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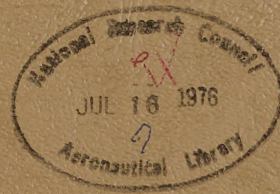
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PROPOSED FLIGHT TEST SCHEDULE AND
INSTRUMENTATION REQUIREMENTS FOR THE
IROQUOIS 2 IN ARROW 2 AIRCRAFT 25207

MALTON ONTARIO CANADA

233095



ORENDA ENGINES LIMITED
MALTON ONTARIO CANADA

Member: A. V. Roe Canada Limited & Hawker Siddeley Group

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ENGINEERING & EXPERIMENTAL DEPARTMENT

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FEBRUARY 1958

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INTRODUCTION

The Arrow 2 aircraft 25207 is to be allocated as a flight test vehicle for a flight test program of the Iroquois engine. The aircraft will be operated by Avro Aircraft, as an associated contractor, as a service to Orenda Engines Limited for the purpose of evaluating and developing the Iroquois engine.

This report contains the preliminary flight test schedule and instrumentation data requirements.

PROPOSED FLIGHT TEST SCHEDULE
AND INSTRUMENTATION REQUIREMENTS
FOR THE IROQUOIS 2 IN THE ARROW 2 AIRCRAFT 25207

1. TEST PROGRAM OBJECTIVES

- 1.1 Primarily to assess the installed performance, function of controls, effects of inlet flow distortion and ejector performance, including optimum nozzle area for subsonic cruise conditions.
- 1.2 To provide O. E. L. technical and engineering personnel integration in an endeavour to keep O. E. L. flight test personnel trained in preparation for the time when the Arrow 2 can be operated by O. E. L. as a necessary aid for production support.
- 1.3 To provide as many instrumentation requirements as the aircraft structure will permit in an endeavour to keep O. E. L.'s requirements of accuracy compatible with instrumentation supplied by O. E. L.

2. REQUIREMENTS

In general, responsibilities of the program will be as follows:

2.1 Orenda Engines Limited

2.1.1 The supply of a fully-instrumented Iroquois 2 engine for installation in the port nacelle of the Arrow 2. This engine will be fitted with all instrumentation items as detailed later in this report.

2.1.2 The following items of recording instrumentation and their ancilliary equipment re-packaged to Avro envelope requirements:-

Pressure logger for performance;

Temperature logger for performance;

36-channel oscillograph for transients and controls;

26-channel oscillograph for vibration;

Magnetic tape unit;

Visual monitoring instrumentation.

2.1.3 Provision of the basic schematic circuitry diagrams between engine, recording instrumentation, telemetry and cockpits.

2.1.4 The publishing of a general flight test schedule (as part of this report) indicating the hours of data reading for performance evaluation, assuming that the investigation into mechanical and controls handling can be done during the same period of time.

2.1.5 The supply of approximately six to eight ground crew personnel for operation of the aircraft during flight testing and two flight engineers for technical supervision of the flight test program.

2.1.6 Provide pilots and any necessary aircrew for the flight testing program.

2.2 Avro Aircraft - in addition to the basic Arrow 2 aircraft 25207

2.2.1 Provide envelope requirements for re-packaging O. E. L. supplied recording instrumentation.

2.2.2 Provide all circuitry, piping, junction boxes, brackets, mountings and miscellaneous hardware within the aircraft for operation of the recording instrumentation.

2.2.3 Provide an airborne telemetry system compatible with both the instrumentation on the engine and Avro's ground read-out equipment.

2.2.4 Operate the aircraft during the proposed flight test program in conjunction with any O. E. L. personnel that may be supplied.

2.2.5 Provide all necessary ground handling equipment for operation of the aircraft.

2.2.6 Provide a chase aircraft for one hour of flight test readings in the supersonic range.

3. REFERENCE DRAWINGS

The following drawings are the schematic circuitry drawings between the instrumentation and the recorders:

- LSK 4301 - Engine Instrumentation Clearances
- LSK 6232 - Schematic of Instrumentation Wiring Requirements
- LSK 6233 - Schematic of Instrumentation Plumbing Requirements

Sketch XFT 643 Issue 2 is attached to this flight test schedule and indicates schematically the number and type of wires and tubing between the engine instrumentation, recorders, cockpit and telemetry. This schematic indicates only the bulk of required wiring and tubing.

4. TENTATIVE ENGINE FLIGHT TEST PROGRAM

The flight test program required for the Iroquois can be broken down into three main headings:-

- (a) Engine Performance Program;
- (b) Mechanical Development Program Including Vibration;
- (c) Controls Program.

4.1 Engine Performance Program

4.1.1 General: The performance instrumentation requirements for the Iroquois in the Arrow 2 are very similar to those on the B-47 flying test bed. The three primary investigations are:-

- (a) The investigation into intake duct performance;
- (b) The measurement of steady state performance;
- (c) The investigation of matching problems during transients.

4.1.2 Steady State Performance: Steady state performance measurement will be used to verify the Model Specification at high inlet pressures and temperatures and to determine compressor, turbine, combustion and afterburner efficiencies and air flow, fuel flow and thrust characteristics.

The effect of inlet flow distortion must be estimated. It is important that losses experienced in the intake duct are not charged against the engine and also that any deterioration in engine performance due to distorted flow at the engine inlet may be recognized. The problem is complicated by the probability that these losses and flow distortions will vary with altitude. A survey utilizing pressure and temperature rakes at the engine inlet is, therefore, required over the full range of steady flight conditions. Also, some quick-response measurements of inlet pressure are also required to assess the effect of turbulence. The free stream conditions are to be taken from the aircraft instruments, as shock configurations make these measurements inadvisable in the engine intake.

NOTE: In measuring thrust both from the final nozzle and the ejector, their total pressures and their geometry must be known. The use of a swinging-boom type pitot probe is essential and incorporation of a quick response thermocouple to this probe would be an extremely desirable feature. However, the requirement of a swinging probe is held in abeyance until further notice.

<u>Item No.</u>	<u>Description</u>
11	Four L. P. compressor outlet temperature rakes of five thermocouples (separate or averaged).
14	Four H. P. compressor outlet total pressure rakes of five pitots (separate or averaged).
13	Four H. P. compressor outlet temperature rakes of five thermocouples (separate or averaged).
272	Six H. P. turbine inlet temperature rakes, five thermocouple points on leading edge of first nozzle guide vane (separate or averaged).
15	Four H. P. turbine inlet averaging pitot rakes.
16	Four L. P. turbine inlet averaging pitot rakes.
17	Four L. P. turbine outlet averaging pitot rakes.
19	Five L. P. turbine outlet temperature rakes of five thermocouples (separate or averaged).
7	One afterburner fuel flow.
848)	One pitot - static temperature probe in line to air
849)	fuel pumps.
850)	
851)	One pitot - static temperature probe in air line to
852)	cabin.
853)	
861	30 inlet total pressure (from rakes).
859	Four inlet static pressures (from rakes).
860	20 inlet total temperature (from rakes).
863	Four fast response inlet wall statics.

<u>Item No.</u>	<u>Description</u>
24	One L. P. rpm.
25	One H. P. rpm.
6	One engine fuel flow.
19	Five averaged JPT rakes.
Swinging Probe	One final nozzle pitot pressure.
On Aircraft	One average of four statics in ejector air at plane of final nozzle.
On Aircraft	One average of four pitots in ejector air.
On Aircraft	One average of four thermocouples in ejector air.

4.1.3 Transient Performance: The knowledge of the behaviour of various parameters in transient operations such as accelerations, decelerations, afterburner light-ups and shut-downs is of great value to the performance analysis as well as to the Controls engineers. Fast response instrumentation will, therefore, be required to pick up these transients and record them on tape or trace recorders.

4.1.3.1 Transient Tests (Subsonic):

Accelerations:

(a) Six accelerations from idling to 90 degree throttle angle -

Altitude - 5000, 25000, 35000, 40000, 45000 feet

Mach Nos. - 0.95, 0.9, 0.8.

(b) Six accelerations and afterburner light-ups from idling to 110 degree throttle angle -

Altitude - 5000, 25000, 35000, 40000, 45000 feet.
Mach Nos. - 0.95, 0.9, 0.8.

4.1.3.2 Transient Tests (Supersonic):

Accelerations:

- (a) Six accelerations from idling to 90 degree throttle angle -

Altitude - 30000, 40000, 50000 feet and ceiling.
Mach Nos. - 1.0, 1.5, limiting.

- (b) Six accelerations and afterburner light-ups from idling to 110 degree throttle angle -

Altitude - 30000, 40000, 50000 feet and ceiling.
Mach Nos. - 1.0, 1.5, limiting.

It is realized that some of the conditions requested may be unobtainable and, therefore, the program is open to modification.

4.1.3.3 Transient Performance Instrumentation: Continuous trace recordings are required for several variables relating to compressor performance in order to check working lines and acceleration characteristics of both rotors. Galvanometer response of 100 cycles per second is adequate for this work.

<u>Item No.</u>	<u>Description</u>
861	One inlet total pressure.
860	One inlet total temperature.
12	One L. P. compressor outlet pitot.
11	One L. P. compressor outlet temperature.
14	One H. P. compressor outlet pitot.
24	One L. P. rpm.

<u>Item No.</u>	<u>Description</u>
25	One H. P. rpm.
6	One engine fuel flow.
19	One JPT. One jet pipe pressure.
862	One inlet velocity head.
7	One afterburner fuel flow.

The swinging-boom readings if and when they become available are also to be taken on continuous trace recordings.

5. MECHANICAL DEVELOPMENT PROGRAM

5.1 General

Considering the present design, the instrumentation provides some indication of temperatures and pressures of various components under high forward speeds. It is considered that a number of the mechanical development problems will be in the process of investigation or will have been answered during the subsonic flight tests in the B-47.

5.2 Instrumentation

<u>Item No.</u>	<u>Description</u>
105	H. P. thrust bearing outer race.
111	Turbine bearing outer race.
61	Front sump static pressure.
58	Front sump sealing air.
80	Rear sump static.

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<u>Item No.</u>	<u>Description</u>
75	Rear sump sealing air.
503	Oil tank oil temperature.
114	Rear sump scavenge temperature.
588	Oil supply pressure. Air temperature of cooling air.

5.3 Vibration Instrumentation

The engines will be instrumented for four continuous blade vibrations via telemetry and 20 channels for blade and engine vibration on an oscillograph recorder.

6. CONTROLS PROGRAM

6.1 General

Considering the envelope outlined by the performance program, problems will probably be encountered on the following control devices. As these problems are encountered, they will be investigated and specific tests specified during the testing program.

- (a) Governor interaction between H. P. and L. P. control.
- (b) Possible overspeeding on L. P. governor.
- (c) P₃ limiter control overshoot.
- (d) Instability of speed governing at altitude.
- (e) Input schedule of acceleration control.
- (f) T₁ compensation of T₇ reference.
- (g) Fuel schedule in respect of P₂.



- (h) Afterburner light-up conditions versus throttle angles.
- (i) Nozzle area control compressor ratios.
- (j) Engine light-up envelope.

It is possible that many of these problems will have been answered during the subsonic testing of the Iroquois in the B-47. However, it is possible that the items above may appear as problems in the supersonic range and will have to be investigated at length.

6.2 Instrumentation

<u>Item No.</u>	<u>Description</u>
6	Engine fuel flow.
7	Afterburner fuel flow.
24	L. P. rotor speed.
25	H. P. rotor speed.
53	Jet pipe temperature (control probes).
55	Engine throttle angle.
23	Final nozzle area.
447	Nozzle actuator head end pressure.
448	Nozzle actuator rod end pressure.
455	Fuel pump delivery pressure.
466	Air throttle valve position indicator.
472	Boost pressure at turbo pump inlet.
484	No. 1 fuel pump outlet temperature.

<u>Item No.</u>	<u>Description</u>
485	No. 2 fuel pump outlet temperature.
803	Metering valve downstream pressure.
149	Control system P ₃ pressure.
765	Air turbine exhaust pressure.
815	Throttle base temperature.
493	Fuel pump outlet pressure No. 1.
494	Fuel pump outlet pressure No. 2.
343	Control P ₇ pitot pressure.
594	P ₂ pressure - control system.
574	Afterburner actuator bellows chamber pressure.
791	Afterburner upstream manifold pressure.
801	Afterburner metering valve downstream pressure.
451	P ₂ in main metering controls bellows chamber.
456	Fuel pressure downstream of shut-off-cock.
458	Fuel pressure downstream of servo throttle valve.
454	H. P. governor regulator pressure.
460	Governor loading pressure.
482	Boost pressure at system manifold.
462	Air pressure upstream of air valve.
463	Air pressure downstream of air valve.

<u>Item No.</u>	<u>Description</u>
43	Inlet fuel temperature.
47	Burner pressure.
469	K. P. P. at pump pressure control.
475	Fuel pressure in hydraulic actuator - rod end.
476	Fuel pressure in hydraulic actuator - piston end.
4	Inlet total temperature.
8	Thrust.
495	Afterburner shut-off-cock inlet pressure.
766	P ₁ air pressure inlet frame.

7. GROUND CHECK RUNS

Initial ground runs will be required to clear instrumentation and engine snags, installation effects on the final nozzle, control settings and to provide correlation with test bed performance. It is estimated that these initial ground check runs will take two hours.

8. TEST TIMES

Steady state (subsonic)	6 hours.
Steady state (supersonic)	10 hours.
Transient tests (subsonic)	9 hours.
Transient tests (supersonic)	<u>2 hours.</u>
Total	27 hours

It should be noted that the total time of 27 hours shown for steady state performance testing is the estimated time for readings.

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It does not include take-off, climb, approach, stooing, etc., which can be estimated by Avro. Neither do these times include further testing that may be required following modification action; e. g. ejector modifications. Although the mechanical development and controls testing can be done concurrently with the steady state performance testing, it should be realized that extensive problems in either of these phases could add hours to the total testing time.

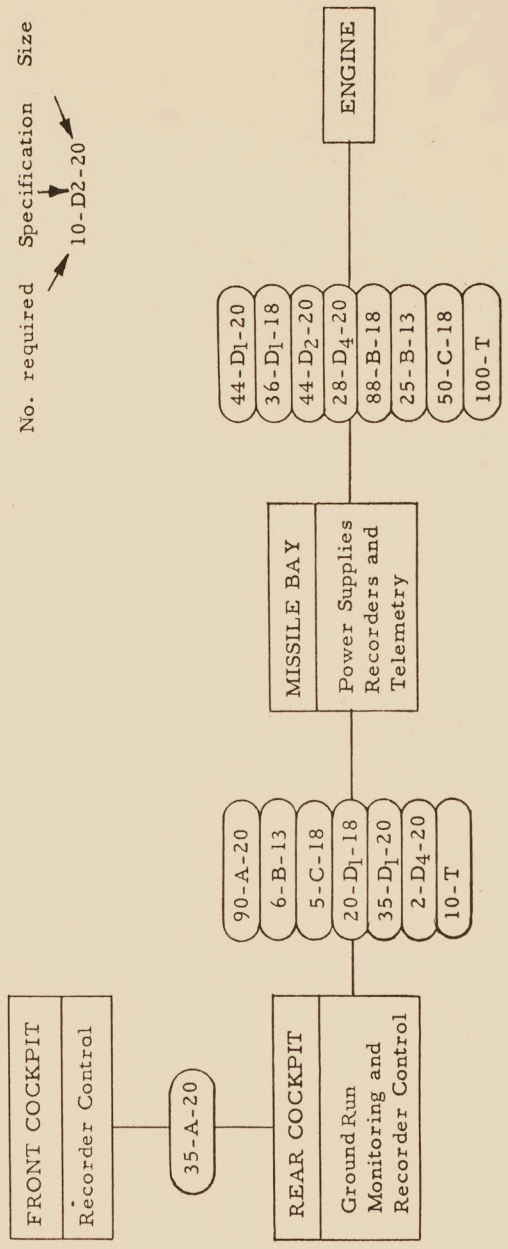


B47 SPECIFICATIONS

NOTE

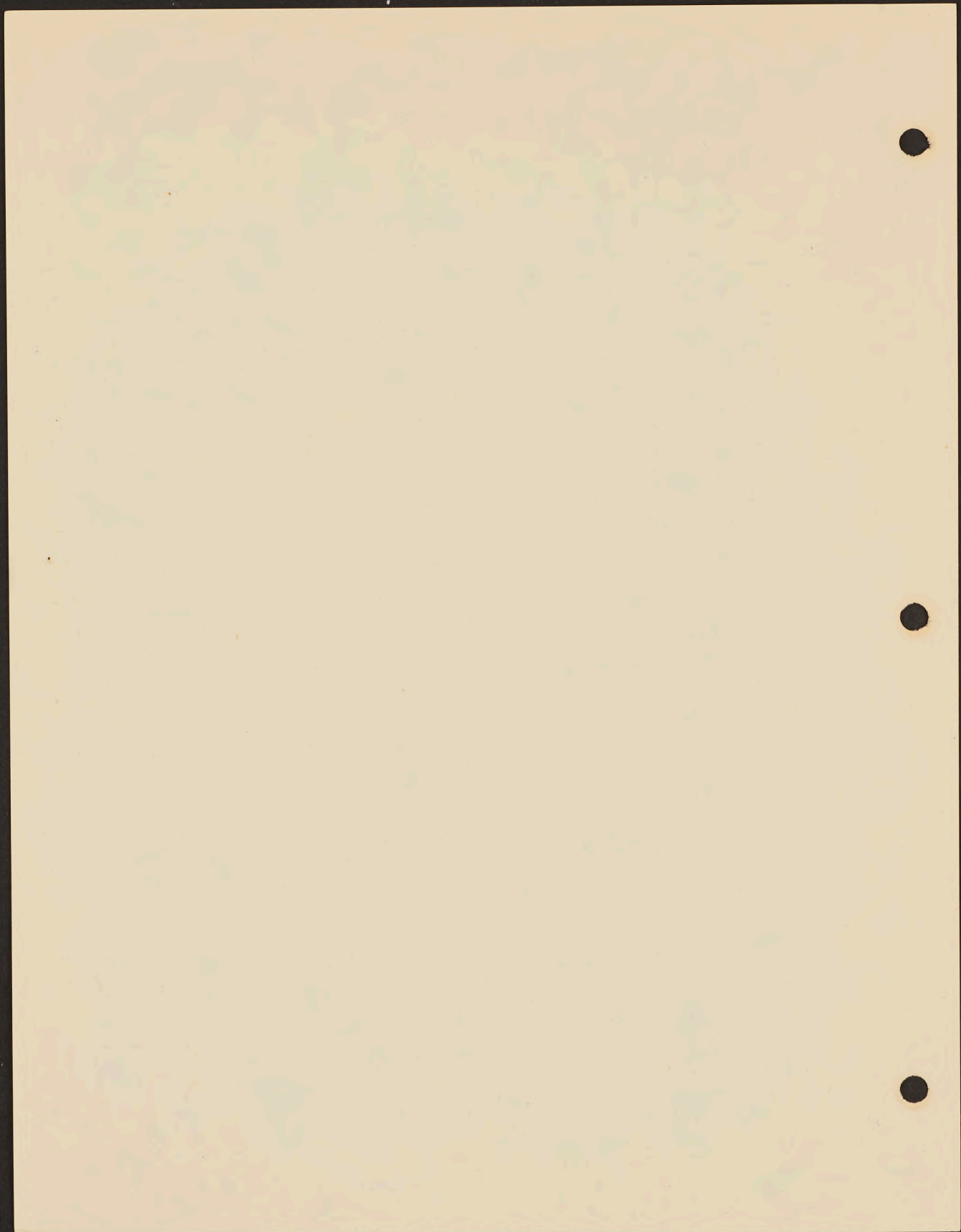
1. Approximately 20 percent copper and 10 percent thermocouple wiring spares have been included.
2. While the wire gauge sizes specified for the B47 are satisfactory, for the Arrow, the actual wire specifications will have to be selected in agreement with both Avro and Orenda.

- A. MIL-W-5086 copper wire.
- B. MIL-W-5845 iron constantin
No. 18 gauge - Type I Class E.
No. 13 gauge - Type II Class B.
- C. MIL-W-5846 chromel alumei
No. 18 gauge - Type I Class E.
No. 13 gauge - Type III Class A.
- D₁. MIL-C-7078 Type II - 1 wire shielded.
- D₂. MIL-C-7078 Type II - 2 wires shielded.
- D₄. MIL-C-7078 Type II - 4 wires shielded.
- T. Commerical tubing 0.055 inside diameter



SKETCH XFT643 Issue 2

SCHEMATIC INSTRUMENTATION REQUIREMENTS,
WIRING AND TUBING



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