72 GEQ 1 Addendum 1

SECRET

ARROW 2

Design Study

on

Mobile Ground Power Units

72/GEQ/1.
ADDENDUM 1.

April 1958.

SECRET

ANALYZED

ARROW 2

DESIGN STUDY ON MOBILE GROUND POWER UNITS

Classification cancelled / Changed to UNCLASS
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Addendum 1

to

Report No. 72/GEQ/1

April 1958

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P R E F A C E

Design Study report 72/GEQ/1 and addendum 1 have been prepared for the Department of National Defence (RCAF) as part of the development contract for the Arrow weapon system between the Department of Defence Production and Avro Aircraft Limited.

Vendor's information and opinions expressed regarding same are of a confidential nature and are not to be disclosed to any person or agency outside the Departments of National Defence and Defence Production of the Government of Canada.

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1. INTRODUCTION

Avro Report No. 72/GEQ/1, Arrow 2 Design Study of Mobile Ground Power Units, issued in November 1957, reviews in great detail various combinations of both Air Cycle and Vapour Cycle Refrigeration Systems combined with an electrical power generator, which might be considered suitable for supporting the Arrow 2 during field maintenance or forward base readiness. This review was based on technical proposals and information submitted by vendors of this equipment. The performance estimates of this equipment were based on environmental conditions laid down by the RCAF in letter reference S-36-38-105-13 (ACE) 1.

It has been shown in Report 72/GEQ/1 that any of the Air Cycle refrigeration systems investigated would pump considerable quantities of free moisture into the aircraft electronic system when operating in the conditions of high humidity that were specified by the RCAF environmental envelope. This fact led Avro Aircraft Limited to recommend that a Vapour Cycle system (using Freon as a refrigerant), be adopted. After reviewing the recommendations contained in Report 72/GEQ/1, the RCAF made it known to Avro Aircraft Limited that they preferred a Gas Turbine Compressor with Air Cycle equipment because of its smaller size and light weight as compared to Piston Engine with Vapour Cycle equipment (letter reference S36-38-105 (APO-1) 6th February 1958).

In order to overcome the technical difficulties, the RCAF then proposed to relax their original environmental requirements so as to bring them within the scope of Air Cycle refrigeration equipment. In letter reference S36-38-105 (APO-1) 28th February, the RCAF requested that Avro Aircraft Limited review all the Air Cycle proposals previously considered, in the light of the relaxed requirements listed in Chapter 2 of this addendum, which also includes deletion of cockpit air conditioning from the mobile ground equipment.

The object of this addendum is to present the requested review and to state the Company's final recommendations.

2. NEW ENVIRONMENTAL CONDITIONS AND AIR FLOW POWER REQUIREMENTS

The Report 72/GEQ/1 was based on the following requirements as originally laid down in RCAF letter S36-38-105-13 (ACE) 1.

Case	Dry Bulb Temp.	Wet Bulb Temp.	Altitude	Air Flow lbs/min.	Delivery Temp. °F	Power KVA
A	120	76	0-3500'	150	55	40
B	100	85	0-3500'	150	55	40
C	-65	-	0-3500'	150	55	40

2. NEW ENVIRONMENTAL CONDITIONS AND AIR FLOW POWER REQUIREMENTS ....Cont'd

As stated in Report 72/GEQ/1, it was found that all the Air Cycle systems considered, pumped considerable quantities of free moisture into the aircraft when operating in Case B.

By letter reference S36-38-105 (APO-1), 28th February 1958, the RCAF have now relaxed their environmental conditions and reduced the air flow requirements by eliminating cockpit air conditioning, as follows:

Case	Dry Bulb Temp.	Wet Bulb Temp.	Altitude	Air Flow lbs/min.	Delivery Temp. °F	Power KVA
A	120	76	0	130	55	40
B	100	80	0-3500'	130	55	40
C	-65	-	0-3500'	130	55	40

It will be seen that the maximum temperature at altitude has been reduced. The air flow decreased by 20 lbs/min. and the wet bulb temperature reduced from 85 to 80°F. This latter reduction has decreased the free moisture content to manageable proportions so that it is possible to re-evaporate it by controlling the inlet temperature to the aircraft as follows.

On entering the aircraft, all equipment cooling air passes through the magnetron heat exchanger which, when operating, will raise the temperature of the air by 15°F. For adequate cooling of the electronic system the air immediately downstream of the magnetron heat exchanger should not rise above 70°F, at which temperature any free moisture left in the air coming from the ground equipment under the new environmental conditions, will be re-evaporated. To cater for the case when the ground equipment is used with certain elements of the electronic system switched off, and the magnetron heat exchanger cold, it is proposed to sense the temperature downstream of the magnetron heat exchanger so that the air delivered from the ground equipment is raised to maintain 70°F, and so evaporate the free moisture which is left after passing through a water trap and before it enters the aircraft.

3. GENERAL CONSIDERATIONS

The design of the power air conditioning unit requires the integration of three basic components or sub-systems. Namely, the engine/compressor, the air cycle refrigeration system and the automatic control system.

In selecting the recommended sub-systems for integration, the major factors for consideration are Availability and Reliability.

3. GENERAL CONSIDERATIONS ....Cont'd

Availability in this instance means the selection of standard components that have already been developed and are readily manufactured.

Reliability is based on the history of the components - their stage of development - the number in use - the experience of the company producing them and field reports of components in use. The unit in question is an important part of the weapon system and thus reliability is of paramount importance.

3.1 Engines

The selection of the engine(s) for the unit's primary power source is based on a number of factors. Firstly, it must be capable of providing the required amount of bleed air flow and shaft horsepower under all environmental conditions specified. Secondly, if two engines are used, it must be possible to parallel their bleed air outputs under varying load conditions. Thirdly, the engine controls must be developed to the extent that full automatic control of starting, speed, temperature and output is possible. In addition the controls must be capable of maintaining all electrical outputs within the close tolerances required by the aircraft electronic system.

Established reliability, ease of maintenance, overhaul life and back up support of the engine is considered of utmost importance.

To indicate some of the problems which have been encountered in the development of turbo machinery it is relevant to note the troubles experienced by the Continental Motors Corporation in this respect.

Some years ago this company obtained licence rights to manufacture the French Turbo-Meca engine which they put into production to meet the MA-1 specification for an engine starter unit for the USAF. A number of these units were produced and apparently suffered from a variety of troubles which included compressor surge and instability of the control system. We were informed by Mr. W.C. Savage of WADC that Continental completely redesigned the control system and again attempted to have the engine qualified. It appears that it was still not satisfactory and the control system had to be modified once again. The engine has finally passed its qualification tests but only within the last few months.

It will be appreciated that Continental's experience does not apply to the 'Palouste' series engines made by the Blackburn Company. The design of this turbine was changed from the original French design. Orenda Engines Limited experience bears out the fact that the Blackburn units they are using have not shown any of the troubles

3.1 Engines ....Cont'd

experienced by the Continental Motors Corporation.

3.2 Air Cycle Refrigeration System

The design of an air cycle system, although simple in concept, requires a great deal of background engineering experience on the part of the manufacturer.

The pressure ratio of the bleed air from the engine chosen, determines the use of a simple air cycle system or of a bootstrap air cycle system. The design aim of either system is to provide maximum cooling for the least power loss plus removal of the maximum amount of free water.

Careful design of ducting and mixing chambers will be required for air temperature control under all environmental conditions. Cooling fan efficiency must be at a maximum in order to minimize the power required for their operation.

3.3 Control Systems

The satisfactory integration of engine(s) and air cycle system is largely dependent on the control system; the required system being a single switch operation controlling automatically every output of the unit.

The system must first control the starting sequence of one or more turbine engines; it must govern the time from "idle" to full speed, for the conservation of engine life. Its role in the provision of electrical power requires "under" and "over" speed control to maintain the close frequency tolerance under varying load conditions. Provision of conditioned air at a constant flow under all environmental conditions means the monitoring of flow and temperature sensing devices located in the aircraft and in the ground unit itself.

Safety devices must be incorporated to shut off the unit in case of failure of air flow or electrical power. Shut down must be automatically initiated in the event of "under" and "over" speeding of the engine, too low or too high air temperatures and pressure, or any other malfunctions.

Development troubles that have been experienced in the electronic controls of the air conditioning system of the Arrow 1 clearly indicate the desirability of adopting a "system approach" in the development of this complicated equipment and that this is best carried out by acknowledged specialists in this field of engineering.

3.4 Packaging

The three sub-systems must be packaged in the most compact manner compatible with efficient operation of the unit. Access for easy maintenance, efficient cooling of the engine and noise suppression without sacrifice of performance are important considerations. Self mobility and ability to withstand the extremes of weather conditions are required. The unit will be operated for prolonged periods and thus must be efficient, rugged and reliable.

4. COMPARISON OF TURBINE AND REFRIGERATOR PROPOSALS

4.1 General

The Gas Turbine Compressors which have been considered for possible use with the Arrow 2 ground power and air conditioning unit and for the engine starting unit are as follows:

- * AiResearch GTCP 100-50
- * Solar Jupiter Mk. 2
- * Boeing Model 514-2A
- Ø Blackburn Palouste/Artouste
- Ø AiResearch GTCP 85 series

These engines fall into two categories,

* Engines with a large output and a compression ratio in the order of 5 to 1.

Ø Engines having a lower output and a compression ratio of approximately 3 to 1.

The high pressure engines will operate satisfactorily with a simple air cycle system, whereas the lower pressure engines must be operated with a Bootstrap system to achieve the required amount of refrigeration. Both simple air cycle and bootstrap systems have been in use for airborne application for several years, and are considered equal in reliability and service life. The estimated performance of the engines, coupled to a suitable air cycle system and providing 40 KVA of electrical power, is shown on Table I. It will be seen that one AiResearch GTCP 100-50 will meet the requirement of both conditioned air and electrical power. One Solar Jupiter 2 is marginal; the Boeing 514-2A is too small, and either one pair of Blackburn Artouste or AiResearch GTCP 85 series engines coupled together, will meet the requirement.

4.2 Re-Evaluation of Gas Turbine Compressors

In order to obtain the latest information on the development of the various Gas Turbine Compressors which may have taken place since Report No. 72/GEQ/1 was written, visits were arranged to the manufacturers concerned, and in some cases, proposals for complete systems based on the revised environmental conditions, were requested. A summary of the information obtained is given below.

4.3 AiResearch GTCP 100-50

The following is an extract from a visit report dated 10th March, 1958 which summarizes the present status of this engine:

"The first engine was run in January of this year and has only accumulated eight hours running time to date. Two more engines will be available by the end of March, and an additional three test engines are to be made. The engine is designed as an airborne power package for fitment in a pod for the U.S. Navy aircraft F4D. The first production engine is to be delivered in December of this year, and will be cleared for operation on the basis of a 50 hour type test. The first test engine has not yet been fitted with a complete control system or accessories. Some instability of the compressor is under investigation at the present time. No work has been done yet to adapt this engine for ground use, and the qualification programme for the engine has not yet been established. It will probably be based on 200 hours of operation but AiResearch are considering doing a 1000 start test as well. The overhaul periods are not yet established but are estimated at present to be somewhere between 200 and 500 hours."

AiResearch were invited to propose a complete system for the Arrow 2 air conditioning ground power unit using a GTCP 100-50 engine as the prime mover. They have advised against this, owing to the undeveloped state of the engine.

In view of the foregoing, this engine cannot be recommended for use with Arrow aircraft at the present time.

4.4 Solar Jupiter 2

The following extract from a visit report made to Solar dated 8th March 1958, outlines the current position of the engine:

"So far about 115 Solar Jupiter Mk. 1 engines have been delivered against a USAF contract. The Mk. 2 uses the same hot end with a redesigned compressor. The compressor

4.4 Solar Jupiter 2 .....Cont'd

has been in existence for the last 18 months, during which time it has accumulated approximately 100 hours of running.

Three Mk. 2 engines have been built. One shaft power version which has run about 70 hours and two air bleed engines which have accumulated between them 50 hours of running time.

The future of the Jupiter 2 seems uncertain. No orders have been received to date, although it has been stated by Solar that both the U.S. Navy and the USAF have expressed interest.

One air bleed engine has been installed in a package, and was demonstrated during the visit. The control system was not yet fully automatic although it was expected to be made so almost immediately.

The Mk. 1 engine, complete with enclosure, currently sells for $44,000 in small quantities and at about $37,000 in batches of 50. It is expected that the Mk. 2 will cost about $2,000 dollars more, and the delivery quoted is in the order of 11 to 12 months."

The Solar performance estimated (by Avro Aircraft Ltd.) for the engine coupled to an air cycle refrigeration system and driving a 40 KVA generator is shown on Table I. It will be noted that the performance is marginal under adverse conditions.

Contact was made with Mr. W.C. Savage, Head of the Turbo Machinery Group at Wright Air Development Centre, with the object of obtaining their up-to-date field experience with the Solar Jupiter 1, and to ascertain the extent of their interest in the Jupiter 2.

He stated that they have not yet had any feedback of information from the Command using the engine. He undertook to obtain this, which, when available, will be passed to the RCAF TSD office at Dayton, Ohio. He stated that some trouble had been experienced with the Jupiter 1 engines under their jurisdiction, which was caused by the control of the compressor surge dump valves which affected the acceleration of the engine. In connection with the Jupiter 2, he stated that they have some interest in this machine and they had received conflicting information from Solar concerning its state of development. As far as he is aware, a complete new control system will be required for this engine.

4.4 Solar Jupiter 2 ....Cont'd

He enquired whether we had been quoted any cost figures for the Jupiter 2. On being given the figures quoted on Page 7 of this report, he stated that they certainly did not agree with the costs that they had obtained from Solar. Although no specific figures were mentioned, he implied that the present development state of the engine might well incur additional costs.

Actual overhaul costs for the Solar engine are not available at the present time. It is, however, suggested that any engine employing a multi-stage axial compressor will be more costly to overhaul than a centrifugal type. Secondly, in the event of foreign matter entering the compressor, the resulting damage is likely to prove much more grievous.

4.5 Boeing Model 514

The following extract from our visit report outlines the present status of the Model 514 engine:

> "This gas turbine compressor was originally designed as an airborne power pack for use with the Douglas C-132 transport, and was designed to deliver 125 shaft horse-power, or 180 lbs/min. bleed air at standard day conditions.
>
> When the C-132 was cancelled about a year ago, the USAF decided to continue development work on the GTC until the funds already allocated ran out. This occurred in early March of this year, and the project has now stopped until a new sponsor has been found.
>
> Two engines have been built which jointly have run a total of some 200 hours."

Apart from the fact that the engine is still in the development stage, one single engine is not capable of providing sufficient quantities of both bleed air and shaft power required for the Arrow 2 ground power and air conditioning unit. The estimated performance of such a system powered by a model 514 engine is shown on Table I.

4.6 Blackburn Artouste and Palouste Gas Turbine Compressors

As a result of discussions with the Canadian representative of Blackburn and General Aircraft, it was ascertained that the situation of these engines has not changed significantly from that described in Report 72/GEQ/1 with the following exceptions.

(a) The engines have now accumulated more running time than previously quoted, and, 4.6 <u>Blackburn Artouste and Palouste Gas Turbine Compressors</u> ....Cont'd

(b) Some reservations were expressed in Report 72/GEQ/1 concerning the paralleling of two engines, as at that time Blackburn had not carried out any tests of this nature.

The following is an extract from a letter from Blackburn, England, to their Canadian representative, which covers this point.

"Regarding Paragraph 5, you will be pleased to learn that we have now run a Palouste in parallel with an Artouste 510 driving an alternator, this test was entirely satisfactorily and no difficulty whatever was encountered regarding the control of the two engines.

Both engines had the 9½ sq. in. matching, each engine was fitted with a sonic venturi, the one fitted to the Palouste being designed to pass the maximum allowable mass flow and the one fitted to the Artouste designed to pass the maximum allowable mass flow when the alternator was on full load. Immediately after the sonic venturis a non-return valve was fitted on each engine; the deliveries were then connected together and the combined discharge passed through a control valve which could be set to simulate the piece of equipment to which the two engines were supplying air.

With this arrangement it is possible to start, accelerate, decelerate and stop either engine when the other is running at part load or full load; it is also possible to vary the alternator load from zero to maximum.

Due to the urgency on this job and the pressure of other work, the scheme was rather a "lash up" and consequently the pressure drop through the system was rather high, but nevertheless, we are now in a position to say that coupling two engines together is a practical proposition and further work will be carried out if there is a definite requirement."

It was ascertained during discussions with the Canadian representative that the engines are not equipped with certain protective devices which automatically protect the engine against overspeed, or high jet pipe temperature. Also, that a control system with the degree of automation we consider desirable is not completely in being at the present time. We have been assured, however, that the latter could be developed and the protective devices incorporated without any undue delay.

4.7 AiResearch GTCP 85 Series

In response to our revised Arrow 2 Requirement Statement, the Garrett Corporation have forwarded a proposal for a complete system which will meet the requirements for the Ground Power and Air Conditioning Unit.

Essentially, this proposal is similar to that outlined in Appendix 'E' of Report 72/GEQ/1 which, with the latest mark of engine and with the revised environmental conditions, does satisfactorily meet our requirements (refer Table I).

ARROW 2 GROUND POWER/AIR CONDITIONING UNIT

REQUIREMENT: 130 lb/min. of air and 40 KVA of 200/115 volt, 3 phase, 400 c.p.s. Electrical Power

PERFORMANCE OF VARIOUS COMBINATIONS OF ENGINE AND AIR CYCLE UNITS

Condition	Unit	Airflow lb/min.	KVA Available
120° F. DB	1 AiResearch GTCP 100-50 with Simple Air Cycle	135.5	40
76° F. WB	1 Solar Jupiter Mk. II with Stratos GEA-120 Package	130	40 *
AT	2 Blackburn Artoustes with bootstrap package	194	40
SEA LEVEL	2 AiResearch 85 series with bootstrap package	137	40
	1 Boeing 514-2A with a Simple Air Cycle	130	6
100° F. DB	1 AiResearch GTCP 100-50 with Simple Air Cycle	133	40
80° F. WB	1 Solar Jupiter Mk. II with Stratos GEA-120 package	130	25.3 *
AT	2 Blackburn Artoustes with bootstrap package	183	40
3500' Ft.	2 AiResearch 85 series with bootstrap package	130	40
	1 Boeing 514-2A with a Simple Air Cycle	130	3

* Calculated from Solar table included in Appendix 'A'.

TABLE I

5. COMPARISON OF ENGINE STARTING UNITS

Chapter 6 of Report 72/GEQ/1 covers the various Gas Turbine Compressors considered suitable for engine starting.

The starting times quoted were based on the original environmental conditions, using a constant torque value based on Sea Level Standard Day aerodynamic drag conditions for the Iroquois engine compressor, and starter performance data provided by Lucas Rotax.

These factors produced pessimistic starting times under the high altitude hot day condition.

Revised starting times based on the new conditions and corrected torque values, together with starter performance curves applicable to the AiResearch starter presently being used by Orenda Engines, are shown in Table 2.

It is worthwhile noting that no advantages can be foreseen using the large expensive turbines for the purpose of engine starting.

Estimated Starting Times of Iroquois fitted with an AiResearch Air Turbine Starter (ATS 100-39)

Gas Turbine Compressor	Sea Level, 59 F	3500',100 F	Sea Level, 120 F
AiResearch GTC 85 series	19.2 Secs.	24.8 Secs.	22.6 Secs.
Blackburn Palouste	16.4 Secs.	19.6 Secs.	18.1 Secs.

TABLE 2

6. CONCLUSIONS

6.1 Ground Power and Air Conditioning Unit

It will be appreciated from the foregoing that both the large engines, namely the AiResearch 100-50 and the Solar Jupiter 2, which offer any possibility of providing all the services from a single prime mover, are still strictly in the early development stage, and as such, cannot be recommended at the present time. The only practical alternative, therefore, is to use two small engines coupled in parallel.

6.1 <u>Ground Power and Air Conditioning Unit</u> ....Cont'd

The choice lies between two Blackburn Artoustes or two AiResearch GTCP 85 series engines.

In deciding between these two alternatives, the following factors should be taken into consideration.

The Blackburn engines are, as far as can be determined, perfectly satisfactory machines. This is borne out by Orenda Engines Limited experience; on the other hand, it should be remembered that the size of this sample is small (two units). Further development, of a suitable automatic control system for the engine, would be required. Finally, Blackburn and General Aircraft are not in the air cycle refrigeration business. It would be necessary, therefore, to match their engines with a suitable air cycle bootstrap system obtained from some other source and develop from scratch an integrated control system for the whole unit. In this connection, the Canadian representative of Blackburn and General Aircraft has stated that he intends to approach certain companies manufacturing refrigeration equipment in the U.S.A. It seems clear that nothing tangible in this regard has been achieved so far, or is in sight within the near future.

The AiResearch GTC 85 series engines are in extensive use, several thousand being in service with the USAF. It is therefore possible to obtain first hand experience from independent sources, such as WADC.

It has been learnt from this source that continuous development by the manufacturer has brought these engines and their associated equipment to a point where they are considered satisfactory, and the field reports are good. The control system for the engines is fully automatic and includes all desirable protective devices. The Garret Manufacturing Corporation is also very definitely in the air cycle refrigeration and automatic control business and have proposed a complete system to meet our requirements, comprising two engines in parallel and a refrigeration sub-system that is already designed and qualified for aircraft application together with a suitable control sub-system. Our experience indicates that the engineering and development of such a system is best carried out by acknowledged specialists in this field of engineering located on this Continent so that close technical control is possible.

On this score it is considered that technically, the AiResearch proposal is by far the most attractive, as it offers prime movers and associated equipment with a widely known background and eliminates the difficult task of matching, and engineering into a complete system, components that otherwise would have to be obtained from different sources.

6.2 Engine Starters

From the performance figures quoted in Table 2, it will be seen that theoretically the Blackburn "Palouste" has a slightly better performance than the AiResearch 85 series engines. On the other hand, under the relaxed environmental conditions, the AiResearch unit does comply with the "scramble" requirements for the Arrow as specified in RCAF specification AIR-7-4. To meet this requirement it is necessary that the Iroquois reaches ~~rolling~~ idling speed within 34 seconds under the worst environmental conditions.

The standard AiResearch starter package would require only minor changes to meet the requirements for starting the Arrow 2 Iroquois engines. Because of this, and because the AiResearch engine is our recommended prime mover for the ground power and air conditioning units, it is considered the logical choice for the engine starter.

7. RECOMMENDATIONS

In submitting our recommendations to the RCAF regarding the most suitable ground power equipment for use with the Arrow weapon system and the best method of handling its development, we wish to repeat certain "Golden Rules" that were stated in one of Avro's previous reports on the same subject, issued in February 1956.

These rules were:

1. The equipment must be technically the best available and to that purpose we should:
2. Learn and benefit by the experience of others.
3. Wherever possible use equipment already proven in service.
4. Avoid untried methods of application.
5. Select a vendor who has specialized in the design and manufacture of similar equipment and who has the engineering, development and manufacturing resources to bring the job to a satisfactory conclusion.
6. The equipment should be manufactured in our country and should incorporate as many Canadian made components as practicable.

Avro Aircraft Ltd's latest list of GSE to support the Arrow development program, Report 70/GEQ/2, amendment 1, calls for 14 air conditioning power units and 14 engine starter units in addition to the interim units already procured. The latest acceptable delivery date for the first units is considered to be the 1st of April 1959. Because of the system complexity of the larger unit, we know by experience that even the most experienced vendor would require a lead time of approximately 12 months from the date of contract to delivery.

7. RECOMMENDATIONS

Based on the RCAF's climatic environment and our detailed engineering studies summarized in this and several previous technical reports and with the above considerations in mind, it is now recommended that,

1. The gas turbine compressors for the air conditioning power unit and the engine starting unit shall be of the AiResearch GTC-85 series; i.e. two compressors in parallel for the former unit and one identical compressor for the starting unit. These prime movers shall supply all the services required from the units.
2. The air cycle refrigeration sub-system and the automatic control sub-systems shall be of AiResearch design similar to their proposal outlined in Appendix 'E' of Avro Report 72/GEQ/1.
3. Avro Aircraft Limited procure all the units to support the 37 aircraft development program. The required quantities and delivery schedule, as proposed in report 70/GEQ/2 and its subsequent amendments, to be approved by the RCAF and procurement authorized by the Department of Defence Production as soon as possible.

It should be noted that Avro Aircraft Limited intends to design, develop and manufacture, or cause to be manufactured, these mobile ground power units in accordance with Avrocan specifications and Proc 100-2 engineering drawings to be approved by the RCAF. Avro Aircraft Limited will carry out the engineering task with the technical assistance of the Garrett Corporation of Canada who will perform the systems analysis and systems development of the major sub-systems. It is of course mandatory that the design rights of all hardware specially designed to meet the RCAF's requirements shall become the property of the Canadian Government.

AMBIENT TEMPERATURE. F	BLEED AIR FLOW. PR. AND TEMP.	MK I NORMAL	MK I NORMAL HALF BOOST *	MK I NORMAL FULL BOOST	MK I 5 MINUTES	MK I 5 MIN. HALF BOOST	MK I 5 MIN. FULL BOOST	MK II NORMAL	MK II NORMAL HALF BOOST	MK II NORMAL FULL BOOST	MK II 5 MINUTES
RATED SPEED		20,400	---------	---------	---------	--------->	20,400	21,500	---------	---------	---------
59	PPM PSIA °F	162 62.0 410	144 67.8 428	133 73.5 449	166 61.7 409	148 67.6 428	137 73.2 447	192 70.5 451	170 77.3 472	158 84.1 496	198 70 448
100	PPM PSIA °F	134 59.5 453	119 65.0 473	111 70.6 496	137 59.3 452	122 64.9 473	113 70.3 495	165 69.5 499	145 76.2 522	135 82.9 548	170 69 496
120	PPM PSIA °F	121 58.5 476	108 64.0 498	100 69.4 522	125 58.1 475	111 63.6 497	103 69.0 520	152 69.2 526	135 75.9 550	125 82.5 581	158 68 524
130	PPM PSIA °F	115 58.0 491	102 63.4 512	95 68.7 536	119 57.6 489	106 63.1 511	98 68.5 535	145 68.8 539	128 75.4 564	120 82.0 593	152 68 536

REFER: CR1815, CR1
CS3392, CS3
CS3599, CS3

NOTE:

1. All quotations at 0.0 S.H.P.

2. Rule of thumb for shaft power effect on air bleed as follows: With increasing S.H.P.; increase bleed
59F to 0.06 PSI at 130 F per S.H.P.; decrease bleed flow 0.30 PPM at 59F to 0.35 PPM at 130F per S.H.

*Note: Air flow c
by employi

TABLE II

T-300J MK I and MK II PERFORMANCE
QUOTATION TABULATION

Received from Solar Aircraft Co.
21 February 1958

FLOW. PR. AND TEMP.	MK I NORMAL	MK I NORMAL HALF BOOST *	MK I NORMAL FULL BOOST	MK I 5 MINUTES	MK I 5 MIN. HALF BOOST	MK I 5 MIN. FULL BOOST	MK II NORMAL	MK II NORMAL HALF BOOST	MK II NORMAL FULL BOOST	MK II 5 MINUTES	MK II 5 MIN. HALF BOOST	MK II 5 MIN. FULL BOOST
D	20,400	----------------	----------------	----------------	--------------->	20,400	21,500	----------------	----------------	----------------	--------------->	21,500
PPM PSIA °F	162 62.0 410	144 67.8 428	133 73.5 449	166 61.7 409	148 67.6 428	137 73.2 447	192 70.5 451	170 77.3 472	158 84.1 496	198 70.0 448	176 76.2 467	163 83.4 493
PPM PSIA °F	134 59.5 453	119 65.0 473	111 70.6 496	137 59.3 452	122 64.9 473	113 70.3 495	165 69.5 499	145 76.2 522	135 82.9 548	170 69.0 496	151 75.7 520	140 82.3 555
PPM PSIA °F	121 58.5 476	108 64.0 498	100 69.4 522	125 58.1 475	111 63.6 497	103 69.0 520	152 69.2 526	135 75.9 550	125 82.5 581	158 68.7 524	140 75.3 548	130 81.9 578
PPM PSIA °F	115 58.0 491	102 63.4 512	95 68.7 536	119 57.6 489	106 63.1 511	98 68.5 535	145 68.8 539	128 75.4 564	120 82.0 593	152 68.2 536	135 74.8 561	126 81.3 589

APPENDIX 'A'

REFER: CR1815, CR1816, CR1817, CS3392, CS3463, CS3464, CS3569, CS3599, CS3831

ations at 0.0 S.H.P.

thumb for shaft power effect on air bleed as follows: With increasing S.H.P.; increase bleed PR. 0.05 PSI at .06 PSI at 130 F per S.H.P.; decrease bleed flow 0.30 PPM at 59F to 0.35 PPM at 130F per S.H.P.

*Note: Air flow can be exchanged for pressure by employing the use of a "boost valve".

TABLE II

T-300J MK I and MK II PERFORMANCE QUOTATION TABULATION

m Solar Aircraft Co.
1958