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AVRO AIRCRAFT

PROPOSED FLIGHT TEST PROGRAM

ARROW 1 - PHASE 1

FAR/C105/2

ISSUE 3

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Signature.....Rank.....

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FORM 1749 A

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1. INTRODUCTION

The following report describes the Phase 1 flight test program for the Arrow 1 aircraft. This program is to be conducted by Avro Aircraft on the first three Arrow 1 aircraft. The tests will be run at Malton, and are schedule to commence at the end of 1957 and will extend over a period of approximately 24 months.

2. OBJECT

The object of this program is to examine the airworthiness, safety of flight and systems functioning of the aircraft and to establish preliminary flight envelope boundaries for safe operation of the aircraft. It is anticipated that this will encompass the greater part of the design flight envelope.

Associated ground testing will be carried out in addition to flight testing to implement this object.

During the period of time allocated to Phase 1, an aircraft will be made available to the R.C.A.F. as a safe, functional vehicle in order that a Phase 2 program may be excuted.

NOTE Definition of Phase I. Ref. DAEng. 33

Airworthiness and Equipment Functioning

Contractor conducted ground and initial flight tests to determine airworthiness, and to ensure that the aircraft with its installed and supporting equipment, meets engineering specifications, and will function.

3. TEST AIRCRAFT

The first three Arrow 1 aircraft will be available for this program.

The powerplant will consist of two Pratt and Whitney J75 Turbojets.

The armament pack has been replaced by an instrument pack in order to accomplish this program, and no fire control system is installed.

4. INSTRUMENTATION

Complete aircraft instrumentation for flight test is given in FAR/C105/1, Issue 7 and subsequent issues for aircraft 1, 2 and 3 (Appendix 1)

Recorded data is obtained by means of three airborne magnetic tape units and by telemetry. Quick look facilities are available in the form of direct reading recorders for both magnetic tape and telemetry.

5. PROGRAM

The phase 1 Flight Test will consist of the following stages:

5.1 Ground tests

5.2 First flight

5.3 Part 1 testing

5.4 Part 2 testing

5.1 Ground Tests

This part of the flight test program will consist of such pre-flight test and ground checkout that are required before the flight program may commence.

Two stages of ground tests will be accomplished.

5.1.1 A minimum test program prior to the first flight of the first aircraft.

5.1.2 A full ground test program prior to Part 1 flight testing.

A synopsis of these tests is given. The difference between the two section is essentially one of detail and is not given here. See Appendix 14.

1. Electrical Functioning Tests

   a) Functioning checks.

2. Oxygen System

   a) Leakage checks.

   b) Flow checks.

   c) Emergency system.

3. Low Pressure Pneumatics

   a) Leakage checks.

   b) Flow checks.

4. Escape System

   a) Bail out warning.

   b) Control functioning.

   c) Canopy operation.

   d) Ejector seat clearances

5. Utility Hydraulics

   a) Landing gear operation.

   b) Nose wheel steering.

   c) Wheel brakes.

   d) Speed brakes.

6. Parachute Brake

   a) Static function check.

   b) Functioning during accelerate - stop runs.

7. Flying Control Hydraulics

   a) Function checks.

   b) Pressure tests.

8. Air Conditioning

   a) Flow distribution.

   b) Cooling turbine checks

9. Damping System and Flight Simulation

   a) Damper system go-no-go tests.

   b) Flight simulation.

10. Flying Controls

   a) Functional tests.

   b) Stick forces and trimming characteristics.

11. Ground Resonance Tests

   a) Frequencies and mode shapes of aircraft resonances.

   b) Feed back of control system valves.

12. Fuel System

   a) Fuel distribution control.

   b) Pressure regulation.

   c) Leakage checks

   d) Venting.

   e) Refueling and de-fueling.

13. Ground Engine Runs

a) Engine handling and set up.

b) Engine Control System.

c) Cooling.

d) Monitoring of aircraft systems.

14. Taxi Trials

a) Wheel brakes.

b) Nose wheel steering.

c) Parachute brakes.

d) Accelerate - stops.

e) Ground handling.

15. Flight Test Instrumentations

a) Set up.

b) Calibration.

16. Telecommunications

a) Interphone.

b) Navigation aids.

c) Antennae.

d) Telemetry.

5.2 First Flight

The object of this flight is to obtain a pilot's assessment of the aircraft and to provide pilots familiarization of the low speed handling qualities.

A minimum of instrumentation will be carried consisting essentially of safety of flight items to be telemetred. These will be monitored and recorded on the ground. (Appendix 2).

The aircraft will be limited in accordance with the Design Certificate and approximately as follows:-

1. 400 kts. EAS 350 knots.
2. M = 0.90
3. h = 20,000 ft.
4. ± 60° roll angle
5. 1 rad/sec rate of roll
6. Normal load factor n = 2.5
7. Maximum take-off weight = 60,000 lb.
8. C.G. between 28.75% and 30% MAC.

Normal and emergency yaw damping will be provided and the pilot may use these at his discretion. Take-off and landing will be with normal yaw mode. Engine afterburner will not be operated during this flight.

Further flights may be carried out if it is considered necessary to achieve the object of this part of the program.

5.3 Part 1 Testing

The object of this series of flights is to provide a short engineering assessment of the various damper modes and to provide monitoring on aircraft system. The completion of this phase will enable an observer to fly in the aircraft and the detailed testing of Part 2 to take place.

It is anticipated that approximately five flights will be needed to accomplish this part of the program. It should be noted that the number of tests does not necessarily indicate the required number of flights.

The aircraft will be limited as follows:-

1. 400 kts. EAS
2. M = 1.50
3. h = 45,000 ft.
4. $\pm$ 60° roll angle
5. 1 rad/sec rate of roll
6. Normal load factor n = 2.5
7. Maximum take-off weight = 60,000 lbs.
8. C.G. between 28.75% and 30% MAC

A minimum of instrumentation is required for this phase and is given in Appendix 3.

The following tests will be accomplished:-

1. Emergency Yaw Mode

Two flight conditions will be checked.

M = 0.70 at 20,000 ft.

M = 0.95 at 30,000 ft.

General procedure in these tests will be to engage the mode required and to perform mild manoeuvres. Differential servo input steps will be made using the flight test panel. The aircraft will be flown from one test point to another using a previously tested mode.

Gain settings will not normally be changed in flight unless this is required as a back-up to ground simulator studies. Take-off and landing will be with the normal yaw mode and no afterburner will be used.

2. Normal Yaw (Roll and Pitch Disabled)

As for emergency yaw system.

3. Normal Yaw and Roll (Pitch disabled)

Three flight conditions will be checked.

M = 0.70 at 20,000 ft.

M = 0.95 at 30,000 ft.

M = 0.60 at 30,000 ft.

At the third flight condition normal mode, gear down will be checked, using the switch which allows this test to be made with the undercarriage raised.

4. Complete Normal Mode

Five flight conditions will be checked.

M = 0.70 at 20,000 ft.

M = 0.95 at 30,000 ft.

M = 0.60 at 30,000 ft.

M = 0.70 at 40,000 ft.

M = 1.40 at 40,000 ft.

Before the fifth flight condition can be checked the afterburner operation must be tested. This will be done at altitude in excess of 25,000 ft.

At the conclusion of these tests a landing and take-off will be made with the normal mode engaged.

5. Static Stability

Static stability parameters will be obtained within the flight envelope.

In particular the following curves will be established.

a) Elevator angle to trim.

b) Elevator angle per 'g'.

c) Stick force to trim.

d) Stick force per 'g'.

e) Rudder angle per degree of sideslip.

f) Rudder force per degree of sideslip.

Pilots familiarization and assessment will be continued during this phase.

In particular the following points will be noted.

1. Speed brake operation - effectiveness.

2. Engine handling - afterburner operation.

All systems which have been instrumentated at this time will be monitored with regard to those items given in the Part 2 program.

5.4 Part 2 Testing

The object of this part of the program will be to complete the requirements of Phase 1. The bulk of the flying will take place at this time. Tests may be divided into several sections. It will be noticed that most of the flying is concerned with the Stability and Control in order to develop a satisfactory damping system. However, systems will be monitored during these tests and a certain number of specific tests are required as noted.

1. Stability and Control

As a result of Part 1 testing a small portion of the flight envelope will have been examined in a preliminary manner.

The principle of testing will be one of probing flights. A segment of the flight envelope will be examined at each step and each mode of control will be developed within the segment.

In the regions where the natural damping of the aircraft is marginal the aircraft will normally be flown with the damper system operative, but the thresholds will be determined by reverting to natural damping only, for short periods.

Acceptable increments of Mach Number and altitude will depend on day to day results and due regard, will be paid to structural considerations.

One advantage of flying the aircraft with no artificial damping, is that stability derivatives may be derived. Sources of disagreement may then be distinguished between aircraft and damping system parameters.

It is not practical to optimize the damping system at all speeds and height and a number of control points have been chosen at which the majority of testing will take place. Flight at other points will then be examined to determine the degrees of optimization.

DESIGNATION	ALTITUDE	MACH NO.	REMARKS
10 07	10,000	0.7	Low Altitude
10 115	10,000	1.15	High 'q' Low Altitude
20 04	20,000	0.4	Landing Mode
20 07	20,000	0.7	Initial Test Point
20 14	20,000	1.4	High 'q'
30 095	30,000	0.95	Transonic Cruise
30 16	30,000	1.6	High 'q'
40 18	40,000	1.8	Highest available Mach No.
50 115	50,000	1.15	Design Altitude
50 16	50,000	1.6	Design Altitude

The aircraft simulator provides an important tool with which to expedite this program.

"Flights" will be made on the ground to simulate airborne conditions. Any aerodynamic differences noted will be incorporated in the simulator and required changes to the damper system gains will be determined. Thus, as much optimization as possible will be carried out on the ground resulting in a consequent saving in time.

The latter part of the program will be devoted to testing the limiting devices. These are given below:

	Approx. Normal Limit Values
1. 'g' limiter	5.5 'g'
2. Rudder monitor	50% fin design load
3. Roll limiter	120°/sec

Controls on these devices will initially be set at artifically low values and gradually increased to their normal values.

Computer programs have been arranged to examine the results of all tests in detail.

Both static and dynamic stability in the longitudinal, lateral and coupled modes have been considered. Appendices 4 to 10 give details of these programs.

2. Systems Testing

It will be noted in the instrumentation list that a considerable quantity of measurements on systems will be made. In general these measurements will be made during all flights in order to assess the operation of the various systems.

1. Flying Controls
2. Engine and Structural Cooling
3. Air Conditioning
4. Telecommunications and Antennae
5. Fuel System
6. Hydraulic System
7. Electrical System

1. Flying Controls

The operation of the flying control system will be examined under the following headings, using the noted flight instrumentation. Evaluation of faults will be backed up with the ground rig.

a) Pilots Controls

Breakout forces.

Force versus surface deflection.

Effect of damper schedules and damper modes.

Effect of trimming devices.

b) Control Surfaces

Operation of servo controls.

Jack operation.

Effectiveness.

2. Engine and Structural Cooling

All instrumentation will be continually monitored to assess the effectiveness of the cooling system. Particular attention will be paid to the operation of the by-pass gills and blow-in doors. Mass flows through the heat-exchanger system and by-pass will be examined.

The following operational regions are of particular interest.

a) Sea Level Static (Blow In Doors)

b) Low Speed (By-pass gills)

c) Cruise (Normal operation)

d) High speeds high altitude (Critical Cooling Condition)

Levels of temperatures may be assessed from the instrument ranges.

3. Air Conditioning

A considerable ground test program has been carried out on the Arrow 1 air conditioning system which precludes the necessity for an exhaustive flight test program. However, instrumentation has been located at critical points in the system in order to monitor the characteristics relative to the ground test program.

In particular the cockpit and equipment temperature control system will be carefully monitored for stability, and the expansion turbine system will be examined.

Calculated parameter variations may be obtained from the instrumentation lists and the following flight regions will be studied.

a) Low Speed, low altitude.

b) High speed, high altitude.

c) Descent from high altitude.

d) High 'q' high mach number.

e) Accelerations at high altitude.

System deficiencies may require steady state flying in order that a suitable analysis can be made.

4. Telecommunications and Antennae

In conjunction with ground test and associated model tests a short, intensive program will be carried out to establish aircraft antenna characteristics.

These programs will be required before aircraft 4 and 5 are delivered to R.C.A.

The following tests are included.

EQUIPMENT	ANTENNAE	TYPE OF TEST
ARN 6	Loop and Sense	Compensations and Range
ARA 25	UHF Homer	Calibration and Range
APX 6A	L Band (Fin and Belly)	Range and Pattern Verification
ARC 34	UHF (Fin and Belly)	Range and Pattern Verification

Test procedures have already been examined using a CF100 in order to expedite the Arrow 1 program. See Appendix 11.

5. Fuel System

No specific fuel system testing is foreseen. However, the instrumentation is reasonably comprehensive and the following points will be carefully monitored.

a) Fuel Distribution (e.g. control)

b) Pressurization system.

c) Fuel/oil heat exhangers (Fuel tempertures)

d) System Capability.

6. Hydraulics System

Flying Control and Utility Hydraulics are included under this heading. Utility Hydraulics include landing gear, dive brakes and the missile lowering mechanism. The latter system will be subject of Phase 3 testing.

System pressures and temperatures will be measured and monitored.

7. Electrical System

The electrical system is closely associated with all other systems in the matter of controls, switching etc. and as such requires careful monitoring.

Instrumentation is such that this monitoring is available and at the same time estimates of load analysis can be checked.

Operation of the power supply system will be of particular interest.

3. Structural and Aerolastic Characteristics

1. Structural Monitoring

In order to proceed with the flight test program, it will be necessary to ensure that it is structurally safe to do so. Initial tests will be made at low load factors and with limited manoeuvring. A great deal of the testing for Phase 1 may be carried out under these conditions.

With the installed instrumentation (a total of 52 positions have been fitted with strain gauges) it will be possible to assess the stress levels at critical points in the structure and obtain approval to continue to higher factors.

This will be most important during the damper limiter tests.

It is not anticipated that the full structural design envelope will be covered during Phase 1. A more elaborate program for Structural Integrity will be carried out on the Arrow 2.

2. Aeroelastic Characteristics.

Testing the damper system will require flight into regions which may approach the flutter boundaries. Probing flights will be required to assess the flutter characteristics of the aircraft.

The following program is required:

Initial Flights

Control taps will be made at stepped Mach Number at an altitude of 30,000 to 35,000 ft.

All controls will be examined at speeds increasing by 0.05 M from M = 0.80 to M = 1.1.

A total of 18 accelerometers are required distributed as follows:

Fin and Rudder	- 4
Wing	- 6
Aileron	- 2
Elevator	- 2
Fuselage	- 4

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Test Program

1. To evaluate wing flutter clearance

Decay curves from elevator differential servo step inputs will be examined at the above Mach Numbers with altitudes decreasing in steps of 5,000 ft.

2. To evaluate Control Buzz

Decay curves from control taps will be examined at speeds from M = 0.95 to M = 1.35. Commencing at 30,000 ft. and increasing in altitude in 10,000 ft. steps.

This will be followed by a similar program decreasing in altitude in steps of 5,000 ft.

A total of 28 accelerometers are required distributed as follows:

Wing - 16

Fuselage - 4

Fin - 8

If trouble is encountered the complete instrumentation of 57 accelerometers will be used.

4. Performance

It is not intended to carry out generalized performance tests, it will be possible to obtain some data on maximum speeds and altitude performance. It will be seen from the instrumentation lists that engine operating conditions are to be measured, and a very limited amount of analysis will be possible with these parameters.

Position errors will not be determined accurately, in the performance sense, however it is expected that the performance analysis will be made, within the accuracy of the present recording system. See Appendices 12, and 13.

6. SCHEDULE

Specific schedule will not be given in this report. It is considered that the nature of this type of program is such that it is not practical.

However, from an analysis of the foregoing scheduled tests, it would appear that the number of hours required is of the order given below.

It should be noted that the first three Arrow 1 aircraft are required to complete this program in the allotted time.

The instrumentation on these three aircraft is such that they are virtually interchangeable on the program and delays due to grounding will be minimized. Flutter testing will be possible on aircraft 25201 and 25202 only.

TYPE OF TEST	ESTIMATED FLYING HOURS
STABILITY & HANDLING	70
STRUCTURAL	15
ENGINE INSTALLATION	10
AIR CONDITIONING	5
TELECOMMUNICATIONS	10
TOTAL	110

6. SCHEDULE Cont'd

To complete this program of 110 hours flying, together with any unforeseen requirements, a total elapsed time of about 18 months will be needed from the start of the flight test program.

Attached, Sheet 1 shows expected availability of aircraft for Phase 1 Flight Testing.

APPENDICES

Appendix 1	FAR/C105/1 Iss. 7		Instrumentation, A/C 1, 2 and 3.
Appendix 2	Memo 1988/02A/J		Arrow 1 Telemetry Required for Initial Flights.
Appendix 3	Memo 9576/01/J		Minimum Requirements for the 1st Arrow 1.
Appendix 4	71/FAR/4		Control Mass Contribution to Hinge Moment.
Appendix 5	71/FAR/5		Control Surface Hinge Moments Derivatives from Flight Test.
Appendix 6	71/STAB/5		Digital Computer Determination of Lateral Derivatives from Oscillatory Flight Test.
Appendix 7	71/STAB/6		Digital Computer Determination of Lateral Derivatives from Oscillatory Flight Test.
Appendix 8	71/STAB/9		Digital Computation of Response Using an Approximation to Lateral Damper System.
Appendix 9	71/STAB/10		Digital Computation of Response Using an Approximation to Pitch Damper System
Appendix 10	71/COMP A/8		Evaluation of Damper Performance During Flight Test.
Appendix 11	71/SYSTEMS/13/3		Antenna Evaluation Program CF-105
Appendix 12	70/PERF/1		Arrow 2 Test Technique & Instrumentation
	70/PERF/1	App. 1	Arrow 2 Thrust Measurements.
	70/PERF/1	App. 2	Arrow 1 Thrust Measurements.
Appendix 13	71/PERF/2	Iss. 2	Programming for Performance Data from Arrow 1 Flight Test.
Appendix 14	RD. 86		Ground Test Department Summary of Pre-Flight Requirements.
Appendix 15	71/STAB/16		Arrow 1 Digital Computation and Analysis of Arrow Lateral Response in Emergency Mode
Appendix 16	71/STAB/17		Arrow 1 Digital Computation and Analysis of Arrow Longitudinal Response in Emergency Mode

SHEET 1

ARROW 1 — ALLOCATION OF AIRCRAFT

PHASE 1

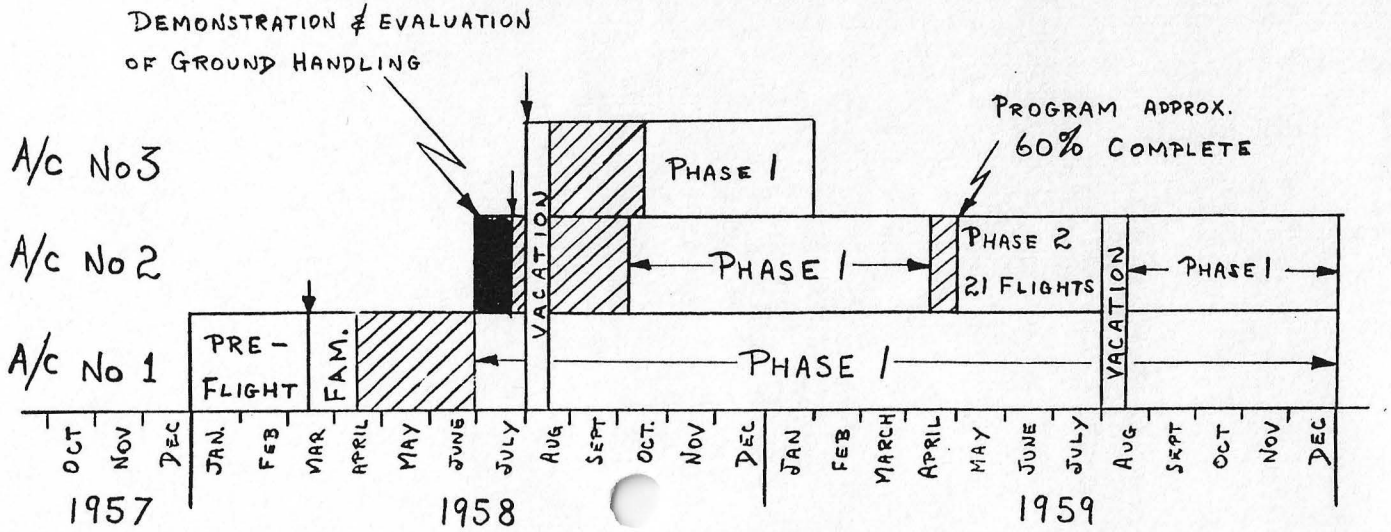
ASSUMPTIONS

1. SEVEN FLIGHTS PER MONTH
2. DURATION OF FLIGHT 3/4 HOUR
3. DATA GATHERING EFFICIENCY 66%

LEGEND

FIRST FLIGHT DATE

A/C ∉ INSTRUMENTATION COMPLETION ∉ COMPANY ACCEPTANCE FLYING.



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