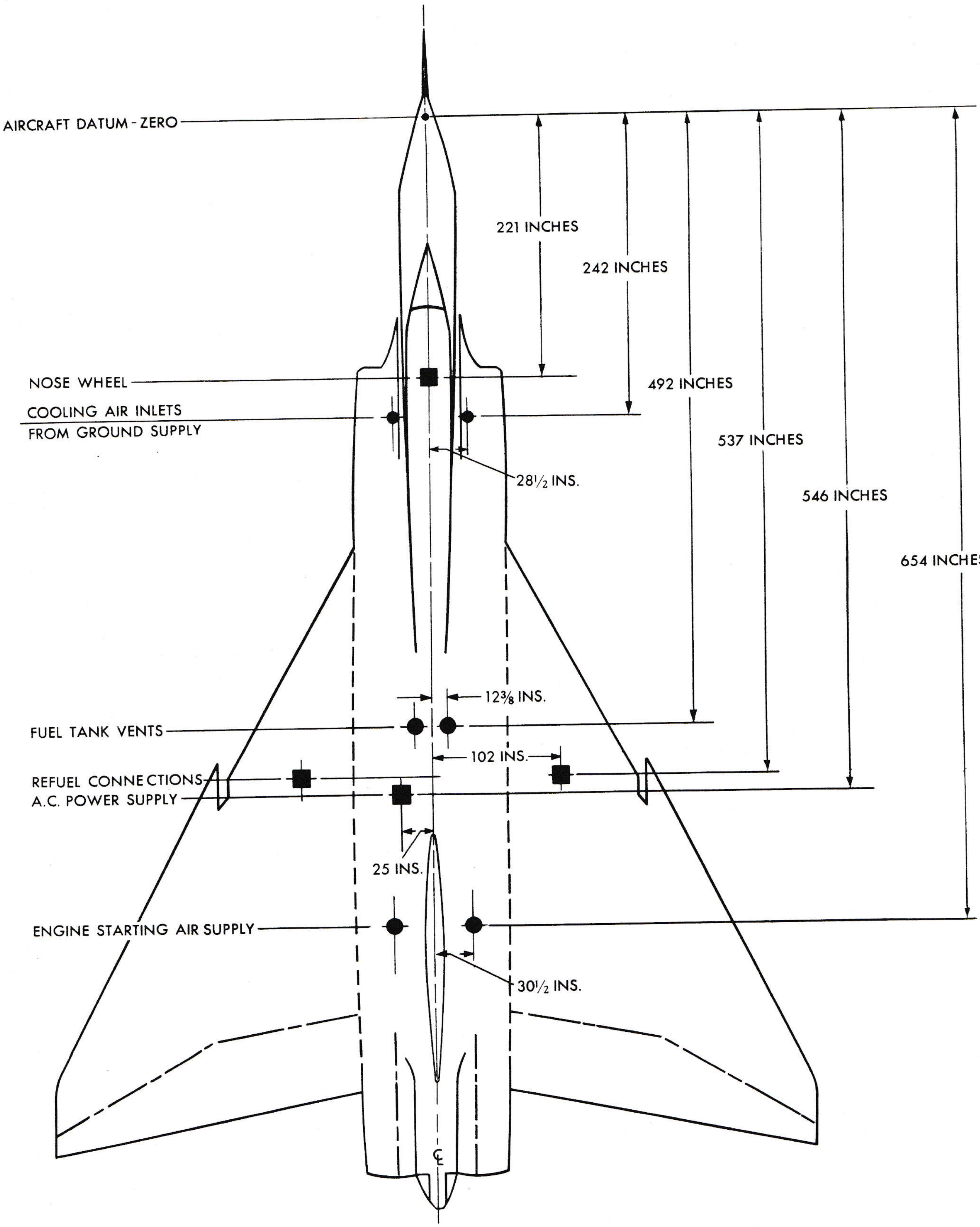

FIG.13 LOCATION OF CONNECTIONS FOR GROUND SUPPORT

To operate the electrical systems with the aircraft engines inoperative, external a-c power may be supplied to the aircraft through an AN3114 automatic quick-disconnect coupling located under the fuselage behind the armament bay as shown in Figure 13. When 27.5V d-c is supplied to pin "E" of this connector, and the aircraft master switch is turned ON, two 3-phase line relays close and both a-c busses are energized. At the same time, a slave relay opens, to prevent the main a-c line relays from closing, thereby preventing feedback to the aircraft generators. Direct current is obtained from the transformer rectifiers as in flight, and the aircraft has no provision for energizing the main d-c busses directly from an external supply. As noted in the previous section, cooling air must be supplied when an external a-c electrical supply is used. The electrical loads for turnaround and first line maintenance work have been assessed and are outlined in AVRO report LOG/105/5, Issue 4, "ARROW 2; Estimate of Electrical Power to be supplied by Ground Power Units". The report stated that a maximum short duration load of 31.5 KVA is estimated, but a 40 KVA ground supply is recommended in order to provide for possible increases in demand, as the aircraft is developed.

Frequency, wave form, and harmonic content of this a-c supply are all critical for some items of electronic equipment in the aircraft and should meet the performance requirement of AVROCAN Specification E-500 Electrical Systems (a-c and d-c) Aircraft and E-501 (Constant Speed Drive Unit for 40 KVA AC Generator); the main characteristics of the current being as follows:

Rated voltage	120/208 V
Voltage regulation	± 1 1/2%
Voltage recovery time	± 1 1/2% in 0.2 sec.
Frequency steady	400 cps ± 1%
Frequency transient	400 cps ± 5%
Amplitude factor	1.41 ± 0.14
Harmonic content - total	$\ngtr$ 5%
Harmonic content any phase	$\ngtr$ 3%
Symmetry (voltage unbalance)	$\ngtr$ 1% for P.F. $>$ .75
Overload	150% for 5 minutes 200% for 5 seconds
Unbalance loads	Voltages within ± 4% and phase voltage angle at generator terminals 120° ± 4°.

4.9.2 DIRECT CURRENT POWER REQUIREMENTS

As outlined in paragraph 4.9.1, all electrical power on the ARROW 2 aircraft is generated as alternating current. Direct current at 27.5 V is obtained from two 4500 watt transformer-rectifier units in the aircraft. In addition, a 15 ampere-hour battery is installed to operate the essential d-c services under emergency conditions. To permit ground operation when a-c power is not being supplied to the aircraft, external d-c power can be supplied to the battery and emergency d-c busses through a receptacle on the nose landing gear leg, as shown in Figure 5. The following services may be operated from this d-c source.

Service	Load
Battery isolation relay	0.26 amp. continuous
Landing gear indicators	0.5 amp. continuous
Fire detection	1.0 amp. continuous
Master warning box	1.35 amp. continuous
Emergency cockpit lights	0.6 amp. continuous
Turn and bank indicator	0.2 amp. continuous
AN/ARC-52 UHF	5.6 amp. continuous
AN/AIC-10A intercommunication	2.9 amp. continuous
Canopy actuation	16.8 amp. for 8 seconds
Fire extinguisher	8.0 amp. momentary
L.P. fuel cocks	12.8 amp. for 1 second
Ignition for engine starting	31.0 amp. for 30 seconds

Power for these services is normally obtained from the transformer rectifiers in the aircraft, and since these are energized from the main a-c external supply, only five amperes at 27.6 V d-c will be required under normal conditions. However, a 50 empere external supply is recommended for operating these services when an a-c supply is not in use.

In addition to the d-c power supply, the nosewheel receptacle has provisions for the following services:

(a) Electrical control of the starter unit to permit cockpit initiation of engine starting. After starting, centrifugally operated switches on the engine starter motors close the engine starter unit control valves when a pre-set engine speed has been attained.

(b) Audio signals from a landling "Telescramble" system to provide two-way communication between the cockpit and an operations controller.

(c) Intercommunication between the cockpits and ground crew.

(d) D-c power to control the external d-c supply to the aircraft, to isolate the aircraft battery and to energize the aircraft interphone system from a towing vehicle.

(e) Single-phase a-c power to warm the amplifiers in the engine fuel flow control units.

4.9.3 TURNAROUNDS

No servicing is required at turnarounds, but an external power supply must be plugged into the aircraft prior to engine shut-down. This is required to maintain the ASTRA system at stand by.

4.9.4 1ST LINE MAINTENANCE

First line maintenance will consist of rectification and inspection checks of:

(a) Circuit breakers and current limiters.

(b) Visual inspection of the transformer rectifier units, ground fault relays and main power panel.

(c) Visual check of the battery, wiring, distribution panels and accessory panels.

(d) Functional checks of internal and external lighting.

4.10 ARMAMENT

4.10.1 ARMAMENT SYSTEM INSTALLATION

The armament system consists of four Sparrow 2D air-to-air guided missiles stowed in a semi-submerged position, in a removable weapon pack, as shown in Figure 14.

FIG.14 ARROW 2 WEAPON PACK AND DOLLY DURING HOISTING

The carriage of missiles in a separate weapon pack has been adopted for the following reasons:

(a) Internal or semi-submerged stowage is used because of the reduced drag of the installation and, the consequent improvement in aircraft performance. It was also considered advisable to accommodate the lowering and launching equipment in a self-contained, removable weapon pack so that should any component become unserviceable, a serviceable pack could be quickly substituted.

(b) By isolating the aircraft primary structure from the armament bay structure, changes in the type of armament to be carried can be made, with a minimum of changes to the aircraft.

(c) Interchangeable weapon packs carrying different weapons can be used, thus adding to the aircraft's versatility.

(d) Reloading the aircraft by changing weapon packs permits the attainment of an acceptable turnaround time, as far as the armament is concerned. This has already been demonstrated during the ARROW 1 mock-up conference. It is extremely doubtful whether the turnaround requirement can be met in any other way than with this system.

The weapon pack is approximately 15 ft long and 10 ft wide, and weighs approximately 3800 lb when loaded. The weapon packs are designed to be fully interchangeable between aircraft and are attached to the aircraft at four pick-up points, one at each corner of the pack. Of these, only the rear attachments are jigged and precise jigging is only required in the spanwise direction. The two front pick-ups mate with self-aligning fittings in the aircraft and therefore do not require precision jigging. All attachments are locked and unlocked individually and are operated manually from outside the package,without the necessity of removing panels. All hydraulic and electrical connections between the weapon pack and the aircraft are made by quick-disconnect couplings, and for safety all missile firing signals are made through a separate connector mounted at one side of the pack. Making this connection constitutes arming the aircraft.

4.10.2 LOADING

A trolley has been designed by AVRO for transporting and hoisting the weapon pack. A tractor, not exceeding five feet in height is recommended for towing the hoist trolley to permit passage under the fuselage. The weapon packs will be towed from the armament storage and test facility direct to the turn-around hangar where they will be positioned ready for loading into the aircraft.

The pack and trolley are hoisted on cables which attach to lifting points on the aircraft structure. The cables are operated by pneumatic actuators powered by 1800 psi air bottles in the trolley. Sufficient air is carried to hoist a loaded pack into an aircraft six times.

Accurate positioning of the trolley is not essential as self-alignment will be made as the load is taken by the hoist cables.

Four men will be required, one at each corner of the pack, to secure the hoist cables to the aircraft and to steady the pack. The sequence of operations have been described in AVRO report 72/GOPS/1 Methods of Loading the Armament - Preliminary Time Study.

4.10.3 TURNAROUNDS

At turnarounds, the weapon pack will be removed and replaced by another which has been serviced and loaded in the armament storage and test facility, as outlined in Avro Report LOG/105/36 Preliminary Study of the Armament and Test Facility.

4.11 THE ELECTRONIC SYSTEM

4.11.1 GENERAL DESCRIPTION

Telecommunication techniques, navigation, weapon firing and automatic piloting of the ARROW have been extensively developed, and combined to form an electronic system known as ASTRA I.

The ASTRA I system is designed to perform the following functions:

(a) Receive and interpret data from ground or airborne sources.

(b) Seek and attack targets.

(c) Return the aircraft to base.

The system is energized by a-c and d-c electrical power from the main aircraft supply, and its power requirement is:

a-c - 20 KVA at 200/115 volts 3 phase 400 cps

d-c - 40 amps. at 27.5 volts.

The main power supply is critical for some items of electronic equipment and has been specified in AVROCAN Specification No. E-500 (40 KVA a-c Generator) and E-501 (Constant-speed drive for 40 KVA a-c Generator).

4.11.2 TURNAROUND AND 1st LINE MAINTENANCE ASPECTS OF THE ELECTRONIC SYSTEMS

During turnaround, the vertical heading and reference system will require orientation with respect to the earth's axes. For this, the heading of the aircraft must be determined to within $\pm 1/4^\circ$. At the present time, the techniques and equipment required have not been definitely established, but a scheme is at present under consideration to use a portable master reference gyro which would be plugged into the aircraft for either manual or automatic adjustment prior to each flight.

No maintenance or functional checks will be required on any part of the ASTRA I system during turnaround. The equipment will be left on standby, i.e. switched on, during the turnaround so that it will be warmed and ready for another immediate sortie. If, however, the ASTRA I system is switched off, a semi-automatic test is required on the fire control system before flight, to verify that this sub-system is serviceable.

First line maintenance will consist entirely of tests using special test equipment to determine if the aircraft is serviceable. In case of unserviceability, auxiliary test sets will be used to localize faults and isolate defective items. These will immediately be replaced by serviceable components which have been tested and calibrated on a complete master ASTRA I mock-up in the 2nd line maintenance facility.

The semi-automatic test equipment required during primary inspections is summarized as follows:

(a) Fire Control System Test Set

A clear indication of the fire control system performance will be shown on the test set. The set will require a ground power supply of 115 volt, 400 cps 3 phase power. The test set is connected to a test receptacle at station 167 on the right hand side of the aircraft's nose wheel well by means of a single cable.

In the event of a fault being discovered, the fire control computator test set will be required to isolate the defective component. The exact location of the test points on the aircraft for this test set have not yet been determined.

During the semi-automatic test of the fire control system it will be necessary to operate the radar antenna. This will require a hydraulic power supply as described in paragraph 5.3, Table 3.

(b) The Automatic Flight Control System Test Set (AFCS)

This equipment determines the serviceability of the AFCS. Detail design of this equipment has not been finalized but serviceability will probably be indicated by green and red, "go/no go" lights. An auxiliary AFCS test set will be provided to isolate defective components, should the AFCS test set indicate unserviceability.

(c) The Flying Control Damping System Test Set

A damping system test set is used to establish the serviceability of the complete damping system. An auxiliary test set for isolating faults, a pitot-static test set and g limiter test set will also be provided for isolation of defective items.

Other test sets are under consideration for use at 1st line maintenance but the requirements for these are not yet established. These include test units for the AN/ARC-52 UHF transceiver, AN/ARN-6 radio compass, the dead-reckoning computer and the doppler radar.

4.12 FLIGHT INSTRUMENTS

4.12.1 GENERAL

The advanced performance characteristics of the aircraft have necessitated a review of the existing methods and instruments used for presenting visual data to the aircrew. Among the new cockpit instruments installed are:

(a) A combined engine performance and exhaust gas temperature indicator. This instrument will display percentage of maximum engine thrust, percentage of maximum afterburner thrust and jet pipe temperature.

Test equipment will be required to establish serviceability and perform field calibrations on these instruments while they are installed in the aircraft. This will facilitate trouble-shooting and ensure instrument integrity when investigating reports of engine malfunctioning.

(b) A liquid oxygen quantity indicator is mounted in each cockpit. This is a remote reading electrical indicator and will be checked for accuracy on connecting the instrument to the fully charged replacement oxygen convertor.

(c) Two navigation instruments: the integrated destination display (IDD), and the flight director/attitude indicator. These instruments receive signals from a vertical and heading reference system which must be aligned with a reference heading, prior to each flight.

(d) A combined indicated air speed, equivalent air speed and stall warning indicator will be mounted in each cockpit. The integrity of this system will be established by periodic removal of the instrument for calibration, and by checks during damping system testing at each primary inspection. The pitot-static system leakage tester type MB-1 (modified) will be used for both this system test and the damping system pitot-static test.

(e) The fuel quantity gauges are transistorized into indicator units reading in pounds. The system is similar in principle to the gauges in current use.

4.12.2 TURNAROUNDS

During turnarounds, it will be necessary for the aircrew to check the fuel contents gauges after refuelling, and the liquid oxygen quantity indicators before and after replacment of the oxygen convertor. It is not envisaged that ground crew should check these gauges during turnarounds since the aircrew's pre-flight cockpit checks, will naturally embrace these items.

4.12.3 1st LINE MAINTENANCE

At primary inspections, a visual check should be made of all instruments, fuel and oxygen quantity indicators and emergency oxygen bottle pressure gauges. A functional test should also be made on the oxygen regulator, using an oxygen mask. An oxygen regulator is located under each crew member's seat but is not equipped with a flow indicator.

Functional testing of the ASTRA I system cockpit displays is performed in conjunction with the electronic tests described in paragraph 4.11.

Malfunctioning of electronic instruments and displays will generally require fault isolation with test equipment designed to indicate the particular portion of any system which is at fault. If a faulty instrument or oscilloscope display is the source of the trouble, the item will be readily replaceable. It is not considered that there should be any difficulty in this respect, as design tolerances are close and the replacement instrument or display would be calibrated on the 2nd line master rig, prior to installation.

4.13 FIRE PROTECTION SYSTEM

A continuous-wire type detector circuit is installed in the aircraft services bay, and in each engine bay. The detector wire senses temperature changes through change of resistivity. At a pre-determined resistivity value it operates either an overheat warning light or a master warning light on the pilot's panel, plus a combined fire warning light and extinguisher switch for each of three protected areas. Actuation of the extinguisher switches initiates the discharge of freon extinguishant from two bottles, to the appropriate area. A high rate discharge system is used, incorporating a double shot feature. This permits selection of a single or double discharge to any one of three areas.

Power supply is normally from the main d-c bus. In the event of failure of this supply, automatic switching is made to feed the detector circuit from the emergency d-c bus, and the extinguishing circuit from the battery bus.

In order to check the detector circuits a test switch is provided on the refuel and test panel (E.21).

Each fire extinguisher bottle contains 12 lbs of freon which is pressurized with nitrogen gas to a nominal 400 psig. Should this pressure be below the appropriate pressure for the ambient temperature, the bottles must be removed and replaced with fully charged units as it is not possible to determine whether the freon or nitrogen has leaked, unless the units are removed and weighed.

4.13.1 TURNAROUNDS

No servicing is required on the fire extinguishing system during turnaround.

4.13.2 1st LINE MAINTENANCE

Primary inspection maintenance checks comprise checking the detector circuits for continuity, by operating the test switch on the refuel and test panel, located at station 490 in the lower fuselage, and checking the fire extinguisher bottle gauges for correct pressure.

4.14 EJECTION SEATS

It is proposed, at this stage, to equip both the ARROW 1 and 2 with Martin-Baker C-5 fully automatic ejection seats.

Each seat will be equipped with a primary cartridge, two secondary cartridges and a drogue gun cartridge. The ejection cartridges are operated by pulling the face blind, which also operates the canopy emergency opening cartridge, prior to ejection of the seat. An alternative operating handle is also provided and is located at the base of the seat.

A quick disconnect coupling at each seat provides connections to the following services: oxygen, pressure, suit, visor-demisting, telecommunications and anti-g suit.

At turnarounds, and at all times when the aircraft is on the ground, precautions must be taken to prevent inadvertent firing of the cartridges.

As soon after landing as possible the safety pins must be inserted in the drogue gun, the alternative seat firing handle, the seat ejection gun sear and the canopy cartridge firing sear.

Prior to each flight, it will be necessary to remove these pins and place them in their stowage positions, after the pilot has secured himself in his seat.

Each seat carries a combined parachute and seat harness. The parachute is considered as part of the seat but may be removed independently for periodic repacking.

Each seat weighs 110 pounds and requires a minimum headroom of five feet for removal. Before removal, the seat must be completely disarmed. Removal may be made by two men, and it is recommended that the seat be removed manually to avoid distorting the seat slipper pads and guide channels. However, it is recommended that an overhead hoist be available to take the weight and lower the seat to the ground,as the task is awkward and hazardous in view of the height of the cockpit. For field use, it is desirable that a self mobile hoist similar to the GIRAFFE model 1-G-40 should be used.

The cartridges must be changed periodically but the change may be phased in with 2nd line maintenance when the seats would be removed from the air-craft. However, the cartridges can also be changed with the seats installed. This is done by elevating the seat pan to maximum installed height, dis-connecting the top attachment pin and tilting the seat to its maximum forward position.

The pressure in the emergency oxygen bottle should be checked and a visual inspection of the seat, parachute and operating mechanisms should be conducted, at primary inspection to ensure cleanliness and serviceability.

4.15 AIRCREW EQUIPMENT

Special flying clothing and equipment will be necessary for aircrew as follows:

1. Pressure helmet
2. Pressure vest
3. g suits
4. Leg restraints
5. Heavy clothing such as boots and mittens.

Facilities for handling this equipment together with aircrew showers, toilets, rest and locker rooms would be desirable and should be located as close to the turnaround hangar as possible.

5.0 GROUND SUPPORT EQUIPMENT

5.1 GENERAL

In chapter 4 the ARROW 2 maintenance requirements during turnarounds and 1st line maintenance were reviewed. From this review, the ground support equipment required for the ARROW 2 has been determined and is summarized in Table 1. Recommendations for specific equipment for field and hangar use are listed in Tables 2 and 3.

Table 1 (a)

TURNAROUND - BASIC REQUIREMENTS

Function		Description of Service Required	Equipment Required
1.	Refuel	2026 Imperial gallons. Total flow of 500 gpm to 1000 gpm max. through two hoses at 50 psi.	-Tender or hydrant system. -Access stands for connecting hoses to refuel adapters. -Fuel vapour exhaust system.
2.	A-c and d-c power maintaining ASTRA I at standby.	Up to 40 KVA of 115/200V, 400 cycle, 3 phase a-c power to Avrocan Spec. E-500. 5 amp. at 27.5V d-c to operate a-c relays in the aircraft. Cooling air supply. Minimum of 150 lbs/minute at 55°F at 4.5 psig at the aircraft.	Combined power and air conditioning trucks or separate static generating plant and separate air conditioning unit.
3.	Reload	Remove pack and replace with loaded pack.	Empty hoist trolley and replacement loaded pack on hoist trolley.
4.	Change of aircrew		Cockpit access platform or access catwalk.

Function	Description of Service Required	Equipment
5. Drag chute	Replace	Replacement drag chute, access stand or drag chute delivery vehicle.
6. Replenish water in air conditioning system boiler.	Add up to 24 Imperial gallons of pure water per combat mission.	Main water supply with overhead delivery hose and automatic shut-off and refill nozzle, or mobile water tanker with heater unit. Access ladder or catwalk.
7. Oxygen, replenish	Change liquid oxygen converter.	Replacement converter, access ladder or catwalk.
8. Engine oil replenish	Max. consumption 3 pints/engine/hour at military rated speed. Refill at pressure point until oil is observed at overflow pipe.	Replenishing trailer 20 gallons oil.
9. Check auxiliary gearbox oil.	Replenish as necessary. Should not normally require replenishment at turnarounds.	Engine oil replenishing unit.
10. Intercom Tele-scramble	Cable connects aircrew, ground crew operations room and engine starters through nose wheel receptacle.	Cable from hangar or from engine starter(s).
11. Align vertical heading & reference system.	Determine aircraft heading to $\pm$ -1/4° Method not yet firmly established).	
12. Engine starting	Hot, medium pressure air; 500 VA at 115V, 400 cps a-c to warm amplifiers in engine fuel flow control units; 50 amp at 28V d-c; signal wires to control starting cycle from aircraft.	Gas turbine compressor unit(s). If two units are used to provide simultaneous engine starts, cabling is required in accordance with AVRO drawing 7-4427-113.

Table 1 (b)

1st LINE MAINTENANCE - BASIC REQUIREMENTS

System	Description of Service	Equipment Required
1. Astra 1	Primary inspection	Ground supply 115/200V 400 cps 40 KVA. Cooling air supply. Main hydraulic power rig. Radar antenna hydraulic power rig. Nose servicing dock. Fin servicing stand. Fire control test set. AFCS test set. Damper test set. Pitot-Static test set. G-limiter test set. UHF test set. Doppler test set. Vert. heading and Ref. system test set. Radar homer test set. D.R. test set.
	Fault isolation	Fire control computer test set. AFCS auxiliary test set. Damper auxiliary test set. Pitot-Static test set. G-limiter test set.
	Rectification	Electronic spares trolley. Electronic replacement units.
	Replenishment	Hydraulic reservoir filler. Cooling oil tank filler.
2. Engines	Primary inspection - air intakes	Access ladder. Flame proof inspection lamp.
	Engine change	Replacement engine in trolley. Engine change stand. Empty transport trolley. 6000 lb. capacity hoist. Aircraft jacks. Engine sling and beam.

System	Description of Service	Equipment Required
2. (Cont'd)	Oil replenishment	Replenishing trailer 20 gallons oil capacity.
	Oxygen replenishment	Replacement bottle.
3. Airframe general	Towing	Tractor 10,000 lbs. draw-bar pull. Tow bar or bridle. Nose wheel steer arm.
	Defuelling	Tender. Air supply 50-60 psia 12 lbs/minute at 350°F (max).
	Fuel transfer & regulation tests	Air supply 50-60 psia 12 lbs/minute at 350°F max.
Nose section	Primary inspection	Access stand (RCAF 4G/1596)
Armament bay	Primary inspection	Access stand (RCAF 4G/1596)
Hydraulic equipment bay	Primary inspection	Hydraulic bleed & charge unit. Compressor, nitrogen 5000 psi
Wing (one side)	Primary inspection	Access stand to landing gear bay roof (RCAF 4G/1596) Rubber mats for upper sur-face
Dorsal area	Primary inspection	Cockpit access stand
Empennage	Primary inspection	Fin servicing stand
Cockpit	Primary inspection	Cockpit access stand. Hoist.
4. Electrical	Primary inspection	Access platform (RCAF 4G/1596)
5. Armament	Primary inspection	Hoist trolley, for removal of pack and transporting it to the armament storage and test facility.

System	Description of Service	Equipment Required
5. (Cont'd)		Aircraft test set (pack and missile simulator)
6. Instruments	Primary inspection	Use access platform already placed.
7. Safety equipment	Primary inspection Drag chute replacement	Hoist for seat removal and replacement. Access platform (RCAF 4G/1596) Asbestos blankets and gloves.

5.2 TURNAROUNDS

The original concept (AIR 7-4 Issue 2) required that a turnaround be completed in five minutes. Consequently, the aircraft has been designed with this in view and can take refuelling flows of up to 500 gallons per minute through each of two points. However, hydrant refuelling and other quick access facilities will be required to achieve turnarounds within the required time. A preliminary time study using this equipment showed that this might be realized in about seven minutes.

The turnaround time has now been relaxed to four aircraft in 15 minutes and this may be achieved using field equipment and tender refuelling. The equipment required is listed in Table 2 (a).

It is desirable that the minimum turnaround time be achieved and it is recommended that the ground support equipment be designed to realize the full capabilities of the aircraft. This equipment is listed in Table 2 (b).

Table 2 (a)

TURNAROUND AT FORWARD BASES

Services Required	Equipment Recommended	Quantity for turn-around in 4 A/C in 15 mins
1. Refuelling	Tender. RCAF have made proposal for GFE tender of 3200 gallons capacity and refuelling rate 250 gal./minute through each of two hoses at 50 psi.	4 in immediate use plus 5 standby, as one tender will only refuel one aircraft.
	Access platform 36 inch high, 4 steps up.	8 (2 per aircraft)
2. (a) Electric power (b) Cooling air supply	A combined air condition and electric power trailer which will provide 115/200V 400 cps 3 phase a-c and 150 lbs/minute air at 4-1/2 psig at 55° (Max) The trailer will have limited self mobility.	4
3. Reload	Weapon pack hoist trolley - empty Weapon pack hoist trolley - loaded with replacement pack	4 4
4. Cockpit	Mobile access platform. Existing alternative types are to be evaluated by RCAF.	4
5. Drag chute replacement	Drag chute collection vehicle. Access stands. Drag chutes Asbestos mats and aprons for personnel	1 vehicle 4 stands 4 drag chutes 4 sets
6. Water replenishment air condition boiler	Trailer 50 gallons with oil-fired heater and special automatic shut-off refilling nozzle.	4

Services Required	Equipment Recommended	Quantity for turn-around of 4 A/C in 15 mins.
7. Oxygen replenish	50 gallon liquid oxygen storage trailer (GFE) Spare converters Insulated trailer for safe stowage and transport of converters. (converters evaporate approx. 1 litre of liquid oxygen in 24 hours)	1 4 1
8. Engine and auxiliary gear box.	Engine oil trailer, 20 gallon capacity Avrocan E-473	4
9. Engine Starting	A gas turbine compressor unit on a mobile trailer is recommended for supplying the hot medium pressure air for engine starting. The unit will consist of: gas turbine compressor, 27.5 V 50 amp d-c generator, battery, a 500 VA 400 cps 115 volt single phase supply, intercom junction boxes, electric and intercom supply cable to the nose landing gear receptacle and two air delivery hoses.	4

Table 2 (b)

TURNAROUNDS IN PREPARED HANGARS

Services Required	Equipment Recommended	Quantity for turn-around in 4 A/C in 4 bays
1. Refuel	Hydrant system to supply 1,000 gallon/minute to each aircraft at 50 psi with satellite storage tanks in turnaround area. This sytem requires a local supply of emergency electrical power for pump house operation as insurance against hydro-electric failure. A dispenser incorporating filters, water separators, meters and an air eliminator is required in each turnaround bay. There are no detailed proposals at present.	4
2. Electrical power	Although the maximum short duration load for 1st line maintenance operation on the ARROW 2 is estimated to be 31.5 KVA at present, it is recommended that motor generator sets be installed to provide up to 40 KVA of 115/200 Volt 400 cps 3 phase power to each aircraft. The characteristics of this power should meet Avrocan Spec. E-500 (40 KVA generators)' and the generator should be driven by a synchronous motor in order to obtain the specified frequency of 400 cps. A unit with suitable current characteristics appears to be the Motor Corporation's Model #1050 of 60 KVA rating. This capacity is in excess of the immediate know requirements per aircraft and a 40 KVA set would be suitable if available. This unit does not meet the overload requirements specified in Avrocan E-500, but this is considered unnecessary for ground operation.	4

Services Required	Equipment Recommended	Quantity for turn-around of 4 A/C in 4 bays
3. Conditioned air supply	Electrically driven stationary equipment, to supply 150 lbs/air minute at 4-1/2 psig at 55°F (maximum), at the aircraft, with the air containing no free moisture. A proposal by the John Inglis Co. Ltd. as submitted in Avro report LOG/105/9 "Readiness Facility" is an example of a suitable unit.	4
Alternative to 2 and 3.	The power/air conditioning unit recommended in Table 2 (a) para. 2 (a) and (b) for use at forward bases might be used in turnaround hangars but this is not recommended for the following reasons: (a) Lower initial cost for industrial machinery. (b) Lower level of skill for maintenance and less frequent maintenance required for industrial machinery. (c) Lower noise level.	4
4. Reload	Weapon pack hoist - empty Weapon pack hoist - loaded with replacement pack	4 4
5. Cockpit access	Mobile access platform. Existing alternative types are to be evaluated by RCAF.	4
6. Drag chute replacement	Access stand Drag chutes Asbestos mats and aprons for personnel.	4 4 4 sets

Services Required	Equipment Recommended	Quantity for turn-around of 4 A/C in 4 bays
7. Water replenish-ment	Water softening plant capable of delivering 12 gallons per minute to each turnaround bay through an over-head hose delivery system.	1
	Hose terminating in a 1 inch diameter automatic shut-off filler nozzle such as "Filomatic" #1811 manufactured by O.P.W. Corporation, Cincinnati, and modified to suit ARROW 2. Flow requirements are based on completing turnaround replenishment of 24 gallons in 2 minutes. Water softening equip-ment is not specified as this will vary with the quality of the water in each locality.	4
8. Oxygen	Replacement liquid oxygen converters. Trailer insulated for transportation of converters (RCAF Drg. 551661)	4
9. Engine & gearbox oil replenish-ment.	Trailer engine oil replenishment 20 gallon GFE to Avrocan Spec. E-473	4
10. Intercom	Cables are required for interconnect-ing the aircraft and starter units; air-craft and ground crew; aircraft and the Bell Telephone Company "Telescramble" system.	4
11. Engine starting	A gas turbine compressor unit com-plete with a generator to supply 50 amp 27.5 volt d-c and 500VA source of 115 400 cps single phase a-c power is proposed for the turnaround hangar. The unit would also carry junction boxes for intercom as des-cribed in item 10. This is identical to the proposed trailer unit recom-mended for field use.	4

Services Required	Equipment Recommended	Quantity for turn-around of 4 A/C in 4 bays
11. (Cont'd)	The direct current from this unit should be fed to a junction box which would also receive an identical supply from a hangar d-c source to operate the intercom system on occasions when the engine starting compressor is not running. The starters should be interconnected so that either starter can start any engine.	
12. Emergency d-c for starting engines and operating intercom when engine starters are not running.	Power rectifier RCAF GFE 5P/47 (Mallory #VA 3000) 220V 60 cps, 3 phase input 20-32 volt 100 amp output or motor generator set 5P/60 500 volt 50/60 cps 3 phase input 23-33 volt 500 amp output.	2

5.3 <u>1st LINE MAINTENANCE</u>

The 1st line maintenance tasks are as follows:

(a) Primary inspections.

(b) Fault isolation.

(c) Fault rectification.

(d) Special inspections.

(e) Alignment of systems

The major 1st line maintenance task is the recurring primary inspection. The equipment necessary to perform this function is listed in Table 3. Cooling air and 400 cycle a-c power will be required for each aircraft. The static machinery already proposed will be adequare in size and quantity.

Table 3

1st LINE MAINTENANCE

Function	Equipment Recommended
1. ASTRA 1 - primary inspection access.	Nose servicing dock. A light-weight tubular structure embracing both sides and front of nose section with facility for radome and radar removal, and suitable storage space for electronic test sets. Design study in hand by AVRO.
Radar antenna transverse for function test	A standard RCAF Greer unit 4G/222 or similar electrically driven unit is recommended for use during fault rectification when the main hydraulic rig is not in use. Estimated power consumption is 5 KVA at 550 volt 3 phase 60 cps a-c. A similar unit with gas motor drive is required for use at forward bases to supply 8 US gallons/min at 1000 psig.
Fire control system test	An estimated 2 KVA of 115 volt 400 cps 3-phase a-c is required for the FCS test set. An outlet from the stationary motor generator set should be provided, since this power should be from the same source as the aircraft source.
Trans-portation radar trans-ceiver and radome	Special handling equipment to be designed by AVRO.
Replenish-ment radar hydraulics	A minimum of 30 psig will be required to replenish this reservoir with oil to specification MIL-O-5606. The tank has 80 cubic inch capacity. The hand-operated Godfrey filler and bleed unit RCAF 4G/1825 could be used for this purpose. The radar cooling system uses OS-45-1 oil. A special filler is being considered for replenishing this system, in view of the small quantity of special oil involved.

Function	Equipment Recommended
2. Air intakes inspection	Servicing stand, elevating RCAF 4G/1596. To be shared by airframe for landing gear inspection in main wheel bay.
Engine change.	AVRO design as illustrated in Figure 13.
Engine oil replenishment	Trailer, 20 gallons capacity, hand operated, to Avrocan Specification E-473.
3. Airframe	The weight of the aircraft will be about 60,000 lb when loaded for its primary combat mission and 68,000 lb for ferry missions. The aircraft is designed to be towed from the nose landing gear, with draw bar loads up to 10,000 lbs. No particular tractor is recommended, but it is desirable that the draw bar pull should be at least equal to the shear pin value in the towbar. The normal towing loads on hard level surfaces will be approximately 3,000 - 4,000 lbs, but will be higher when starting on grades or in snow. A "Unitow" tractor Type D.8 is suitable for normal purposes and is a convenient size for handling the weapon pack trolley.
4. Defuelling	A tank and suction unit of at least 3200 gallon capacity will be required to receive the full load from one aircraft. It is recommended that defuelling be carried out by using tender suction and compressed air. It is proposed to use air from the engine starter after it has been passed through a heat exchanger and filter. The heat exchanger and filter are presently being designed by AVRO. A 10 micron filter and water trap will be required in the air supply line.
5. Defuel, air pressure (also required for flow tests)	Air supply from engine starter unit via a mobile heat exchanger unit, employing air-to-air cooling.
6. Hydraulic	A hydraulic replenishing trailer of 8 gallon capacity RCAF GFE 4G/1825 manufactured by Godfrey Engineering Co. and modified by AVRO to take alternative filters and couplings is being evaluated.

Function	Equipment Recommended
6. (Cont'd)	Each compensator is replenished through the aircraft low pressure ground connections. The total capacity of the hydraulic system is 26 Imp. gallons and the delivery rate of the dispenser is 1/2 gallon per minute at 150 psi.
7. Hydraulic systems functioning	A trailer manufactured to Avrocan Specification E-466 will provide up to 40 U.S. gallons/minute at pressures up to 4000 psig, for ground testing of the hydraulic system operation of the flying controls and retraction of the landing gear, missile launchers, speed brakes etc. The trailer is equipped with two hydraulic pumps each driven by 50 hp motors, one hydraulic pump with a 10 hp motor and two fan motors rated at 1/3 hp each. The rig operates from a 550V, 60 cps, 3-phase a-c supply. Power is supplied to the electric motors which drive the hydraulic pumps, through a 100 foot cable consisting of 3 size 'O' conductors and 1 size 12 conductor. The cable terminates in a 200 amp. 4 pin plug, type CROUSE-HINDS #AP20468, which mates with wall receptacle CROUSE-HINDS Type A.R.E.A. 20427. The motors are started by Allen Bradley magnetic starters Part No's. B.U.L. 709 (D.O.C.) and 709 (C.O.C.) and 709 (A.O.T.).
8. Pneumatic systems charging	A trailer manufactured by the Godfrey Engineering Co. to Avrocan Specification E-333 will provide either air or nitrogen at up to 5000 psig at 15 SCFM for charging aircraft pneumatic systems, inflating tires, replenishing the air bottles in the weapon pack hoist trolley and the landing gear emergency nitrogen bottles. The trailer is equipped with a compressor driven by a 15 hp motor powered from 550 volt, 60 cps, 3-phase supply. A 100-foot long power supply cable terminates in a three-pin, four-wire plug, Type CROUSE-HINDS #APJ3463. This mates with wall receptacle Type CROUSE-HINDS # AR 342 (30 amp).
9. Fin servicing stand	A standard RCAF stand (4G/1230) is proposed for access to the upper parts of the fin and rudder.

Function	Equipment Recommended
10. Ejection seat removal	A mobile, elevating and extending hydraulic powered hoist is being investigated for removal of ejection seats, canopy doors, rudders and control boxes. A recommendation will be made in the near future.
11. Oxygen recharging ejector seat & engine re-light oxygen bottles.	A standard RCAF gaseous oxygen supply trailer is suitable for this purpose.
12. Liquid oxygen	A trailer to RCAF Drg. 551661 for the transportation of converters.
13. Additional items	Special tools, boresighting equipment and slings are necessary for various operations at 1st line maintenance. These will be listed in the maintenance schedule against the operation for which they are required.

6.0 PROCEDURES AND PERSONNEL

A preliminary study has been made of the procedures and personnel necessary for rapid and efficient performance of the turnarounds and first line maintenance functions.

Three cases have been considered and the findings are presented under these separate headings:

1. Turnarounds at forward bases.
2. Turnarounds at main base in prepared hangar.
3. First line maintenance functions.

It is realized that these items are estimates and will have to be confirmed by practical demonstrations, when an aircraft becomes available. It is proposed that this be done during the contractor's demonstration of the complete weapon system.

No attempt is made to place servicing functions within the revised RCAF trade structure now being planned. The number of men suggested in this report is based on the optimum number of men required to perform certain tasks within a time limit. Existing tade classifications have been used.

6.1 TURNAROUNDS AT FORWARD BASES

To meet the operational requirements of four turnarounds in 15 minutes, it will be necessary to position the mobile ground equipment ready for immediate use. The equipment should be positioned in a manner similar to that illustrated in Figure 18 for the turnaround hangar at a main base.

The time study illustrated in Figure 15 is based on four sets of mobile equipment being positioned on a planned site with each aircraft taxiing up to the correct position. Some time will be lost in bringing the mobile cockpit access platform, refuelling tender and water tanker into position when compared with the fixed facilities in the turnaround hangar.

From Figure 15, a time of 8-1/2 minutes appears reasonable under ideal weather conditions for the completion of a turnaround at a forward base. However, an allowance should be made for adverse weather conditions, when some of the work will be hazardous and more difficult to perform.

The tasks to be performed at a forward base turnaround are listed in Figure 15. From this analysis the number of men required to handle one aircraft is as follows:

Safety equipment workers	1
Armourers	4
Tender drivers	1
Airframe mechanics	2
Refuellers	2
Engine mechanic	2
Electrician	1
Turnaround controller	1
Total	14

Four such teams will be required to complete four turnarounds within fifteen minutes, handling four aircraft simultaneously. In addition, extra personnel and equipment will be required if it is desirable to sustain forward base activities for any length of time. These will be employed on the additional refuelling tenders necessary, and on servicing and replenishing the ground equipment rigs.

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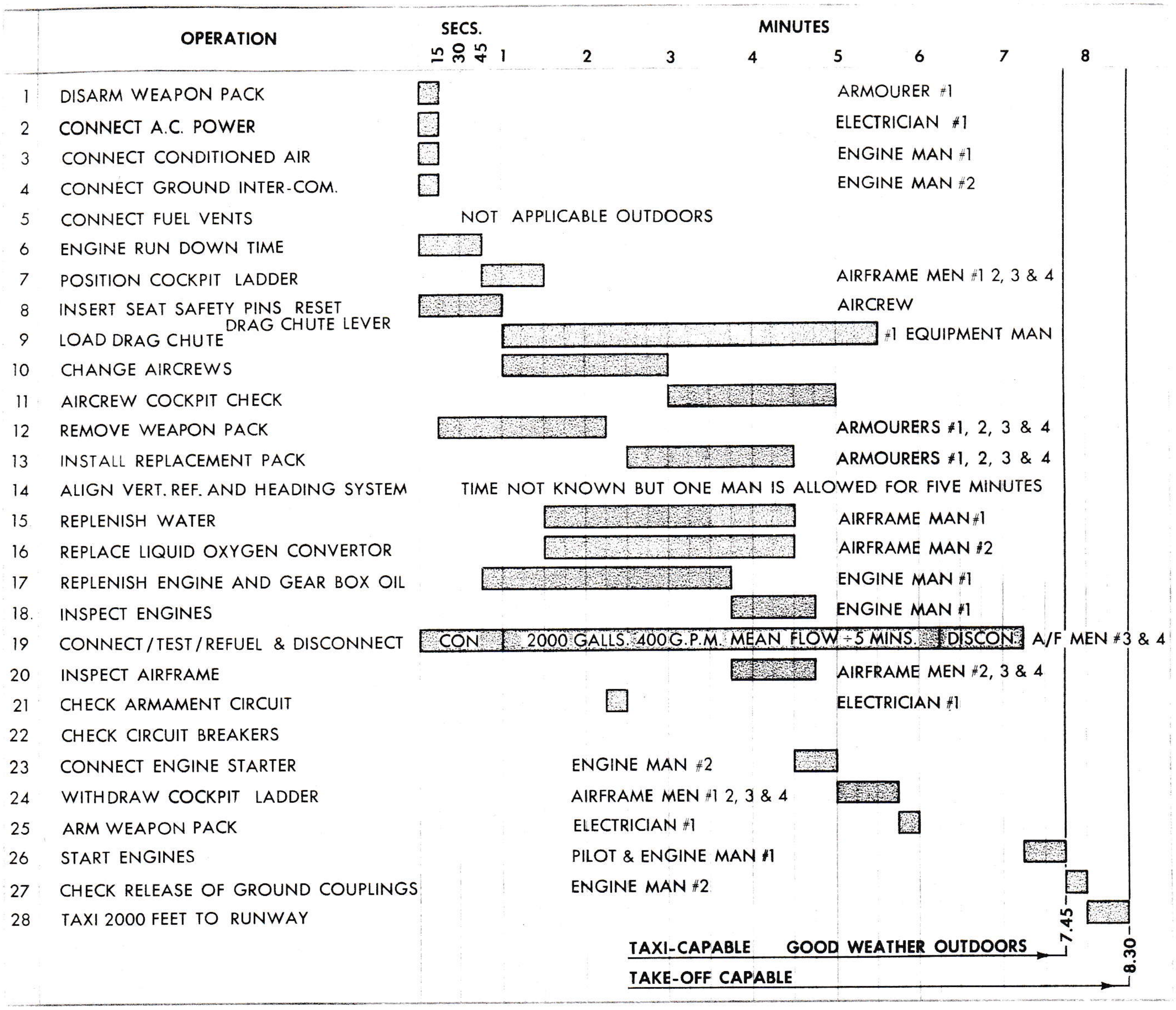

TOTAL TEAM

SAFETY EQUIPMENT	-1	
ARMOURERS	-4	
AIRFRAME	-4	(INCLUDES 2 REFUELLERS)
ENGINE	-2	
ELECTRICIAN	-1	
TENDER DRIVER	-1	
CONTROLLER	-1	SERVES TWO AIRCRAFT

REFUEL WITH ONE TENDER AT 500 GPM / MAX. AND ESTIMATED MEAN FLOW 400 GPM

FIG. 15 TURNAROUND TIME STUDY - FORWARD BASE - OUTDOORS

As the estimated time is 8-12 minutes, there are 6-1/2 minutes in hand to allow for adverse weather and still complete the turnarounds within 15 minutes.

It should be noted that the proposed refuelling tender is of 3200 gallon capacity and that one tender will therefore be required to refill each aircraft to the combat mission load of 2026 gallons.

6.2 TURNAROUNDS AT MAIN BASE

The RCAF has specified that turnaround at main bases should be performed under cover, and proposed that a type of turnaround hangar be built to realize the full turnaround capability of the ARROW.

It is suggested hydrant refuelling be incorporated at a flow rate of 1000 gpm through two hoses to each aircraft. This will reduce to an estimated 700 gpm due to shut-off of certain aircraft tanks as they become full, and this figure is used in the calculation.

The procedure to be adopted in the turnaround hangar is similar to that to be followed in the field, i.e. the aircraft taxies into the hangar. Electrical power and cooling air are plugged in prior to shutting down the engines, and the aircraft is then refuelled, rearmed and serviced. The aircraft may then be started and taxied out, or maintained at either readiness or standby.

From Figure 16 which lists the operations to be performed, it is calculated that an aircraft should be ready for taxiing in six minutes. Thus, two aircraft could be phased through one turnaround bay within fifteen minutes and one servicing team could handle the two aircraft.

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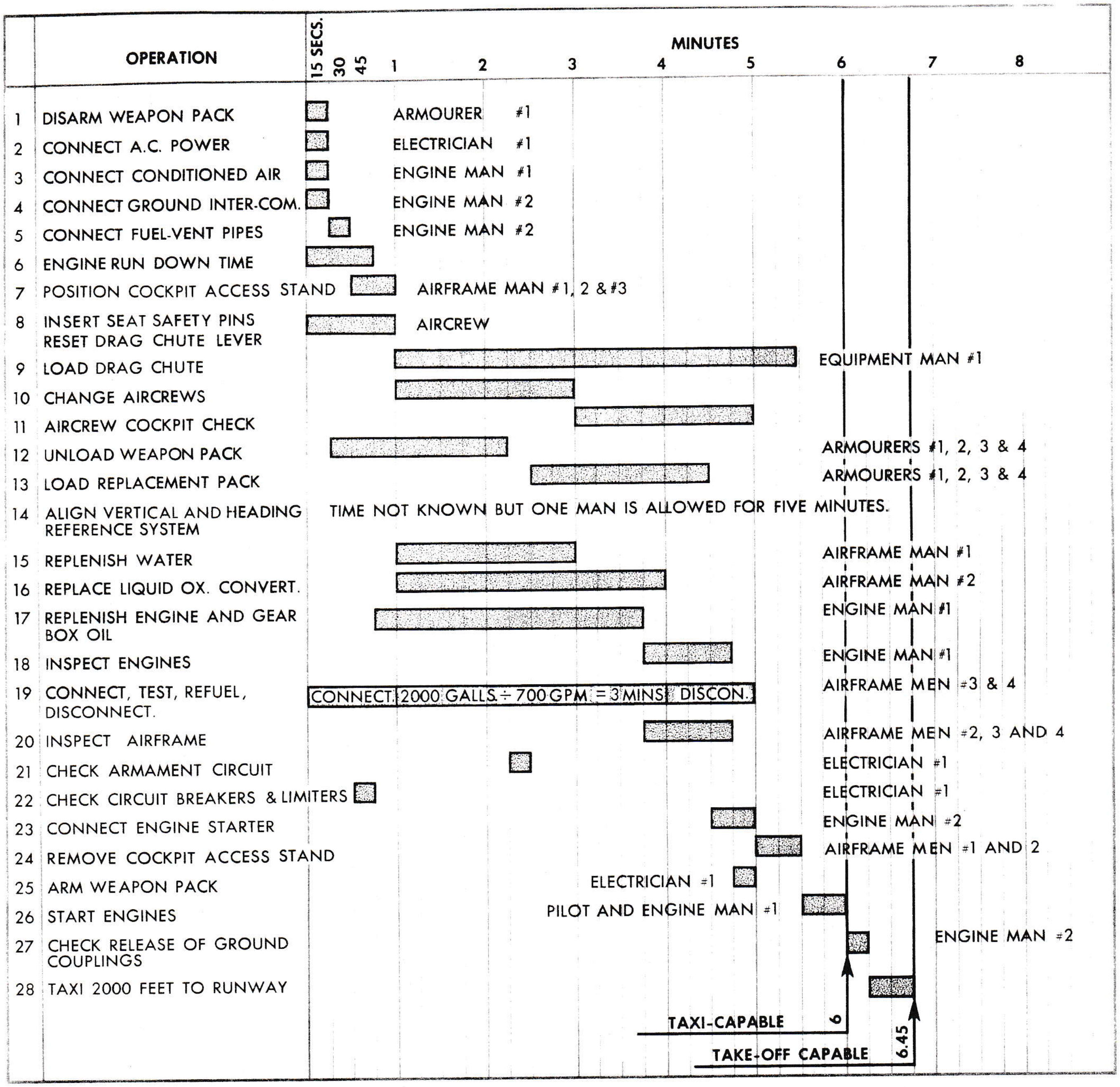


TOTAL TEAM: SAFETY EQUIPMENT —1
ARMOURERS—4
AIRFRAME—4 (INCLUDES 2 REFUELERS)
ENGINE —2
ELECTRICIAN —1
HYDRANT MAN—1 (SERVES 2 BAYS)
CONTROLLER—1 (SERVES 2 BAYS)

REFUEL FROM HYDRANT AT 1000 GPM/MAX. AND ESTIMATED MEAN FLOW OF 700 GPM

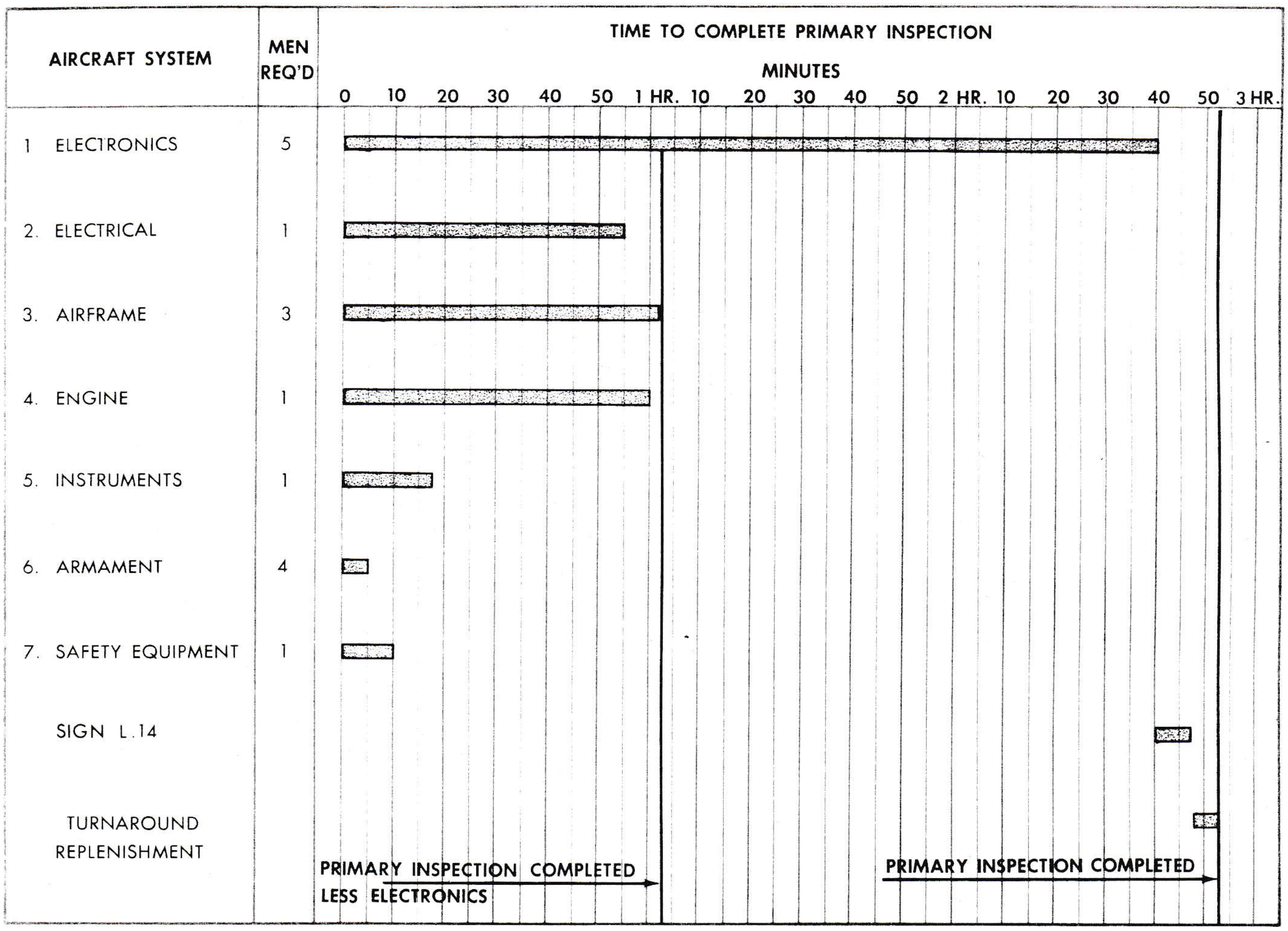
FIG. 16 TIME STUDY - TURNAROUND IN PREPARED HANGAR

Each team will consist of 14 men, as follows:

Safety equipment worker	1	
Armourer	4	
Airframe	2	
Refuellers	2	
Engine Mechanics	2	
Electrician	1	
Hydrant operator	1	serves 2 bays
Turnaround controller	1	serves 2 bays
Total	14	

6.3 FIRST LINE MAINTENANCE

It is considered that the primary inspection is the major function in 1st line maintenance and is typical of the work, the ground support equipment and manpower required. An assessment of the tasks to be performed has been made, using the ARROW 1 preliminary maintenance schedule, with due allowance for the ASTRA I system and other differences between ARROW 1 and 2 known to exist at present. These tasks are listed in Figure 17 as functions to be performed. No attempt has been made to determine an optimum sequence, as it is felt that this can only be achieved realistically, by practical demonstration. However, estimated times for primary inspection functions for the various trades are shown in Figure 17. This reveals that a primary inspection on the aircraft (less the ASTRA I system) may be completed in about 1 hour 5 minutes. However, it appears that 2 hours 55 minutes may be necessary to complete a primary inspection on the aircraft when the ASTRA system is included. Although the primary inspection cycle will ultimately be much longer, it is believed that the ARROW will be initially placed on a primary inspection cycle of 24 hours. It follows therefore, that about three hours will be spent each day on this task. A preliminary report



THE FOLLOWING ASSUMPTIONS HAVE BEEN MADE IN THIS ANALYSIS

THAT COCKPIT MAN A IS A SENIOR TECHNICIAN

THAT COCKPIT MAN B IS A SENIOR ELECTRONICS TECHNICIAN

THAT UNKOWN ASTRA MAINTENANCE REQUIREMENTS WILL NOT BRING TOTAL TIME OF PRIMARY INSPECTION TO MORE THAN 2 HOURS 40 MINS.

THAT NO RECTIFICATION WORK IS NECESSARY

FIG. 17 TIME STUDY SUMMARY - PRIMARY INSPECTIONS (CHART 1 OF 10)

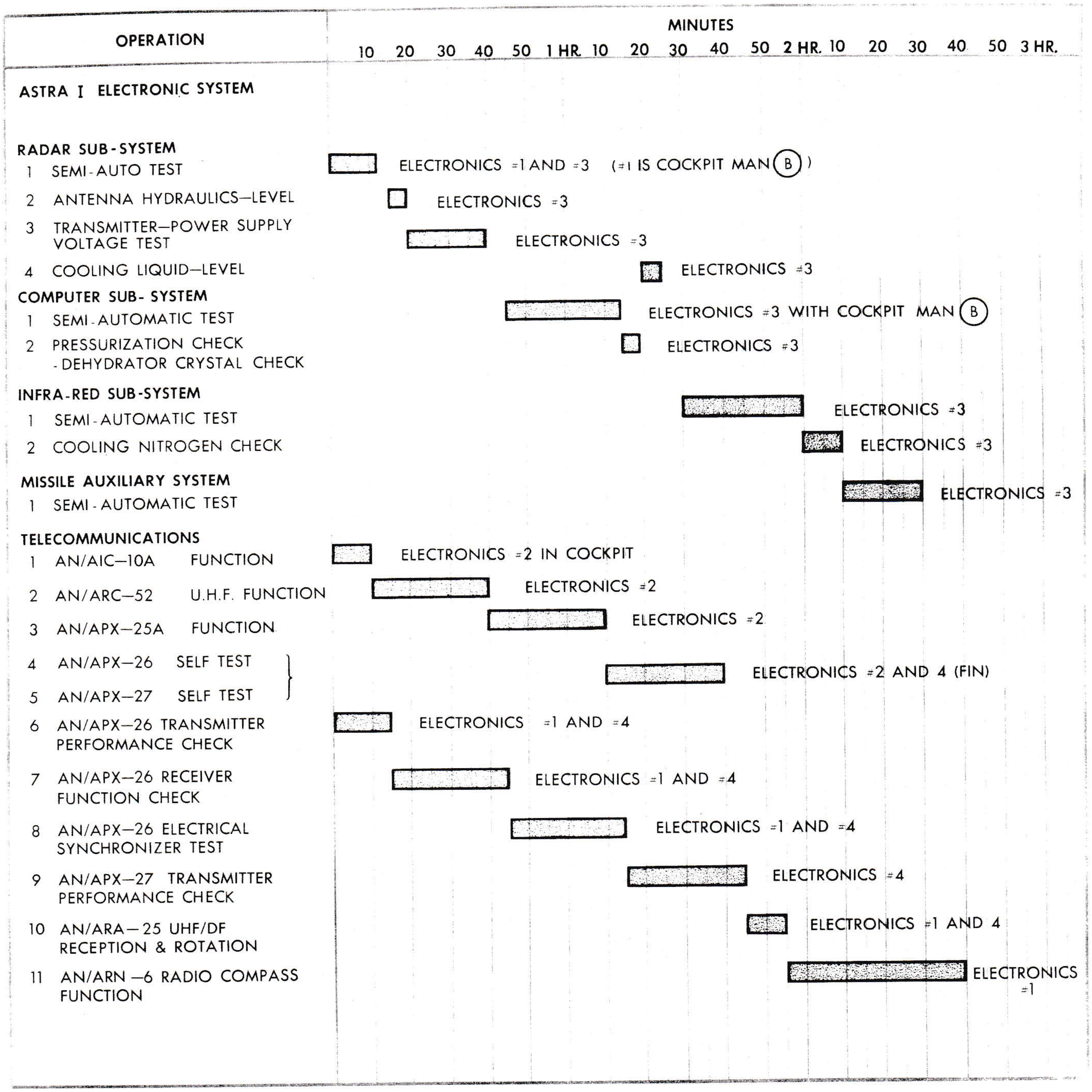


FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 2 OF 10)

OPERATION	MINUTES 10 20 30 40 50 1 HR. 10 20 30 40 50 2 HR. 10 20 30 40 50 3 HR.
DOPPLER TEST	NOT KNOWN AT PRESENT
VERTICAL HEADING AND REFERENCE SYSTEM	"
AUTOMATIC FLIGHT CONTROL SYSTEM TEST	"
DAMPING SYSTEM TEST	ELECTRONICS #2 AND #5
DEAD RECKONING COMPUTER TEST	"
RADAR HOMER AN/ARD 501	"

NOTE:
IT IS ASSUMED THAT TESTS ON THE ABOVE WILL BE CARRIED OUT BY COCKPIT MEN A AND B AND ELECTRONICS MAN #5 AND THAT THE TIME TAKEN WILL NOT BRING THE AGGREGATE BEYOND 2 HOURS 40 MINUTES.

TOTAL ELECTRONICS TEAM 5 MEN.

FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 3 OF 10)

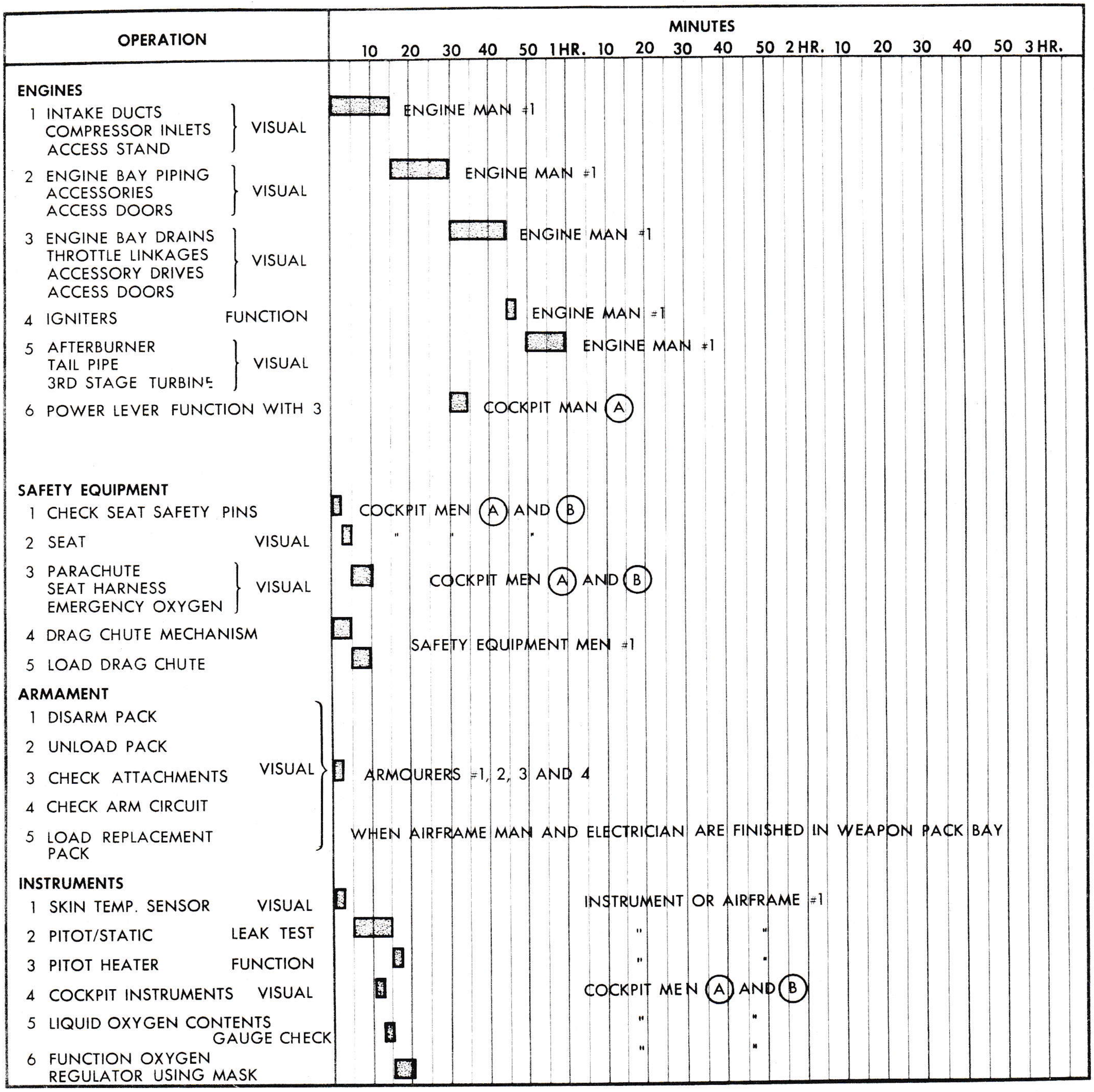


FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 4 OF 10)

OPERATION	MINUTES (10 20 30 40 50 1 HR. 10 20 30 40 50 2 HR. 10 20 30 40 50 3 HR.)
AIRFRAME NOSE	
1 NOSE LANDING GEAR — CLEAN TIRES — CHECK AND CHARGE 2 LANDING GEAR NITROGEN — CHECK 3 FLYING CONTROLS — CHECK 4 HYDRAULIC COMPONENTS — VISUAL 5 ELECTRONICS ACCESS DOORS. REMOVE AND REPLACE 6 WORKSTAND PLACE AND REMOVE	AIRFRAME MAN #1
ARMAMENT BAY ROOF	
1 FUEL LEAKS — VISUAL 2 BRAKE CONTROL VALVE — VISUAL 3 MANUAL DUMP VALVE — VISUAL 4 HOT AIR FILTER — VISUAL 5 WEAPON PACK ATTACHMENT — VISUAL 6 WORKSTAND PLACE AND REMOVE	AIRFRAME MAN #2
DUCT BAY	
1 ACCESS DOORS 1, 2, 3 REMOVE AND REPLACE 2 FUEL TANKS — DRAIN CONDENSATE 3 FUEL TRANSFER PUMPS 4 FUEL PRESSURE REGULATORS — VISUAL 5 DIFFERENTIAL AIR AND PRESSURE REGULATOR 6 PRESSURE RELIEF VALVE — VISUAL 7 FUEL PIPING 8 FUEL LEAKS — VISUAL	AIRFRAME MAN #2

FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 5 OF 10)

OPERATION	MINUTES: 10 20 30 40 50 1HR. 10 20 30 40 50 2HR. 10 20 30 40 50 3HR.
FUSELAGE DUCT	
1. ELECTRONIC EQUIPMENT ACCESS DOORS REMOVE AND REPLACE	AIRFRAME MAN #1
2. HYDRAULIC ACCUMULATORS COMPENSATORS BLEED/PRESSURIZE/TOP UP FLUID/ CLEAN / VISUAL POSITION AND REMOVE HYDRAULIC BLEED & CHARGE RIG NITROGEN TROLLEY	AIRFRAME MAN #1
3. OIL/FUEL HEAT EXCHANGERS SPEED BRAKE SELECTOR VALVE LANDING GEAR SELECTOR VALVE EMERGENCY EXTENSION BYPASS VALVE HIGH PRESSURE FILTER PRESSURE CONTROL VALVE SPEED BRAKE ACTUATORS THERMAL BY-PASS VALVE VISUAL CHECK ON ABOVE	AIRFRAME MAN #1
4. L.P. FUEL SHUT-OFF AND CROSS-FEED AND ISOLATION VALVE. CHECK IN CONJUNCTION WITH COCKPIT CONTROL	AIRFRAME MAN #1
ENGINE BAY	
1. ACCESS PANELS NOS. 1, 2, 3, & 4 REMOVE AND REPLACE	AIRFRAME MAN #2
2. AIR PRESSURE REGULATORS RELIEF VALVES AND PIPING — VISUAL	AIRFRAME MAN #2
3. ACCUMULATOR, HYDRAULIC PUMPS, PRESSURE SWITCH, HIGH PRESSURE FILTER } VISUAL	AIRFRAME MAN #2
4. ACCUMULATORS COMPENSATORS BLEED, PRESSURIZE TOP-UP FLUID VISUAL AND CLEAN	AIRFRAME MAN #2
5. AILERON AND ELEVATOR PARALLEL SERVO — VISUAL	AIRFRAME MAN #2

FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 6 OF 10)

MINUTES: 10 20 30 40 50 1 HR. 10 20 30 40 50 2 HR. 10 20 30 40 50 3 HR.

OPERATION		MINUTES
WING (ONE SIDE)		
1 MAIN LANDING GEAR LIQUID SPRING COMPENSATOR; TIRES; STRUCTURE; DOORS; WHEELS AND BRAKES PRESSURE CHECKS	CLEAN AND VISUAL	AIRFRAME MAN #1
2 MAIN JACKS DOOR JACKS UPLOCKS	VISUAL AND CLEAN.	AIRFRAME MAN #1
3 REFUELLING ACCESS DOOR REFUELLING ADAPTOR AND CAP GATE VALVE	VISUAL	AIRFRAME MAN #1
CONDENSATE DRAIN NO. 4	DRAIN	
TANK		
4 INTEGRAL FUEL TANKS-	-FUEL LEAKS	AIRFRAME MAN #1
CONDENSATE DRAIN #3, 5, 6, 7, 8 TANKS	DRAIN	
5 REFUELING CONTROL PANEL	VISUAL	AIRFRAME MAN #1
6 ELEVATOR AND AILERON CONTROL BOXES	LEAKS	
WING (OTHER SIDE)		
SAME AS ABOVE		AIRFRAME MAN #2
DORSAL AREA		
1 PLACE LEADING EDGE ACCESS LADDER		AIRFRAME #3
2 PLACE WALK MATS		AIRFRAME #3
3 AIR CONDITIONING EQUIP.	VISUAL	AIRFRAME #3
4 WATER BOILER	VISUAL	AIRFRAME #3
5 OXYGEN CONVERTOR STOWAGE	VISUAL	AIRFRAME #3
6 ACCESS FAIRINGS	VISUAL	AIRFRAME #3
7 REMOVE LADDER AND MATS		

FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 7 OF 10)

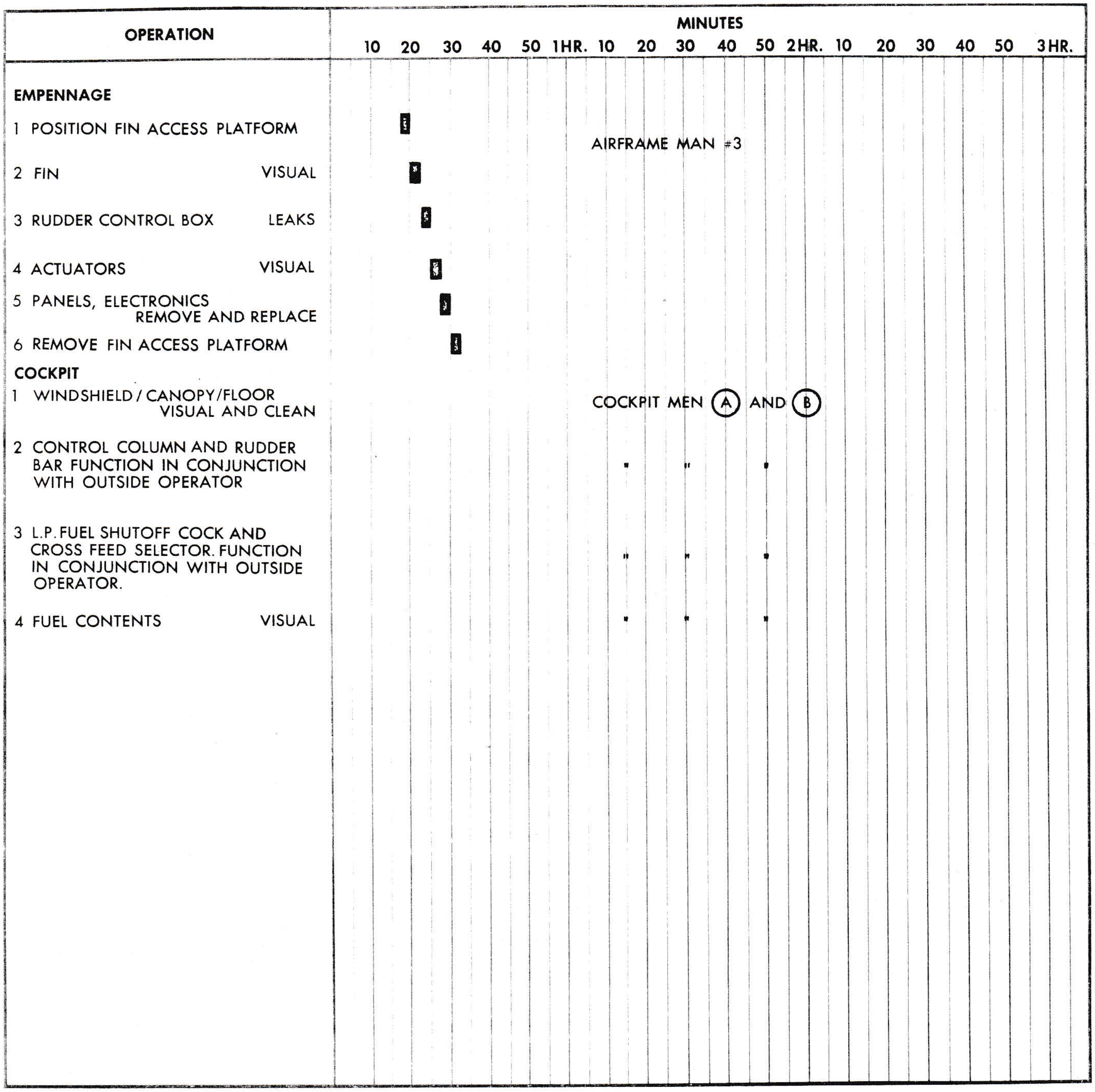


FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 8 OF 10)

OPERATION	
ELECTRICAL	
NOSE	
1 BATTERY	VISUAL
2 WIRING	VISUAL
3 RADAR NOSE AIR CONDITIONING VALVE	SWITCH AND LISTEN
4 RAM AIR VALVES	SWITCH AND LISTEN
5 LANDING GEAR LOCK MICROSWITCHES TRANSFORMERS CIRCUIT BREAKERS LANDING AND TAXI LIGHTS PANEL E3 AND E6 TERMINAL STRIP E8 AND E9 MASTER WARNING BOX ELECTRICAL CONNECTORS AND WIRING	VISUAL
ARMAMENT BAY	
1 ACCESSORY PANEL DISTRIBUTION PANEL TERMINAL STRIPS WIRING	VISUAL
DUCT BAY	
1 MAIN REFUEL AND TEST PANEL MAIN POWER PANEL GROUND FAULT RELAYS TRANSFORMER RECTIFIERS WIRING CONNECTORS	VISUAL
2 FUEL TRANSFER PUMPS	SWITCH AND FUNCTION
3 FIRE EXTINGUISHERS TEST SWITCH	FUNCTION
ENGINE BAY	
1 FIRE EXTINGUISHER BOTTLE SECURITY	AND PRESSURE CHECK
2 WIRING AND CONNECTORS	VISUAL

MINUTES: 10 20 30 40 50 1HR. 10 20 30 40 50 2HR. 10 20 30 40 50 3HR.

ELECTRICIAN #1

FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 9 OF 10)

OPERATION		MINUTES (10 20 30 40 50 1 HR. 10 20 30 40 50 2 HR. 10 20 30 40 50 3 HR.)
ENGINES		
1. ELECTRICAL CONNECTORS AND WIRING IGNITERS ETC.		ELECTRICIAN #1
WINGS AND FIN		
1. NAVIGATION LIGHTS	VISUAL	
2. LANDING GEAR MICROSWITCH	VISUAL	
3. ELECTRICAL CONNECTORS AND WIRING	VISUAL	ELECTRICIAN #1
4. REFUELLING PANEL LIGHTS AND SWITCHES	FUNCTION	
COCKPIT		
1. FIRE DETECTION	TEST	COCKPIT MAN (A) AND (B)
2. COCKPIT LIGHTS	TEST	COCKPIT MAN (A) AND (B)
3. BAILOUT WARNING LIGHTS		COCKPIT MAN (A) AND (B)
4. NAVIGATION AND LANDING AND TAXI LIGHTS	TEST	COCKPIT MAN (A) AND (B)
5. CANOPY ACTUATORS INTERNAL AND EXTERNAL	TEST	COCKPIT MAN (A) AND (B)
6. DRAG CHUTE SOLENOID	TEST	
FINAL		
1. SIGN L14 OR EQUIVALENT MAINTENANCE CARDS		
2. TURNAROUND COMPLETED		

FIG. 17 TIME STUDY - PRIMARY INSPECTIONS (CHART 10 OF 10)

UNCLASSIFIED SECRET

on the ASTRA maintenance, recommends that this equipment should have a primary inspection every 48 hours. Consequently, it is desirable that the ARROW match this as soon as possible.

While the aircraft is on primary inspection, it appears desirable that a senior technician (basically an airframe technician), should occupy the front cockpit to perform complete cockpit checks, plus an electronic specialist in the rear cockpit.

The number of men necessary to perform the primary inspection has been calculated from the tasks to be performed (as listed in Figure 17). The team is as follows:

Electronic mechanics	5
Electricians	1
Airframe mechanics	3
Engine mechanics	1
Instrument mechanics	1
Safety equipment worker	1
Electronic technician (rear cockpit)	1
Controller, senior technician	1
Total	14

+ 10 servicing crew = 24 men

Refuelling and reloading have not been included in the figures above. These functions are considered as part of the turnaround, and it will be advisable to complete them before commencing the primary inspection. Rearming and the replacement of the liquid oxygen converter would of course be performed after the primary inspection was completed.

Astra System Techs must be added for Cold Lake operations

7.0 HANGARS

7.1 OPERATIONAL REQUIREMENTS

Specification AIR 7-4 Issue 4 states that the building facilities for one squadron will consist of the following:

(a) Hangar(s) to accommodate two aircraft at standby

(b) Hangar(s) to accommodate five aircraft undergoing turnaround or first line maintenance.

(c) Hangar(s) to accommodate seven aircraft undergoing 2nd or 3rd line maintenance.

This was based on a squadron strength of 12 operational and 2 trainer aircraft.

However, the specification will be amended to show a squadron strength of 12 aircraft disposed as follows:

(a) Two aircraft in the standby hangar(s)

(b) Four aircraft in the turnaround and 1st line maintenance hangar(s)

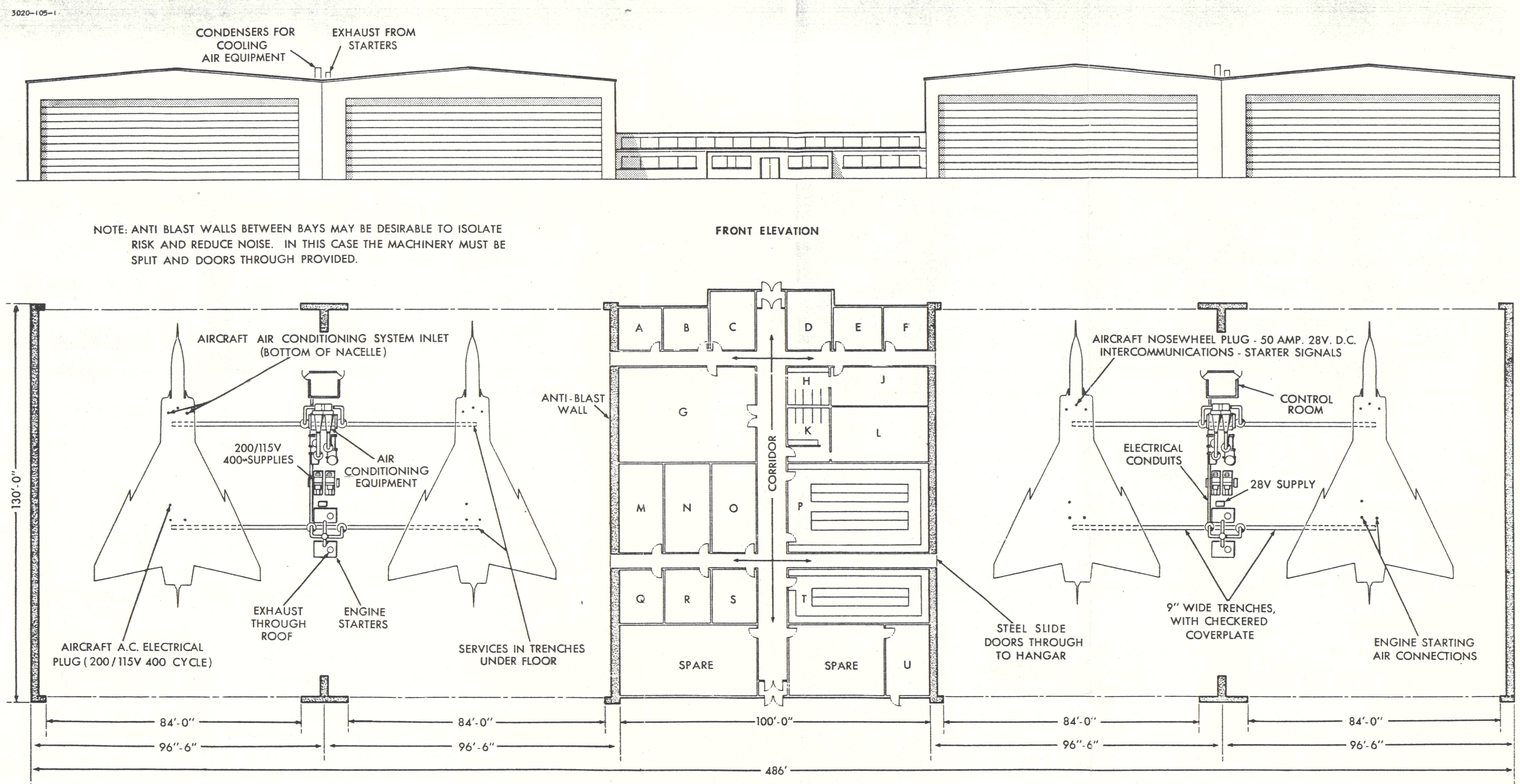
(c) Six aircraft in the 2nd line maintenance hangar(s)

This aircraft distribution assumes a 50% aircraft availability for 1st line activity. However, this figure can be expected to improve and 75% should be considered as a reasonable wartime objective.

7.2 PROPOSED HANGAR SIZES

7.2.1 COMBINED TURNAROUND AND 1st LINE MAINTENANCE HANGAR

To meet the 100% covered space requirements for aircraft undergoing 1st line maintenance and to satisfy the turnaround specification, this hangar



KEY

A	SPARE	H	WASHROOM	P	STORES
B	L 14	J	WOMEN'S LOCKERS	Q	ARMAMENT SHOP
C	LINE CREW	K	WASHROOM	R	TELECOMMUNICATIONS
D	MAINTENANCE CONTROL	L	MEN'S LOCKERS	S	INSTRUMENTS
E	MAINTENANCE CONTROL	M	ELECTRIC SHOP	T	TOOL CRIB
F	RECORDS	N	ELECTRONICS	U	INFLAMABLE STORES
G	SMOKE ROOM	O	BATTERY SHOP		

FIG. 18 POSSIBLE LAYOUT FOR COMBINED TURNAROUND AND 1ST LINE MAINTENANCE FOR ONE SQUADRON

will have to incorporate separate bays, large enough for engine changing for which 30 feet is required behind the aircraft. Space will be required for servicing equipment, personnel, spares, sub-stores and offices.

The hangar and its associated services are illustrated in Figure 18. It should be noted that the blast wall in this illustration separates each pair of bays from the shop area only.

7.3 HANGAR LOCATION

Two points dictate the optimum sites for 1st line hangars. These are:

(a) Department of Transport regulations.

(b) The noise nuisance factor.

Condition (a)

The Department of Transport regulations require that hangars should not be sited within 1000 feet of the centre line of runways. It will be seen from Figure 19 that this requirement is met in the proposed layout of an ideal air base for the ARROW weapon system.

Condition (b)

The noise nuisance factor associated with a single ARROW 2 at take-off is presented in Tables 1, 2 and 3. These figures have been derived from empirical rules but are, however, believed to be sufficiently accurate for this appraisal, pending the publication of field trials results. These trials were recently conducted on an Iroquois engine at RCAF station North Bay. It will be seen from Table 2 that at 1500 feet from the centre line of the runway, a noise level of 123 decibels may be expected in still air. Attenuation due to distance would be further varied by weather conditions and the

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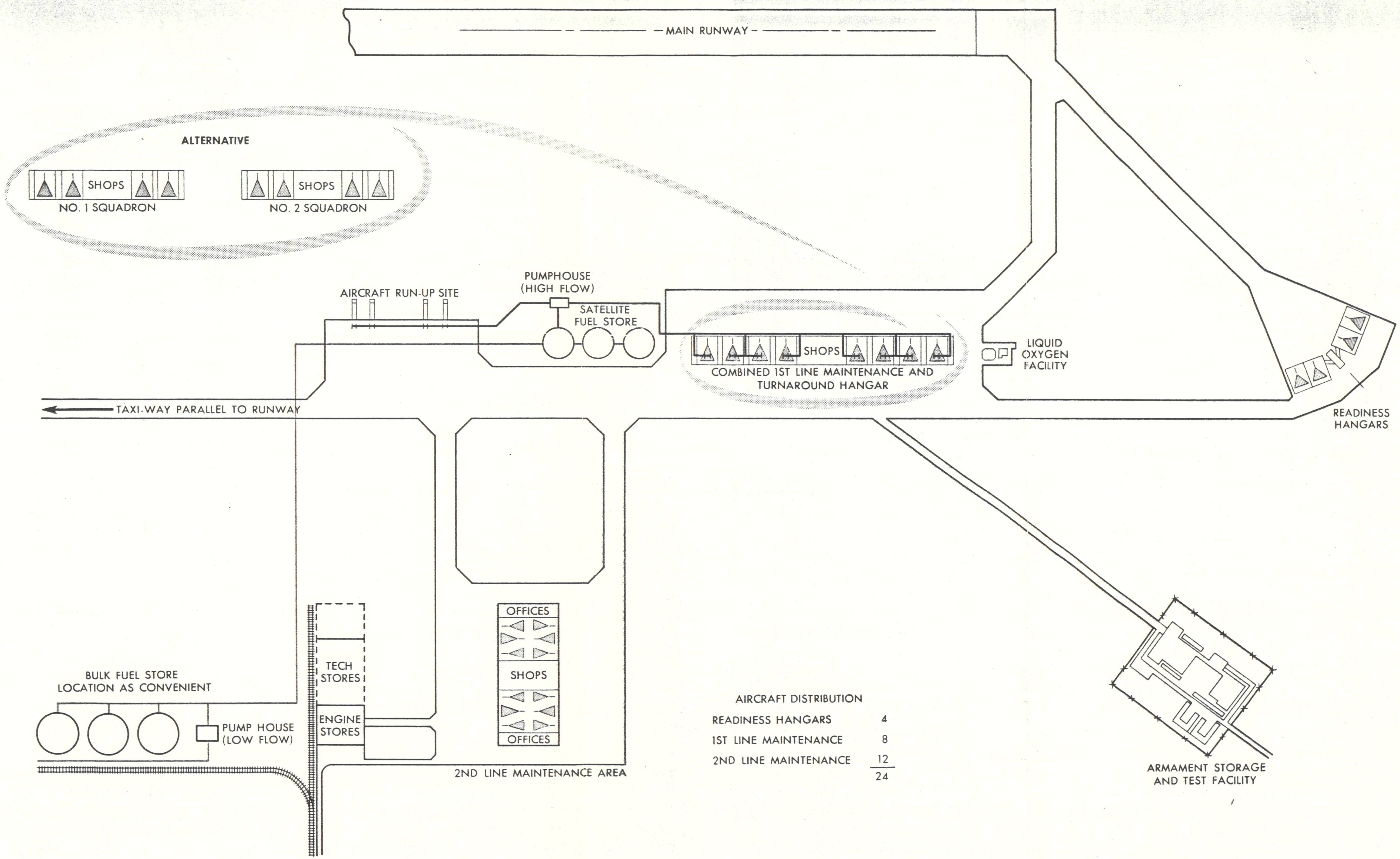


AIRCRAFT DISTRIBUTION	
READINESS HANGARS	4
1ST LINE MAINTENANCE	8
2ND LINE MAINTENANCE	12
	24

FIG. 19 PROPOSED AIR BASE LAYOUT FOR 2 SQUADRONS (TURNAROUND AND 1ST LINE MAINTENANCE COMBINED)

insulating effect of buildings. For example if this level reduces to 118 decibels, a noise level is achieved comparable to that which may be expected within the turnaround hangar from aircraft taxiing in and out.

Table 1

SOUND PRESSURE LEVELS AT TAKE-OFF

ENGINES	CONDITION	STATIC THRUST PER ENGINE	NOISE LEVEL AT 150 FEET
2-Orenda Iroquois	Afterburner OFF	18,400 lb	141 decibel
2-Orenda Iroquois	Afterburner ON	25,000 lb	148 decibel

Table 2

ATTENUATION DUE TO DISTANCE

DISTANCE (FEET)	DECIBEL DROP	NOISE LEVEL AFTERBURNER OFF	NOISE LEVEL AFTERBURNER ON
150	NIL	141	148
225	2	139	146
300	6	135	142
500	12	129	136
1000	20	121	128
1500	25	116	123
2000	30	111	118
2500	33	108	115
3000	36	105	112
4000	42	99	106
5000	48	93	100
6000	53	88	95
7000	60	81	88

Table 3

INTERPRETATION OF NOISE LEVELS

DECIBELS	LEVELS
70	Average street
80	Noisy office
90	Noisy factory
100	Boiler factory
110	Annoyance level
120	Discomfort level
140	Pain threshold
150	Mechanical damage threshold to human tissue

The maximum noise level occurs at approximately 135° and 225° from the aircraft heading. Consequently, a distance of 1500 feet along either of these lines will give a distance of $1500 \div \sqrt{2}$, say 1000 feet from the line of travel of the aircraft.

The performance of 1st line maintenance in the turnaround hangar will necessitate the hangar being sited farther from the main runway, than if it was reserved for turnarounds only. In order to obtain attenuation of take-off noise to 115 db, it will be necessary to site the hangar at least 2,000 ft from the main runway.

The 2nd line maintenance area will be at least 2,000 ft from the turnaround area, and 4000 ft from the main runway in order to reduce the noises from these sources to approximately 103 db. This noise level is estimated to occur approximately nine times per day, i.e., the peacetime number of daily sorties, per squadron.

7.4 LIGHTING AND HEATING

7.4.1 LIGHTING

(a) No new major lighting requirements are necessary in the existing RCAF hangars for 1st line maintenance, but all lighting in the turnaround hangar should be explosion proof in view of the large quantity of fuel to be handled at turnarounds.

The hydrant pressure-refuelling proposed for use in the turnaround hangar comprises a completely closed circuit with the aircraft fuel tanks being vented to atmosphere by extractor fans through flexible piping. However, it is recommended that all lighting be explosion proof to reduce the fire risk - if a fuel leak did occur during refuelling it would be at very high flow rate.

(b) Explosion proof, portable underwing lighting is desirable for 1st line maintenance in view of the high wing construction of the ARROW and the fact that most of the work will be carried out from under the aircraft.

(c) Taxiing into the turnaround hangar at night would be facilitated if the internal hangar lights were arranged to form a centre line, i.e. a guide line for the pilot.

7.4.2 HEATING

The temperature in the combined turnaround and 1st line maintenance hangar should be at least 50°F. This will provide a comfortable working temperature and prevent freezing of the water supply lines for replenishing the aircraft's water boiler.

7.5 EQUIPMENT INSTALLATION

The equipment, comprising engine starters, air conditioning plant and a-c generators should be readily removable for overhaul. The cooling air, starting air and fuel venting pipes should be ducted under the hangar floor to locations under the aircraft. Flexible hoses would be run from these outlets. Refuel hoses and power leads would be reeled out from the hangar wall.

The position of the aircraft in the hangar will be constant and the relative positions of the ground service connections on the aircraft are shown in Figure 13.

The connections at the aircraft, reading from the front of the aircraft to rear, are summarized in the following table:

GROUND SERVICE CONNECTION	DETAILS OF CONNECTION
1 Nose leg receptacle Wiring Quantity - 1 per A/C	Lanyard operated quick disconnect plug to AVRO STANDARD 2 CS-C-142 Plug manufactured by E. B. Wiggins #9500 A 5V.
2 Air conditioning supply Hose Quantity - 2 per A/C	Automatic quick disconnect couplings to AVRO Dwg. 7-2252-198 3-1/2 inch dia. insulated flexible hose

GROUND SERVICE CONNECTION	DETAILS OF CONNECTION
3 A-C supply Wiring Quantity - 1 per A/C	ARROW 1 AM 3430 - complete with cable in standard lengths ARROW 2 AVRO Standard CS-P-123 complete with cable (This item not yet qualified) AVRO Dwg. 7-4427-79 and AVRO Spec. E-531
4 Static discharge A/C to hangar floor Quantity - 1 per A/C	Quick disconnect, static coupling complete with cable. Appleton Electric Co. Type #9386
5 Engine starting, compressed air connections (2) Hoses (2) Line diagram - Starting air supply to two bays	Lanyard-operated, quick-disconnect coupling, Wiggins # GSC-141-3A 3-1/2" insulated, flexible hoses
6 Refuel nozzle (hose) Refuel adaptor (aircraft) Quantity - 2 per A/C	MIL-N-5878 A (to mate with A/C adaptor MIL-A-5878 B)
7 Fuel tank vent outlets Quantity - 2 per A/C	Figure 9. NOTE: The hangar fuel tank vent outlet must be protected by a safety gauze to eliminate possibility of ignition flash back to the venting system

Controls for engine starting, intercom. and telescramble should be routed to a control room. The control room should be well insulated against aircraft and equipment noise. It is suggested that this room be constructed of metalclad, soundproof material similar to the soundproof rooms manufactured by Industrial Acoustics Co. Inc., New York or Koppers Co. Inc., Baltimore. These vendors offer what appears to be suitable soundproof rooms with attenuation of better than 40 decibels, particularly in the frequency ranges which would effect voice communication. "Noise lock" windows and doors are also available plus "quiet duct" ventilators for use when the doors are closed. As noise levels of up to 120 decibels may be expected in the turn-around hangar during taxiing away a reduction in noise levels down to 80-85 is essential if communication is to be maintained.

The catwalk from the crew room to the cockpit should be suspended from the roof to permit a clear taxi-way for the aircraft after completion of the turn-around. The end of the catwalk must be retractable to ensure adequate tail clearance, and it is suggested that at least ten feet of the catwalk should be either capable of withdrawal or hoisting back to the vertical position.

7.6 POWER REQUIREMENTS

7.6.1 TURNAROUNDS ONLY

During turnarounds the ASTRA I system will be maintained at standby. Consequently a 550 volt 60 cycle 3 phase power supply will be required to each aircraft as follows:

(a)	400 cps generator (output 40 KVA)	- 50 KVA
(b)	Cooling air machinery (esimated)	- 134 KVA
(c)	28 volt d-c 50 amp (rectified)	- 1.5 KVA
(d)	Hydrant refuel pumps 2 per aircraft (estimated 30 KVA per pump delivering 500 gpm at 70 psi.)	- 60 KVA
	Total	245.5 KVA

For a four bay-turnaround hangar in which four aircraft are being turned around simultaneously, a total of 982 KVA will be required. The other hangar services such as lighting and heating which have not been included should be added to this total.

7.6.2 1st LINE MAINTENANCE

For 1st line maintenance, 550 volt 60 cycle 3 phase electrical power outlets will be required at each aircraft position to operate ground servicing rigs, in addition to the a-c power and cooling air. These are as follows:-

(a)	400 cps generators (output 40 KVA)	- 50 KVA
(b)	Cooling air machinery	- 134 KVA
(c)	28 volt d-c 50 amp (rectifier)	- 1.5 KVA
(d)	4000 psi hydraulic rig	- 105 KVA
(e)	Radar hydraulic rig	- 5 KVA
(f)	Nitrogen compressor	- 14 KVA
	Total	309.5 KVA

In addition, 110 volt 60 cycle outlets will be required for electronic test equipment at 10 KVA.

In a 4-bay turnaround hangar, in which maintenance is to be performed, each bay should be equipped with outlets for the above equipment, but is is unlikely that each bay would consume maximum power simultaneously.

Assuming that two aircraft are on turnarounds and two on first line maintenance, the total load for four bays would be as follows:-

2 turnarounds at 245 KVA each	=	490 KVA
2 1st line maintenance at 309 KVA each		618 KVA
Total		1108 KVA

The other hangar services such as lighting, heating and power tools which have not been included should be added to this total.

An emergency supply should be provided as insurance against main hydro-electric failure.

7.7 HYDRANT REFUELLING

7.7.1 THE CASE FOR HYDRANT REFUELLING

Hydrant refuelling is proposed for use in turnaround hangars at air bases which are to be equipped with ARROW 2 squadrons. This is the most economical and efficient method of dealing with the large quantities of fuel involved in the daily operation of interceptor squadrons, using high performance gas turbine aircraft. The main advantage of the hydrant system is its ability to handle the large quantity of fuel involved at all times, and at delivery rates in excess of that proposed for the squadron tenders. The daily quantity of fuel required by two squadrons operating at 25 combat missions per day at the present combat fuel load, is 25 x 2026 Imperical gallons, i.e. 50,650 gallons. (It should be noted also that the combat fuel load is likely to be increased on subsequent marks of ARROW).

7.7.1.1 Tender Requirements

The proposed tender will have a capacity of 3,200 gallons and a delivery rate of 250 gallons per minute through each of two hoses. Each tender can serve one aircraft through two refuelling points. Thus four tenders will be required per squadron to actively support the turnaround hangar to meet the specification that four aircraft be turned around in fifteen minutes. Consequently on a two squadron airbase eight tenders will be required. Since one tender can fill only one aircraft to the combat load of 2,026 gallons, it follows that a redeployment of tenders must be made to meet a succeeding wave of four aircraft. In this case, two tenders will be required per aircraft as the tenders now only hold 3200 - 2026 = 1174 gallons. The eight tenders would then need replenishing from bulk stock. Replenishment of these eight tenders would be required twice a day, on the basis of total fuel required per day, divided by total tender capacity as follows:

$$\frac{\text{25 sorties (2 squadrons) x 2026 gallons per sortie}}{\text{8 tenders x 3200 gallons each}}$$

$= \frac{50,650}{25,600}$ i.e. 2 refills are required.

During these two refuelling periods there would be no refuelling facility available at the turnaround hangar, unless four more tenders were stading by, already filled, while the eight empty tenders were being refilled.

The total number of tenders required will therefore, be 12 plus one in immediate reserve. This figure does not allow for rotation through the garage for periodic maintenance. At this minimum figure of 13 tenders, the total capital outlay is estimated to be $312,000. The cost of garage and maintenance facilities, spares, overheads and labour must be added to this figure.

7.7.1.2 Hydrant Requirements

The hydrant system only requires the following:

(a) Satellite storage tanks located near the turnaround hangar.

(b) 16 pumps at 500 gpm each (i. e. two for each of eight turnaround bays). These pumps plus two reserve pumps, would be located in a pump house near the satellite tanks.

(c) Piping from the satellite tanks to the aircraft.

(d) Pumps and piping from the bulk store to the satellite tanks.

(e) Dispensers with filters, water separators, air separators and flow meters.

The pumps proposed for the hydrant system would be capable of delivering 500 gallons per minute per hose, making a total of 1000 gallons per minute to each aircraft. The aircraft has been designed to receive fuel at 1000 gallons per minute through two refuel points at 50 psig at the nozzle with a desirable maximum surge pressure of 90 psig (but not exceeding 120 psig).

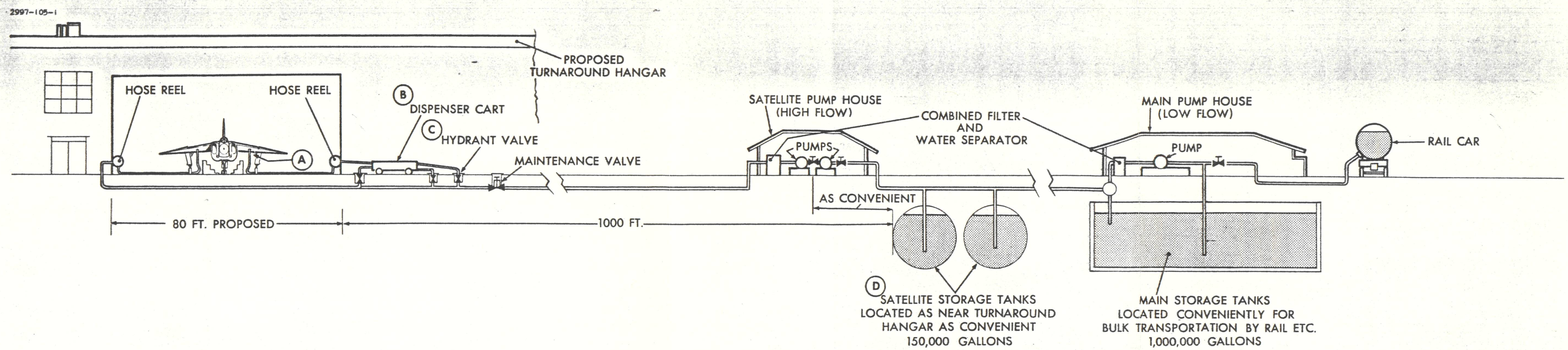
It is evident that the hydrant system will double the tender delivery rate. This is mainly due to the fact that a larger pumping station may be used than could be transported in a tender.

Other advantages of the hydrant system are:

(a) Elimination of the eight tenders, which are major items requiring large space for manoeuvring, with consequent hindrance to other operations.

(b) Subject to further investigation, the possible elimination of cooling requirements for the fuel. The fuel in the aircraft tanks should not exceed 70°F prior to take-off on a mission involving flight at Mach 2 or 110°F prior to take-off on missions involving flight at Mach 1.5.

Fuel in tenders standing in hot sun can attain 110°F and although this problem will require a solution for forward base activities it can be minimized by the use of hydrant supply from buried storage tanks and delivery lines, at main base.



EACH HOSE IS REQUIRED TO DELIVER 500 IMP. GALS/MIN. PRESSURE: NORMAL 50 P.S.I.G. MAX. SURGE 90 P.S.I.G	FILTER 5-10 MICRON PRESSURE GAUGE $^{+100}_{-20}$ p.s.i. METER. 0-600 I.G.P.M.	TOTAL FLOW 1000 I.G.P.M. PER BAY	

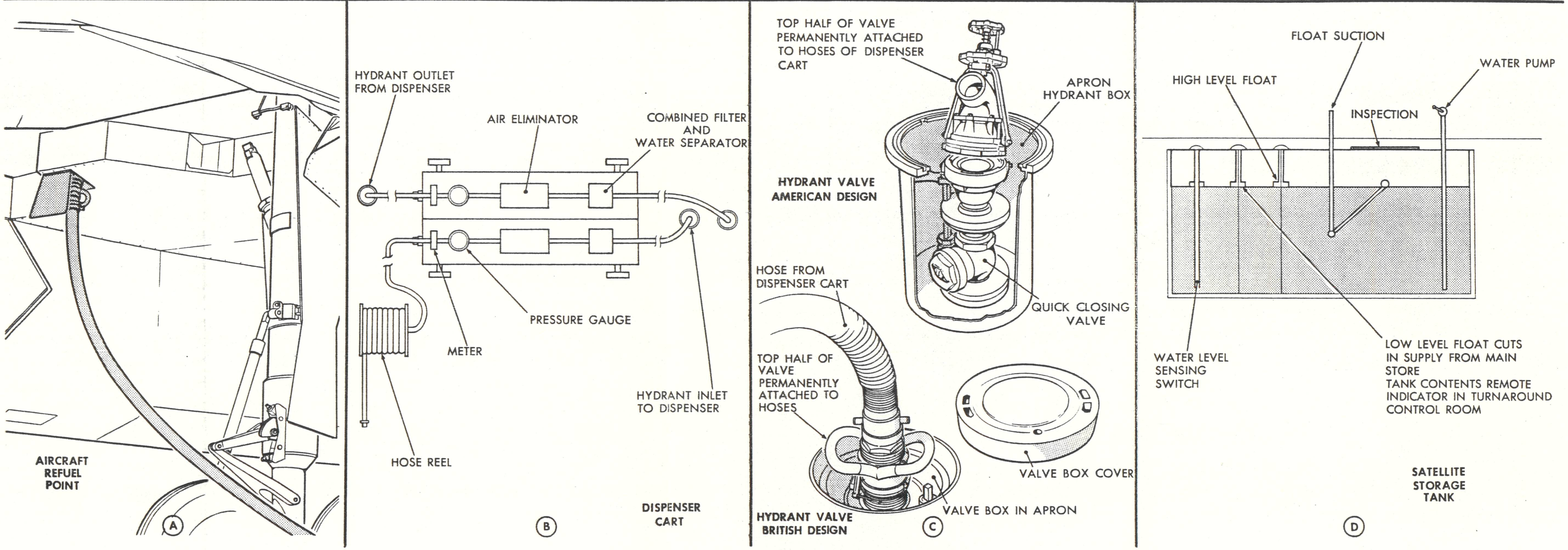


FIG. 20 LAYOUT OF ESSENTIALS OF HYDRANT REFUEL SYSTEM

7.7.2 ESSENTIALS OF PROPOSED HYDRANT REFUELLING SYSTEMS (FIGURE 20)

(a) Main Storage Tank Area

This area contains the main tanks which may be above or below ground. The location of the area will be dictated by the geographical characteristics of each air base and the local facilities for receipt of bulk supplies.

It is desirable that these tanks be below ground to ensure a supply of cool fuel. The size of the tanks will be dictated by operational considerations. This will be based on the number of sorties to be flown from the air base, the combat role fuel load and the duration of combat conditions which it is desired to maintain, without the need for bulk replenishment. As this information is not yet available, the following examples of fuel quantities involved, have been based on 25 training missions per day, per two squadrons.

Assuming a 20 day period of sustained hostilities without replenishment of the main base supply, the bulk store would require a capacity of 1,013,000 gallons. i.e. 20 days at 25 sorties per day using 2026 gallons per sortie.

(b) Satellite Tanks

The satellite tanks would be required as close to the turnaround hangar as possible in order to minimize the delivery line length. The satellite tanks will be replenished at a lower rate from the main storage tanks, by pumping units located at the main bulk store. The capacity of the satellite tanks will be determined by the daily consumption rate and the duration of time considered tolerable for isolation from the bulk supply.

Assuming a three day isolation from main tank area, the capacity of satellite tanks would be 3 days at 25 sorties per day using 2026 gallons each sortie = 151,950 gallons.

(c) Pump Houses

A pump house is required at each of the storage tank areas. The main bulk fuel store pump house will be capable of maintaining the satellite tanks full at all times. This will ensure that full capacity is available at the satellite tanks in the event of any failure or breakdown in the fuel supply system.

The satellite tank pump house will deliver fuel at 500 gpm through each of two lines to two hydrant valves for each aircraft, with 50 psig pressure at the aircraft nozzle. An emergency electric power supply will be available at each pump house.

The maximum number of aircraft to be refuelled simultaneously in the proposed turnaround hangar is eight. Thus, the total power requirements will be based on 16 pumps, each pumping 500 gpm at the same time, and this amounts to an estimated 16 x 30 = 480 hp. There should be two standby pumps with suitable change-over valves to permit them to supply any delivery line.

A typical pump, to meet the requirement, is the GORMAN-RUPP centrifugal pump. This pump consumes 30 hp at delivery head of 70 psig. The basic dimensions of this unit are estimated at 6 ft by 2 ft by 2 ft high, weighing about 400 lbs. Further investigation is proposed, to establish optimum pumps and equipment layout, before firm recommendations can be made.

(d) Pipe Lines

The major factors in the design of pipe lines are fluid pressure, fluid velocity, type of fluid, pipe line lengths and shut-off closing times. Pipe line lengths should be kept to a minimum, particularly in the case of the lines from the satellite tanks to the hydrant valve in order to reduce the friction losses to a minimum. All underground pipe lines should be treated to prevent corrosion. Above ground route markers should be laid to prevent inadvertent damage by excavators. Two pipe lines carrying 500 gpm each will be required from the satellite tanks to each aircraft position.

There will be a total of eight aircraft bays in the prepared turnaround hangar and 16 lines will be required from the satellite tank pump house, i.e. two lines to each aircraft.

Flexible link-up hoses will be 2 1/2 in. diameter of proven material, terminating in a nozzle at the aircraft coupling.

(e) Filtration

A ten micron filter will be required in each of the delivery lines to the aircraft. Specifications MIL-F-5007 and 8593 require gas turbines to operate on fuel strained to 200 mesh (74 microns). Standard practice for normal use, as recommended by the American Petroleum Institute (Bulletin 1501/55) is ten microns. Five to ten micron filtration equipment is available with combined water separation capabilities. A typical unit for flow rates at 500 gallons per minute is the Fram-Warner Lewis vertical separator/filter, four feet in diameter and seven feet high. The use of these units assumes separate lines at 500 gpm. In this case, two units will be required per aircraft.

It is desirable that these units be located as close to the aircraft as possible in order to eliminate the possiblity of foreign matter, such as pipe scale, being delivered to the aircraft tanks. The aircraft filters will retain small quantities of contaminants without prejudice to the fuel flow, but large deposits of scale could cause fuel starvation.

(f) Hydrant Valves

These hydrant valves are specially designed for quick coupling and uncoupling without loss of fuel and are set flush in the floor. Hydrant valves in current use are available to take a 2-1/2 inch hose. As these are the same size as the NATO aircraft coupling, it would be economical to standardize on this size. Two valves would be required for each aircraft; i.e. each refuelling bay in the turnaround hangar would have four hydrant valves. A shut-off valve is required in each line upstream of the hydrant valve, to shut-off the supply for maintenance on the valve.

(g) Hydrant Dispensers

These are normally mobile carts or self-propelled trucks carrying hose reels, air eliminators, metering units, filters and water separators.

The units are mobile to permit their removal from the flight apron to give incoming aircraft free access to the hydrant. In the proposed turnaround hangar the dispensing equipment would be located in a central section between each pair of bays. Mobility is required, however, so that the equipment can be moved for servicing and filter cartridge changing. The mobile rig should be vapour proof to localize fumes from leads. A ventilation outlet in the trolley would be connected to a blown air duct with an outlet at hangar roof level.

There is no known trolley suitable for the purpose discussed, but design would only consist of mounting standard equipment on a suitable trolley.

One trolley would be required to service one aircraft. Each trolley would carry two sets of the following:

Air eliminator.

Fuel meters.

Combined water separator and filter

Anti-surge valve

Inlet hose - short (hydrant to dispenser)

Outlet hose - short (dispenser to hangar floor pipe)

Stowage for pipes

(h) Method of Control

The main feed pumps at the satellite tanks may be started automatically by pressure drop at commencement of refuelling, or by push button control. The latter method is preferred as the hazards of maintaining the system constantly under pressure are eliminated. Push button control may be effected by either the operator who couples the hose to the aircraft or by the man who reads the refuel meters and operates the flow control valve on the dispenser unit. As the latter does not require remote electrical control, it is to be preferred.

7.7.3 CONCLUSION

The case for hydrant refuelling has been reviewed and shown to be desirable from the operational point of view, in that double the tender flow rates may be used with consequent improvement in turnaround time. Ultimate operating costs are considerably less than using the equivalent mobile tenders. It is also believed that the initial capital cost may be acceptable when offset against the reduced number of tenders required. However, the initial capital cost has not been investigated. This is deferred pending RCAF acceptance of the hydrant refuelling concept.

8.0 FACILITIES REQUIRED FOR STORING AND HANDLING LIQUID OXYGEN

8.1 SERVICING TECHNIQUE

For crew breathing, liquid oxygen is carried in the aircraft in a 5 litre (1.32 U.S. gallon) converter. An inherent feature of liquid oxygen converters is that a delay of about 10 minutes is required between filling and production of gaseous oxygen. This time plus the five to ten minutes required for refilling means that the turnaround time becomes excessive. Consequently, the converter has been designed to be readily removable and replaceable with a fully charged unit. Thus, a supply of fully charged converters will be necessary. These must be stored outside the hangar area in a location free from oil and grease. The storage facility would also be required to handle the converter servicing and periodic checks. AVRO's proposals for this facility are illustrated in Figure 21 and described as follows:

8.2 DESCRIPTION OF PROPOSED FACILITY

The facility consists essentially of three areas:

1. Carport area for bulk storage tanks.
2. Workshop and converter storage room
3. Garage and loading area.

8.2.1 CARPORT AREA FOR BULK STORAGE TANKS

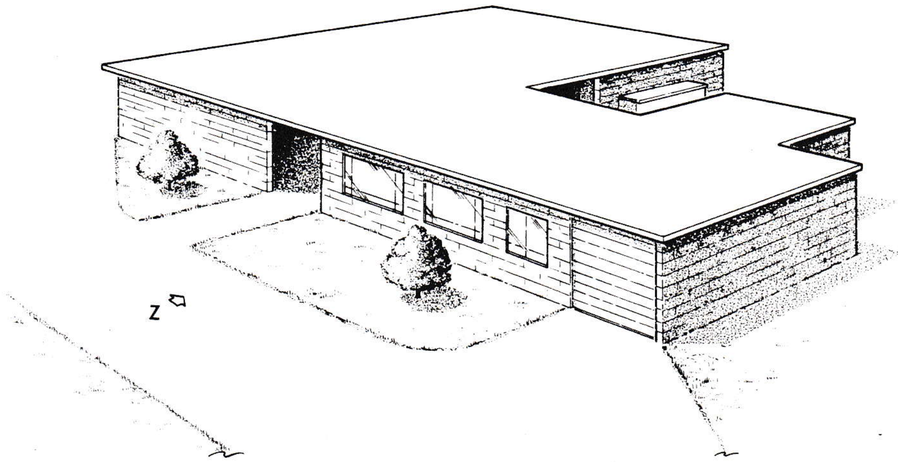
This area will house the bulk storage tanks and mobile trailers. The requirements for one squadron are calculated to be one 500 gallon tank and one 50 gallon tank. The tanks are stored in the open but are protected by a roof and side walls. Storage in the open is more economical since building cost is reduced and there is no requirements for special ventilation

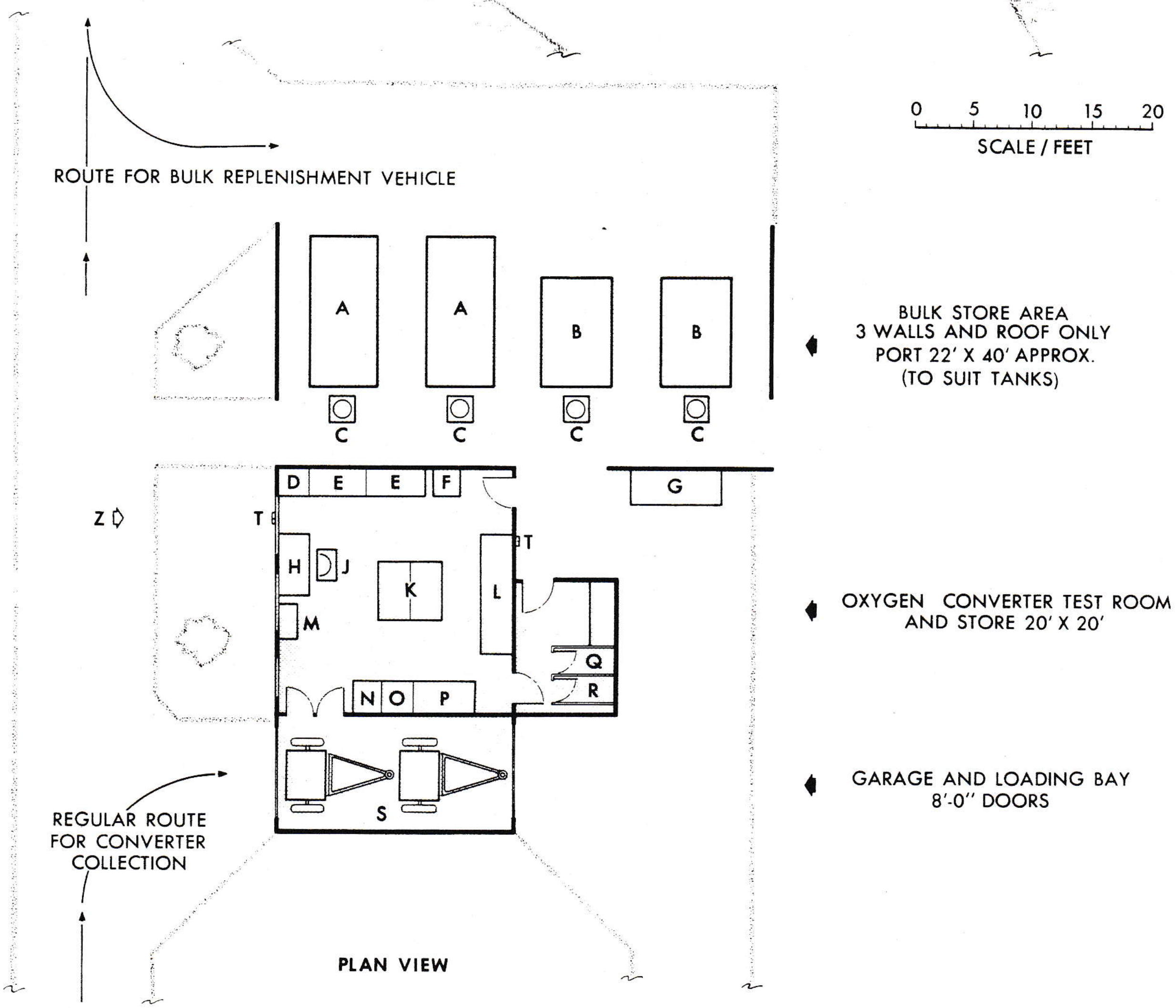
3082-105-1

KEY

A 500 GALLON TANK 12½ X 5½ X 6 FT.
B 50 GALLON TANK 9 X 6 X 5 FT.
C BENCH & TRAY FOR CONVERTER FILLING
D ELECTRICAL AND INSTRUMENTS BENCH
E BENCH
F FIRST AID
G FIRE EXTINGUISHERS
H DESK
J CHAIR
K WORK BENCH
L STORAGE RACKS FOR CONVERTERS
M CABINET
N SPECIAL CLEANING EQUIP.
O TOOLS
P SPECIAL CLOTHING LOCKER
Q SHOWER
R TOILET
S TRANSPORTATION FOR CONVERTERS
T FAN EXTRACTOR

PERSPECTIVE VIEW





PLAN VIEW

FIG. 21 LIQUID OXYGEN FACILITY (PROPOSED LAYOUT FOR AIR BASE WITH TWO ARROW SQUADRONS)

equipment to prevent concentration of oxygen gas. Details of the tanks are as follows:

(a) <u>50 gallon trailer (USAF Type MA-1)</u>

This consists of a vacuum insulated container mounted on a four wheel trailer. The unit is normally used for charging converters in aircraft on the flight line, but in this case it is proposed for static use pending airlift for forward base activities.

The leading particulars of the trailer are:

Weight-full		1550 lb
Weight-empty		1000 lb
Length		106 in.
Height		51 in.
Width		67 1/2 in.
Evaporation loss rate	-	2.5 gallons (5%) per 24 hours.

The loss rate over a seven days period would be 17.5 gallons, leaving 32.5 gallons for servicing aircraft converters. This quantity would fill 24 converters if there was no wastage during filling. However, a wastage factor must be allowed because during the initial stages of converter filling there will be a discharge of gas until the delivery hose is cooled down to liquid oxygen temperature (- 297°F). This figure will depend on the length of hose and frequency of filling. A realistic figure cannot be quoted until some operating experience is obtained. However, a 50 gallon trailer will be adequate for the forward base activity specified in AIR 7-4 i.e. six aircraft at forward base for refill on landing, and six refills after a combat sortie to enable the aircraft to return to main base.

(b) 150 gallon storage tank (USAF Type B-1)

This tank is similar in construction to the 50 gallon trailer and may be mounted on a trolley or skid. It is air transportable and may be used instead of the 50 gallon trailer to support forward base activities if extended operations are likely.

The leading particulars of this tank are as follows:

Weight-full	2330 lb
Weight-empty	890 lb
Length	100 1/2 in
Width	50 in
Height	54 1/2 in
Evaporation	3.3 gallons in 24 hours (2.2%)

The loss rate over seven days will therefore be 23 gallons, leaving 127 gallons for servicing aircraft converters. This quantity would fill 97 converters if there was no wastage during filling.

(c) 500 gallon storage tank (USAF Type C. 1)

This tank is normally reserved for bulk storage at main base. It is normally used to replenish the 50 gallon trailer which in turn charges the converters. However, the tank could be modified to enable it to fill converters direct. This is desirable in the proposed facility.

The leading particulars are:

Weight-full	7315 lb
Weight-empty	2340 lb
Length	146 1/2 in
Width	65 1/2 in
Height	70 1/2 in
Evaporation	5 gallons in 24 hours (1%)

The loss rate in seven days would amount to 35 gallons, i.e. 140 gallons in a four week period. This would leave 360 gallons for filling converters, if there was no wastage.

The peacetime requirement per squadron will be based on nine sorties per day. Assuming 20 effective days per month, and a full converter required at each sortie, 180 converter fills will be required per month. This will amount to 252 gallons which can be met from the 360 gallons left in main tank, with 30% left over for wastage. The actual amount likely to be wasted is not known, but if operating experience shows this to be higher, the total quantity stored may be increased.

From the foregoing, a suitable bulk storage for one squadron would consist of one 500 gallon tank plus one 50 gallon trailer. Double this quantity would be required for two squadrons. The proposed method of storage would be in the carport area already described, with converters being filled in the open. The converters would be placed on mounting trays secured to a stand positioned near to the bulk tank. This will reduce the wastage as short delivery pipes could be used and advantage taken of natural ventilation to avoid concentration of oxygen gas. This is possible in an enclosed building as the technique of filling converters necessitates an initial discharge of gas to cool the pipes and convertors, and finally a discharge of liquid to ensure that the converter is full.

A vacuum pump will be required for periodic maintenance of the vacuum insulation of the foregoing tanks. A rotary vacuum pump, type USAF/MA-1/ number 8200-957320 or similar, will be necessary. A power supply will be required to operate the pumps.

8.2.2 WORKSHOP AND CONVERTER STORAGE ROOM

A space of 20 ft by 20 ft appears necessary to accommodate the following:

(a) Storage shelves for converters, at a convenient height. Space for 30 converters should be allowed for two squadrons:

Number of aircraft in 1st line requiring space converters.	12
Number of aircraft in second line with converters removed for storage and servicing	12
Spare	6
Total	30

The space required would amount to approximately 15 ft by 3 ft by 7 ft. The dimensions of the converter are shown on AVRO drawing 7-2154-14.

(b) Workbench for checking converter quantity capacitance probe. A liquid oxygen quantity gauging system will be required for this purpose. The wiring diagram is illustrated in AVRO report No. 72/SYSTEMS 21/30. A mains power supply will be required to operate a rotary converter for supply of 115V 400 cycle A-C power at 2 amps.

(c) Work bench and scales for weighing and checking evaporation loss.

(d) Locker to store special clothing for personnel employed in filling converters.

(e) Locker for special tools and cleaning materials.

(f) Desk and records.

(g) First aid equipment. The requirement for special clothing and first aid suitable for handling liquid oxygen has not been investigated as it is felt this should be the subject of specialist advice.

8.2.3 TRANSPORT TRAILER GARAGE

This area is proposed for parking the trailers when they are not in use, and for providing a covered space for loading. The transportation trailers are designed to RCAF drawing 55165. The trailer will be in constant use and the approach and exit route shown on the proposed layout will confine oil spillage from the tractors to an area remote from the bulk store.

8.3 SAFETY PRECAUTIONS

(a) The installation of bulk liquid oxygen should be made in consultation with specialists of the supply agency. Outside storage is to be preferred for reasons stated previously, and for quick access for removal of tanks in the event of a fire in the area.

(b) Special safety precautions for personnel are contained in RCAF EO 20-115-9A and in AVRO report 71/MAINT 21/2 (ARROW 1 - Oxygen, Ground Servicing Equipment).

(c) The workshop and converter storage room should be adequately vented.

(d) A basement is undesirable as oxygen gas is heavier than air.

(e) A plensiful water supply should be available in case of spillage of liquid oxygen.

(f) A staff of two is desirable in this facility at all times in case of accidents.

(g) Heating should be piped from an adjacent area if possible in order to avoid having a heating unit near the oxygen facility.

9.0 REFERENCE DOCUMENTS

1.	AIR 7-4 Issue 3 and 4.	RCAF Specification for Supersonic All-Weather Interceptor Aircraft CF-105.
2.	RCAF Report S 1038 CH-180 (AMTS/D.M.Eng) 30 April 1956.	Concept of Base Operation for CF-105.
3.	RCAF Report S 1038 CH-100 December 1955.	CF-105 Aircraft - Maintenance Concept.
4.	RCAF Report (Appendix A to Minutes to 32nd Meeting of the ARROW Co-ordinating Committee).	CF-105 Aircraft - Basic Data for Maintenance Planning.
5.	AAMS 105/2 Issue 2 EMS-8	Model Specification for ARROW Mk.2 Supersonic Interceptor Fighter. Model Specification for Iroquois.
6.	AVRO Report P/Systems 8R	Load Analysis and Power System for ARROW 2 Aircraft.
7.	AVRO Report LOG/105/24	Evaluation Study of Proposed Mobile Ground Power Equipment.
8.	AVRO Report LOG/105/4	Automatic Disconnect Couplings
9.	AVRO Report LOG/105/43	Power Plant Ground Support Equipment.
10.	AVRO Report LOG/105/1	Preliminary Analysis of Operational Ground Facilities.
11.	Motor Generator Corporation Report MISC. No. 1	Problems in Power Distribution 120/208V. 3 Phase; 4 wire, 400 cycle.
12.	AVRO Report LOG/105/9	ARROW 2 Readiness Facility.
13.	AVRO Report LOG/105/36	CF-105 - Preliminary Study of Proposed Armament Storage and Test Facility.
14.	AVRO Report LOG/105/5/4	Estimate of Electrical Power to be Supplied by Ground Power Units.
15.	AVRO Report LOG/105/16	Evaluation of the Method and Time Required to Carry Out an Engine Change on the CF-105.

16. AVRO Report LOG/105/18	Refuelling and De-fuelling.
17. Society of Automotive Engineers Report #61. March 1957.	Hydrant Refuelling
18. RCA Report	Preliminary Maintenance Study ASTRA I.
19. RCAF Report S1006D - 100 (AMTS/D.I.E. ENG)	Liquid Oxygen Ground Support Equipment Required by RCAF.
20. Air Research Manufacturing Co. G.T. 5189-R 6 Jan./56	Proposal for Gas Turbine Compressors for Trailer Mounted.
21. AVRO Report LOG/105/49	Defuelling and Air Pressurization Requirements.
22. AVRO Report No. 71/ Systems/16/53	ARROW Defuel Requirements.
23. AVRO Report No. 72/ Systems 18/29	ARROW 2 Low Pressure Pneumatic Systems
24. AVRO Report No. 72/ Systems 22/48	Air Conditioning System.
25. AVRO Report No. 72/ Systems 20/51	Ice Protection System.
26. AVRO Report No. 72/ Systems 13/17	ARROW 2 ASTRA I Systems
27. AVRO Report No. 70/ Maint 13/1	Damper System.
28. Motor Generator Corporation Report.	Electrical Servicing of Commercial Jet Aircraft.
29. Motor Generator Corporation Report.	Aircraft Ground Power Equipment (Motor Generator Corp.)
30. AVRO Report C1-5-R-0022	A Proposal for Cables and Junction Boxes in the Readiness Hangars (Intercom).
31. AVRO Report No. 72/ Systems 21/30	Oxygen System - ARROW 2.

32. AVRO Report No. 71/ MAINT 21/2 — Maintenance Instructions - ARROW 1

33. RCAF EO 20-115-9A — Storages and Handling of Liquid Oxygen.