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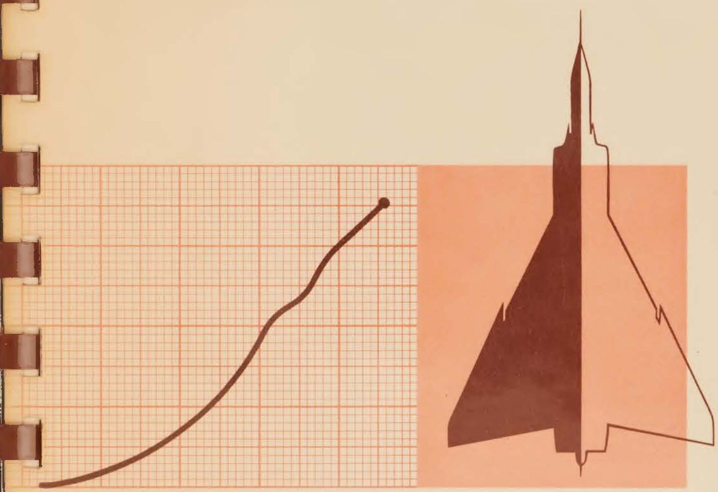

AVRO ARROW

quarterly technical report

FOR THE PERIOD ENDING

June 30 1958

AVRO AIRCRAFT LIMITED

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ARROW

QUARTERLY TECHNICAL REPORT

70/ENG PUB/8

FOR PERIOD ENDING 30 JUNE 1958

Prepared by: PROJECT MANAGEMENT SERVICES
ENGINEERING DIVISION

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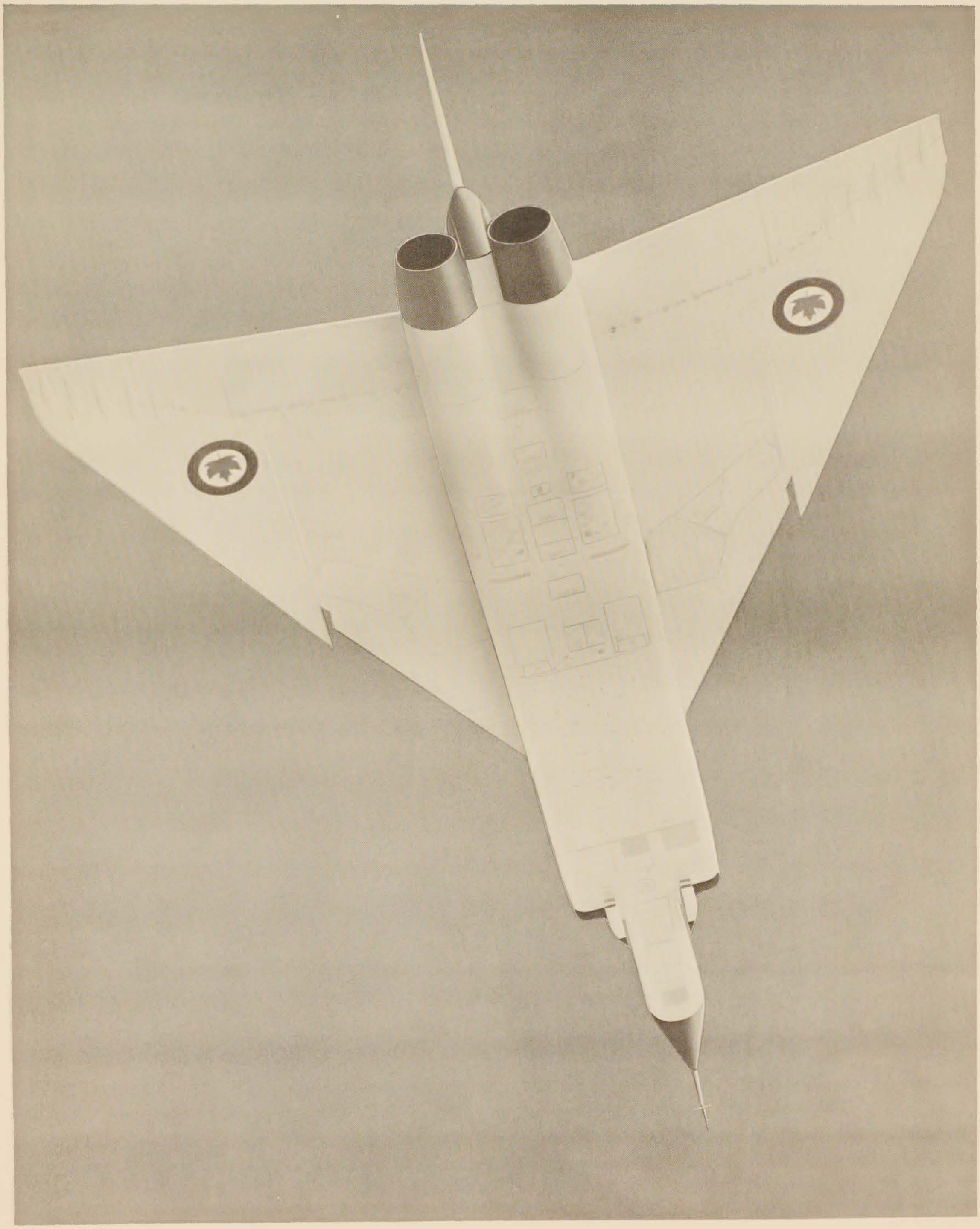

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PART 1

GENERAL INFORMATION

1.0 INTRODUCTION

1.1 SCOPE OF QUARTERLY TECHNICAL REPORT

This is the fourth Quarterly Technical Report on the AVRO ARROW aircraft project. The object of the report is to inform the Canadian Government of technical development of the project during the three months period ending 30 June 1958.

The report presents a description of work performed and the results obtained in the design and development activities of the project; it summarizes technical progress, changes and problems, in all phases of the program during the report period. The text is divided into seven major sections which cover design, testing and development.

1.2 THE ARROW

The ARROW is a high altitude, supersonic interceptor of advanced design, being developed by Avro Aircraft Limited at Malton, Ontario.

There are two versions of the ARROW; the ARROW 1, designed to RCAF specification AIR 7-4 Issue 3, and powered by two Pratt & Whitney J75 turbojets. The ARROW 2 is being designed to RCAF specification WSC 1-2, and is powered by two Orenda Iroquois turbojets. The ARROW 1 is normally considered as an unarmed aircraft used for development purposes, but one aircraft (25203) will be equipped with a weapon pack for simulated air vehicle (SAV) missiles. The first five aircraft will be ARROW 1 and subsequent aircraft will be ARROW 2.

Both ARROW 1 and ARROW 2 have essentially the same basic configuration but the more powerful engines of the ARROW 2 will give it superior performance. The ARROW 2 is designed to operate at altitudes up to 60,000 feet and speeds in excess of Mach 1.5.

1.3 BRIEF DESCRIPTION OF ARROW AIRCRAFT

The ARROW 1 carries a crew of two, pilot and flight observer, in a pressurized and air conditioned cockpit, which is equipped with two split clam-shell type canopies and automatic upward ejection seats.

The airframe is an all-metal stressed skin structure and consists of the following major sections: The radar nose, front fuselage, centre fuselage, duct bay, engine bay, rear fuselage, inner and outer wings, elevators, ailerons, fin, rudder and speed brakes. The elevators and ailerons are hinged to the wing trailing edge, forming part of the wing area. The rudder, elevators and ailerons, are split at about their mid-span position in order to alleviate control surface buckling when the surfaces are moved under deflected wind and fin conditions. The landing gear is an electrically-controlled, hydraulically-actuated tricycle type, with the main gear retracting inward and forward into the inner wing. The steerable nose gear retracts forward into the front fuselage.

The landing gear, wheel brakes, nosewheel steering and speed brakes are actuated by a 4,000 psi utility hydraulic system. A compressed air system is available for emergency lowering of the landing gear. The fully powered and irreversible flying control surfaces are operated by a separate 4,000 psi hydraulic system consisting of two completely independent circuits.

Power for the electrical system is provided by two engine-driven alternators with constant speed drives for alterating current, and two transformer-rectifiers for conversion to direct current.

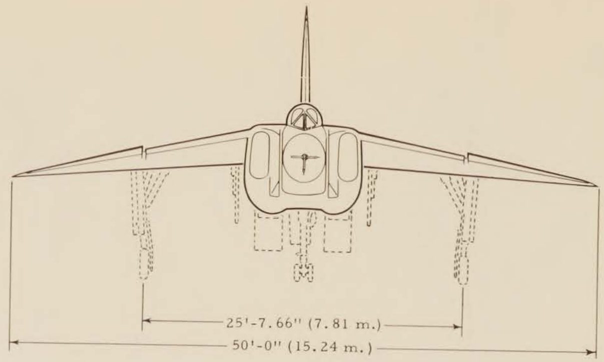
Where necessary space in the radar nose and weapon bay is utilized for test equipment and instrumentation to enable the development aircraft to carry out their designated role as flight test vehicles.

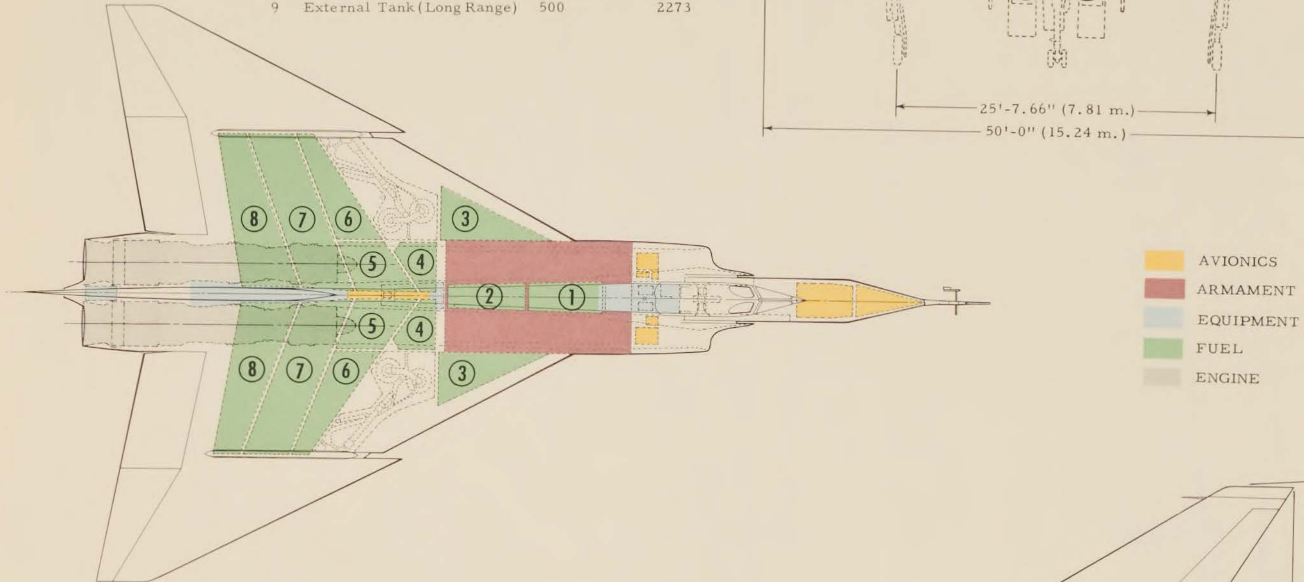
The external configuration of the ARROW 2 is basically the same as that of the ARROW 1. However, there are major internal differences, namely the weapon pack carrying four Sparrow 2D air-to-air guided missiles, installation of the ASTRA I electronic system, and replacement of the J75 engines with Orenda Iroquois engines. Provision is made for a jettisonable external fuel tank, and the mechanical proportioner type fuel system used for centre of gravity control on the ARROW 1 is replaced by an electrically controlled sequencing system.

1.4 FIXED DIMENSIONS AND GENERAL DATA

CHARACTERISTICS:	ARROW 1 and ARROW 2
Length of aircraft (excluding probe)	(77 ft 9.65 in (See Note 1) (76 ft 9.65 in (See Note 2)
Height of aircraft over highest portion of fin	21 ft 3.0 in
Ground angle (Angle between aircraft reference line and ground static line)	4.55 degrees
Tread of main wheels	25 ft 5.66 in
Wheel base	30 ft 1.0 in
WINGS:	
Wing area (including ailerons, elevators and 390.5 sq ft of fuselage and not including 28.63 sq ft of extended leading edge)	1,225.0 sq ft
Span	50 ft 0.0 in
Chord - Root	45 ft 0.0 in
- Construction tip	4 ft 4.98 in
Mean Aerodynamic Chord	30 ft 2.61 in

Tank	Location	Capacity Imp.Gal.	Capacity Litres
1	Fuselage	252	1145
2	Fuselage	254	1155
3	Wing	151 each	686
4	Wing	90 each	409
5	Wing (collector)	146 each	664
6	Wing	154 each	700
7	Wing	279 each	1268
8	Wing	173 each	787
9	External Tank (Long Range)	500	2273





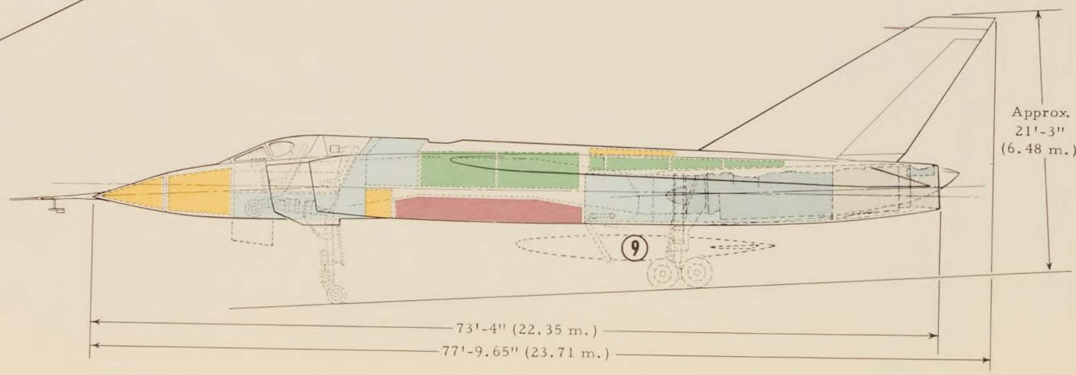


FIG. 2 EQUIPMENT ZONES

CHARACTERISTICS	ARROW 1 and ARROW 2
Airfoil section - Inner wing profile	NACA - 0003.5-6-3.7 (Modified)
- Outer wing profile	NACA - 0003.5-6-3.7 (Modified) NACA - 0003.8-6-3.7 (Modified)
Camber	.0075 (Modified)
Incidence - At root	Zero degrees
- At construction tip	Zero degrees
Anhedral of chord plane	4.0 degrees
Aspect ratio	2.04
Taper ratio	0.0889
Thickness ratio - parallel to ℄ of aircraft	3.5 and 3.8%
Sweepback at 25% chord	55 degrees

AILERONS:

Aileron area (aft of hinge line) - Total	66.55 sq ft
Span	10 ft 0.0 in
Chord (average percent of wing chord) - Root	25.735
- Tip	35.0

ELEVATORS:

Elevator area (aft of hinge line) - Total	106.90 sq ft
Span	10 ft 2.0 in
Chord (average percent of wing chord) - Root	14.109
- Tip	25.735
Vertical tail area (including rudder)	158.79 sq ft
Span	12 ft 10.5 in
Chord Root	19 ft 0.0 in
Construction tip	5 ft 8.0 in
Mean aerodynamic chord	13 ft 6.41 in
Airfoil section	NACA - 0004-6-3.7 (Modified)
Sweep Back - Leading edge	59.34 degrees
- Trailing edge	33.08 degrees
- 1/4 chord	55.0 degrees
Aspect ratio	1.04
Taper ratio	0.2982
Thickness ratio (parallel to aircraft datum)	4.0%
Rudder area (aft of hinge line)	38.17 sq ft
Rudder - Span (average)	9 ft 11.0 in
- Chord (average percent vertical fin chord)	30.0

SPEED BRAKES:

Speed brake area (2) - Projected	14.37 sq ft
Span (each)	2 ft 1.08 in
Chord	4 ft 1.0 in

CONTROL SURFACES AND CORRESPONDING CONTROL MOVEMENTS

CHARACTERISTICS: ARROW 1 and ARROW 2

		Surface Movement	Control Movement
Ailerons:	Up and Down	19°	4.98 in
Elevators:	Up	30°	Aft. 6.63 in
	Down	20°	Fwd. 4.37 in
Rudder:	Left	30°	Fwd. 3.28 in
	Right	30°	Aft. 3.03 in
Speed Brakes		60°	-

Note 1. Aircraft 25201, 25202, 25203

Note 2. Aircraft 25204 and subsequent aircraft

2.0 WEIGHT AND CENTRE OF GRAVITY

2.1 ACTUAL WEIGHING - AIRCRAFT 25201

An actual weighing of aircraft 25201, in accordance with the RCAF requirements stated in CAP 479, chapter 30.03 (5), has been obtained. The results of this weighing will eliminate the need for weighing the aircraft before each flight, except when a weighing is specifically requested. All weight changes, due to modifications or alterations to the aircraft, will in future be applied to the empty weight obtained by this actual weighing.

A comparison of estimated and actual weight and balance data for the operational weight empty (less trapped and residual fuel) is as follows:

	Estimated	Actual
Weight (lb.)	49100	48923
Centre of Gravity (inches from nose datum)	539.92	540.20

The estimated weight given is derived from the basic weight recorded in the final monthly weight and balance report for aircraft 25201 (Report No. 7-0400-44 Issue 16, Aircraft 25201 Weight and Balance, April 1958).

The aircraft basic weight obtained from this weighing, and which will be used in the preparation of Flight Test Weight and Balance reports is 48378 lb. The corresponding centre of gravity position for corresponding to this weight is located 543.97 inches from the nose datum.

2.2 ARROW 2 WEIGHT AND BALANCE

The ARROW 2 weight history is shown in Figure 3. A summary of current weights is given in Table 1, with appropriate foot-notes to explain the weight changes which have occurred during this quarter. Weight accounting, as used in the foot-notes, refers to recorded weight changes arising from minor design changes, revised weights obtained from production drawings, and the incorporation of actual weights or vendor-quoted weights. Significant weight changes occurring for reasons other than normal weight accounting are explained by more detailed foot-notes.

TABLE 1 - STATEMENT OF WEIGHT

ARROW 2 - OPERATIONAL AIRCRAFT

	Weight - Pounds			
	Present	Previous	Change	Notes
Structure	19163	19161	+ 2	(a) + 2
Landing Gear	2658	2584	+ 74	(b) + 74
Power plant and services	10814	10800	+ 14	(a) + 9 (c) + 5
Flying controls group	1932	1927	+ 5	(a) + 5
Fixed and removable equipment	9094	8916	+ 178	(a) + 103 (d) + 41 (e) + 38 (f) + -4
Basic Weight	43661	43388	+ 273	
Useful load (less fuel)	2799	2799		
Operational weight empty	46460	46187	+ 273	
Normal combat mission fuel	17605	17530	+ 75	(g) + 75
Normal combat weight	64065	63717	+ 348	

Notes:
(a) Weight accounting.
(b) Anticipated increase for main landing gear wheels equipped with higher capacity brakes.
(c) Change from an integral to a separate constant-speed drive oil system.
(d) Introduction of retractable snubbers for the main landing gear doors.
(e) Introduction of anti-skid system.
(f) Reclaimed unusable fuel.
(g) Due to increase in operational weight empty.

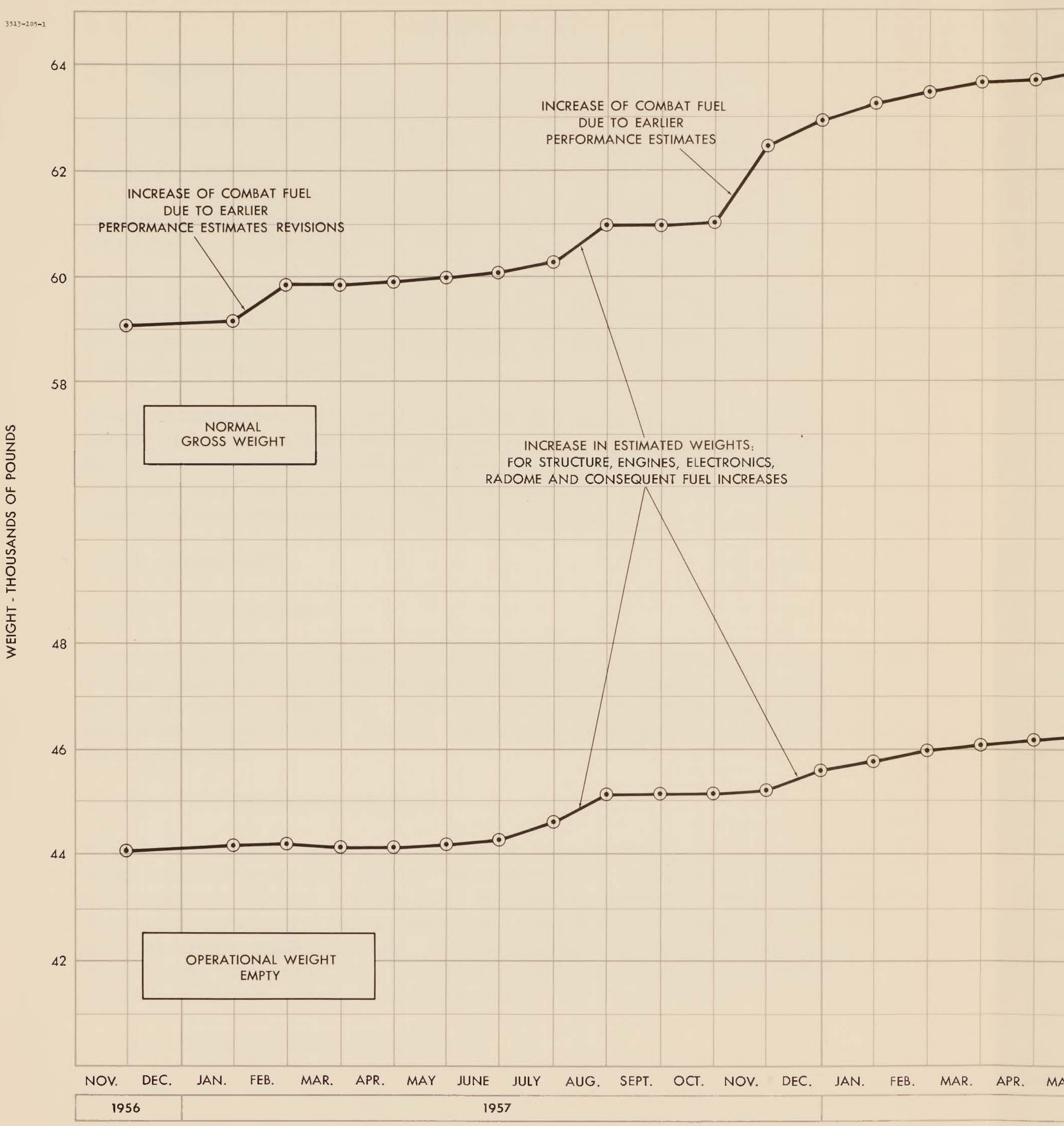
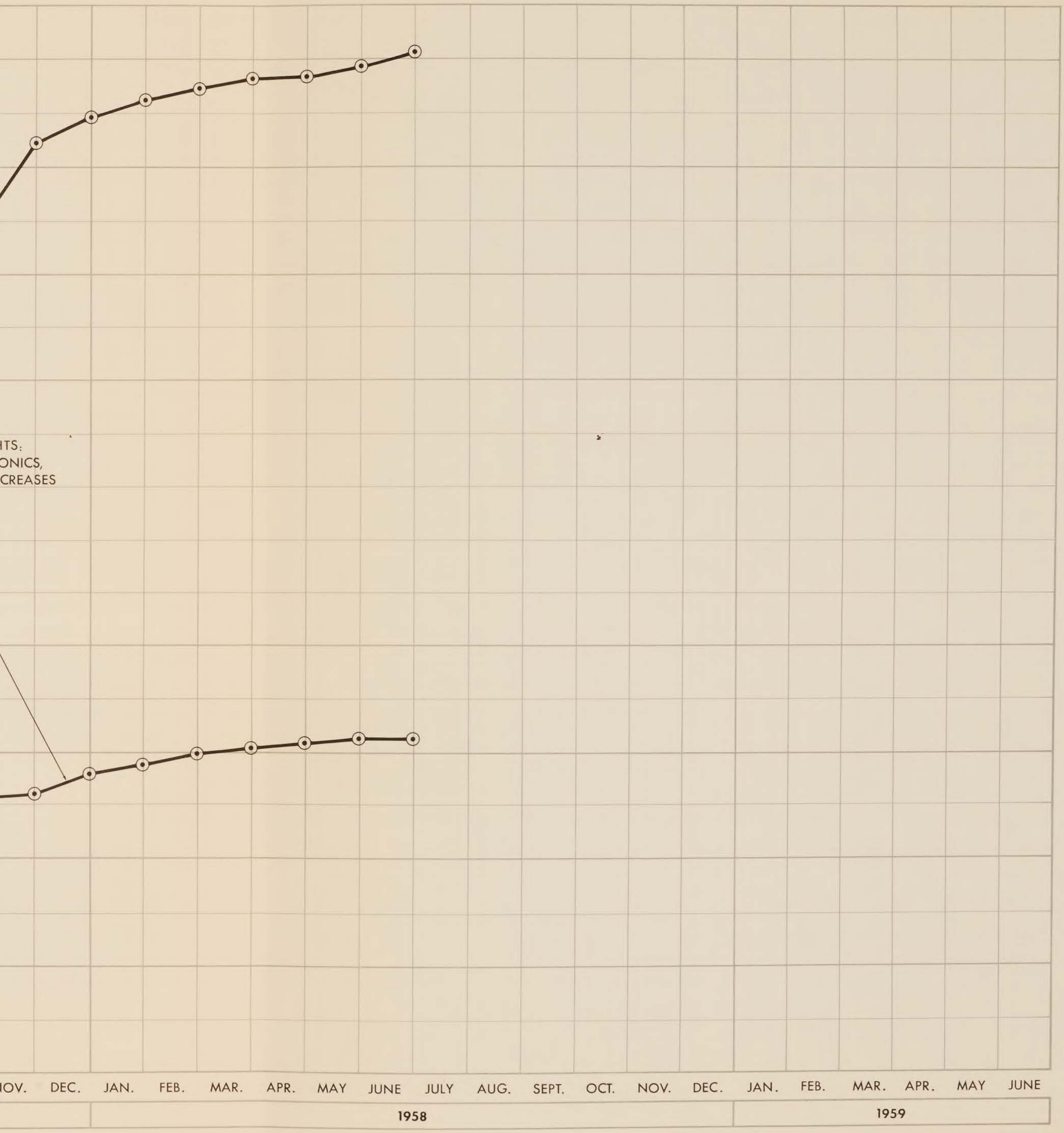


FIG. 3 WEIGHT HISTORY - ARROW 2 - OPERATIONAL



HT HISTORY - ARROW 2 - OPERATIONAL AIRCRAFT

3.0 PERFORMANCE

3.1 ARROW 1

3.1.1 FLIGHT TEST ANALYSIS

3.1.1.1 General

An analysis of the take-offs and landings for the first nine flights of aircraft 25201 has been completed.

During these flights, no attempt was made to obtain optimum take-off and landing performance. The test results however, will confirm or dispute the estimated take-off and landing distances, and should assist in establishing a practical piloting technique.

From photographed time histories of height and runway distance, ground speeds and accelerations were calculated by first and second derivatives of the time versus distance curves. The true airspeeds and lengths of run were corrected to standard sea-level conditions, zero wind and zero runway slope, and are referred to as "flight test" data.

3.1.2 TAKE-OFF

3.1.2.1 Ground Run

At an average take-off weight of 65,750 pounds, and with afterburners off, the average estimated and the average flight test ground runs were 3,750 feet and 4,452 feet respectively. This increase over the estimated ground run is attributed to high unstick speeds, which were approximately 30 knots higher than estimated.

3.1.2.2 Air Distance to 50 Feet

With the conditions noted in para. 3.1.2.1 the air distances to a height of 50 ft. were considerably shorter than estimated. (estimated - 6,300 feet; flight test - 2,715 ft.). In this case the shorter distance is due to the total effect of maintaining a low acceleration, combined with a more rapid climb, and also higher unstick speeds. This resulted in an increased net accelerating force, since total drag is considerably reduced at the lower angle of attack associated with the increased speed.

3.1.2.3 Total Distance to 50 Feet

In all flights with afterburners off, the shorter air runs more than offset the longer ground runs, resulting in approximately 30% shorter total distance to 50 feet than had been estimated.

3.1.3 LANDING

3.1.3.1 Air Distance From 50 Feet

For the first seven flights, the average air distance from 50 feet to touchdown was approximately 38% shorter than estimated (estimated - 2,670 feet; flight test - 1,983 feet, at an average aircraft weight of 53,650 pounds). Flights number eight and nine had longer air runs, the average of which was approximately 12% more than had been estimated. These two flights had long floating periods prior to touchdown, at which point the aircraft speed was approximately 15 knots over the estimate.

3.1.3.2 Ground Run

The lengths of ground runs were not obtained, as the aircraft was not brought to a full stop after landing, and no attempt was made to achieve maximum braking.

3.1.4 REMARKS

The considerable difference between estimated and flight test speed (the latter being the higher), for both take-off and landing, is probably a good indication of the overall position error (with ground effect) and/or the pilot's choice of attitude to obtain better visibility.

Flight test results have been used to modify the existing input data and non-dimensional curves, which are used in the process of estimating performance.

3.2 ARROW 2

3.2.1 ZOOM CEILINGS

An investigation has been completed to ascertain the gain in altitude which could be achieved by the ARROW 2 through zoom climb tactics. This has revealed that for all supersonic initial speeds within the flight envelope and with afterburners operating, the maximum altitudes reached during a zoom, represent a considerable increase over the 1g power limited ceiling, with a maximum increment of approximately 12,000 feet.

With initial speeds of Mach 1.0 to 1.5, the maximum altitude which can be reached in a zoom climb, with continuous afterburner operation, is limited by afterburner flame-out. The zoom ceiling is limited by afterburner flame-out first, and beyond this point, by the elevator trim limits or buffet. Of course, zoom ceilings could be increased if zooms were continued after flame-out of afterburners, until limited by elevator trim limits or buffet.

Several zoom cases have been considered to determine the optimum initial load factor and angle of climb for the greatest gain in altitude, (from various initial Mach numbers and altitudes). The initial load factors were held only until the desired climbing angle was established, after which they were reduced to normal. The angles of climb used in the calculations were 30°, 20° and 10°. In every case the 10° climb angle gave the maximum zoom height increment and in general, close to the minimum time taken to reach a given altitude.

Figure 4 shows that, starting with an initial Mach number of 2.0 at the 1g power limited ceiling of 58,000 feet, the ARROW 2 can be zoomed, with a 1.5 g initial load factor, to an altitude of 70,000 feet and 1.65 MN. At this altitude, afterburner flame-out will occur. For a starting Mach number of 1.5 at the 1g power limited ceiling of 57,500 ft., and with an initial 1.25g load factor, the aircraft can be zoomed to an afterburner flame-out altitude of 62,000 feet and a Mach number of 1.3. If no flame-out is assumed, this ceiling can be raised to the 1.2g buffet limit at 67,000 feet and a Mach number of 1.1.

As shown on the graph (Figure 4), the aircraft, with present afterburner flame-out limitations, could maintain an altitude of 65,000 feet for 2.43 minutes, starting at 1.79 MN and finishing at 1.43 MN.

3.2.2 N_H CONTROL EFFECTS

Avro has been advised by Orenda, that the "overspeeded" Iroquois engine, with the N_L (low pressure compressor speed) governed control system, will be replaced by engines having a N_H (high pressure compressor speed) governed control system. An analysis of the effect of this control system change has revealed that the performance of the ARROW 2 propulsion system will deteriorate with any increase over 288°K in the free stream temperature, since only at this temperature is maximum RPM possible on both rotors at the same time.

At M = 1.5, at 50,000 feet, the loss in propulsion system net thrust is 0.5% where T (free stream temperature) = 314°K. Thrust loss tends to increase to approximately 4% between M = 2.0 and M = 2.3, at 50,000 feet where T is greater than 390° or less than 446°K. However, these losses beyond M = 1.5, may be reduced by the installation of a T-bias along with the N_H control. Reference: 72/INT.AERO/16 - Loss in Thrust of Iroquois Installation with N_H Control rather than N_L "Deluxe" Control. - May 1958

3.2.3 DISTORTION LEVELS AT COMPRESSOR FACE

An investigation is in work to determine the extent of the variation in pressure over the engine compressor face, and the influence of such variations on the propulsion system performance.

Air flow disturbances arising from shock waves, and their interaction with the ramp boundary layer, plus the forced change in airflow direction at the intake

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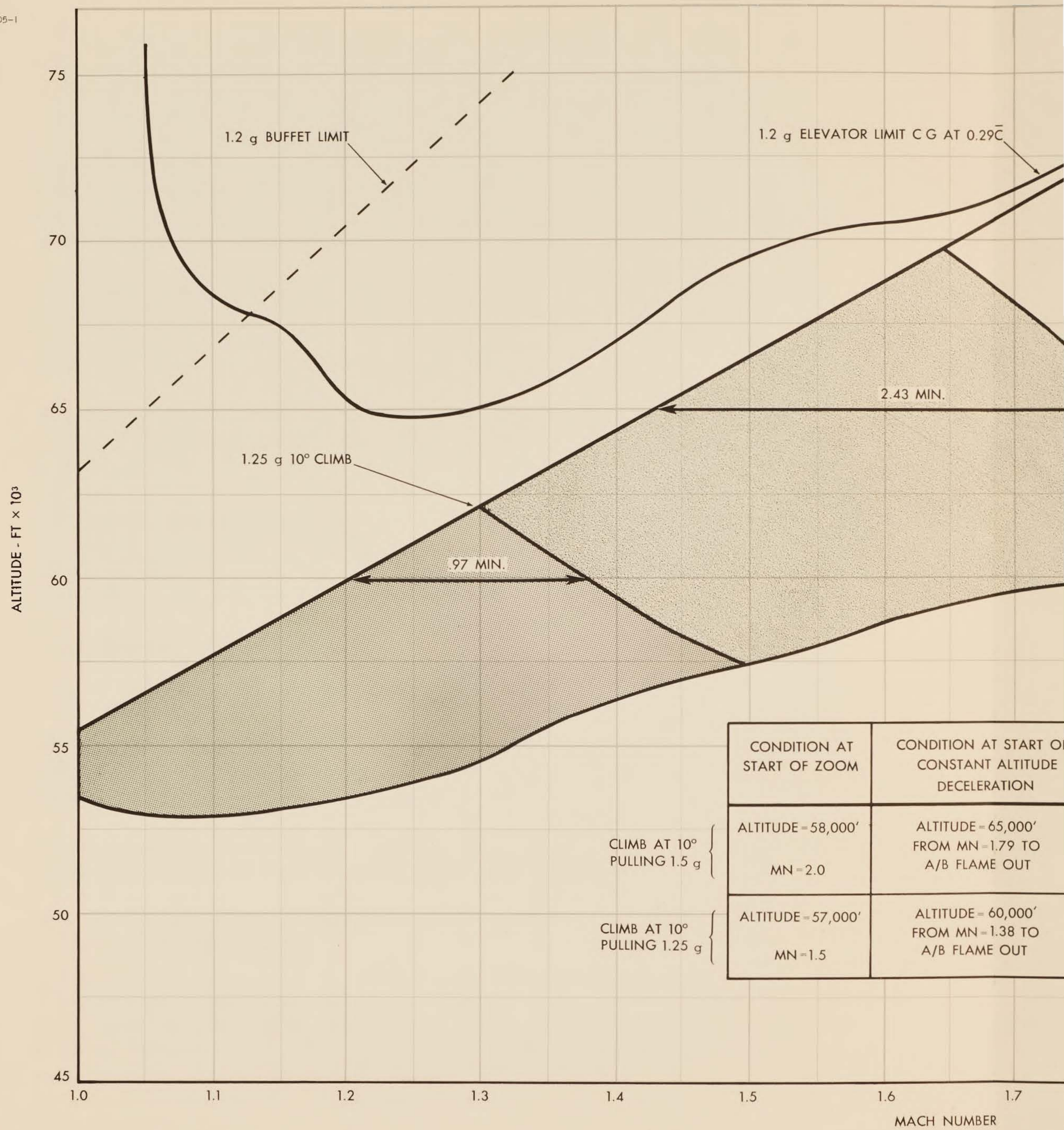
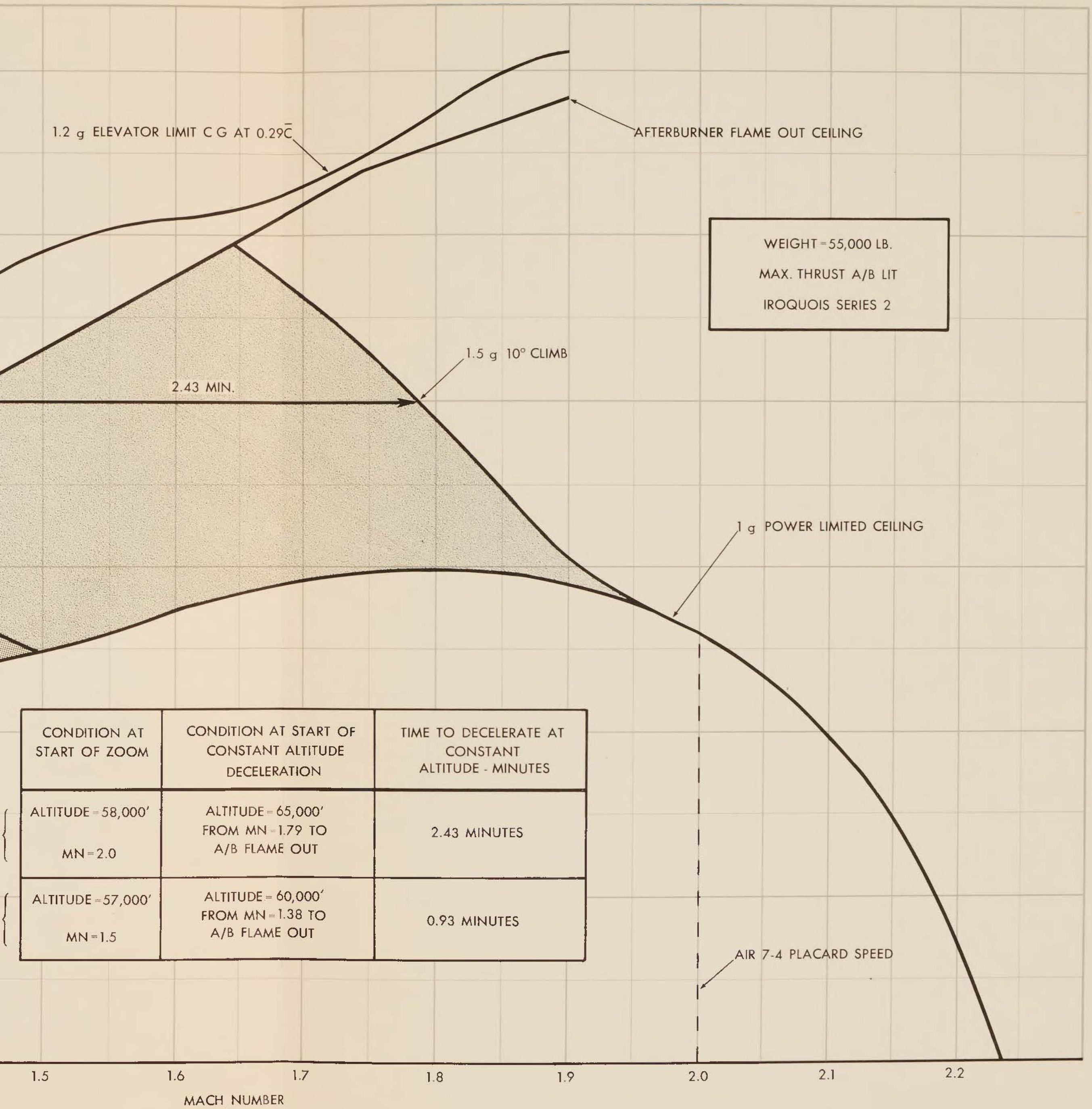


	CONDITION AT START OF ZOOM	CONDITION AT START O CONSTANT ALTITUDE DECELERATION
CLIMB AT 10° PULLING 1.5 g	ALTITUDE = 58,000′ MN = 2.0	ALTITUDE = 65,000′ FROM MN = 1.79 TO A/B FLAME OUT
CLIMB AT 10° PULLING 1.25 g	ALTITUDE = 57,000′ MN = 1.5	ALTITUDE = 60,000′ FROM MN = 1.38 TO A/B FLAME OUT

FIG. 4 ZOOM CEILINGS - ARROW 2



CONDITION AT START OF ZOOM	CONDITION AT START OF CONSTANT ALTITUDE DECELERATION	TIME TO DECELERATE AT CONSTANT ALTITUDE - MINUTES
ALTITUDE = 58,000′ MN = 2.0	ALTITUDE = 65,000′ FROM MN = 1.79 TO A/B FLAME OUT	2.43 MINUTES
ALTITUDE = 57,000′ MN = 1.5	ALTITUDE = 60,000′ FROM MN = 1.38 TO A/B FLAME OUT	0.93 MINUTES

FIG. 4 ZOOM CEILINGS - ARROW 2

throat, give rise to irregularities in the total pressure pattern across the intake air flow. These are partially reduced by the intake duct length. However, other disturbances are introduced by duct bends, sensing devices, reversed scoops etc., so that the final pressure pattern over the compressor face is variable. A measure of this variation in total pressure is referred to as "distortion". This may be defined as the difference between the maximum and minimum total pressures and is expressed as a percentage of the average total pressure over the compressor face, excluding the boundary layer regions at the nose bullet and duct wall.

Two effects arising from pressure distortion are induced rotor blade vibration and local "hot spots" through the engine. Therefore, to prolong engine life, distortion levels must be minimized. No figure has yet been established as an acceptable level for the Iroquois Series 2 engine.

The distortion expected on the ARROW 2 has been estimated from thrust calculations and experimental data using 1/6th and 6/10th scale model tests. It has been shown that the distortion level will not exceed 12% for afterburner off and full afterburner on cases, at maximum RPM and throughout the flight envelope. The distortion level at subsonic and supersonic cruise will also be kept to within 12% by reducing the bypass flow restrictor area. Orenda requires that the restrictor be relocated, and the modification to reduce the restrictor area can be made at the same time.

3.3 TACTICAL EVALUATION

3.3.1 DIGITAL COMPUTER PROGRAMS

Midcourse Guidance Under Sage Control - The mathematical model for this study is nearing completion, and the programming for IBM 704 computation should be completed during the next quarter.

Terminal Phase Evaluation - The programming for this study is nearly complete and computer results will be available shortly.

3.3.2 EFFECT OF STEERING LOOP GAINS ON INTERCEPTION CAPABILITIES

The Quarterly Technical Report for March 1958, stated that the steering loop gain could be reduced to one-quarter of its present value, without loss of tactical effectiveness. This has not bee confirmed by an extended study of considerably increased scope. The statistical analysis of a large amount of data has shown that the conversion probability falls off very sharply if the gain is reduced below one-half of its present value. However, the earlier conclusions were confirmed concerning the increase of firing errors with the reduction of the gain. Investigations have only been conducted on the Sparrow missile, and the results do not therefore give quantitative evidence concerning Genie. However, they do indicate that it may be impossible to achieve the accuracy required for the launch of Genie in the automatic mode, for any amount of steering loop gain.

3.3.3 SEEKER LOCK-ON RANGE REQUIREMENTS FOR THE SPARROW 2D MISSILE

On 30 June 1958, U.S. contracts on the Sparrow 2D missile development and testing program will expire. The subsequent development of this missile system will be largely Canadian sponsored. In view of this, and since the missile system did not meet the original specification, it has been suggested that a new specification be written to define the performance required for the ARROW weapons system. (Ref. Report No. 72/Tactics/11, Seeker Lock-On Range Requirements for the Sparrow 1242D Missile, June 1958).

An investigation has been made to determine the minimum values for missile seeker lock-on range, which will enable the missile to function as suitable armament for the ARROW 2 aircraft.

It is considered essential that the lock-on range, and the lock-on detection delay in non-automatic operation should be made compatible with attack capability at all aspect angles; (this angle being between the line of sight from interceptor to target, and the target's direction of motion).

3.3.4 IFF BLIND REGIONS

The location of the X-band antenna in the vertical fin is such that the downward coverage by the APX-27 IFF transponder is limited in the forward hemisphere. In addition, a blind area exists below the aircraft, in which no response to IFF interrogation from another interceptor is possible. As a result, a condition may arise in which one aircraft, operating in the blind region of another, may attack the other, assuming it to be hostile, in the absence of a correct response.

Reference: Para. 7.5.9, Quarterly Technical Report - 31 March, 1958.

4.0 STABILITY AND CONTROL

4.1 STABILITY AND CONTROL DIGITAL ANALYSIS PROGRAMS

A series of programs has been prepared to facilitate flight test data analysis by automatic means, and to reduce the need for the manual handling of such data. These programs will determine, by digital computation of recorded flight data, the aerodynamic derivatives which govern the transient or oscillatory response of the aircraft, due to control motion.

The present response analysis programs include lateral and longitudinal aircraft motions for the natural aircraft and the normal and emergency damping modes. These programs may eventually include all degrees of freedom simultaneously for the various modes.

Provision has been made to adapt these programs to flight cases where certain channels of information may be missing, due to sensor or recording equipment malfunction. This will be accomplished by utilizing digital techniques of differentiation and integration.

These programs have only a limited application to the early flights of the ARROW, since full instrumentation is not yet available. In addition, the digitizing equipment, designed to work with data tape, is not yet in operation and therefore, the fully automatic analysis of data cannot be made. However, by the manual insertion of flight recorded data into these programs some results will be obtained, when minimum instrumentation requirements are met.

4.2 DAMPER SYSTEM

Difficulties have been encountered in the roll and pitch damper.

The dynamic response of the differential servos was found to be inadequate due to the linkage elasticity and required modification. Further tests and evaluations are in progress.

An interim solution exists for the stick steering mode oscillation problem. An experimental electronic filter was introduced into the circuitry and acceptable results were obtained. Certain characteristics cannot be represented faithfully on the test rig, and it will be ncessary to confirm these results on the aircraft, by performing a simulation test with the aircraft connected to the computers. A filter, designed specifically to eliminate stick oscillation, has been ordered from Honeywell, but delivery is not expected until December 1958. Efforts to improve the characteristics of the experimental filter will continue, so that damper development will not be delayed.

An investigation has been made to determine the causes of a persistent 1 cps oscillation in the normal and emergency yaw dampers. The oscillations are of varying amplitude, depending on the flight condition. Although not critical from any point of view, they are an undesirable characteristic, and result in small lateral accelerations, noticeable to the pilot.

The possible causes of these oscillations could be related to the following:

(a) A too-sensitive aileron feel.

(b) Electronic filter characteristics.

(c) Lateral accelerometer location and mounting.

(d) Variations in aerodynamics derivatives.

(e) Variations in damper settings.

(f) Quadrature rejection circuitry in the damper.

These points have been investigated in detail on the flight simulator, and it was found that by moving the lateral accelerometers to a forward position the oscillatory tendency could be reduced. In order to determine the optimum location for the accelerometers, a thorough examination of the damper was made over the entire flight envelope. This change of position was made on aircraft 25201 and flight evaluation was satisfactory.

4.3 OBJECTIVES OF THE FLIGHT TEST PROGRAM

The overall objective of this flight test program is to demonstrate that an acceptable pilot - controls - aircraft combination has been achieved. The particular objectives are as follows:

(a) To demonstrate that the control system is mechanically satisfactory.

(b) To demonstrate that the feel and trim characteristics are acceptable in all control modes.

(c) To demonstrate that all required manoeuvres can be performed safely, from the control standpoint.

(d) To demonstrate that the damping system equipment is free from oscillations or spurious signals and is compatible with the emergency control mode.

(e) To demonstrate that damper action results in proper co-ordination and damping during manoeuvres.

(f) To demonstrate performance of limiting devices where practical.

(g) To investigate the in-flight effects of partial failures in the damper system.

(h) To demonstrate compliance with Military Specifications on aircraft handling and structural integrity.

The program has been arranged into one continuous project to combine the testing of the principle areas of interest:

4.3.1 FLYING CONTROL DEVELOPMENT TESTS

Evaluation of pertinent control system characteristics can be conducted simultaneously with the stability and control test. General flying, under various flight conditions will provide all the information required.

4.3.2 STABILITY AND CONTROL ASSESSMENT TESTS

The main objective of these tests is to evaluate stability derivatives. In order to accomplish this, a number of specific manoeuvres are required. A similar type of manoeuvre is required at each of approximately 17 selected Mach number and altitude conditions.

The extent of these tests depends on agreement of flight test data with predictions. Should a reasonable agreement be obtained at a relatively small number of test points throughout the flight envelope, the amount of testing will be reduced to a minimum.

4.3.3 DAMPER SYSTEM DEVELOPMENT TESTS

For the purpose of damper development, the flight envelope of the ARROW will be represented by ten flight conditions agreed to by AVRO and Honeywell. The damper performance will be examined in detail at these flight conditions and the test results will be projected into the remainder of the flight envelope.

4.3.4 STRUCTURAL INTEGRITY DEMONSTRATION

Since only a limited amount of structural integrity instrumentation will be available, it will not be possible to extend the demonstration to full design limits. Due to controllability conditions, each manoeuvre will be investigated in detail on the flight simulator. This investigation will be based on flight test aerodynamic data previously obtained. A step by step method will be applied in which the results from the first tests will be extrapolated analytically to provide an exact prediction for the next step. Particular attention will be paid to the rolling pull-out type of manoeuvre. Due to cross coupling effects, this manoeuvre tends to produce large structural loads in the majority of flight conditions, while in the dampers-off configuration. The normal damper mode will be used in these tests so that excessively large loads will be avoided. An exact knowledge of damper performance is therefore required for these tests, together with firm predictions as to the behaviour of its limiting devices.

These topics have been combined so that the entire program can be executed economically. Flight test information is required simultaneously on all the foregoing topics in order to proceed with development in the most efficient manner. In addition, in order to explore certain parts of the flight envelope, the damper system must be in working order and checked out quantitatively. Finally, structural integrity testing (due to controllability problems in certain areas) must be combined with the development of the damper and associated limiting devices.

4.4. DEMONSTRATION PROGRAM

The object of the demonstration program is to show compliance with Specification MIL-F-8785, "Handling Qualities of Piloted Airplanes". For these tests, the flying control system and the damping system must be fully developed. The program will consist of demonstration flights covering a number of specific manoeuvres. At this stage of the flight test program, a number of flights required by the specification will have been completed in the course of the development. As much as possible of this information will be used to demonstrate the compliance with the specification. For this reason, a full coverage of the specification requirements will not be necessary in the demonstration and only manoeuvres and flight conditions not previously tested will be included in this program.

4.5 WIND TUNNEL TESTING

4.5.1 MISSILE COCOON JETTISON TESTS

A series of low speed wind tunnel tests has been proposed in order to investigate the jettison characteristics of the missile cocoon design proposals.

For the initial tests, a blower tunnel (10 x 5 inch nozzle) will be used with .07 scale model cocoons, mounted on a large flat plate. It is expected that these tests will determine which configurations will warrant further investigation.

A second series of tests will be conducted using the NAE low speed tunnel and .07 scale models of the cocoons and aircraft. These tests should establish an optimum design for jettison characteristics.

A third and final series of tests again using the .07 scale model in the NAE low speed tunnel, will investigate in detail, the final model cocoon configuration selected from the second series of tests.

4.5.2 AIR DATA NOSE BOOM - ARROW 1

Pitot-static probe - Anti-icing tests have been conducted at the NAE low temperature laboratory, using the 5 x 8 inch blower tunnel. These tests were conducted in order to prove heater design and to determine the power distribution required to meet the specific anti-icing conditions recommended by NRC.

The tests performed to date have been for development purposes and do not cover all the possible conditions. However, the results indicate that heating intensities and distribution are satisfactory, but a control should be incorporated to prevent overheating, when maximum heat input is not required.

Relative wind sensor - To date, only limited anti-icing tests have been completed, using the same facilities as for the pitot-static probe. Test results indicate that, with sufficient power applied, the "bob" and vane post heaters are adequate. However, the vane support should be heated along its entire length and the vane leading edge will require additional heat.

Testing of the complete assembly (i.e. pressure probe and both relative wind sensors) has not yet been conducted.

4.5.3 IR POD INSTALLATION ON FIN

The vertical fin and rudder from the .04 scale ARROW model, equipped with a removable IR pod, is being tested in the 16" by 30" NAE supersonic wind tunnel. The purpose of the test is to determine the effects of the IR pod installation of the previously established fin and rudder side force coefficients, the fin centre of pressure and the rudder hinge moment data.

4.5.4 SPIN AND RECOVERY CHARACTERISTICS

This testing program has been delayed while the NAE wind tunnel facilities are undergoing modification (Ref. previous Quarterly Technical Report, 70/ENG PUB./6).

4.5.5 POST STALL GYRATION TESTING

Model launchings to date have shown that model retrieving remains a problem and is causing considerably delay. The preliminary development work for these tests has been NAE's responsibility. In order to hasten progress, AVRO will take a more active part in future testing.

6.0 THERMODYNAMICS

6.1 AIR MASS PROPERTIES

A study of North American air mass properties, from ground level to 50,000 feet, is in work. The object of the study is to show, statistically, the average deviation in temperature, at various altitudes, from that given by standard atmospheric data.

6.2 ALTERNATOR COOLING (ARROW 1)

More accurate test data on the electrical load, power factor and efficiency of the 30 KVA alternator has become available since the previous Quarterly Technical Report. Calculations, based on this new data, have been made to determine the conditions necessary for adequate alternator cooling.

For a minimum electrical load of 23 KVA, a power factor of 0.92 and efficiency of 88%, adequate cooling will be provided within the flight envelope of the aircraft to an altitude of 55,000 feet on a standard day. Under hot day conditions, adequate cooling will be provided to an altitude and Mach number envelope as shown on Figure 5. Flight conditions within the shaded portion of the graph may result in overheating of the alternator.

Reference Report: No. P/EQUIP/61 - APPENDIX I AND II - ARROW 2 Alternator Cooling - June 1958.

6.3 ANTI-ICING OF J75 ENGINE NOSE BULLET

An analysis of the nose bullet anti-icing provisions for the ARROW 1, with the double-skin nose bullet design, has been completed, using revised data from Pratt and Whitney.

For the P-3 (prototype) and the P-5 (production) engines, the nose bullet anti-icing provisions were found to be adequate, under all stabilized flight conditions. Under sea level engine idling conditions (static), the anti-icing provision is adequate for ambient temperatures above -10°C for the P3 and above -15°C for the P-5 engines.

Calculations to determine the adequacy of the porous nose bullet anti-icing are still in work.

6.4 DRAG PARACHUTE TEMPERATURES - ARROW 2

Calculations indicate that parachute temperatures, in the stowed position, do not exceed 250°F. The maximum mean parachute temperature, in this position, is proably in the order of 150°F. However, through radiation and convection heating of the stowage box, the parachute may reach local temperatures of up to 250°F.

With the parachute streaming, the maximum temperature expected anywhere on the parachute, under the worst possible conditions, is estimated to be 350°F. There is a possibility that hot spots of up to 400°F may occur near the joint of the shroud lines and risers. It is also estimated that the time of maximum temperature exposure, in the streaming case, is approximately five seconds.

Reference: Report No. 72/THERMO/28 - Parachute Temperatures - May 1958.

6.5 TRANSIENT FUEL TEMPERATURES ON ARROW 2

An analysis has been made of transient fuel temperatures at the engine fuel inlet on the ARROW 2. This analysis indicates that, with the present oil cooling system configuration, it is possible to obtain high fuel temperatures at the engine inlet during transient conditions within the aircraft flight envelope. These high fuel temperatures are due to the presence of fuel-oil heat exchangers which do not incorporate fuel overheat control devices.

High fuel temperatures are hazardous from the point of view of engine fuel pump cooling, formation of fuel vapour in the system and fuel breakdown causing gum deposits. The critical conditions at which the hazards exist, are those where fuel flow is small, and oil temperature is high, with little or no cooling air available. These conditions are found during:

(a) Sea level static idling RPM.

(b) High Mach number at idling RPM.

Since the latter case is the more critical, due to extremely low fuel flow at idling RPM at high altitude, the analysis of the fuel temperature has been based on a descent from 60,000 feet at M = 2.0, and a 90% recovery temperature (T_R) of 250°F. This assumes that the throttles are instantaneously moved back to idling from maximum RPM-plus-afterburner and the aircraft put into a dive to maintain T_R = 250°F. A peak fuel temperature of approximately 295°F is estimated to occur at the beginning of the 30-second transient condition during descent.

With the pressures expected at the engine fuel inlet, JP-4 fuel will vaporize at 200 to 250°F. As a result, the formation of vapour in the engine fuel pump appears to be certain. It has not yet been determined whether the pump and fuel control systems can function satisfactorily with vapour present during the transient period.

Some alleviations to high fuel temperatures may be accomplished by various oil system modifications designed to reduce the oil inlet temperature to the cooler. An increase in idling fuel flow at altitude would also contribute to reduced fuel temperatures.

7.0 ELASTICITY

7.1 EFFECT OF ACCELERATION ON TEMPERATURES AND THERMAL STRESS DISTRIBUTION

The rapid acceleration of an aircraft capable of supersonic speeds may result in such a degree of aerodynamic heating that the structural integrity is threatened. Although of a transient nature, the thermal stresses produced by the heating may develop into warping, buckling and loss of stiffness. In order to cope with these detrimental heating effects, a study has been made to determine the manner in which temperature distribution and thermal stress distribution are influenced by various factors. Some of these factors are flight conditions, material, the presence of structural discontinuities (such as joints), size of structure and the depth of fuel contained in the tanks. The study provided information, in a non-dimensionalized form, indicating the trend in influence of the various factors. This will provide quick and fairly accurate values to determine the thermal stresses. Reference: Report No. 70/THERMO/26 - Effect of Acceleration on Temperature and Thermal Stress Distribution - April 1958.

7.2 ARROW 1 DEFLECTION INFLUENCE COEFFICIENTS

As was reported in section 6.2 of the Quarterly Technical Report for March 1958, the ground resonance test of the complete aircraft provided data that did not entirely agree with data predicted through calculation. In order to obtain agreement between test result and theory, the stiffness values of the outer wing and fuselage have been revised.

Outer wing - The spanwise bending stiffness of the leading edge and rear spar regions has been increased through the inclusion of structure not previously considered effective. The leading edge region, in chorwise bending, was also increased in stiffness. These changes increased the outer wing torsional stiffness for a small increase in bending stiffness.

Fuselage - Originally the torsional stiffness of the fuselage was estimated assuming warpage of the structure. This method of calculation has been replaced by one (the Batho method) in which restraint against warping has been assumed. The revised values from this method were used in calculations for the anti-symmetric cases.

The bending stiffness was originally estimated assuming the centre portion of the fuselage "floor", between the engines, to be ineffective in reacting bending loads. This raised the calculated fuselage bending frequencies to compare very favourably with test results.

The alterations to the stiffness distribution have improved the correlation of theory with ground resonance test results. The antisymmetric modes are in good agreement with test results. Several modes were predicted which were not found on test, but all test modes appear in the theoretical calculations. Agreement has also been established between theory and test result in the symmetric modes, with the exception that the second mode shape differs from the test results in the outer wing region. The revised stiffness values, which are now in agreement with ground resonance test results, will be used in revised flutter calculations.

8.0 ELECTRONIC SYSTEM

8.1 MINIMUM ASTRA SYSTEM

By means of a realistic assessment of development time allowances, it is now possible to define the minimum ASTRA system capability which can be made available for delivery to squadron service in January 1961. In order to expedite availability of the additional portions of full ASTRA, not included in the minimum system, it is proposed, where possible, to fabricate these in parallel with the minimum system and to store them for subsequent retrofit to aircraft after RCA and AVRO testing.

The minimum ASTRA system (ASTRA MK 1A) has been defined as the minimum electronic system which will enable the ARROW interceptor to perform a combat mission. The minimum system consists of:

(a) A fire control sub-system capable of manual or automatic attack and manual manoeuvring with four Sparrow 2D missiles (less infra-red, radar operation at full power, Genie capability and certain ECCM capabilities).

(b) UHF communication and homing.

(c) Radio compass.

(d) Intercommunication.

(e) Air-to-ground IFF.

(f) DR navigation computer (manual inputs).

8.2 ALLOCATION OF AIRCRAFT

Aircraft allocation and delivery schedules for ASTRA I systems have been established. These will provide a basis for future planning when they have been agreed to by all parties concerned, and finally accepted by the RCAF. In addition to aircraft 25204, 25205 and 25209 (ASTRA system development vehicles), AVRO considers it necessary to allocate an additional ARROW for ASTRA system development by RCA. Aircraft 25210 has been suggested for this purpose. This change in aircraft allocation will move the programs previously assigned to aircraft 25210 - 25215, progressively back by one aircraft.

It has been further suggested that aircraft 25204 be eventually replaced by an ARROW 2 aircraft so that 25204 can be used for target and chase duties. Aircraft 25222 has been proposed as the replacement.

The allocation of contractor aircraft for ASTRA system installation is now as follows:

(a) Aircraft 25204 and 25205 are flying test vehicles for ASTRA development by RCA. In addition to the necessary communication equipment, they will be equipped with fire control and navigation sub-systems (including infra-red provision).

(b) Aircraft 25209 and 25210 will be used by RCA for integration of ASTRA, the missile and missile auxiliaries.

(c) Aircraft 25211 will be utilized to establish compatibility of the ARROW 2 airframe, the ASTRA system and the missile. It will also be used to familiarize AVRO personnel with ASTRA and the complete weapon system.

(d) Aircraft 25212 and 25213 have been allocated to Canadair for missile qualification firing tests.

(e) Initially aircraft 25214 will participate in 25211's program but will later be reallocated to join 25215 in the weapon system demonstration program.

(f) Aircraft 25222 will be allocated to RCA as an eventual (ARROW 2) replacement for 25204, and will incorporate full ASTRA for the continuation of system development.

Partial ASTRA systems will be installed in the following contractor aircraft:

(a) 25206 (Airworthiness flights, engine/airframe compatibility trials and airframe systems development).

(b) 25207 (Iroquois engine development).

(c) 25208 (Airframe systems development).

(d) 25216 (Airframe structural integrity work). This aircraft will incorporate provisions for full ASTRA.

8.3 INSTALLATION DESIGN

8.3.1 ARROW 1

Engineering design on the wiring modifications for the flight test damper system in aircraft 25201, 25202 and 25203 is nearing completion. These changes were necessitated by the relocation of the parallel servos and feel units, introduction of an electronic filter for the rudder differential servo, incorporation of the g-limiter system and repositioning of normal and lateral accelerometers for improved performance. Revisions to the q_c actuator for introduction of an AVRO-designed system, are complete.

Wiring changes were made for the incorporation of the automatic UHF antenna selector and the Humphrey stick force transducer with command signal filter. Wiring provisions have also been made for the incorporation of electronic filters for the parallel servo Moog valve signals.

The weapon pack wiring for aircraft 25203, is currently being redesigned so that the missile actuation system will be more compatible with the production version in ARROW 2.

The ASTRA I development vehicles (aircraft 25204 and 25205) will be equipped with an interim electronic system for initial flights, but this system will be replaced with interim development ASTRA for the development flight test program. The program proposal for these aircraft has now been issued to the RCAF.

ASTRA installation and wiring design for 25204 and 25205 is approximately 75% complete. However AVRO cannot proceed with the installation of these units since information on radar nose cameras for these aircraft will not be available until August 1958.

Modifications to wiring for incorporation of the development damper system are currently in work.

8.3.2 ARROW 2

Accumulated modifications to the wiring for partial ASTRA aircraft have been incorporated in production drawings. Design work on the partial ASTRA system for aircraft 25206, 25207 and 25208 is complete, with the exception of modifications for the introduction of the development damper. It is AVRO's intention that later aircraft, which do not have the full ASTRA system shall have full ASTRA wiring provisions despite the fact that certain items of electronic equipment have been deleted from the system.

The wiring position for aircraft 25209 to 25215 (full ASTRA) has recently been clarified. RCA has stated that the majority of the wiring will be similar to that for aircraft 25204 and 25205. AVRO is proceeding on the basis that aircraft 25204 and 25205 are identical to aircraft 25209 in this respect. Instrumentation requirements have not yet been fully defined.

As the installation of ASTRA equipment and the wiring design in 25209 is based on 25204 and 25205, completion of these two aircraft is necessary before engineering work on 25209 can be expedited. A definition of the ASTRA composition for aircraft 25209 has not yet been received from RCA.

8.4 INSTRUMENTATION

RCA has now defined the ASTRA instrumentation requirements for aircraft 25204 and 25205, and has requested that certain environmental parameters be supplied by AVRO instrumentation. RCA will support its own instrumentation at Malton, and will use the IRIG standard tape recording equipment. The instrumentation system will be basically the same for all other ASTRA development aircraft. Instrumentation wiring design for aircraft 25204 and 25205 is approximately 50% complete.

The ASTRA instrumentation requirements for aircraft 25209 are expected to be the same, or similar to those for 25204 and 25205, but this has not yet been clarified by RCA. Therefore, AVRO is again proceeding on the basis that the instrumentation requirements will be identical.

AVRO is currently investigating the instrumentation requirements for aircraft 25211. The parameters to be measured have been established and standard pack wiring proposed. AVRO is mainly interested in the measurement of inputs and outputs of electronic equipment, rather than internal circuit characteristics, but the instrumentation wiring will be the same as for aircraft 25209 and 25210.

8.5 MISSILE AUXILIARIES

The RCAF has requested AVRO to study the relocation of the Sparrow 2D missile auxiliaries in the fuselage. A preliminary evaluation has been conducted and, although relocation from the weapon pack to the armament bay roof is feasible, it appears that re-packaging of the auxiliary units may be necessary to make use of the limited available space. RCA is to report on this study before further action is taken by AVRO.

8.6 COCKPIT LAYOUT

As a result of recent meetings with the RCAF, the cockpit layout has been finalized for production purposes. However, certain modifications are currently being studied as follows:

(a) Introduction of a Beta display on the pilot's instrument panel.

(b) Revision and relocation of the UHF channel indicator on the pilot's instrument panel, to allow for the introduction of the Beta display.

(c) Location of a UHF channel indicator on the OBS/AI's instrument panel.

(d) Addition of the q_c actuator system warning display in the pilot's cockpit.

The present cockpit layout and composition of displays is shown in Figures 6 and 7 (location of items (c) and (d) above has not yet been decided).

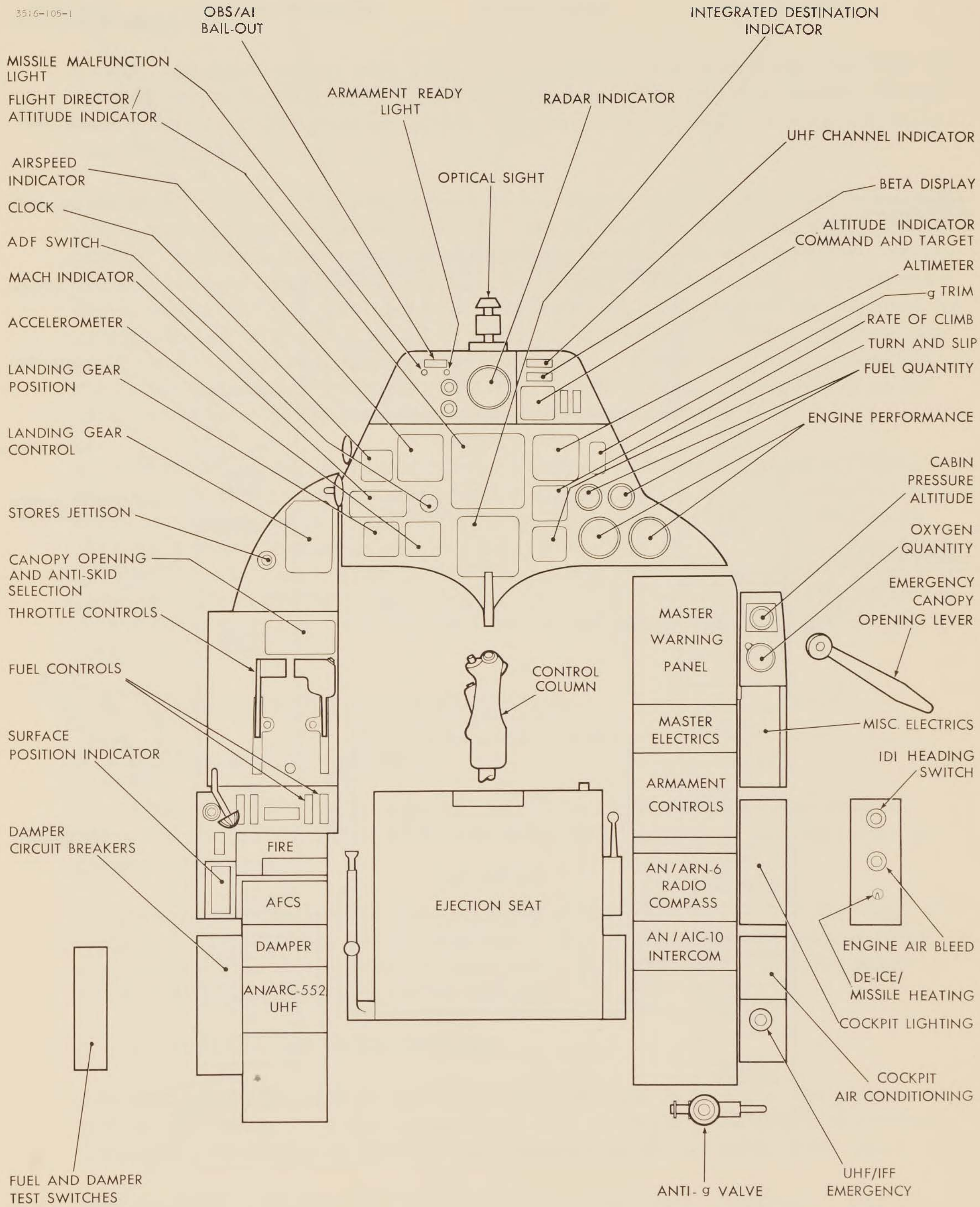


FIG. 6 LAYOUT OF PILOT'S COCKPIT - ARROW 2

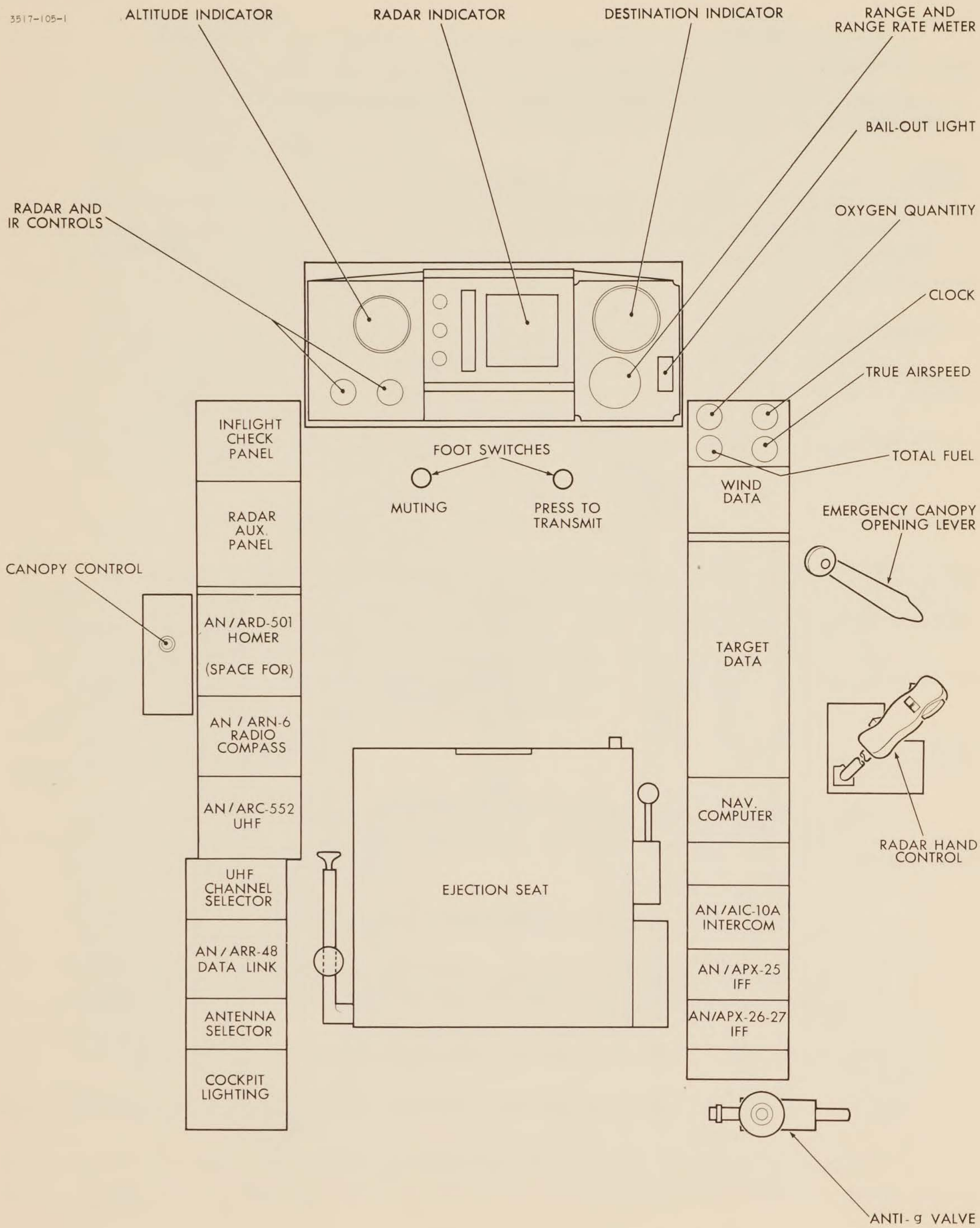


FIG. 7 LAYOUT OF OBS/AI'S COCKPIT - ARROW 2

8.7 RADOME

AVRO, in collaboration with RCA, has prepared and issued the finalized specification for aircraft 25204 and 25205 radomes. The radome vendor (Brunswick-Collender Company of Canada Limited) has agreed to the specification requirements.

The AVRO digital computing program for power transmission and boresight error assessment was completed for both uniform and tapered wall configurations. Analysis of the results shows that the uniform wall radome, having a more divergent boresight error than the tapered wall version, may be more easily corrected. In addition, the transmission advantage of the tapered wall was predicted to be very small at critical look angles. This study has indicated that the tapered thickness wall may not, as was originally supposed, be the better choice for optimum electrical performance. The results of the calculation have been sent to the radome manufacturer.

An automatic boresight range, procured from California Technical Industries, is currently being assembled at Malton. This equipment will permit AVRO to study the effects of boresight correction rings and lenses, and will allow checks to be performed on the vendor's boresight error figures. The effect of the radome characteristics on ASTRA system performance will also be studied using the automatic boresight range. An MG 2 fire control system antenna with a CF-100 radome will be used for initial familiarization with the equipment.

8.8 TELECOMMUNICATION ANTENNAS

8.8.1 UHF BELLY ANTENNA

The ARROW 1 UHF belly antenna, which had limited flight approval for operation up to an altitude of 40,000 feet, will be cleared for operation at greater altitudes.

Construction of the production prototype of the ARROW 2 UHF (annular slot type) belly antenna has been completed. The dielectric foam was omitted, as a suitable material could not be obtained. Preparations are being made to conduct qualification tests on the antenna.

8.8.2 MODEL PATTERN STUDIES

Antenna pattern studies on the 1/10 scale CF-100 model are complete. The results are being used for comparison with in-flight pattern measurements, to establish a technique to develop the antennas on the ARROW (Ref. para. 8.8.3).

Pattern studies on the 0.07 scale ARROW model have continued. Pattern measurements for the UHF and L-band belly antennas were completed satisfactorily, and measurements of the fin cap antenna are currently in work.

Measurements will also be made for the AN/ARA - 25 UHF homer antenna to assess the effect of a strike camera fairing on the pattern. Bleed air ducts were incorporated on the model to assess their effect on UHF belly antenna performance. No serious degradation of the antenna patterns was evident.

8.8.3 ANTENNA EVALUATION PROGRAM

The object of the antenna evaluation flight test program is to verify that model range patterns are essentially the same as those obtained in actual flight. The flight test program on CF-100 aircraft 18186 has now been completed and the results showed an 85% order of accuracy for model pattern measurement. The model technique is therefore considered fully satisfactory for antenna performance evaluation. Pattern measurements will be made on the ARROW 1, and the results compared with model patterns to verify model results for full antenna coverage.

8.8.4 MODEL ANTENNA RANGE

AVRO is investigating the installation of a model antenna range system to be set up at Malton. This facility would be advantageous for the ARROW antenna evaluation flight test program and for future modifications or developments of telecommunication antennas. It would allow greater flexibility than present arrangements, as ARROW model pattern measurements could be more closely integrated with flight test data.

8.8.5 X-BAND ANTENNA

Further information concerning the pattern requirements for the AN/APX-27 (X-band) IFF antenna is required from the RCAF before further studies can be undertaken.

8.8.6 RADAR HOMER

Information on the radar homer (AN/ARD-501) design philosophy is not yet available. Consequently, antenna development has not progressed beyond the stage of an initial pattern study.

8.8.7 DOPPLER RADAR

The type of doppler radar equipment for the ARROW has not yet been specified. Space reservation only has been provided, and antenna pattern investigations have not yet started.

8.8.8 AUTOMATIC ANTENNA SELECTOR

The Autonetics antenna selector is currently being installed in aircraft 25202 for trial installation and flight tests. This equipment will be used for the first three aircraft only, as antenna switching becomes an RCA responsibility on 25204 and subsequent aircraft.

9.0 ENGINE INSTALLATION

9.1 ENGINE RE-OILING PROVISIONS

9.1.1 J75 RE-OILING - (ARROW 1)

In order to prevent over-filling and the subsequent bulging of the engine oil tanks, a drain valve is being installed by AVRO in the J75 engine power take-off gear box.

9.1.2 IROQUOIS RE-OILING - (ARROW 2)

The RCAF requires that engine and accessory systems re-oiling provisions be designed so that aircraft turnaround times are held to a minimum. AVRO and Orenda have agreed upon the provisions to be made, and have submitted them to the RCAF.

AVRO will provide a readily accessible visual engine oil level indicator. The indicator will provide a positive signal when engine oil level is below one half of the engine oil tank capacity.

Orenda will incorporate a positive visual signal in the re-oiling system to indicate when the oil tank is full. This indicator, will be located on a panel behind the engine oil replenishment access door. The panel will also contain indicators to show the following:

(a) The content of the engine relight oxygen bottle.

(b) The oil level in the engine hydraulic system reservoir.

9.2 AIRFLOW RESTRICTOR - (ARROW 2)

The airflow restrictor in the engine tunnel is being moved from station 660 to the vicinity of station 630. It is considered that this will solve Orenda's problem in providing the engine with an air restricting baffle and shroud of acceptable strength-weight characteristics. The requirement for the air flow restrictor was created when Orenda deleted the air-to-air heat exchanger (Ref. paragraph 9.3.2.1 of Report No. 70/ENG. PUB/4 Arrow Quarterly Technical Report, September 1957).

9.3 ACCESSORIES DRIVE GEAR BOX SYSTEM

With the selection of higher power fuel booster pumps for the ARROW 2 (Ref. previous Arrow Quarterly Technical Report), it was necessary to investigate the adequacy of the pump drive mechanism. This investigation has been completed and the manufacturer of the drive system (Sargent Engineering) informed of the new transmission load requirements. Only minor changes are expected in the present drive system.

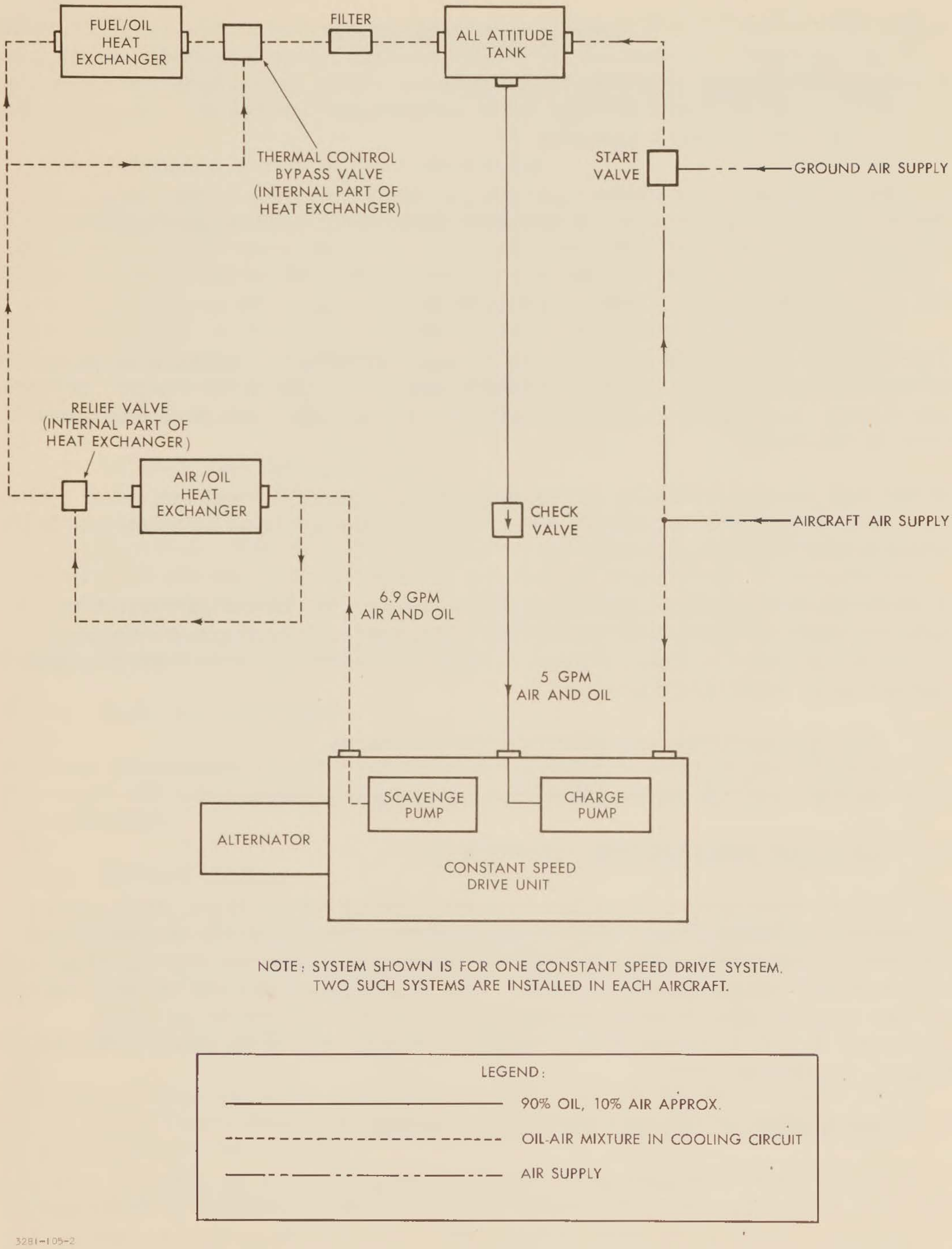


FIG. 8 CONSTANT SPEED DRIVE - SEPARATE OIL SYSTEM - ARROW 2 (SCHEMATIC)

9.4 CONSTANT SPEED DRIVE OIL SYSTEM - ARROW 2

Further development work has been conducted on the constant-speed drive independent oil system. This has resulted in some changes to the system as described in the previous Quarterly Technical Report (70/ENG. PUB/6 para. 8.4.3.2). These changes are incorporated in the schematic diagram shown in Figure 8. The most significant change has occured in CSD starting provisions. Other notable changes are the replacement of the de-aerator and present oil tank with an all-attitude tank, and the relocation of the filter. The all-attitude tank is capable of supplying the CSD charge pump with a correctly proportioned air-oil mixture, regardless of aircraft attitude.

9.4.1 CONSTANT SPEED DRIVE STARTING

To prevent damage to the CSD unit during starting, it is essential to establish a supply of oil to its charge pump as quickly as possible. This will be achieved by pressurizing the all-attitude tank with air bled from the engine air turbine starter supply. The air is bled from a tap in the engine starter inlet scroll, and passed to a pressure-operated start valve. During starting, the start valve closes the air supply to the CSD unit and accessories drive gear box (Ref. Figure 9), and admits air to the all-attitude tank only. When the ground air supply is cut off, the start valve returns to its normal position and closes the supply from the starter.

9.5 ENGINE PERFORMANCE INDICATING SYSTEM

Some delay in delivery of components for the engine performance indicating system is expected, as Orenda has recently established that high pressure rotor governing, instead of low pressure rotor governing, will be used in the Iroquois engine. Otherwise, the development of system components is progressing satisfactorily, and effectivity has been established for aircraft 25209.

The equipment involved in system development is as follows:

(a) Engine performance indicator.

(b) Engine performance computer and transducer pack.

(c) Nozzle area transducer.

(d) Compressor inlet total temperature sensor.

(e) Compressor inlet total pressure probes.

(f) Turbine outlet total pressure probe.

The relationship of these components within the system relative to each other and to the engine is shown in Figure 10.

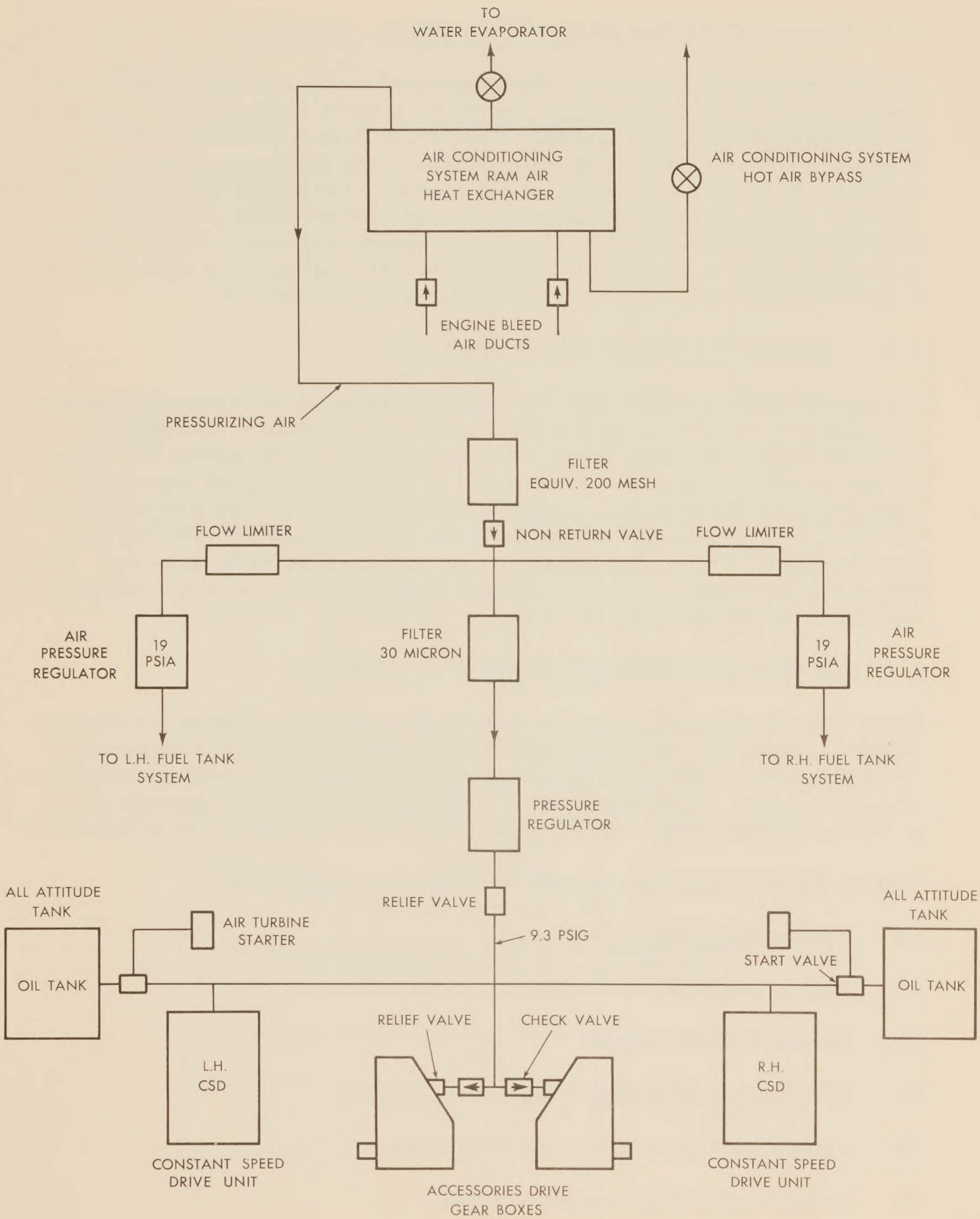


FIG. 9 OIL SYSTEM AIR SUPPLY - ARROW 2 (SCHEMATIC)

The components are arranged in three separate circuits to provide separate indication of:

(1) Engine performance.

(2) Percentage afterburning.

(3) Exhaust gas temperature.

The pressure probes and the inlet temperature sensor provide the data for the engine performance indicating circuit. The nozzle area transducer serves the percentage afterburner indicator circuit, and a chromel-alumel thermocouple serves the exhaust gas temperature indicator.

10.0 ELECTRICAL SYSTEM

10.1 POWER SYSTEM

10.1.1 ARROW 1 (Aircraft 25204 and 25205)

The power requirements of the ASTRA 1 system will be incorporated in aircraft 25204 and 25205. This has necessitated modifications to the ARROW 1 electrical system wiring for the additional electronics power supply and control required by the ASTRA system.

The AC supply for the left intake duct de-icing will be rendered inoperative for initial flights and will be used to supply the electronics instrument pack. If duct de-icing is later required, additional controls will be necessary to select either instrument pack power or de-icing.

10.1.2 ARROW 2

Composite wiring has been introduced into ARROW 2 to permit the installation of either the Westinghouse or the Lucas-Rotax electrical power system, on an interchangeable basis. It is expected that a firm decision on the power system supplier will be made by mid-July 1958.

10.1.3 BATTERY

DRB has recommended additional insulation for the aircraft battery. Battery and environmental temperatures are currently being studied to determine the insulation requirements and a decision will be reached in conjunction with the RCAF.

10.2 ELECTRICAL SUB-SYSTEMS DEVELOPMENT

10.2.1 MAIN LANDING GEAR DOOR OPERATION

ARROW 1 main landing gear doors are now closed prior to landing by means of a mechanically sequenced actuation system (ref. para. 13.2) and is to be a trial installation on one ARROW 1 aircraft. Left and right main gear uplock limit switches have been added to the electrical system to ensure that the left and right landing gear position indicators will indicate "UP" only when both the gears and the doors are locked up. In addition, this will ensure that hydraulic pressure to the UP system is not shut off before all gears and doors are locked up. This is achieved by wiring the UP supply shut-off control in series, through the new limit switches, with the door UP switches.

10.2.2 SPEED BRAKE CONTROL

Alterations have been made to the speed brake and missile control electrical circuitry to achieve speed brake retraction coincident with missile lowering (ref. para. 13.4). These changes are applicable only to aircraft 25203 at this stage.

10.2.3 NOSEWHEEL STEERING

Additional electrical equipment and wiring were incorporated in ARROW 1 design for the nosewheel steering trial installation in aircraft 25202 (ref. para. 13.6).

10.2.4 FUEL PROPORTIONING WARNING

Originally, the ARROW 1 refueling adaptor door operated limit switches to provide a signal to the pilot's fuel proportioning warning light. Since these switches only indicated door position and not valve position, a minor fault in door operation could have caused the warning light to give a false signal. To obviate this possibility, the switches have now been deleted.

10.2.5 FUEL PROPORTIONING BYPASS CONTROL

In order to facilitate post-flight inspection of the ARROW 1 fuel proportioning bypass valve, the bypass locking relay has been altered to a latch type. The earlier relay was de-energized on touchdown, thereby permitting the bypass valve to reset to the "meter" position, after a "fuel-proportioning" warning in flight (i.e. proportioner bypass). Use of a latch relay will hold the valve in the bypass position after aircraft power has been shut off, thus permitting proper valve inspection. Operation of the master refueling switch will de-energize the relay and reset the bypass valve to "meter". The valve is retained in this position until after the nose gear scissors switch is actuated at take off.

10.2.6 AFTERBURNER INDICATION

Left and right "afterburner on" green indicator lights, which include press-to-test and dimming features, have been added to the pilot's cockpit. These lights are illuminated when the afterburner has been selected and the nozzle opened.

10.2.7 MISSILE CONTROL SYSTEM

The missile control system circuitry for aircraft 25203 has been modified to connect the firing relay control signals through the hydraulic compensating valves "parallel position" switches. This was done to prevent missile firing, if the compensating valves had not been energized to the parallel position.

11.0 AIR CONDITIONING SYSTEM

11.1 TEMPERATURE CONTROL SYSTEMS

As noted in the previous Quarterly Technical Report, the Hamilton-Standard cockpit temperature control units proved unsatisfactory and the design and development of these units was undertaken by AVRO. The AVRO-designed unit has been tested in the system ground test rig, and proved satisfactory.

11.1.1 ARROW 1 SYSTEM

A total of fourteen temperature control units are being manufactured by AVRO for ARROW 1 installation; seven for the cockpit and seven for the equipment area. The units will be installed in the aircraft when they have successfully completed the qualification test program.

The valves used in the Hamilton-Standard control systems will be used in the AVRO systems. However, CF-100 air conditioning system temperature sensors will be installed in place of those used in the Hamilton-Standard system. These sensors have proven reliable in CF-100 service, and possess more favourable temperature-resistance characteristics than the Hamilton-Standard type.

11.1.2 ARROW 2 SYSTEM

It was originally intended to install vendor-designed and developed temperature control systems in ARROW 2 aircraft. The AiResearch system appeared to be the best of several proposals submitted. However, further study of the AiResearch system proved it to be inadequate, and it has been decided to a adopt the AVRO-designed temperature control system for the ARROW 2. Manufacture of controllers for the ARROW 1 will be sub-contracted.

11.1.3 CONTROLLER DEVELOPMENT

The development of the AVRO-designed ARROW 1 cockpit temperature-controller was based on a number of tests performed on the air conditioning system test rig. The test results were used for an analogue simulation of the complete system. Based on control requirements, a breadboard controller was constructed and checked on the analogue computer. When a satisfactorily functioning controller was obtained, it was installed in the test rig and its performance assessed. This assessment proved that the basic philosophy applied to control system design was satisfactory.

11.1.4 CONTROLLER DESCRIPTION

The AVRO temperature controllers are completely transistorized units. Controller circuitry includes integrators, amplifiers and summing networks.

Thermal stabilization of the transistors and voltage stabilization of the power supply are incorporated into the circuitry.

The configuration of the ARROW 1 cockpit temperature control system (Ref. Report No. 71/SYSTEM 22/164, A Cockpit Temperature Controller for the ARROW 1 Air Conditioning System, April, 1958) is shown in Figure 11. Cockpit inlet temperature is controlled by the inner loop of the system. The outer loop is modulating, which satisfies the demands of the cockpit temperature selector. Use of this two loop system provides good control stability.

The equipment temperature controllers are similar to the cockpit temperature controllers, except that the equipment temperature controllers have no outer control loop. ARROW 2 temperature controllers will be similar to the ARROW 1 units.

11.2 ASTRA COOLING AIR SUPPLY

11.2.1 GENERAL

The adequacy of available cooling capacity for ASTRA equipment is assessed by RCA, using AVRO supplied data on cooling air mass flow, supply pressure, supply temperature and permissible pressure drops through equipment. Previously this data has been supplied to RCA when requested. This information is now contained in a single report. (AVRO Report No. 71-2/SYSTEM 22/140, ASTRA Cooling Air Supply, April 1958). The data contained in this report is based on latest performance estimates for the ARROW air conditioning system.

The cooling capacity of the ARROW 2 air conditioning system is adequate to satisfy all ASTRA cooling requirements. However, the ARROW 1 system has a low cooling capacity, and an auxiliary air conditioning system is required in ASTRA test vehicles. In addition, the main system in ARROW 1 is modified by the introduction of two air-oil heat exchangers as shown in Figure 12.

11.2.2 AUXILIARY AIR CONDITIONING SYSTEM - ARROW 1

To provide adequate cooling air for instrumentation in the ASTRA test vehicles (aircraft 25204 and 25205), an auxiliary air conditioning system is being installed in the instrument pack. The system and its relationship to the main aircraft system is shown schematically in Figure 12.

The auxiliary system operates on hot engine-bleed air from the main system's ram air heat exchanger. A water evaporator, and two turbine-compressor units connected in parallel, are the principal components of the system. Space limitations have dictated the use of two turbine compressors. In addition, these units have been fully qualified and are readily available. Air for the loading compressors is taken from the armament bay and discharged to atmosphere.

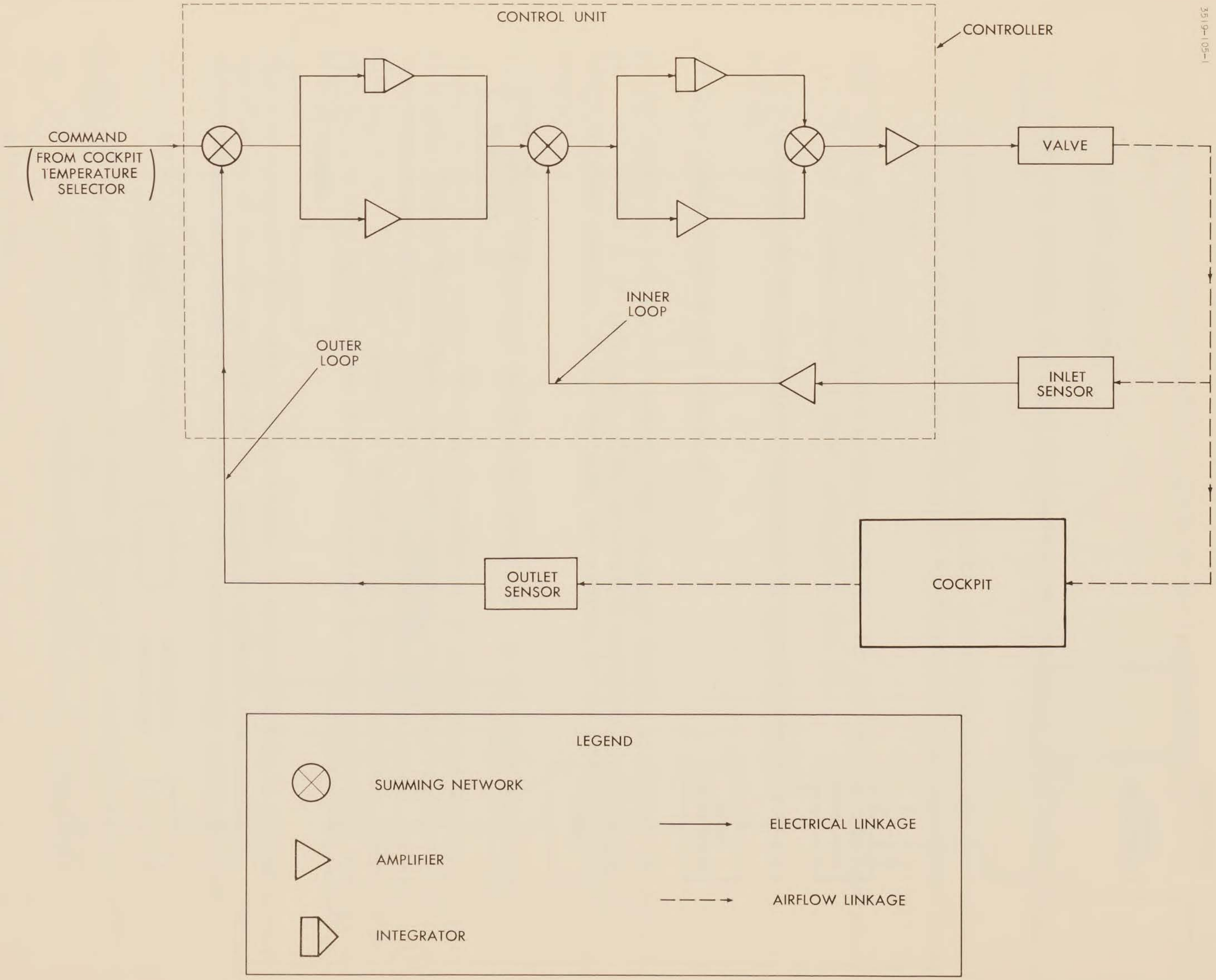


FIG. 11 BLOCK DIAGRAM - COCKPIT TEMPERATURE CONTROL SYSTEM

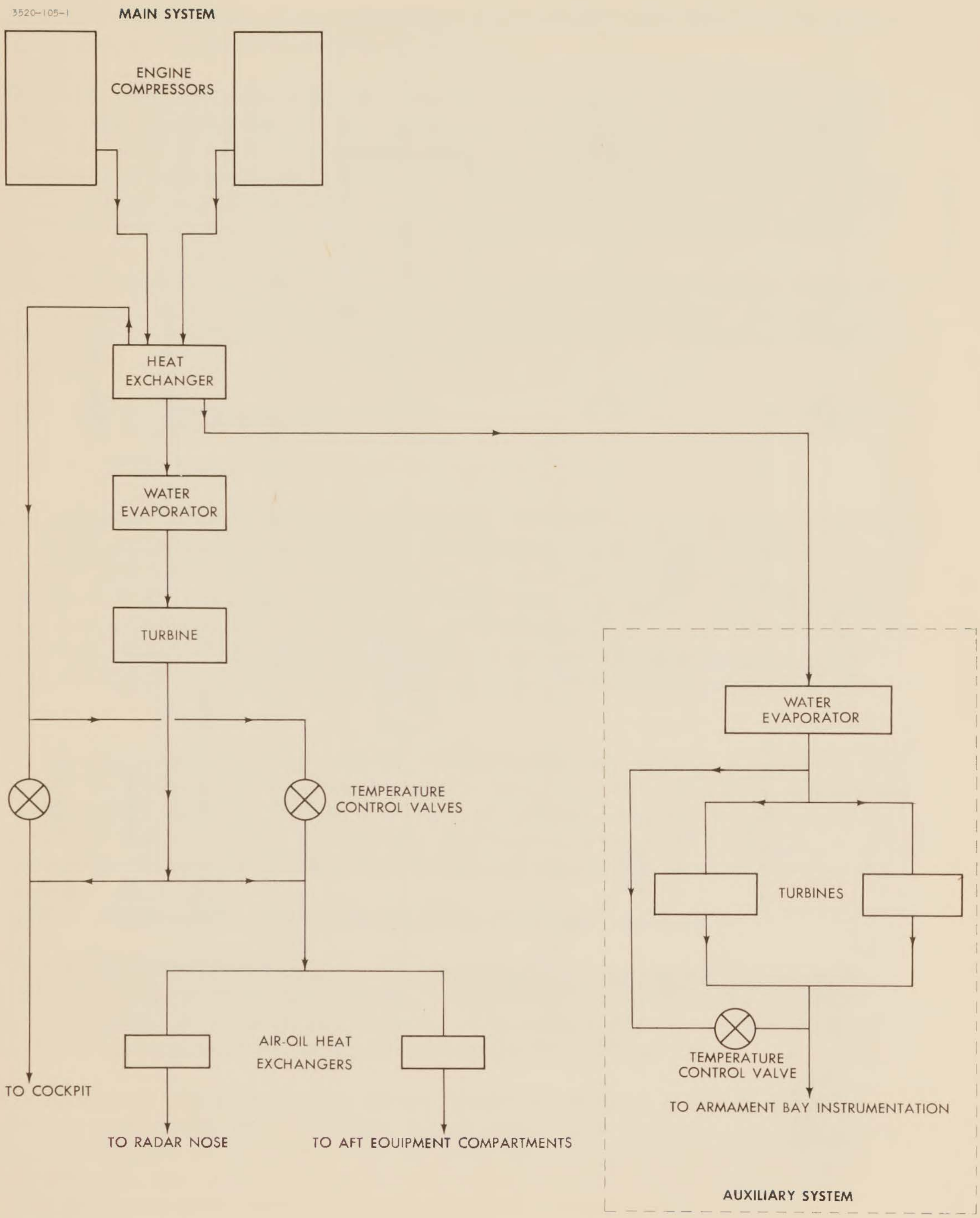


FIG. 12 FLOW DIAGRAM - AIR CONDITIONING SYSTEM - ARROW 1 - ASTRA TEST VEHICLE

The performance of this system is given in the report referred to in para. 11.2.1

11.2.3 IR POD COOLING

Two separate systems are used for cooling the equipment in the infra-red seeker pod:

(1) A cooling air supply from the aircraft's air conditioning system maintains the seeker head and electronic units environment at an acceptable temperature level.

(2) A high pressure nitrogen system cools the IR detector to a temperature in the neighbourhood of liquid nitrogen (-196°F).

The disposition of the principal components of these systems is shown in Figure 13.

11.2.4 AIRCRAFT'S AIR SUPPLY

An insulated duct in the fin leading edge supplies cooling air to the IR seeker pod. This duct is an extension of the aircraft's equipment cooling air distribution duct system. From the pod, the cooling air is discharged to atmosphere.

11.2.5 HIGH PRESSURE NITROGEN SYSTEM - IR SEEKER COOLING

Since the infra-red seeker develops sensitivity in the desired spectral region only when cooled to extremely low temperatures, a cooling medium is necessary. Gaseous nitrogen, cooled in a Linde liquefaction process, is used for this purpose. Nitrogen cooling is based on the Joule-Thompson effect, with throttling producing the main temperature drop in the regenerative refrigeration process.

The high-pressure nitrogen cooling system is primarily RCA's responsibility. Installation of the nitrogen bottle and piping is AVRO's responsibility. Except for the bottle and piping, the system is contained entirely within the pod.

11.3 ARROW 2 FLOW CONTROL

A flow control device proposed by AVRO (Report No. 72/SYSTEM 22/137, Proposed Mass Flow Controller, March 1958) offers a possible solution to the flow control problem in the ARROW 2 air conditioning system (Ref. 70/ENG PUB/5 ARROW Quarterly Technical Report No.2 para. 10.3). A model of the device is being constructed, and will be used to test the theory upon which the mass flow controller design is based.

During the coursc of ARROW 2 air conditioning system development, it has

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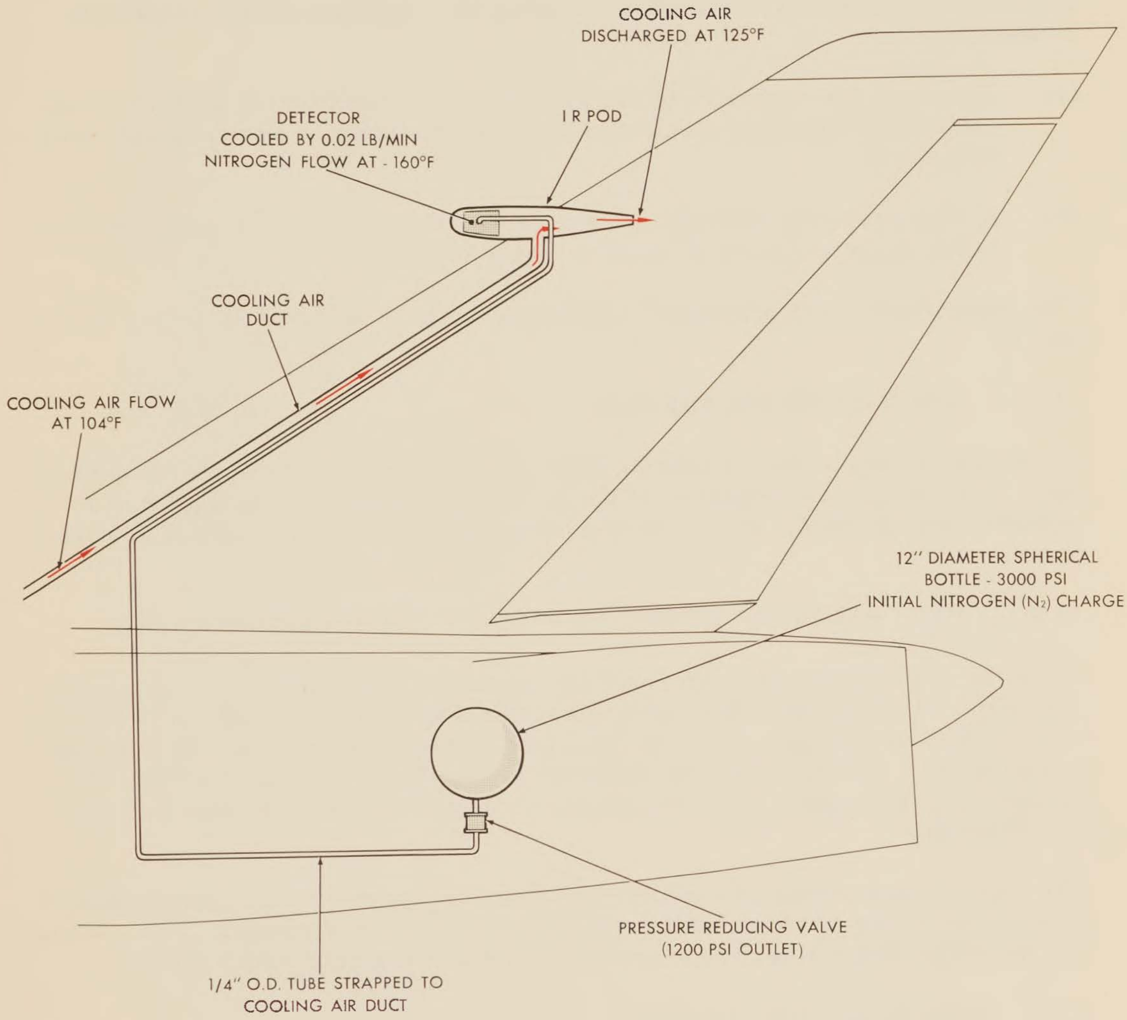


FIG. 13 COOLING FOR FIN IR POD - ARROW 1 AND 2

been established that air conditioning equipment vendors are unable to produce a mass flow controller. Flow controllers currently in use are based on a venturi or a pitot head. In their simplest form, they control to a constant $1/2 \rho V^2$. By correcting for pressure, they approach a constant $M\sqrt{T}$ control, but are unable to give a true constant mass-flow control. The proposed AVRO controller, however, senses true mass flow, and being independent of temperature, pressure and density, provides a means for true constant mass-flow control.

11.3.1 CONTROLLER THEORY

If the air flowing in a duct is passed through rotating blades, a retarding torque is exerted on the blade rotor. The magnitude of this torque can be shown as:

$$Q = \frac{m\omega}{2} (r_2{}^2 + r_1{}^2)$$

where Q = the retarding torque on the rotor

m = mass flow in the duct

ω = angular velocity of the rotor

r_2 = blade tip radius

r_1 = blade root radius

From the expression, it is obvious that if rotor speed is held constant, the retarding torque is directly proportional to the mass flow. The sensing of changes in this retarding torque, and the translation of these changes into control signals, is the basis of control device design.

11.3.2 THE FLOW CONTROL DEVICE

Since a 400-cycle electrical supply, accurate to ± 1%, is already available in the ARROW aircraft, a synchronous motor offers the best means for driving the blade rotor at constant speed. The reaction of the motor to varying torque loads controls mass flow. The proposed control device would be installed in the cockpit air inlet duct. As shown in Figure 14, it will consist of a honeycomb insert, the blade rotor, the synchronous motor and the control output mechanism. The honeycomb insert is an anti-swirl device, installed to establish an airflow, parallel to the blade chord. The blade rotor is the flow sensing element, and is driven by the output shaft of the motor. The motor case, combined with the output gearing, constitutes the control mechanism.

The motor case is mounted on bearings to allow free rotation, but is restrained by a spring attached between the motor case and the supporting structure.

Output control shaft drive is provided by a gear anchored to the motor case.

11.3.3 INTEGRATION IN A FLOW CONTROL SYSTEM

The output control signals from the cockpit controller will be utilized to control the turbine inlet nozzle. The design of this portion of the system is currently in progress.

Flow control system design is based on maintaining a constant 27.5 lb/min flow to the cockpit. Air conditioning system design is such that if this flow is provided, adequate equipment cooling airflow is maintained. Thus, total system flow can be controlled by the cockpit flow controller.

11.3.4 ADVANTAGES OF PROPOSED CONTROLLER

The main advantages of the proposed controller are:

1. It is independent of pressure, temperature and density, and therefore provides true mass flow control.

2. The torque available to operate a control device can be increased to any required value, by reducing the restraining spring stiffness, and increasing the reduction-gearing between motor case and output shaft rotation.

3. The flow being maintained by the controller can easily be changed by increasing or decreasing the restraining spring torque.

4. The sensitivity of the device is independent of mass flow and can be altered to any required degree, by varying the spring stiffness.

11.4 ENVIRONMENTAL PROTECTION FOR CREW MEMBERS

Air-conditioning system design is a compromise between performance, complexity and weight. It is therefore inevitable that in some regions of the flight envelope system performance may be marginal. In order to protect the crew in these regions, additional equipment such as a ventilated suit or a pressure suit could be used. A recently completed study (Report No. 72/SYSTEM 22/170, Environmental Protection for Crew Members, ARROW 2, May 1958) evaluates the added complexity and weight penalties involved, and the improvement in crew protection provided by the use of such clothing. This study was made at the request of the RCAF, and AVRO will be advised of the requirements when the report has been evaluated.

11.4.1 PROBLEM AREAS

The problem areas where ARROW 2 air-conditioning system performance is marginal are:

(a) Cockpit cooling during standby, using the support vehicle.

(b) Cockpit cooling while taxiing.

(c) Cockpit cooling and pressurization during descent.

(d) Pressurization during zoom to high altitude.

(e) Emergency situations caused by system failure.

11.4.2 PROTECTIVE EQUIPMENT

Apart from the air-conditioning system, the only equipment currently provided to protect the crew members from environmental hazards is a partial pressure suit (pressure vest) and an anti-g suit. These garments do not provide adequate protection against temperature and pressure in the marginal problem areas. The use of aircrew clothing and equipment, now in the development stages, however, could provide more adequate protection.

The RCAF's Institute of Aviation Medicine (IAM) is now developing a ventilated suit for protection against high temperatures. IAM is also developing a full pressure suit which, in addition to performing the function of the ventilated suit, provides protection for indefinite periods against reduced pressures at any altitude.

Either of these garments may be adopted for the ARROW 2, but selection of a garment is dependent on the added protection required, and the added complexity and weight involved in providing an air supply to the garment.

11.4.3 GARMENT AIR SUPPLY

Proposed air supply systems for the garments include air supplied by the air conditioning system, and emergency nitrogen systems combined with air from the air conditioning system. Four different air supply systems have been investigated. Three of these are applicable to the ventilated suit, and one to the pressure suit. The system for the pressure suit provides full protection against temperature and pressure. The three systems for the ventilated suit provide protection against temperature only, the extent of protection required determining the nature of the air supply system.

The nature of the air supply system, the extent of protection provided, as related to the previously noted problem areas, and the weight penalty involved for each of the four systems investigated are summarized in Table 2.

TABLE 2 COMPARISON OF PROTECTION PROVIDED

Problem Area	Standby using Ground Support Vehicle	Taxi	Desce (Normal Op
System Deficiency	Inadequate Cockpit Cooling	Inadequate Cockpit Cooling	Air Flow M for Cockpit and Pressu

CREW'S PROTECTIVE GEAR	AIR SUPPLY	Weight Penalty (Air Supply only)	PROTECTION PROVIDED BY A	
Existing - Partial Pressure Suit (Vest) Anti 'G' Suit (Pants)	- Oxygen System - Low Pressure Pneumatic System	0	Not satisfactory for high ambient temperatures	Not satisfactory for ambient temperatures above 65°F with canopy closed.
Existing plus ventilated suit (Ground use only)	Ground support vehicle through low pressure side of air conditioning system.	5.5 lb	Complete protection.	As above.
Existing plus ventilated suit (Ground and flight use).	Ground support vehicle or aircraft's air conditioning system. Same as above except for introduction of booster fan and heater.	12 lb	Complete protection.	Marginal
Existing plus ventilating suit (Maximum utilization).	Same as above except for addition of a liquid nitrogen system for emergency use.	94 lb	Complete protection.	Complete protection when emergency supply used.
Full pressure suit (Ventilated)	Bleed from high pressure side of air conditioning system turbine; no booster fan required but additional cooler (heat exchanger) required. Liquid N_2 for emergency use. Ground support vehicle for ground use.	100 lb	Complete protection.	Complete protection when emergency supply used.

ISON OF PROTECTION PROVIDED IN PROBLEM AREAS

Taxi	Descent (Normal Operation)	Zoom to high Altitude	System Failure
quate Cockpit Cooling	Air Flow Material for Cockpit Cooling and Pressurization	Inadequate Protection against loss of Cockpit Pressure at High Altitude (70, 000 ft)	Inadequate Cooling in Deceleration from M. No. 2. 0

PROTECTION PROVIDED BY AIR CONDITIONING SYSTEM AND CREW'S PROTECTIVE GEAR

satisfactory high ambient peratures	Not satisfactory for ambient temperatures above 65°F with canopy closed.	Not considered a problem, since case is likely to be a transient of fairly short duration, with steady state conditions never being attained. In any event, a descent technique can be worked out to minimize the problem.	Protection for 1 min at 70, 000 ft. 5 min at 65, 000 ft.	Marginal
nplete protion.	As above.		As above.	As above.
nplete protion.	Marginal		As above.	As above.
nplete protion.	Complete protection when emergency supply used.		As above.	Complete protection using emergency supply.
nplete protion.	Complete protection when emergency supply used.		Complete protection . Emergency supply used for descent from 70, 000 air conditioning system for cruise home	Complete protection. Emergency supply used during deceleration, air conditioning system for cruise home.

12.0 FUEL SYSTEM

12.1 FUEL BOOSTER PUMPS

A satisfactory solution to the booster pump bypass problem (Ref. Report No. 70/ENG PUB/6, Arrow Quarterly Technical Report, March 1958, para . 13. 1) has been submitted by the vendor, and the pump has now been cleared for use in the first eight aircraft.

12.2 FUEL-NO-AIR VALVES

The selected vendors of the fuel-no-air valves for the fuel transfer system have experienced difficulty in producing a valve to meet AVRO's specification requirement. The vendors' main difficulties were in achieving correct and reliable functioning of the valve over the wide range of attitudes (± 80° pitch, ± 10° roll) and fuel flow rates (up to 100 gpm) required. In addition, the specified vibration requirements could not be met unless vibration damping mountings were used in the installation. Consequently, AVRO has conducted an investigation on the design and experimental manufacture of a new type valve. The results of this investigation indicated that an improved fuel-no-air valve could be developed by AVRO (Ref. Report No. 72/AIREQ 16/2 "Investigation of the Feasibility of Developing an Improved Fuel-No-Air Valve", March 1958). A design development program is currently being conducted.

12.2.1 AVRO PROPOSAL

The proposed AVRO valve is shown in Figure 15. The main difference from the valves presently in use are as follows:

(a) Use of an electrical device, instead of a float, to discriminate between fuel and air at the valve inlet.

(b) Use of air pressure gradient from feeder tank to collector tank, instead of differential fuel pressure across the valve as the source of servo energy operating the fuel valve.

(c) Use of a self-aligning swing valve instead of a poppet valve in the fuel passage.

(d) Use of a 1-3/4 inch diameter fuel outlet with a screwed connection, instead of a 2-1/2 inch diameter fuel outlet with a bolted flange type connector.

The proposed electrical fuel/air discriminator, is an ultrasonic liquid level sensor in which the basic sensing element exhibits the piezoelectric effect. When this sensing element is exposed to air, a solenoid valve is actuated to admit tank air into the servo cylinder; the swing valve is then operated to

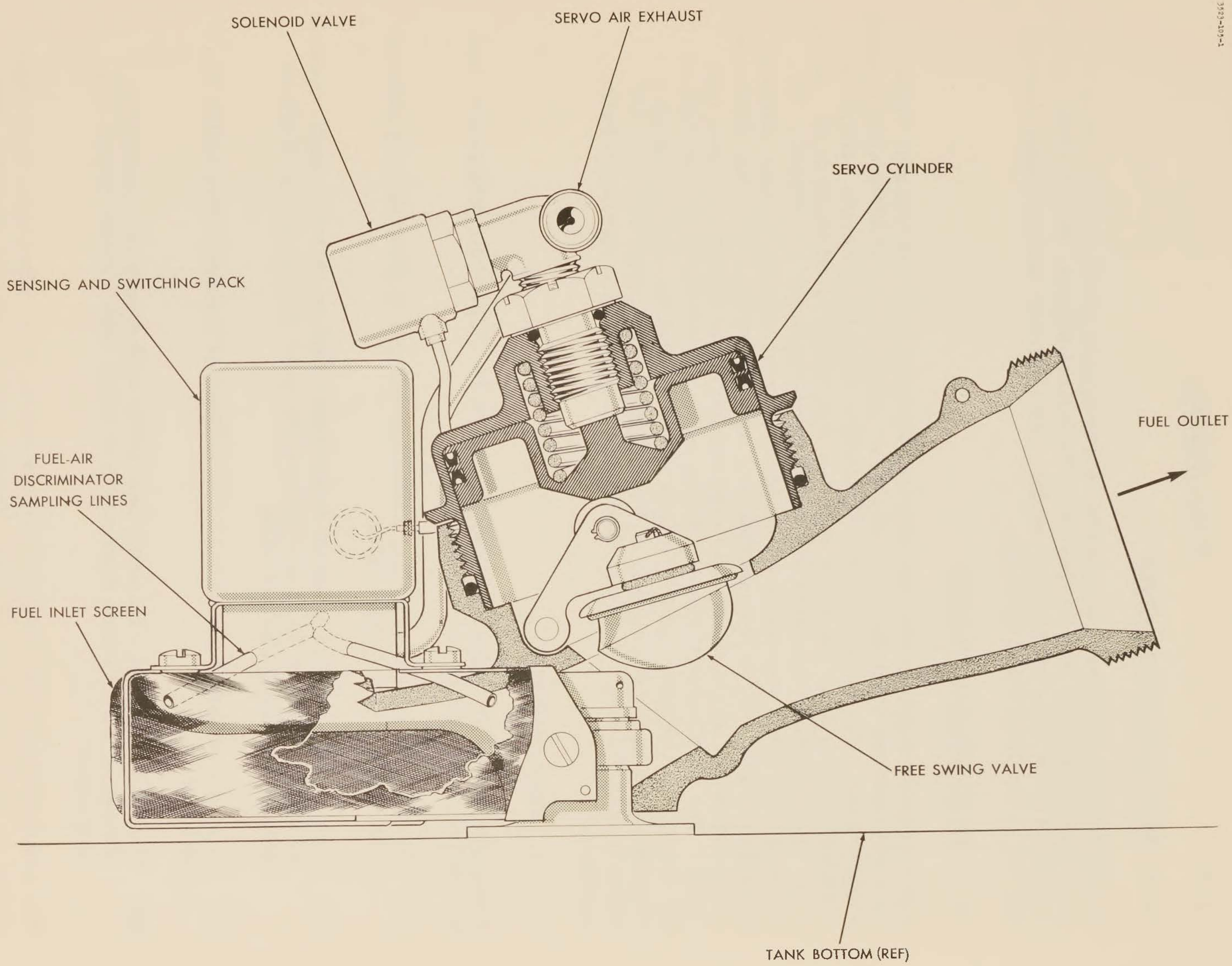


FIG. 15 FUEL-NO-AIR VALVE

close the fuel passage. Unlike the present fuel-no-air valves, in which float type discriminators are used, the proper functioning of the AVRO valve is independent or orientation with respect to the aircraft plane of symmetry. The sensor sensitivity, combined with the greater servo pressure available with tank pressurizing air, provides valve opening and closing response times of less than 1/2 second. A further improvement in valve performance is obtained by reducing pressure losses in the fuel passage, and designing the inlet so that any tendency toward formation of vortices is minimized.

12.3 FLAME PROOFING OF FUEL VENTS

A recently completed report (70/SYSTEM 16/213, "Preliminary Report - Flame Proofing of Fuel Vents" - ARROW Aircraft", June 1958) suggests that further investigations be made to determine the degree of protection provided by existing fuel vent flame traps. The present location of the vents renders the fuel vent discharge vulnerable to ignition during missile firing. Since it is difficult to theoretically predict the degree of protection afforded by the flame traps, a series of ground rig tests may be required. This investigation would have to be completed before any airborne live firings were attempted.

The fuel vent discharges will support combustion and propagate flame travel in the vent lines only when liquid or vapor fuel is present in the discharge. Thus, a dangerous situation occurs only when missile firing coincides with flamable discharge from the fuel vents. Whether such hazardous situations do occur could be established by a theoretical investigation. The purpose of a theoretical investigation would be to determine the range of fuel-air mixtures encountered, together with their velocities in the discharge pipe, during flight conditions producing flammable mixtures. The ultimate object of the study would be to prove that a flame front would not advance along the vent pipe.

The possibility of repositioning the fuel vents is currently being investigated. This can be accomplished in a much shorter time than either the theoretical study or the proposed tests. Should the repositioning of the vents prove feasible, the problem will be solved.

13.0 HYDRAULIC SYSTEM

13.1 UTILITY POWER SYSTEM INVESTIGATION

The requirement for modification of the ARROW 2 hydraulic system to allow the ASTRA 1 radar antenna to be driven from the utility system has now been cancelled by the RCAF. AVRO does not consider that the reliability of the flying controls hydraulic system is in any way degraded by use of the flying controls hydraulics 'A' circuit to power the antenna drive system.

13.2 OPERATION OF LANDING GEAR DOORS

As previously reported, the nose landing gear hydraulic circuit has been redesigned to automatically close the nose gear door following extension of the gear. This improves directional stability during approach and landing. An electrically-sequenced hydraulic circuit has been devised for ARROW 1. The ARROW 2 will be equipped with a similar system.

Investigations and flight tests have shown that similar action may be required for the main landing gear doors, to prevent in-flight buffetting. The main gear door hydraulic circuits have been redesigned to automatically close the doors using the mechanical sequencing method, when the gear is extended. This will be done on a trial installation basis on one ARROW 1 aircraft only.

The system devised for closing the main gear doors is similar to that which was proposed for the ARROW 2 nose door (Ref. para. 14.3 of the previous Quarterly Technical Report). A mechanically-operated door selector valve and ground-actuated door selector valve are added to each main door hydraulic circuit. Additional sequence valves, shuttle valves, restrictors, tubing and fittings are introduced, giving a total weight increase of about 30 lb.

13.3 WHEEL BRAKE HYDRAULIC SUPPLY

Further investigations have been conducted into the effects of failures in the existing wheel brake hydraulic sub-system. In the event of a failure in the normal brake supply, emergency braking is provided by the (1,500 psi) reduced pressure line. However, should failure occur in the emergency supply, a total loss of wheel braking could result. Loss of pressure in the 1,500 psi line would d-pressurize the utility system compensator and allow the pumps to cavitate, resulting in loss of normal brake system pressure.

It is proposed to redesign the wheel brake system by deleting the 1,500 psi emergency supply to the brakes and duplicating the normal pressure circuit. This ensures that braking pressure is still available in the event of a failure in one of the wheel brake circuits. The new wheel brake system incorporates the following features:

(a) Two independent, wheel braking sub-systems, arranged as shown in Figure 16 so that failure in either one would leave the other in operation. A failure in any other utility sub-system would not affect the wheel brake circuits.

(b) A separate 110 cubic inch accumulator in each wheel brake sub-system, replacing the single 200 cubic inch emergency accumulator in ARROW 2 (Two 110 cubic inch accumulators already exist in ARROW 1).

(c) One of the sub-system accumulators is connected to the main utility system through a solenoid-operated shut-off valve (see Figure 16). During the initial engine starting cycle this valve is opened, allowing the brake accumulator to supply reduced pressure to the bottom of the compensator, via the pressure control valve. This ensures that the pump suction line is pressurized before the pumps start to operate.

(d) Each wheel brake sub-system incorporates a thermal relief valve to prevent excessive pressure build-up due to increasing fluid temperature during flight.

(e) Each wheel brake sub-system incorporates a pressure warning switch, connected so that the cockpit warning light will be illuminated only in the event of loss of both sub-systems.

(f) When the cockpit emergency brake warning light for the main utility system indicates loss of hydraulic pressure, it would have to be assumed that both the utility power circuit and one of the wheel brake circuits had failed. A minimum of ten brake applications could then be made before losing the accumulator pressure in the remaining wheel brake circuit. To conserve braking power under these conditions, the anti-skid system (if incorporated) would be shut-off.

(g) Duplicated components will not be incorporated in common housings, so that a structural failure of one item will not endanger both circuits.

13.3.1 WHEEL BRAKE PIPING

The wheel brake hydraulic piping, in the vicinity of the landing gear, has been modified to reduce its vulnerability to damage and the subsequent loss of braking pressure. Shuttle valves, previously located on the main wheel bogies, have been relocated into the wings to simplify and improve the piping on the main landing gear legs. Each wheel brake unit is supplied by a line from a separate shuttle valve. Since a leak in either of the brake supply lines can cause loss of fluid when the brakes are operated, hydraulic fuses have been introduced to isolate the damaged line. Brake line pressure gauges will be installed downstream of the fuses on the ARROW 1 and 2. This modification is applicable to ARROW 1 and 2, but where the anti-skid facility is installed, the requirement is covered automatically by the resulting system alterations.

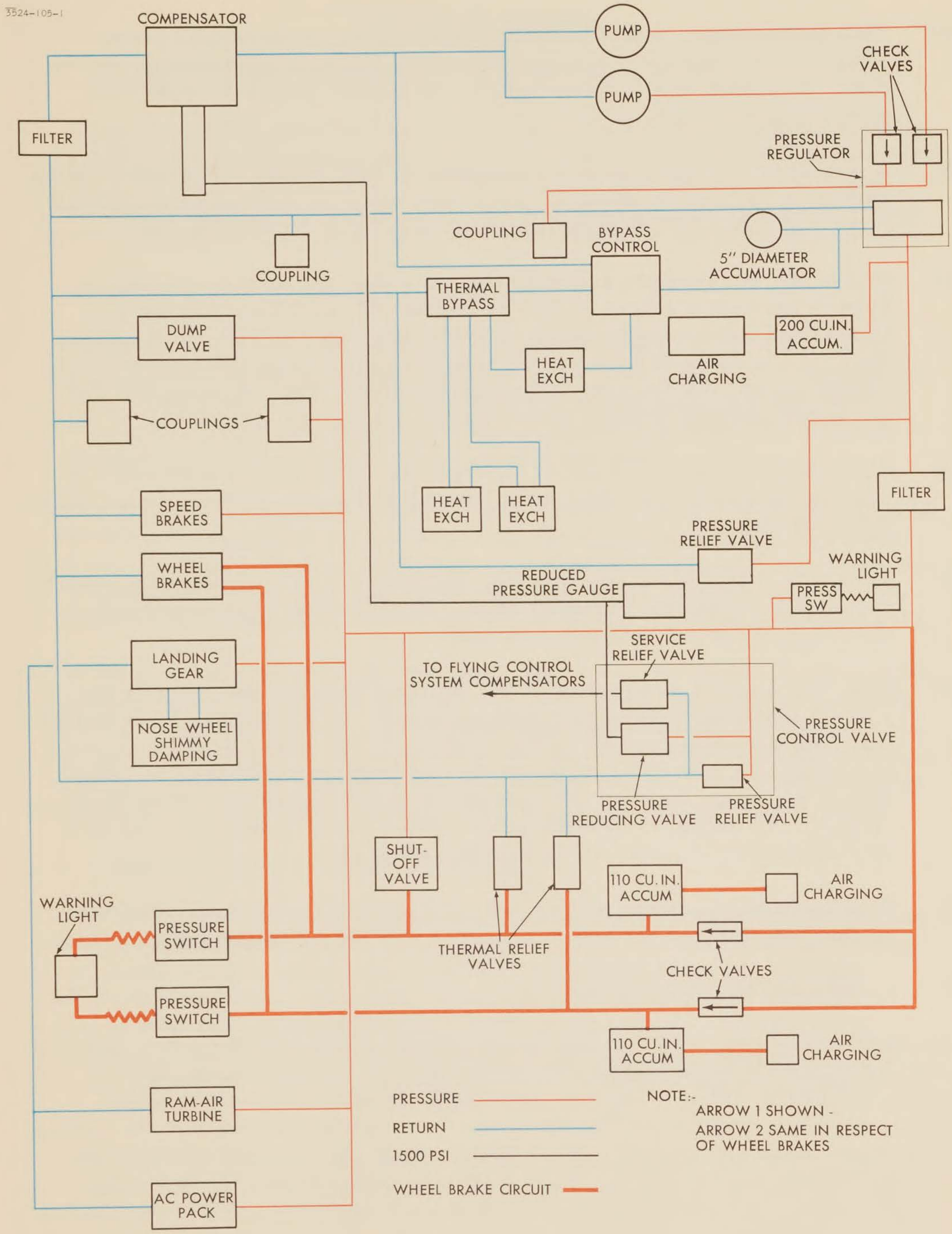


FIG. 16 UTILITY HYDRAULIC POWER SYSTEM - SHOWING REVISED WHEEL BRAKE CIRCUIT

13.4 SPEED BRAKES

In order to maintain the operational flexibility of the aircraft during missile launching, it should be possible to fire the missiles with the speed brakes deployed. It has been calculated, however, that the missile blast loads on the fully extended speed brakes would be unacceptably high. (Ref. section 14.5 of the previous Quarterly Technical Report). Further studies have shown that the structural limits for the speed brake jack and supporting structure will not be exceeded if speed brake retraction is initiated coincident with missile extension. The missile and speed brake electrical control circuits have been modified to provide the speed brake selector valve with a "retract" signal, when missile lowering is selected.

Normally the missiles are fired 1.5 seconds after the missile doors start to open. Therefore, the speed brakes will retract for the same period of time before missile blast occurs. Calculations have shown that the speed brakes will retract to at least the 30° position before the missiles are fired, at which point the blast load will not be critical. Under certain flight conditions, the hydraulic pumps will cavitate as the missiles are extended, causing loss of pressure. This allows the speed brake selector valve to go into the "HOLD" selection, preventing further blow-back retraction of the speed brakes. To avoid this situation, the selector valve will be modified to retain the "RETRACT" selection, in the absence of full hydraulic pressure. Air loads will then continue to blow back the speed brakes.

13.5 ANTI-SKID SYSTEM

A trial installation of the Bendix-Pacific anti-skid system will be conducted on an ARROW 1 aircraft. In the light of present knowledge and experience, this system appears to offer the most satisfactory method available for skid control. However, both Bendix-Pacific and Hydro-Aire have been asked to submit proposals for ARROW 2 and are currently investigating anti-skid performance on this aircraft, particularly with respect to the "leg walking" problem. AVRO is also engaged in an analysis of the leg walking problem, and the influence of the brake pressure application rate on the problem.

13.6 NOSEWHEEL STEERING SYSTEM

An electro-hydraulic nosewheel steering system is being designed by AVRO to replace the original mechanically-operated system. A trial installation will be conducted on aircraft 25202 in order to determine the requirements for an operational system for ARROW 2. For the trial installation, a manual selection switch will permit the pilot to select three different steering control characteristics. This will facilitate an assessment of the relative merits of linear and non-linear control of nosewheel angle versus rudder pedal deflection. AVRO will then formulate a specification for the system, based on this assessment.

13.7 HYDRAULIC SYSTEM CONTAMINATION

The question of hydraulic system contamination is currently being studied. This was a primary consideration in design of the ARROW hydraulic systems, and consequently contamination is not expected to become a serious problem.

The following features of the hydraulic system should minimize contamination:

(a) Pressure filling of the compensators from a ground rig equipped with a 5-micron (nominal) filter.

(b) An airless system, in which there is no contact of hydraulic fluid with (dust laden) air.

(c) Adequate micronic filter arrangements.

(d) All hydraulic equipment used is specified for operation with a nominal 10 micron filtration tolerance.

In order to establish the effectiveness of the precautions taken against contamination in the basic hydraulic system design, the following test program will be conducted by AVRO:

(a) A controlled program of periodic contaminant measurement for: bulk hydraulic fluid, fluid from all hydraulic ground rigs used with the ARROW, and fluid tapped from the hydraulic systems of the first three ARROW 1 aircraft.

(b) A controlled flight test program of filter changes and analysis of contaminant contained in these filters.

(c) Consideration of a special test program in respect of contamination in electrical servo valves. These are the only items of equipment which may be marginal with respect to the hydraulic system contamination spectrum.

14.0 FLYING CONTROLS AND DAMPER SYSTEM

14.1 FLYING CONTROL SYSTEM

14.1.1 INTRODUCTION

During initial flights in the ARROW flight test program, several flying control system characteristics required attention. These were concerned mainly with the feel system and the q_c actuator system. In addition, several system improvements are being investigated on the flying controls test rig (ref. para. 27.2).

14.1.2 FEEL SYSTEM - PITCH AND ROLL

Several undesirable characteristics of the pitch and roll feel systems (more significant in roll axis) were revealed during the flight test program. Excessive backlash between the stick and feel units was eliminated, and the friction reduced on the feel units. This has improved the pitch and roll feel characteristics.

14.1.3 ELEVATOR FEEL AND TRIM UNIT

The elevator feel and trim unit emergency release will not be used for the ARROW 2. Instead, a dual motor feel and trim unit will be used to provide the required reliability of the unit. The trim actuator will be driven by two identical constant stall motors, through a differential gear assembly.

14.1.4 BOB-WEIGHT

The weight of the bob-weight was decreased in order to prevent bob-weight motions during pitch oscillations. This will also reduce the stick force per g. In addition, the bob-weight balancing spring was redesigned to reduce friction. The redesigned components were incorporated on aircraft 25201, and will be incorporated on all other ARROW 1 aircraft.

14.1.5 q_c ACTUATOR SYSTEM

The q_c actuator, which was fitted to aircraft 25201, failed prior to the first flight, and was replaced by a similar type actuator. Subsequently, an actuator having a constant stall motor was obtained and installed on aircraft 25201. The problem of the limit switches discussed in the previous Quarterly Technical Report, has been eliminated by the inclusion of a constant stall motor.

The actuator to be used on the ARROW 2 will incorporate two thermally protected motors. One motor will operate in the automatic q_c actuator system and the other will operate in conjunction with the pilot override system. This type of actuator will be retrofitted to ARROW 1 aircraft.

14.1.6 HINGE MOMENT LIMITER

It is proposed that a fixed breakout force be included in the upper and lower feel units of the rudder hinge moment limiter. During tests, this change resulted in an improvement in rudder centring. If incorporated, the rudder pedal self-centring spring will no longer be required. (Ref. 70/ENG PUB/5 ARROW Quarterly Technical Report, December 1957).

14.2 DAMPER SYSTEM

14.2.1 INTRODUCTION

Tests have continued on the flight simulator, in conjunction with the flying controls test rig and analog computer. Results of these tests were encouraging and a mechanization study is now being conducted. Development of the Humphrey stick force transducer is continuing.

Some damper system changes will be required in order to make the present development system compatible with the automatic flight control system (AFCS). However, the existing flight test program does not require that these changes be made at the present time. AVRO is currently considering the installation of the AFCS in conjunction with the flight test damper in aircraft 25202 to check the damper system compatibility.

The possible deletion of the landing gear down mode is being considered. This will affect the proposed redesign of the amplifier calibrator. However, further flight testing will be required before any change to the landing gear down mode can be established.

Circuit diagrams are being prepared for the flight test, developmental and production dampers. These will provide damper circuit information for pre-installation checks and trouble-shooting. The production damper specification (AVROCAN E-644) has been issued.

14.2.2 STICK FORCE TRANSDUCER

Testing continued on the Bell grip and Humphrey grip transducers. Results of these tests indicated that the phase shift of the Bell transucer was excessive. The Humphrey transducer was satisfactory in this respect and will be temporarily installed on aircraft 25202, in order to activate the three axes damping. Further transducer development is required.

14.2.3 CONTROL STICK BUZZ

Stick buzz (mentioned in the previous Quarterly Technical Report) was investigated on the flight simulator. An adaption of the 1.5 volt filter, as used for the structural mode oscillation problem (ref. para. 14.2.4), will be utilized in conjunction with the flight test damper, in order to achieve three axes damping. A suitable filter will be tested on an ARROW 1 aircraft as soon as possible.

14.2.4 YAW AXIS STRUCTURAL MODE PROBLEMS

The problem of rudder divergent oscillation due to the excitation of the normal and emergency lateral accelerometer (ref. previous Quarterly Technical Report), has now been solved by the introduction of a 1.5 volt filter (A_y), and the relocation of the lateral accelerometer (ref. para. 14.2.5).

14.2.5 ACCELEROMETERS

Several problems exist on the accelerometers as follows:

1. Heaters - It is suspected that leakage from the accelerometers is caused by the high pressure inside the accelerometer, which is in turn caused by the high temperatures generated by the existing heaters. Honeywell is currently investigating the use of blanket type heaters.

2. Thermostatic Switch - This switch was subject to repeated failure, and is being changed by Honeywell. The modification will be retrofitted to all other accelerometers.

3. Accelerometer Damping - Honeywell will consider viscous damping for the accelerometer in place of the magnetic damping used at present.

4. Mounting of lateral accelerometers (yaw axis) - After the first flight following the grounding period, it was discovered that the two lateral accelerometers were installed 180° out of position. AVRO is now installing a bracket which will prevent the mounting of the accelerometers in the wrong position.

5. Location of Accelerometers - The 1 cps oscillation in the normal and emergency yaw dampers has been eliminated by repositioning the two lateral accelerometers from the armament bay roof to the equipment bay. This caused minor relocationing of the pitch damper accelerometers also located in the equipment bay.

14.2.6 g-LIMITER

AVRO has now received information for the installation of the g-limiter and associated equipment and wiring. Deliveries of the g-limiter from Honeywell will begin during July and the equipment will be retrofitted to all aircraft. In order to improve the accessibility of the aft g-limiter accelerometer, it has been repositioned from the duct bay, under the wing, to inside the dorsal, on the right-hand side of the aircraft centre line. To make the system components compatible, the forward g-limiter accelerometer was also moved to the right-hand side of the aircraft centre line (in the armament bay).

14.2.7 POSSIBLE DELETION OF THE LANDING-GEAR-DOWN MODE

The effects of deleting the landing-gear-down mode will be investigated and will require flight testing of the complete damper system. The deletion of this mode would result in the increased reliability of the damper system.

14.2.8 INSTRUMENT PACK

Difficulties were encountered when the instrument pack was connected into the aircraft damping system. The installation of instrumentation is therefore being reviewed. It is anticipated that the necessary changes will be completed before the next flights.

15.0 OXYGEN SYSTEM

15.1 OXYGEN CONTENTS INDICATORS

All ARROW 1 aircraft and the first three ARROW 2 aircraft will be equipped with a Honeywell oxygen gauging system. This system includes a contents indicator with a built-in amplifier located in the pilot's cockpit, and repeater indicator in the rear cockpit. The fourth and subsequent ARROW 2 aircraft will be equipped with improved contents indicators, also developed by Honeywell. The indicators will incorporate integral lighting and will be identical for each cockpit. The rear indicator, however, will still be a repeater of the front cockpit indicator.

15.2 WATER DRAINS

In order to absorb moisture formed by condensation at the base of the converter, a removeable sponge will be mounted below the tray. It is considered that normal evaporation will prevent saturation of the sponge.

15.3 ARROW 2 OXYGEN CONVERTER

The installation of the liquid oxygen converter was not demonstrated at the ARROW 2 mock-up conference held in September 1957. Approval of the location and mounting of a Bendix converter was obtained following a demonstration given by AVRO in May 1958.

16.0 ARMAMENT

16.1 ARROW 1

Discussions have continued between AVRO and Canadair on the testing of Control Test Vehicles (CTV). It has been agreed that Canadair will be responsible for obtaining the use of a missile firing range, conducting the tests and arranging with the RCAF for the type of aircraft to be used (CF-100 or ARROW). Aircraft will be selected from those allocated to the Canadair Sparrow missile development program.

16.2 ARROW 2

The following subjects are currently under review with reference to their effects on the Sparrow 2D missiles installation:

16.2.1 DEFLECTION EFFECT ON ANTENNA LINE OF SIGHT

The magnitude of the deflections between the aircraft antenna and missile antenna is still under investigation. Final results, which will be based on ground resonance tests, are not yet available.

16.2.2 MISSILE INTERFERENCE (STRUCTURAL DEFLECTIONS)

Investigations have shown that when allowance is made for all adverse tolerances and deflections, it is possible for a foul to exist between the missile body and launching rails. Investigations are currently being conducted by AVRO and Canadair into the best method of protecting the missile from damage in both stowed and launch positions.

Missile and launcher side deflections will be restricted by guide plates located on each side of the openings in the weapon pack bottom skin, when the missile launchers are in their stowed position. When side loads are applied to either the launcher or missiles, the plates will guide them to a central position, thus protecting the sealing strips around the pack opening from damage.

16.3 MISSILES

The previous Quarterly Technical Report stated that AVRO is responsible for determining and recording the environment in which the Sparrow 2D missiles must exist and function, up to the time the missile wings were unlocked. This should have read that AVRO is responsible for determining and recording, that part of the environmental conditions in which the Sparrow 2D Missiles must function as part of the ARROW weapon system, up to the time of umbilical plug separation.

AVRO will also be responsible for qualification testing of that portion of the umbilical plug located on, and forming part of the missile launcher. In addition, AVRO will be responsible for qualification testing of the mating portion of the plug (located in the missile), but will not be responsible for the plug location attachment or associated wiring insofar as the missile is concerned.

16.3.1 MISSILE PROTECTION

A jettisonable cover is being designed to protect the missile from excessive skin temperatures. The covering will be installed over the nose and body of each missile but not over the missile wings or fins. Wind tunnel tests will be conducted at NAE to check the jettison characteristics of these covers. Jettison will be initiated by the opening of the missile doors.

16.3.2 UMBILICAL PLUG

Geometry drawings of the proposed AVRO umbilical plug retraction mechanism, based on the use of a Deutsch connector (DM9606-37), have been sent to Canadair. Missile design changes, to accommodate this connector, will be Canadair's responsibility.

16.3.3 MISSILE WING ACTUATION TIME

The method of controlling the missile wing hydraulic unlock is still under consideration. AVRO has stated that for aircraft safety reasons, the missile wings must remain locked until the launched missile is 32 feet forward of its pre-launch position. At the same time, in order to minimize dispertion, flight control of the missile must be obtained as soon as possible after the commencement of missile launching.

16.3.4 DESIGN CONSIDERATIONS

AVRO has been advised by Canadair of changes to the external profile of the Sparrow 2D missile. These changes are due to the addition of spotting charges, flares, telemetry cables etc. to various Canadair test vehicles. Canadair has been requested for a drawing of all profile variations, so that the various types of missile test vehicles can be accommodated in the weapon pack structure.

17.0 ESCAPE SYSTEM

At the RCAF's request AVRO has prepared a program to evaluate the ARROW escape system. Report No. 72/SYSTEM 24/205 - Development Program for the ARROW Escape System outlining the proposed test and development program, was completed in June 1958.

17.1 EJECTION SEAT DEVELOPMENT

Martin-Baker is currently conducting a development program on leg, arm and head restraints, for use with the MK. C5 seat.

17.1.1 LEG, ARM AND HEAD RESTRAINT

Leg Restraint - The front face of the seat pan will be extended by four to five inches, provided there is sufficient space in the cockpits. The extended area will be padded to cushion the pressure between the pilot's leg and the forward face of the seat pan and will prevent the legs being blown back under the seat. It is anticipated that problems could arise with the leg restraint line due to the additional structure required to support the proposed extension.

Arm Restraint - Investigation and experimental testing of arm restraints, are being conducted. The result of these tests are not yet available from Martin-Baker.

Head Restraint - Martin-Baker considers that any mechanical means of head restraint could be extremely dangerous. The RCAF proposed head restraint will therefore be integrated with the face screen, and will be operated by one hand, while the other hand operates the "D" ring.

17.1.2 DUPLICATE CANOPY FIRING CARTRIDGES

Martin-Baker is not in favour of providing duplicate canopy firing cartridges, or alternating firing control in the suggested location between the crew members' legs. Martin-Baker has further stated that the present seat firing assembly is 100% reliable, and since the canopy release uses the same principle of firing assembly (not duplicated) as the seat, it would not seem logical to duplicate the seat ejection cartridges. Martin-Baker has, however, been informed that duplication is a requirement and they have been invited to develop a system.

17.2 SLED TESTING OF THE ESCAPE SYSTEM

The original sled testing requirements have been changed, due to the assessment of the existing escape system (see para. 17.0). Consequently, a simulated forward fuselage shell, with production cockpit equipment, will be used in place of the proposed production ARROW front fuselage section. Coleman

Engineering have been notified of the requirement changes. Contractual negotiations are being conducted with Coleman Engineering for the execution of the sled tests required in the new evaluation program.

18.0 DRAG CHUTE

18.1 ARROW 1

For the initial flights of aircraft 25201, it was necessary to remove some of the drag chute box door seals to improve door operation. Consequently, the possibility of water entering the stowage box and ice forming on the doors is being investigated. The detrimental effect of ice on the door operation, and the use of more effective seals will also be considered.

Testing has revealed the possibility of the release mechanism unlocking prematurely. A tension spring has been added to the mechanism to overcome this problem.

With the present system of drag chute deployment, it is suspected that damage is caused to the drag chute lines by the shackle after jettison. An alternative method of deployment, in which the deployment bag is retained in the aircraft, will be tested on aircraft 25202. With this method, the drag chute and lines will be contained in a sleeve, and pulled from the aircraft by the drogue chute. The weight of the drag chute will be distributed over the length of the sleeve during the streaming operation; the drag chute being clear of the runway at speeds above 80 knots. The drogue chute will be attached permanently to the drag chute, and the sleeve only will be jettisoned when the canopy inflates. It is considered that this method may also reduce the tendency for the drag chute to stream to one side of the jet blast.

18.2 ARROW 2

The operating characteristics of a 24-foot ground streaming drag chute, and a 21-foot air streaming drag chute are shown in Table 3. The 21-foot chute gives a shorter landing distance, but in view of the unpredictable effect of an air-streamed chute on the aircraft, a 24-foot ground streaming drag chute has been retained for the ARROW 2.

The existing loads and conditions with the 24-foot diameter drag chute permit a coning angle of $\pm 9^\circ$. However, the drag chute attachment structure will be strengthened, and this will enable the drag chute to be streamed at a coning angle of $\pm 15^\circ$; i.e., the swirling motion may produce a maximum angle of 15° between the drag chute axis and the aircraft directional axis, without endangering the attachment structure by side or vertical loads.

19.0 STRESS ANALYSIS

19.1 THERMAL STRESS ANALYSIS

The thermal stress analysis program has been established and will be conducted in three phases.

The first part of the program is nearing completion, and is primarily an exploratory study to determine the extent of visualized thermal problems, and the importance of these problems on the ARROW. To enable a simpler and more rapid evaluation of the thermal conditions which may exist in the wing, the analysis assumes various constant fuel levels throughout any mission. Also, the effects of fuel splashing is neglected, and the local effects of fuel splashing is neglected, and the local effects due to stringers are not fully included.

Part 2 aims to establish the thermal restrictions to the flight envelope, and the extent of the study will depend upon information established by part 1. The thermal effects at several constant altitudes will be studied for various rates of accelerations and acceleration times. The thermal effects will then be interpreted in terms of the reduction of allowable manoeuvre factor. This information can then be presented as a family of curves which may be superimposed on the flight envelope for each altitude. The information received during this study will also be used in the third structural matrix (discussed in previous Quarterly Technical Report), which has been programmed to include the determination of the thermal stress effects.

In part 3, the effects of creep and fatigue will be studied. Although these effects will be considered to some degree in parts 1 and 2, they will be examined more fully in this part of the program.

19.2 INITIAL STRUCTURAL INTEGRITY PROGRAM

The initial structural integrity tests are scheduled to be conducted between August and December 1958, in conjunction with tests on stability, control, flutter and systems. It is intended to flight test only those manoeuvres which can be monitored safely with available instrumentation. Consequently, the termination points will be the attainment of 80% of limit loads or 80% limit stresses, whichever are lower.

It is proposed to work within the framework of cases which have been issued and analyzed. These causes include steady pull-out, checked pull-out, steady push down, checked push down, rolling pull-out, and rudder manoeuvres.

A number of structural temperatures will be measured during the tests. The results will serve to check the accuracy of estimated temperatures used in the design of structural components, and in the thermal stress analysis. Internal pressures will also be measured to ensure that the structural maximums are not exceeded.

19.3 STRESSING OF HYDRAULIC PIPING

The hydraulic piping stress investigation has been concerned mainly with the high pressure piping of the ARROW flying control system. The basic requirement for the piping is an infinite life under both pressure and flexing pulsations. Pressure pulsations were taken as 0-5300 psi, and in accordance with ANC-5, the infinite life span is taken as 10^7 cycles. An allowable 3-1/2% ovality was considered.

The existing piping is of stainless steel made to CS-T-162 (M-7-14) and CS-T-163 (MIL-T-6845). As required fatigue curves and endurance limit stresses were not available for piping made of this material, the required information was extrapolated from test data. This data established an endurance limit of 45,000 psi circumferentially and 60,000 psi in the longitudinal direction. These values were then used to develop the interaction stress curve which was used to determine the fatigue life of the various piping.

The endurance limit is being checked through pressure pulsation tests conducted on tubing of various diameter and wall thickness combinations. The test results show the endurance hoop stress limit to lie between 41,000 psi and 44,000 psi. However, the tests are being conducted on specimens of MIL-T-6845 material for which the ultimate tensile strengths range from 112,000 psi to 119,000 psi. By using M-7-14, material, which has a minimum specified ultimate tensile strength of 125,000 psi, the endurance limit may be achieved.

The results of the investigation have shown that all pipes on the pressure side of the flying controls hydraulic system (4,000 psi system) will have to be replaced. These will be replaced by pipes to CS-T-173 (M-7-14), which have a slightly larger wall thickness.

20.0 MOCK-UP

20.1 SUMMARY OF MOCK-UP ACTIVITIES

As the result of the ARROW 2 mock-up conference in September, 1957, a total of 252 change requests required investigation. The effects of these changes are being determined by AVRO, RCA, Martin-Baker and the RCAF.

20.2 STATUS OF MOCK-UP CHANGE REQUESTS

The current status of the 252 changes are listed below:

Subject	Code	Items Not Evaluated	Change Req'sts	Initial Investigation	Undergoing Corrective Action	Completed	Demonstration Req'd
Cockpit	A	1	62	11	12	39	5
Structure	B	1 + #	51	5	8	38	1 *
Engine Installation	C	-	17	-	3	14	-
Electrical	D	-	22	2	4	16	-
Air Cond'g	E	-	7	-	2	5	-
Low Press. Pneumatics	F	-	1	-	-	1	-
Fire Exting. System	G	-	3	-	-	3	-
De-Icing	H	-	2	-	-	2	-
Fuel System	I	-	11	2	1	8	1
Hydraulics	K	-	15	2	2	11	-
Oxygen System	L	1 + #	5	-	1	4	1
Instruments	M	-	7	2	1	4	-
ASTRA I	N	1	34	9	8	17	1 *
Armament	O	1	15	4	2	9	1
		5	252	37	44	171	10

* Explanatory data will be provided in lieu of demonstration for these items.

Two items previously listed as not evaluated, have now been approved.

20.3 FURTHER DEMONSTRATIONS

The remaining five items of the original ten not evaluated during the mock-up conference will be demonstrated at a later date.

The following items will be either demonstrated or covered by letter(s) to the RCAF.

Description	Ref. Code	Form of Demonstration
Pilot's and observer/AI's seat	A. 24	Aircraft
Console lights	A. 8 (Cat. 1)	"
Cockpit lights	A. 12 (Cat. 1)	"
Map lights	A. 37 (Cat. 1)	"
Intensity of light	A. 38 (Cat. 1)	"
Facilities for bladder tank removal	B. 11, Pt. 2	Letter
Facilities to remove fuel booster pump gear box	I. 1 (Cat. 1)	Mock-up
Seat oxygen equipment	L. 5	Aircraft
Antenna multiplexing	N. 18	RCA to clear by letter
Missile umbilical plug and rail	0. 7	Test rig

Items in the above list with their category marked in brackets e. g. (Cat. 1) were changed as a result of the mock-up conference, and will be redemonstrated.

21.0 COMPONENT DESIGN

21.1 WING DESIGN

In addition to splitting of the ailerons as mentioned in the previous Quarterly Technical Report, the elevators have also been split to alleviate the effects of control surface movement under deflected wing conditions. Each elevator has been split at approximately mid-span. Two stainless steel angles are riveted to rib number 7 to form the seals which slide over the outboard portion of the elevator in the area of the split. A shear fitting is attached at the trailing edge.

The failure of the aileron on test, which was reported in the previous Quarterly Technical Report, was caused by the aileron being deflected beyond the design limits.

Other design work on the ARROW 1 includes schemes for the addition of lightening holes in the inner skin of the main landing gear doors. Design work on the ARROW 2 includes the installation of nitrogen lines for cooling the IR seeker and schemes for remote greasing of elevator and aileron controls.

Due to difficulties encountered during assembly, the attachment of rib number 4 (auxiliary spar to main spar) to the main spar has been redesigned. The redesign will be incorporated on aircraft 25209 and subsequent aircraft.

21.2 WING STRESS - ARROW 1 and 2

The fatigue analysis, based on obtaining a 3,000 hour fatigue life, is continuing on the elevator and aileron control boxes. Comprehensive tests, including a fatigue test of the elevator on the static test aircraft, will serve to check the theoretical analysis.

The analysis of the inner wing posted box test results has been completed. Results have been satisfactory, although a zero strength margin was obtained for some cases, and these are being rechecked.

21.3 RADAR NOSE DESIGN

21.3.1 RADAR NOSE DESIGN - ARROW 1

Schemes for the fixed camera installations in aircraft 25203 are in work. A preliminary investigation on the installation of a strike camera and a servo camera (coupled with radar antenna) on aircraft 25204 and 25205, is currently in progress.

21.3.2 RADAR NOSE DESIGN - ARROW 2

RCA indicated that the cooling air flow in the radar nose was inadequate, and a redesign of the structure to increase the flow has been completed.

Present design work includes the provision of instrumentation in the radar nose of aircraft 25207.

21.4 RADAR NOSE STRESS - ARROW 2

The preliminary evaluation of the radome materials has been completed. Five different materials have been considered, but additional tests will be required before complete evaluation can be made. The radome will be manufactured by Brunswick-Balke-Collender to AVRO specification.

21.5 FRONT FUSELAGE DESIGN

21.5.1 FRONT FUSELAGE DESIGN - ARROW 1 and 2

Flight experience on aircraft 25201 showed that a redesign was necessary on the air intake side skins and stiffeners (between stations 202 and 255), to prevent cracking of the external side skins. This redesign has been completed for ARROW 1 and is in work for the ARROW 2.

21.5.2 FRONT FUSELAGE DESIGN - ARROW 2

Present design work includes the incorporation of flying control boosters in the aileron control system. In addition, design work is being carried out on the cockpit ducting and silencers, to reduce cockpit noise.

21.6 FRONT FUSELAGE STRESS - ARROW 2

The investigation is continuing on the use of Sierracin 880 with sierracote demisting medium for the windshield and canopy. Evaluation tests are currently being conducted on this material.

The test requisition for the Obs/AI's canopy window is being issued and includes requirements for proof and ultimate pressure testing, thermal shock and thermal cycling.

21.7 CENTRE FUSELAGE DESIGN

21.7.1 CENTRE FUSELAGE DESIGN - ARROW 2

The equipment bay side access doors (at station 255 - 292) have been modified to provide horizontal opening to facilitate the installation and removal of doppler radar equipment. Production drawings for this work have been completed.

The fabrication process for the Fiberglass heat exchanger outlet duct has been completed and submitted to the sub-contractor.

21.8 CENTRE FUSELAGE STRESS - ARROW 2

The drawings for the equipment bay side access doors (ref. para. 21.7.1) are being processed.

The stress analysis of the weapon/instrument pack has been completed.

The Fiberglass heat exchanger outlet duct will employ NA91LD resin. Re-design of this duct employing a light core material for the top hat stiffeners is being investigated. The first manufactured duct of this type will be used for material evaluation.

21.9 DUCT BAY DESIGN - ARROW 1 and 2

No major design work has been done on the duct bay during the past quarter.

21.10 DUCT BAY STRESS - ARROW 2

The investigation of loads on the extended speed brakes during missile firing, mentioned in the previous Quarterly Technical Report, has been completed. The increased loads will be accommodated by hydraulic system changes, and no modifications are required to the speed brake structure. (Ref. para. 13.4).

21.11 ENGINE BAY DESIGN - ARROW 2

Following the investigation on moving the air flow restrictor forward in the engine bay, requested by Orenda Engines, the restrictor shroud and variable restrictor will be repositioned in the vicinity of station 630, (ref. para. 9.2).

21.12 ENGINE BAY STRESS - ARROW 2

A stress investigation into the effects of moving the air flow restrictor forward has been completed with satisfactory results.

21.13 REAR FUSELAGE DESIGN - ARROW 2

Schemes are approximately 50% complete for the jettisonable nozzle (ref. previous Quarterly Technical Report). Production drawings for structural provisions are being completed.

21.14 REAR FUSELAGE STRESS - ARROW 2

A strength survey was conducted on the ARROW 2 rear fuselage structure to determine the required changes, should a larger drag chute be installed. However, it has been decided to retain the 24-foot diameter drag chute as presently employed on the ARROW 1. The loads produced by this drag chute are within the capabilities of the existing ARROW 2 fuselage strength, and the drag chute attachment structure will be further strengthened to permit a coning angle of ± 15° (ref. para. 18.2).

21.15 FIN AND RUDDER DESIGN - ARROW 1 and 2

The rudder has been split to alleviate control surface buckling when the surfaces are moved under deflected fin conditions. The split separates the rudder in two parts at approximately mid-span. The seals are similar to those on the elevator; i.e. they consist of two stainless steel angles, riveted to rib number 12, and slide over the upper portion of the rudder in the area of the split. Shear connections are provided at the front spar and trailing edge member. The shear connection at the front spar also supports the weight of the upper portion of the rudder.

21.16 FIN AND RUDDER STRESS - ARROW 1 and 2

The split rudder design is currently being stressed.

21.17 LONG RANGE TANK

The design work on the long range tank is progressing satisfactorily and production drawings have been issued for the forward section. An investigation on tank jettisoning revealed interference between the rear fairing and fuel disconnect, resulting from the yawing and rolling of the tank when released from the aircraft. To eliminate the possibility of the fuselage structure being damaged during tank jettisoning, a weak portion will be introduced in the rear fairing of the tank at the fuel disconnect location. In addition the length of the rear fairing has been increased to reduce aerodynamic drag. The design of the aft release mechanism will be changed to prevent possible premature releasing of the tank, under deflected fuselage conditions.

21.18 LANDING GEAR DESIGN

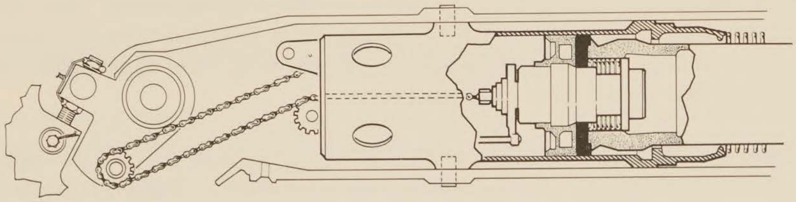
During the completion of the eleventh flight of aircraft 25201, the left-hand landing gear locked in the down position, but failed to extend fully. As a result, the wheel bogie failed to twist into a position parallel with the aircraft's longitudinal axis.

When the main gear uplock is released, and the landing gear begins to lower, a spring acting on the extension mechanism begins to extend the gear. At the same time a helical cam track causes the lower part of the gear (and wheel bogie) to rotate. As extension continues, the spring force decreases, after which the weight of the lower part of the gear provides the main extending and twisting force. When the fully extended position is reached, the wheel bogie becomes locked in the extended and in-line position. To effect shortening during retraction, a chain is attached to the sliding barrel of the extended portion of the leg which passes to the top of the leg and over a sprocket wheel. The chain then passes around a second sprocket wheel, which is attached to a dust cover, and its end attached within the leg. The dust cover is fixed in relation to the wing structure, so that as the leg retracts, the effective length of the chain shortens and the extension mechanism is eventually forced against the spring. Similarly as the leg lowers, the chain will control the movement of the extension mechanism.

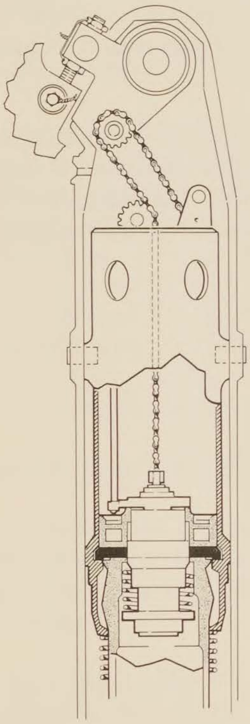
It is suspected that the failure of the gear to extend fully was caused initially by excessive friction in the extension mechanism. This allowed the chain to slacken and become trapped between the dust excluder and the top of the main leg. As a result, the extension mechanism was held short of its locking position when the gear locked down, as shown in Figure 18.

Subsequent to the accident to aircraft 25201 tests were conducted at Dowty in which the friction of the extension bearing was increased. Lowering of the gear under this condition caused the chain to loop and jam at the dust cover. On one occasion, when it was thought that the chain was clear, the gear was allowed to continue lowering. In actual fact the chain had jammed, and caused damage similar to that occurring on the L. H. gear extension mechanism of aircraft 25201.

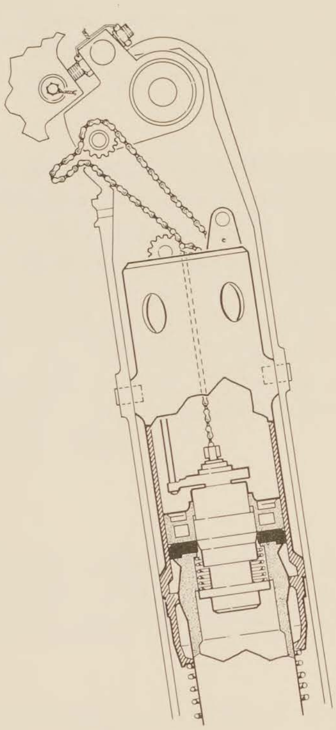
To prevent the possible recurrence of this condition, the extension spring force will be increased from 600 lb. to 1000 lb. in the contracted position. Also, before installation on the aircraft, each leg will be subjected to the most rigorous tests to ensure that the extension mechanism functions properly.



NORMAL RETRACTED POSITION



NORMAL EXTENDED POSITION



ABNORMAL EXTENDED POSITION

FIG. 18 DETAIL OF LEG SHORTENING MECHANISM

22.0 MAINTENANCE AND RELIABILITY

22.1 MAINTENANCE ENGINEERING

During the reporting period, the efforts of Maintenance Engineering group have been concentrated towards the Personnel Requirements Data (PRD) study of ARROW 1 maintenance instructions and revision of GSE list. In addition, maintenance design change requests resulting from experience gained on aircraft 25201 and periodic inspection schedules have been issued.

22.1.1 PERSONNEL REQUIREMENTS DATA STUDY

AVRO maintenance analysts have been engaged on the PRD study since 1 April 1958, and the study is now 20% complete. In May, AVRO and the associate contractors (Orenda, RCA and Canadair) established a schedule for the delivery of PRD information. The RCAF has since agreed to the proposed target date of 1 April 1959 for the initial submission of the complete airframe program. It was emphasized that in order to meet the schedule, immediate contractual coverage by the RCAF for the sub-contractors would be necessary. In addition, it was stated that the associated contractors portion of the program would slip proportionately with the date of receipt of the contractors coverage. Contractual coverage has not yet been provided for Orenda, Canadair and RCA, and consequently AVRO has not received inputs from these companies.

22.1.2 FLIGHT TEST COVERAGE

It is considered that the twenty-four hour maintenance coverage of experimental aircraft is no longer required. However, the maintenance of aircraft in Experimental Flight Test is being monitored throughout the normal working day by maintenance analysts. Recommendations continue to be made to the Product Design Department for improving the maintenance and accessibility aspects of the aircraft.

22.1.3 INSPECTION SCHEDULES

The periodic (25 hours) inspection schedule has been issued along with the revised special inspection requirements, resulting from the qualification test program on airborne equipment.

22.2 GROUND SUPPORT EQUIPMENT LIST

The revised list of ground support equipment (70/GEQ/2) for the thirty-seven aircraft program was submitted 30 April 1958 for RCAF approval. Further revisions to this list are now in work as a result of a change in the aircraft scheduling program, and additional RCAF requirements. These changes are being made in conjunction with all associate contractors and the RCAF.

22.3 RELIABILITY ENGINEERING

22.3.1 EQUIPMENT QUALIFICATION

The total number of bought-out equipment items for the ARROW 1 has been revised from 965 to 798 due to segregating the CS parts from the bought-out equipment items. The qualification status of bought-out equipment is as follows:

Qualified items applicable to ARROW 1	-	202
Limited flight approval items	-	289
Items which do not require qualification action	-	231
Government furnished airborne equipment	-	49
Items to be qualified	-	27
Total	-	798

All items with limited flight approval based on engineering judgement, have now been raised in status to limited flight approval with specific limitations.

The quantity of ARROW 2 bought-out equipment items has also been revised due to the policy of dealing with CS parts separately. This has reduced the number of items from 924 to 797. The qualification status is as follows:

Qualified items applicable to ARROW 2	-	11
Qualified items common to both ARROW 1 and 2	-	72
Items which do not require qualification action	-	63
ASTRA I and Government Furnished Airborne Equipment	-	186
Unqualified items common to both ARROW 1 and 2	-	172
Unqualified items applicable to ARROW 2	-	293
Total	-	797

A complete re-issue of Report No. 71/REL 00/1-2 (Qualification Status Airborne Equipment) was issued in May and an amendment to the above was issued in June.

22.3.2 RELIABILITY ANALYSIS

Development defects and utilization data, have been collected on aircraft 25201 and 25202 during the past quarter. In order to evaluate the problems associated with the actual collection of defects, the responsibility of compiling development defects and utilization data in the Experimental Department has been transferred to flight test sub-foremen and to quality eontrol personnel in Production Flight Test. To date, two defect summaries and IBM tabulations, complete with code books, have been issued to the RCAF. In future these will be issued monthly. The first utilization record is expected to be completed by August.

23.0 GROUND SUPPORT EQUIPMENT

23.1 ARROW 1

Engineering is complete on the J75 P5 afterburner sling. Four items remain outstanding to complete the ARROW 1 ground support equipment; a winch to raise the fire extinguisher bottles into the aircraft, and a tool for removing the canopy pip pin. Two new items, a Goodyear brake wrench, and a P5 engine alignment template, have been added to the list and are currently being designed.

23.2 ARROW 2

The following items have been added to the ARROW 2 ground support equipment list, and the drawings completed:

- Jacking pad adaptor.
- Air conditioning heat exchanger system.
- Air conditioning water tank sling.
- Air conditioning turbine and compressor sling.
- Offset fitting grease gun.
- Main landing jack tool adjuster.

Drawings for the following outstanding items of ARROW 2 ground support equipment have been completed:

- Missile trailer/hoist.
- Engine exhaust covers.
- Air conditioning pack.
- Canopy locking actuator.
- Iroquois engine change stand.
- Iroquois change crane.
- Fuel tank test intercooler unit.

The ARROW 2 radar maintenance stand is being designed.

Engineering is still outstanding on the following items required for the ARROW 2 ground support equipment:

- Engine air turbine starter.
- Power and air conditioning truck.
- Armament harmonization stand.
- Weapon pack test console.
- Auxiliary external fuel tank trailer.
- Aircraft component slings for:
  - Aileron control box
  - Ailerons
  - Tailcone

Main landing gear installation stand.
Nose landing gear installation stand.
Universal stand for removal of aileron and elevator control boxes.

23.3 MOBILE GROUND POWER UNITS

The procurement of air conditioner/generator units and starter units has been discussed with the RCAF during this reporting period. Delivery of the first pair of these units to support the ARROW 2 development program is required in twelve months. As a result of these discussions, AVRO decided to either procure the units from a sub-contractor or design and produce the units, with engineering assistance from vendors specializing in this equipment.

It was felt that in view of the time factor, the first alternative would not be possible. AVRO therefore recommended the second alternative and it was approved in principle by the RCAF. However, the Department of Defence Production did not agree with the recommendation, and the units are to be procurred from a sub-contractor.

A general AVROCAN specification has been prepared and submitted to equipment vendors.

Addendum 1 to Report No. 72/GEQ/1 (ARROW 2 Design Study of Mobile Ground Power Units) was issued in April. This addendum was prepared to meet the revised RCAF requirements, detailed in the previous Quarterly Technical Report.

23.4 INFRA-RED SYSTEM NITROGEN SUPPLY

Preliminary investigations have been made to provide a pure nitrogen gas supply as a cooling medium for the IR seeker. It is proposed to store this gas in a bottle permanently installed in the aircraft. The method of cooling is described in para. 11.2.

23.4.1 GROUND SUPPORT PROBLEMS ASSOCIATED WITH THE NITROGEN SYSTEM

Two problems are involved in providing a nitrogen cooling supply:

(a) Purification of nitrogen.

(b) Replenishment of nitrogen storage bottle within the specified turnaround time.

Pure nitrogen is required since contamination of the gas in excess of the following specified levels will block the nozzle and cause failure of the system. (Contamination by water vapor should not exceed -100°C (-148°F) when the dew point is 1,000 psig. Contamination by hydrocarbons, oxidation products including CO_2, must not exceed 50 parts per million.) The ARROW 1 nitrogen compressor (ground equipment) is unsuitable for providing nitrogen of the required purity and the additional equipment required to obtain this purity would be too bulky. In addition, the gas would be contaminated by hydrocarbons present in the compressor lubricating oil.

The replenishment of the aircraft storage bottles in the allotted turnaround time, using a compressor, is impracticable since an excessive number of compressors would be required. In addition, an excessive amount of filtration equipment would be required in order to purify the amount of gas required in the available time.

Preliminary investigations have shown that the storage bottles can be replenished by using a fixed facility containing a compressor designed for use with fluorinated lubricants (non-hydrocarbons) and equipped with filtering and drying equipment. The gas produced from this compressor would be fed into mobile storage bottles which will be charged to 5,000 psig. These bottles would then be used to charge the aircraft storage bottles to 3,000 psig.

A report will be prepared and issued when the investigations have been completed.

23.5 WEAPON PACK TEST CONSOLE

A technical proposal is being prepared for the RCAF which states AVRO's requirements for the design of a weapon pack test console. In order to ensure that a weapon pack test console will be available for aircraft 25203, an interim unit is being designed. This console will also serve as a mock-up for determining finalized console requirements.

23.6 EVALUATION OF DAMPER TEST EQUIPMENT

Flight tests on aircraft 25201 have provided the opportunity to evaluate the damper test equipment, and Honeywell is now preparing a proposal on the finalized version of the test equipment.

24.0 AIR BASE FACILITIES

24.1 ENGINE RUN-UP FACILITY

In May, 1958, Report No. 72/GEQ/8 (ARROW 2 Study of the Basic Run-Up Facility) was issued at the RCAF's request. The report discusses the engine maintenance concept, and describes the proposed facility which will adequately achieve the engine and airframe manufacturer's recommended maintenance procedures.

24.2 AIRCRAFT RUN-UP BASE

A study for an aircraft run-up base is currently being prepared and will be issued in August. The report will outline the requirements for tie down loads and points of applications, sound levels at various locations, personnel requirements, instrumentation and ground support equipment.

24.3 2ND LINE MAINTENANCE FACILITY

A study of the 2nd line maintenance facility is being prepared, and it is anticipated that a preliminary issue will be available in August, 1958. The proposal for air base workshops, contained in the report, will be finalized in conjunction with the conclusion of the PRD (Personnel Requirements Data) study scheduled for issue at the end of 1958.

25.0 WEAPONS SYSTEMS TRAINER

25.1 AIRCRAFT SYSTEMS TRAINER

A technical proposal for the ARROW 2 Aircraft Systems Trainer (AST) submitted to the RCAF in January 1958, has not yet been approved.

25.2 GROUND EQUIPMENT TRAINER

A technical proposal for the ARROW 2 Ground Equipment Trainer (GET), described in the previous Quarterly Technical Report, was submitted to the RCAF in June 1958 for approval.

26.0 STRUCTURAL GROUND TEST PROGRAM

26.1 STATIC TESTING OF THE COMPLETE AIRCRAFT

Installation of the static test aircraft in the test rig has been completed and all electrical wiring has been installed for the strain gauges and strain recorders. Erection of the deflection measurement system has been completed. The counter-balancing system has been completed and tested, and the automatic loading system has been functioned and adjusted. Initial tests, involving the application of loads up to 25% of the limit loadings, showed that operation of the strain recorders was unreliable. After consultation with the manfacturer, the typewriters from the recorder were returned for adjustment. In addition, the print command relays were changed, and arrangements were made to eliminate dust from the room in which the recorder and associated equipment is installed. An increase in the load to be applied to the main landing gear during the landing gear spring back tests has necessitated minor changes to the fuselage down-loading whiffletree system. These changes were required in order to keep the bending moment in the fuselage at Stn. 485 to an acceptable level. The changes are complete, and the formal test program for the landing gear springback case is about to begin.

Tests are being continued to investigate the effects of time and environment on strain gauges. These tests are of particular importance to the strain gauges designated for long term testing, and so far the results indicate the time and environment do not materially affect the gauges.

26.2 COMBINED LOADING AND TRANSIENT HEATING OF WING BOX

The combined loading and transient heating tests on a wing box section are now in abeyance.

26.3 TEMPERATURE DISTRIBUTION THROUGH TYPICAL STRUCTURAL SECTIONS

Tests conducted on a small box specimen, representative of the forward fuselage side skin and duct, gave satisfactory results.

26.4 DEVELOPMENT OF HIGH TEMPERATURE STRUCTURAL TEST TECHNIQUES

Tests have been completed to determine the suitability of Monsanto "Aroclor" 122, as a substitute for JP 4 fuel during transient heating tests. Results are now being compared with results from similar tests previously completed on JP 4. Tests are continuing to assess the suitability of Tatnall stabilized and temperature-compensated foil-type strain gauges for use during high temperature testing. No conclusive results are yet available.

26.5 FATIGUE TESTS OF MODEL FUEL TANK NO. 4

Fatigue tests were satisfactorily conducted on the model fuel tank and were discontinued when a total of 3,000 loading cycles had been accummulated.

The steel doubler plates on the tank access door were replaced with aluminum doublers, in accordance with the latest design, but subsequent test results were not entirely satisfactory. Testing is now in abeyance pending further instruction from the Technical Design Department.

26.6 PANEL RESPONSE TO SOUND PRESSURE AND FREQUENCY

Tests are being conducted to determine the effect of adding damping material to a fuselage side skin panel subjected to acoustical excitation. Difficulties have been experienced with the test panel strain gauge installation due to fracturing of the gauge lead wiring after short periods of testing. This problem is currently being investigated and testing continues.

26.7 BASIC INVESTIGATIONS INTO ACCOUSTICAL FATIGUE OF STRUCTURES

Tests conducted to determine the effect of damping materials installed on aluminum panels have been successful, but further testing has been delayed due to motor breakdown. Testing will resume when repairs have been completed.

A further siren test rig, which will enable testing to be conducted on a variety of specimens simultaneously, is currently being manufactured by AVRO.

26.8 BEARING RETENTION DEVELOPMENT

Modifications were completed to the roll swaging tool, and further tests have been conducted on bearings which had been roll swaged in the bearing housing. Results show that this method of bearing retention compares well with the press-swaged sleeve retention method previously tested. No further bearing retention tests are anticipated.

26.9 ENGINE LIFTING MECHANISM FATIGUE TEST

Two more engine lifting mechanism specimens completed fatigue tests satisfactorily at Krouse Testing Machines Inc. Further tests will be conducted on three additional specimens, under various loading conditions, when they become available from the Manufacturing Division.

26.10 PRESSURE TEST ON RAM AND FAN EXHAUST DUCT

Tests on the critical regions of the ram and fan exhaust duct were completed satisfactorily. No further tests are anticipated.

26.11 AILERON JACK FATIGUE TEST

The jack fork-end has been strain-gauged to directly indicate the applied load. Fatigue testing started, but the rig operating speed was considered excessive. A new sprocket has been designed to reduce the cyclic testing speed and the associated rig modification is now in progress.

26.12 ADDITIONAL TESTS ON INNER WING POSTED BOX

Testing of the inner wing posted box has been completed. Initial tests were conducted, combined with bending and torque loadings and internal fluid pressure. In the final test, bending only was applied with internal pressure, and resulted in failure of the specimen at 110% of ultimate load. This is considered satisfactory, and no further tests are anticipated.

26.13 PRESSURE TESTS OF ARROW 2 ARTICULATED DUCT

Design of the pressure test rig for the ARROW 2 articulated duct has been completed. Rig manufacturing drawings have been issued to the Experimental Department, and instrumentation equipment has been ordered. Delivery of the specimen is scheduled for the end of August and testing will commence shortly after that date.

26.14 TESTS ON SIMMONDS LATCH ASSEMBLIES

Tests to establish the strength of Simmonds latch assemblies showed that the results are influenced by the attitude in which the latches are mounted. Samples of other types of latches are to be submitted for test when available, and results will be assessed on a comparative basis.

27.0 SYSTEMS GROUND TEST PROGRAM

27.1 FUEL SYSTEM

The ARROW fuel system test program has undergone further revision to accelerate completion of testing on the ARROW 2 system. The program is now as follows:

1. Balance of original test program conducted on the low pressure system.

2. Test rig changeover to ARROW 2 fuel management system (sequence transfer control).

3. ARROW 2 fuel management system tests (sequence transfer control).

27.1.1 TEST PROGRESS

Main System - Tests on the fuel system test rig were delayed while the air pressure regulators, damaged in previous tests, were being repaired. A commercial type air pressure regulator was used to conduct pre-installation tests on a quantity of fuel-no-air valves. However, repairs to the original regulator proved satisfactory, and they were re-installed in the test rig. Tests have been conducted on the low pressure fuel system. Normal fuel transfer tests, simulated mission tests and tests involving dynamic pitch conditions have been completed satisfactorily, and the test rig is now being modified for the ARROW 2 fuel system test program.

Back-up Tests - Further tests have been conducted to develop a suitable air ejector for the collector fuel tank. Redesigned mixing tubes showed improved results under testing with symmetrical inlet flows, but were unsatisfactory during asymetrical inlet flows. The specimen will be redesigned for further testing.

The Purolator filter, which was damaged during testing, was repaired by the manufacturer and returned to Avro. Tests were conducted but excessive leakage occurred at the relief valve. This was overcome by installing a stronger relief valve spring. Subsequent tests indicated that the filter now meets specification requirements.

Assessment tests have continued on fuel pipe flexible couplings, using "On Mark" couplings provided by Aviation Electric Ltd. These couplings have proved very satisfactory and additional samples have been ordered for further testing.

Tests have been conducted to develop an AVRO-designed fuel-no-air valve. Initial results have been encouraging, and the valve is being modified to improve performance prior to further tests.

27.2 FLYING CONTROLS SYSTEM

27.2.1 COMPLETE MECHANICAL SYSTEM TEST

Development testing, using the complete system test rig, has been in continuous progress.

The results from the flight simulation test program have now been analyzed and agree with the pilots' assessment that aircraft control could be safely maintained within the flight envelope being used for the initial flight tests.

Installation of the elevator and aileron controls in the complete system test rig has enabled evaluation tests to be conducted on the stick force mode in the pitch and roll axis. The Humphrey stick-grip proved superior to the Bell stick-grip which showed system instability to be incipient for both pitch and roll for a variety of gain settings.

New feel unit springs were manufactured, and a pilot's assessment of the aileron and elevator feel units showed that spring rates of 75 lb./in. for the aileron and 105 lb./in. for the elevator were acceptable.

A 2-1/2% sensitivity linkage was installed on the aileron and elevator actuators, and tests were conducted. The tests showed that the system was unstable without dampers, but became stable when dampers were installed at the control valves. However, excessive motion of the input linkage occurred under the influence of differential servo operation. In addition, there was a considerable lag between manual operation of the controls and the response at the control surface. The aileron controls damper was relocated at the rear quadrant, but subsequent tests showed that the system was unstable with the damper in this position. The dampers were then removed from the aileron and elevator circuits, and accumulators were installed at the control valve inlets. Tests showed that the systems were still unstable.

Linkages of 5% sensitivity were installed on the aileron and elevator jacks and frequency response tests conducted with the dampers installed at various points in the jack follow-up linkages.

Tests are now in progress to develop improved dampers for the elevator and aileron systems and to determine the most suitable damper fluid viscosity for each system.

Tests were conducted to compare pressure surges in the flying control hydraulic systems when using a Vickers pump and a New York Air Brake Corporation pump. Results are currently being analyzed.

Further tests conducted on cable tension regulator quadrants revealed that the production type quadrant and AVRO-designed quadrant are both satisfactory. The choice of quadrant for future use is under consideration.

27.2.2 AILERON CONTROL SYSTEM FUNCTIONAL TESTS

A test rig aileron is being split at approximately mid-span position in accordance with the latest aileron design. When this is completed, loaded surface functional tests will be undertaken.

27.2.3 RUDDER CONTROL SYSTEM FUNCTIONAL TESTS

Repairs have not yet been completed to the rudder damaged in previous stiffness testing. Preparations are in progress for a test program on a reduced chord length rudder. The test specimen is to be split at approximately mid-span position, in accordance with latest rudder design.

27.2.4 ELEVATOR CONTROL SYSTEM FUNCTIONAL TESTS

Design work is in progress to split the reduced chord and full chord elevators to conform with the latest split elevator design. Further tests will be conducted when the modification has been completed.

27.2.5 HYDRAULIC FITTINGS FOR 4,000 PSI PRESSURE

The results of tests conducted on the 4000 psi fittings are being assessed. The necessity of further testing will be predicated upon this analysis.

27.2.6 WIG-O-FLEX COUPLINGS FOR LOW PRESSURE HYDRAULIC SYSTEM

Tests have been satisfactorily completed on a wide range of samples and no further tests are anticipated.

27.2.7 HYDRAULIC SYSTEM STEEL TUBING TESTS

Pressure cycling tests have been conducted on a variety of bent steel tubing specimens and are continuing. These tests are being conducted at the Weatherhead Co. and test results to date are detailed in the following table:

TABLE 4 HYDRAULIC SYSTEM STEEL TUBING TEST RESULTS

NO. OF SPECIMENS TESTED	O/D	WALL THICKNESS	TEST PRESSURE	MATERIAL	RESULT OF TESTS
13	1/4"	.02"	4700 psi	MIL-T-6845 1/8 Hard	Specimens failed between 124,000 and 396,000 cycles
14	1/4"	.02"	4600 psi	MIL-T-6845 1/8 Hard	Specimens failed between 149,000 and 540,500 cycles
6	3/8"	.035"	6800 psi	MIL-T-6845 1/8 Hard	Specimens failed between 85,000 and 10 million cycles
19	3/8"	.035"	6600 psi	MIL-T-6845 1/8 Hard	Specimens failed between 207,000 and 805,000 cycles
20	3/8"	.035"	6600 psi	MIL-T-6845 1/8 Hard	Continue on test
9	1/2"	.042"	6800 psi	MIL-T-6845 1/8 Hard	Specimens failed between 79,000 and 272,000 cycles
12	1/2"	.042"	6000 psi	MIL-T-6845 1/8 Hard	Specimens failed between 126,000 and 556,000 cycles
6	1/2"	.042"	6000 psi	MIL-T-6845 1/8 Hard	3 Specimens failed between 270,000 and 385,000 cycles. 3 continue on test
5	1/2"	.042"	6000 psi	MIL-T-6845 1/8 Hard	Specimens failed between 322,000 and 610,000 cycles
11	1/2"	.042"	5600 psi	MIL-T-6845 1/8 Hard	Specimens failed between 220,000 and 10 million cycles

Tests on 5/8" O/D and 3/4" O/D specimens are in preparation.

One specimen of rudder actuator piping achieved 1,875,000 cycles of testing. This is considered satisfactory, and further fatigue tests have been cancelled. Pressure lines in various configurations are now being subjected to bending tests in order to assess the influence of pipe shape upon its strength.

27.3 AIR CONDITIONING SYSTEM

Development testing of the temperature control system has continued. All performance testing on the turbine outlet temperature control system was completed satisfactorily, using AiResearch pneumatic equipment, and the system has now been approved for installation in the ARROW 1.

Further tests conducted on AVRO-designed cockpit and radar temperature controllers were satisfactory and flightworthy versions of the controllers are being tested.

Design of the ARROW 2 air-conditioning system test rig has been completed, and the rig is being manufactured. Completion is being delayed by the lack of bought-out equipment. Calibration of duct orifices, venturis and static heads is in progress.

27.3.1 COCKPIT ENVIRONMENT TESTS

As a result of tests to reduce the cockpit noise level, ducting and outlet silencers have been redesigned and have been approved for use in the aircraft.

Temperature distribution tests conducted in the front and rear cockpits of the metal mock-up, resulted in smoke in the cockpits. Samples of the insulating materials used in the cockpit, and their adhesives, are being investigated by the Metallurgical Laboratory. The cockpits were thoroughly cleaned and all insulation removed. Tests are now in progress to locate the source of the fumes.

27.3.3 LEAK DETECTION TEST

Leak detection tests, using Fenwall equipment, were satisfactory. The operating temperature at the sensing element proved to be $400^{\circ}F \pm 20^{\circ}F$ and the system operated satisfactorily under conditions simulating a broken sensing element.

27.4 ELECTRICAL SYSTEM

27.4.1 TEST PROGRESS

Circuit faults revealed during initial testing of the armament electrical system breadboard have now been rectified, and tests have been completed satisfactorily.

Circuit diagrams for incorporating the loadbanks into the complete ARROW 2 electrical breadboard have been completed. The breadboard and loadbanks will be completed when equipment now on order, has been delivered.

Tests have been conducted on CS-R-122 relays, to ensure that they conform to specification. Results showed that the voltage drop of all loaded sets of contacts exceeded the specified maximum. In addition, the pickup voltage of one relay was 30% above specification. Dielectric breakdown occurred between one pair of adjacent terminals of one relay after inductive cycling tests, and the moving contacts were damaged due to high temperatures imposed during testing. The relays are still being used in the aircraft, but will be tested periodically.

27.5 LANDING GEAR SYSTEM

The test program for the landing gear system tests has been changed, and is now as follows:

(1) Right-hand main landing gear tests (with door).

(2) Tests of the full landing gear system with various flight case loadings.

(3) Full system tests at low and high temperatures.

27.5.1 TEST PROGRESS

27.5.1.1 Nose Landing Gear System Tests

The redesigned nose wheel steering system has been installed in the rig. This system utilizes a Moog hydraulic valve which is controlled from a potentiometer on the rudder crossbar.

Frequency response tests were conducted over a range of gain settings and with various sensitivity characteristics. Centring tests were conducted and a pilot's assessment was completed. No instability was evident and the system has been approved by the pilots. Further tests will be conducted to measure nosewheel steering breakout forces when an aircraft equipped with the new installation is available.

27.5.2 MAIN LANDING GEAR

The assembly of the main landing gear test rig has been completed, with the exception of the door jacks. These jacks were returned to Dowty for modifications but have not yet been received by AVRO. Landing gear door system tests will commence when the door jacks are installed.

27.5.3 MISCELLANEOUS SYSTEM TESTS

27.5.3.1 Tests on Automatic Quick-Disconnect Couplings for Ground Energizers

Initial functional tests on the ground energizer automatic quick-disconnect couplings showed that the angle of the intercommunication coupling should be improved to avoid damage during disconnection, and that greater clearances in the coupling housing were necessary. In addition, the air conditioning coupling proved unreliable. Modifications were completed on the couplings and further tests have been successful for all couplings except the air conditioning disconnect, which is now being redesigned.

27.5.4 ASSESSMENT OF HYDRAULIC SNUBBER

A snubber will be installed in the flying controls hydraulic system, in order to protect the hydraulic pressure gauge from damage due to pressure surges in the system. Tests to provide a comparative assessment of two samples of snubber have been completed, and the results are being analyzed.

27.6 CANOPY AND ESCAPE SYSTEM

Arrangements are being made to sub-contract the escape system tests. Specifications are being prepared by AVRO for a suitable tower test-rig and a cockpit assembly for the rocket sled tests. Tests on canopy actuators showed that the light-alloy shear pins failed at 800 lb., and the actuator failed to operate at loads in excess of 830 lbs. Tests will be conducted on the aircraft (25201) to determine the canopy opening and closing loads, so that the suitability of the light-alloy shear pin and actuator can be established.

27.7 SPARROW MISSILE PACKAGE

27.7.1 TEST PROGRESS

The launcher development tests and single missile mechanism tests are currently being conducted.

27.7.2 MISSILE PACKAGE DOOR TESTS

Initial tests on the missile body seals revealed that the seal installation was distorting the weapon pack door structure. The door structure was reinforced locally, and 200 door operation cycles were completed at room and elevated temperatures. A simplified seal, of softer rubber, has been satisfactorily tested. The operating speed of the door actuating mechanism was increased. Subsequent tests of normal operation were satisfactory, but the mechanism jammed when it operated in a dust-laden environment. The standard door rollers were replaced with undersized rollers and further dust environmental tests were satisfactory. The amount of free movement introduced into the door mechanism using undersized rollers has been assessed, and is considered to be acceptable.

27.7.3 MISSILE EXTENSION MECHANISM TEST

A breadboard of the hydraulic system for the missile extension mechanism has been assembled and tested. Minor component and electrical faults have been rectified, and the system is now operating satisfactorily.

Assembly of the main test rig has been delayed by a shortage of lower drag link castings. Delivery of these is being expedited and formal testing is expected to begin early in July.

27.7.4 MISSILE INSTALLATION ON ARROW 2

Manufacture of a test rig for functional and firing tests on the ARROW 2 missile installation is approximately 50% complete. The installation of strain gauges and associated wiring is complete in areas which will be inaccessible after the missile pack has been assembled. Additional instrumentation is also being installed in the pack.

27.7.5 DEVELOPMENT OF MISSILE LAUNCHER

The assembly of the dummy missile umbilical connector has been completed. A total of 46 test firings, using the connector, has been conducted satisfactorily, and has resulted in minor improvements being made to the plug sealing design. Damage caused to the anodized surface of the launcher rail, during previous firings, did not adversely affect the tests, and methods of improving the protective coating of the rail are under consideration. Tests on the launcher rail were considered satisfactory after 26 firings.

Preparations are in progress for a test program on a production type launcher. On the initial assembly the launcher rail was found to be twisted. This was partially corrected during the final assembly and the rail is considered satisfactory for the forthcoming tests.

Development tests have continued on the missile retaining shear pins and they are now satisfactory. No further tests are anticipated.

27.7.6 QUALIFICATION OF DOUGLAS-MADE DETONATOR ASSEMBLIES

Tests have been conducted on the detonator assemblies which are incorporated in the launchers to jettison the missiles. Results showed that after prolonged exposure to high temperatures and humidity, the detonator samples failed to shatter the bolt assembly in which they were housed. Further information has been requested from the manufacturers on the deterioration rate of the detonators, so that their usable life can be established. Modifications to the bolts are under consideration, and a further test program is planned.

28.0 FLIGHT TESTING

28.1 AIRCRAFT 25201

Aircraft 25201 was grounded, after completing nine flights, to undergo a major inspection. The first two flights were described in the previous Quarterly Technical Report. Of the seven remaining flights prior to the grounding period, five flights were made to assess the aircraft handling qualities at progressively increasing speeds and altitudes. Two flights were familiarization flights, one for an RCAF pilot and the second for an AVRO test pilot.

A total of 8 hr 10 min. flight time was accumulated during the nine flights, of which 6 hr 45 min. was within the period covered by this report. The maximum speed attained during this flight test program was Mach 1.52 at 49,000 ft. The maximum altitude so far achieved was 50,000 ft. Both figures were obtained during the seventh flight.

Flight test results confirmed that directional control in flight was improved by use of the yaw damper in both normal and emergency mode. Oscillations in pitch became evident in flight. These could be eliminated by the pilot at low speeds (approximately 250 kts.) by releasing hold of the stick grip, and at higher speeds (400 kts. and above) by holding the stick grip firmly. Efforts to excite aileron flutter under various conditions were unsccessful. As altitude increased, maximum engine speed showed a tendency to decrease. At 32,000 ft. it was noted that the maximum engine speed attainable was 93% of maximum RPM with jet temperatures of 510°C to 520°C. This problem is being investigated. The accuracy of the test fuel gauges installed in the aircraft became doubtful and the system was recalibrated in an effort to establish accuracy. Structural temperatures in critical areas have not been excessive during flight. Some flight records have not been complete, due to poor reception of telemetered signals. This has been overcome by switching from the ventral antenna to the fin antenna for telemetry transmission, when fading became evident. During the later flights, intake duct vibration became noticeable at approximately 300 kt. EAS. This is currently being investigated.

During the fifth flight, following a 2.5 g left turn, the landing gear indicator showed the left-hand gear to be unlocked. The landing gear was lowered, and subsequent attempts to retract the gear were unsuccessful. The remainder of the flight was therefore limited to measuring the angle of attack at various speeds and altitudes within the limitation imposed by the extended landing gear. The landing gear malfunction was found to be due to maladjustment of the micro-switches and actuating links associated with the landing gear position indicating system.

On landing, at the termination of the eighth flight, the right-hand forward main wheel seized, causing damage to the brake pads, discs and rims etc. Investigation revealed that this was due to a faulty brake assembly.

During the ninth flight, the left-hand constant-speed alternator drive unit failed, and has since been replaced.

28.2 GROUNDING PERIOD FOLLOWING THE FIRST NINE FLIGHTS OF AIRCRAFT 25201

On April 24 1958, aircraft 25201 was grounded in order to complete a major inspection, replace equipment unqualified for further flights, and to install additional instrumentation required in later flight tests.

A 25-hour inspection was completed on both engines and an improved roller track and attachment brackets for the air-conditioning system bleed duct were installed in the left-hand engine bay. Bevel gears and shaft in the main auxiliary gear boxes were replaced, in accordance with the manufacturer's modification. New constant-speed drive shafts were installed, and the J75-P3 type fuel control units were replaced by J75-P5 type control units in an effort to improve engine RPM at altitude.

Due to difficulty in maintaining correct cockpit air temperatures, an AVRO-designed cockpit temperature control system was installed (less the temperature controller) in addition to the existing Hamilton-Standard system. The AVRO temperature controller will be installed when available.

The fuel pumps in #5 fuel tank were replaced with improved pumps, and the fuel transfer pump repriming solenoids were modified to prevent false indication of loss of prime. Standard aircraft fuel contents gauges were installed to replace the test gauges, which had proved unreliable. Where necessary, equipment from the fuel system was removed for inspection, and retested before re-installation.

An improved type of hydraulic charging gauge was installed and improved fluid level indicators were installed on the hydraulic compensators. Time-expired pressure warning switches in the flying control and utility hydraulics systems were replaced.

Improved disc brakes were installed on the landing gear in an effort to improve the aircraft braking performance. The left-hand main landing gear door jack had developed excessive backlash and was replaced. In order to reduce the possibility of damaged brake lines in the event of excessive tire deflation, the brake hydraulic lines were altered to increase clearances between the pipes and tires. The electrical anti-spin installation for the main wheels was replaced by an hydraulic installation. The door sequence valve was re-adjusted to allow proper lowering and retraction of the landing gear.

An elapsed time indicator was installed for the Honeywell damper rate gyro, and adjustments were made to eliminate backlash from the elevator feel and trim unit quadrant. Cable tensions were adjusted, where necessary, in all flying control systems. Parallel servos were installed in the flying control systems in preparation for operation of the stick force steering mode.

The engine starter circuit was modified to permit engine starting from one starting vehicle. Several electrical connectors in the engine bays were relocated because of their high temperature environment, or to improve accessibility, the fire extinguisher inertia switch was replaced by a pilot-operated switch.

28.3 FLIGHT #10 - AIRCRAFT 25201

Flight #10 was made on 6 June 1958. The purpose of the flight was to check the aircraft after the grounding period and to assess its handling characteristics at subsonic speeds.

During this flight, the yaw damper malfunctioned in both normal and emergency modes, and the landing was made with the damper disengaged. Post-flight inspection revealed that the lateral accelerometer associated with the system was installed 180° out of position and was thus generating incorrect signals to the flying control damper system. The nosewheel door would not lock in the retracted position during flight, due to a faulty circuit breaker and malfunction of the uplock microswitch actuating arm. Consequently the air conditioning system failed to function correctly since the cockpit shutoff valve is opened by the action of the door uplock switch.

Loss of engine power was again experienced at 30,000 ft. The left-hand engine operated at 98.5% of maximum RPM while the right-hand engine operated at 95.5% of maximum rpm. The drag chute operated satisfactorily when streamed at 170 kts, though minor damage was caused to the suspension lines and deployment bag. Instrumentation indicated that the drag chute had not been subjected to temperatures above 200°F, which was considered satisfactory. Wheel and brake temperatures during landing and taxiing were considered satisfactory.

Operation of the speed brakes in flight resulted in a noticeable "kick" in the brake pedals. Ground tests confirmed this, and the kick is considered to be caused by the system hydraulic pressure decreasing when the speed brakes are applied.

28.4 FLIGHT #11 - AIRCRAFT #25201

Flight #11 took place on 11 June 1958. The purpose of this flight was to further check the aircraft after its grounding period and to assess the handling qualities at subsonic speeds. During flight it was again noted that engine power decreases with increasing altitude.

Instrumentation for this flight included measurements of structural temperatures. Tests were conducted during flight to excite vibration in the various control surfaces, and results recorded indicated good damping qualities in both wing and fin.

At the completion of the flight, the landing gear collapsed causing damage to the aircraft. The accident is discussed in detail in Report No. 71/ENG PUB/9 Report on Accident to AVRO ARROW 1 Aircraft 25201 at Malton - 11 June 1958.

28.5 AIRCRAFT 25202

On completion of a low speed taxi test, the aircraft was grounded to incorporate current modifications. Instrumentation is being installed in preparation for forthcoming flight tests. The object of the low speed taxi test was to assess the damping system, brakes and drag chute during taxiing. At the same time noise level measurements were made while the right-hand engine was run at military power.

Brake temperatures were satisfactory during the tests. Operation of the yaw damper system was satisfactory, though twice during the tests, when the aircraft was stationary, the damper switched from normal to emergency mode. This was considered to be caused by low hydraulic pressure, resulting in premature opening of the pressure switch. The nose wheel was lifted while taxiing at 110 kts, and the drag chute was streamed at 100 kts.

28.6 FLIGHT TEST INSTRUMENTATION

28.6.1 TELECOMMUNICATION AND NAVIGATION SYSTEM

Tests have been conducted to establish a technique for evaluating the ARROW antenna, and the antenna field pattern. Flight tests were conducted, using a CF-100 aircraft equipped with an AN/ARC-34 UHF radio transceiver, a micro-match r.f. power output monitor and a UHF fin cap antenna. The aircraft was flown over a ground station in clover-leaf patterns at constant altitude and speed. The ground station antenna height which had been determined during previous testing, was 36 ft. Signals were transmitted from the aircraft at a predetermined position, and the signal strength at the ground station was measured during runs at various headings. The antenna pattern plotted from test results compared favourably with model tests results at the Sinclair Radio Laboratories, and on this basis, the test technique is considered to be satisfactory for subsequent tests of the ARROW antennas.

28.6.2 AIRCRAFT INSTRUMENTATION

The installation of instrumentation has continued in all aircraft. Installation in aircraft 25201 is now 86% complete, in aircraft 25202, 80% complete - in aircraft 25203, 72% complete - in aircraft 25204, 34% complete and in aircraft 25205, installation is 16% complete.

Where test requirements are known, the work of providing instrumentation and calibrating equipment continues on a three work shift per day basis. The instrumentation patch panel for aircraft 25201 has been completed and is now being installed. The patch panel for aircraft 25202 has been installed and checked.

28.7 DATA HANDLING SYSTEMS

Results from the ARROW datatape development test program have shown that low-level commutated signals using an ASCOP commutator are unsatisfactory. Improvements to the existing system are being developed by the laboratory until an alternative system has been devised. Bench tests are in progress to establish the interference levels that can be tolerated by system components.

In view of the problems involved in handling a large number of parameters, both from the equipment servicing and data handling aspects, AVRO has decided to limit the number of parameters to be measured at any one time, to a maximum of one hundred.

On the first flights of aircraft 25201, provisions were made for telemetering data on twelve channels, recording twenty parameters on a continuous trace oscillograph, and recording pilot's comments on a tape recorder. Telemetered data was recorded at the ground station using Sanborn recorders. Additional instrumentation is now being activated on aircraft 25201 and 25202, and will provide recording facilities as follows:

- Twelve continuous transmission telemetry channels.
- Twenty-five channels on a continuous trace oscillograph.
- Two magnetic tape recorders recording forty-five compound modulated (CM) parameters in addition to pilot's comments.

When a satisfactory system has been developed for telemetering and recording commutated-Pulse Duration Modulated signals, data handling provisions for these aircraft will be increased to the following:

- Eleven continuous transmission telemetry channels.
- Forty commutated PDM telemetry channels.
- Twenty channels on a continuous trace oscillograph.
- Two magnetic tape recorders recording pilot's comments, forty-five CM and 80 PDM parameters.

An IRIG analogue tape system and one oscillograph will be installed for data handling for the armament test program on aircraft 25203. Information is presently being sought on equipment characteristics so that structural provisions may be made in the aircraft for installation of the IRIG equipment. It is planned to use an IRIG analogue tape system for aircraft 25204, 25205 and 25209, as the number of parameters requested by RCA, are in excess of the one hundred specified by Flight Test department for recording at any one time.

An IRIG analogue tape system has also been requested by the RCAF for installation in aircraft 25210, 25211, 25212, 25213 and 25214, so that the aircraft system will be compatible with ground facilities at RCAF Station Cold Lake.

A digital tape system is proposed for aircraft 25216, as this is considered most suitable for the test program for which this aircraft has been allocated.

28.8 GROUND STATION

The telemetry ground station has operated satisfactorily during the flight test programs so far completed. The FM/FM continuous transmission data faded at times during flight tests. In an attempt to overcome this fault, an antenna located on the fin, was used. However, this proved unsuccessful, and the problem is being investigated.

The new design of Millisadic intervalometer has been completed and is now installed.

A C.E.C. tape reader has been received and is now being checked prior to installation. This unit feeds the Millisadic digitising equipment output directly into the IBM 704 computer and allows faster processing of the data.

29.0 SPECIFICATIONS ISSUED

29.1 MODEL SPECIFICATIONS

Report No.	Description	Issued
72/M.S/1	Model Specification For ARROW 2 Airframe and Government Supplied Material Installation.	June 1958 (Draft Issue)

29.2 AVROCAN SPECIFICATIONS

To date, approximately 439 AVROCAN equipment specifications (series "E") have been prepared for the ARROW. An index of these specifications (AVRO ref. E.I. Gen. 489/197 dated 30 June 1958) has been issued to the RCAF.

29.3 DESIGN CERTIFICATES

Report No.	Description	Issued
71/PROJ 7/1-2	Design Certificate for Flight Trials of ARROW 1 Aircraft Serial #25201	May 1958
	Amendment #1	June 1958
71/PROJ 7/7	Design Certificate for Flight Trials of ARROW 1 Aircraft Serial #25202 - 25205 Inclusive.	May 1958
	Amendment #1	June 1958
	Amendment #2	June 1958

30.0 REPORTS ISSUED

30.1 PRELIMINARY DESIGN PROPOSALS

Report No.	Description	Issued
72/PROJ 7/11	ARROW 2 - Proposal for Extended Combat Radius	June 1958

30.2 WEIGHTS AND BALANCE

Since weight and balance reports are issued monthly, as required by CAP 479, an index of these reports will not be included in the Quarterly Technical Report.

30.3 WIND TUNNEL DATA

Report No.	Description	Issued
71/W.TUNN/11	N.A.E. Wind Tunnel Icing Tests of Pitot Static Probe - Series 1.	April 1958

30.4 PERFORMANCE REPORTS

Report No.	Description	Issued
72/PERF/15	ARROW 2 Performance with 32.8 Cylindrical Ejector, with Particular Reference to Overload Mission	May 1958
72/PERF/17	Design Study of an Ejector Plug Nozzle to Increase the Aircraft Range in Sub-sonic Flight Case.	April 1958
72/PERF/18	ARROW 2 Zoom Performance	April 1958

30.5 STRUCTURAL STRENGTH TEST

No formal structural test reports were issued during the reporting period.

30.6 AIRCRAFT GROUND AND FLIGHT TESTS

No Ground Test reports are available.

Report No.	Description	Issued
71/FAR/11 Iss.2	ARROW 1 Instrumentation - Armament Development Aircraft 25203.	April 1958

Report No.	Description	Issued
71/FAR/22	Analysis of Take-Off and Landing	May 1958
71/FAR/23	Stability and Control, Damper Optimization and Handling Flight Test Requirements - ARROW 1	April 1958
71/FAR/24	Summary of Preliminary Analysis of Flights 1 to 9	May 1958
71/FAR/25	Preliminary Analysis of ARROW 1 Flight Test Times	May 1958
71/FAR/26	Preliminary Analysis of Flights No.'s 1 to 9	May 1958
71-2/FAR/27	Objectives, Requirements and the Program for ARROW Stability and Control. Also Structural Integrity Flight Testing	June 1958
71/FAR/29	Phase 2 Instrumentation	June 1958
72/FAR/14	ARROW 2 - Aircraft 25209 and 25210 Instrumentation	June 1958

30.7 FUNCTION TYPE TESTS

Each item of equipment to an AVROCAN specification will undergo qualification testing. All functional type test data and qualification test reports, for bought-out equipment, are being indexed under AVRO drawing numbers and retained at AVRO.

30.8 VENDOR'S REPORTS

Vendor's reports on equipment supplied to AVRO, for use on ARROW aircraft, will be retained on file at AVRO. Their use is required in the preparation of the equipment approval statement issued for each item of equipment procured to an AVROCAN specification.

30.9 ASTRA I SYSTEM

AVRO has not compiled any formal reports relative to the ASTRA 1 System during the period covered by this report.

30.10 STRESS ANALYSIS REPORTS

Report No.	Description	Issued
7/0500/32	Thermal Distribution using I. B. M. 704	June 1958
7/0500/41	Thermal Buckling of Plates	June 1958
7/0500/46	Dorsal Structure Fin/Wing Fillet Fairing	June 1958
7/0552/6 Iss. 3	Obs/AI Seat Bulkhead	June 1958
7/0552/20	Radar Nose Structure	June 1958
7/0558/22	Loading and Detailed Stress Analysis of Heavy Frame Station 663.75	June 1958
7/0558/66 Iss. 2	Side Skin - Station 485 - 742	June 1958

30.11 SYSTEMS REPORTS

Report No.	Description	Issued
70/SYSTEM 13/142	Tests Performed on Humphrey Stick Force Transducer No. 6	April 1958
70/SYSTEM 13/147	Report on Functions of the Ground Test Unit Assembly for Testing ARROW Weapon Pack and Contents	April 1958
70/SYSTEM 13/189	Lead Collision Fire Control Mode as Mechanized in ASTRA I (Revised P/SYSTEM/54)	May 1958
70/SYSTEM 13/204	Electronic Break-Out System for Stick Force Transducer.	June 1958
70/SYSTEM 16/213	Flame Proofing of Fuel Vents	June 1958
70/SYSTEM 19/208	Theoretical Investigation into Leg Walking Problem	June 1958
70/SYSTEM 19/214	Spin Up Time - ARROW Main Wheels	June 1958
70/SYSTEM 19/215	Time History of Brake Application	June 1958

Report No.	Description	Issued
70/SYSTEM 24/132	AVRO Comments on Crewman's Leg Clearance Ejection Tests	April 1958
71/SYSTEM 15/80	Slamming of Pilot's Canopy During Emergency Operation	May 1958
71-2/SYSTEM 15/207	Modifications to the q_c Actuator System to meet the Hinge Moment Limiter Requirements	June 1958
71/SYSTEM 16/143	Booster Pump Adequacy in 19 psia System (proportional)	April 1958
71/SYSTEM 16/177	Investigation of a Temperature Controlled Fuel Warning Switch	June 1958
71-2/SYSTEM 16/183	Fuel Transfer Schematics	May 1958
71-2/SYSTEM 16/184	Pressurization System Schematics	May 1958
71/SYSTEM 19/148	Deletion of Nose Wheel Steering Selector Valve	April 1958
71/SYSTEM 19/149	Schematic Drawing - A. C. Power Pack	April 1958
71/SYSTEM 19/150	Schematic Drawing - Wheel Brake System	April 1958
71/SYSTEM 19/152	Schematic Drawing - Nose Wheel Steering	April 1958
71/SYSTEM 19/153	Schematic Drawings - Speed Brake, Sub-System	April 1958
71/SYSTEM 19/154	Schematic Drawing - Landing Gear, Sub-Assembly	April 1958
71/SYSTEM 19/155	Schematic Drawing - Utility Pump Circuit and 1500 psi Circuit	April 1958
71/SYSTEM 19/156	Schematic Drawing - A.C. Power Pack	April 1958
71/SYSTEM 19/163	Schematic Drawing - Aircraft 25201 Landing Gear	April 1958

Report No.	Description	Issued
71/SYSTEM 19/168	Effects Due to the Lack of Temperature Compensation on the Main Landing Gear Liquid Spring	May 1958
71-2/SYSTEM 19/178	Modification of Wheel Brakes Hydraulic Supply	May 1958
71/SYSTEM 19/196	Landing Gear Circuit Schematic	May 1958
71/SYSTEM 19/197	Schematic - Adaptor Block	May 1958
71/SYSTEM 19/198	Schematic of Hydraulics	May 1958
71/SYSTEM 19/199	Mag. Amp. and Moog Valve Connections	May 1958
71/SYSTEM 19/200	Circuit Diagram of Steering System	May 1958
71/SYSTEM 19/201	Transmitter Potentiometer Tapping Details	May 1958
71/SYSTEM 21/175	Schematic - Oxygen System	May 1958
71-2/SYSTEM 22/140	ASTRA Cooling Air Supply ARROW 1 (Aircraft 25204 and 5, and ARROW 2)	April 1958
71/SYSTEM 22/164	A Cockpit Temperature Controller for the ARROW 1 Air Conditioning System	April 1958
71/SYSTEM 23/174	Schematic - Fire Extinguisher System	April 1958
71/SYSTEM 24/187	Schematic - Emergency Ejection and Canopy Operation	May 1958
71-2/SYSTEM 24/203	Production Test - Escape System	June 1958
71/SYSTEM 32/158	Schematic Drawing - Flying Control Hydraulics - A/C 1, 2 and 3	April 1958
71/SYSTEM 32/159	Schematic Drawing - Flying Control Hydraulics - A/C 4 and 5	April 1958
71/SYSTEM 32/160	Schematic Drawing - Hydraulics	April 1958
71/SYSTEM 32/191	Flying Control Circuit - Heat Generated	May 1958

Report No.	Description	Issued
71/SYSTEM 32/212	Static Pressure in the Flying Control System	June 1958
72/SYSTEM 11/167	Transparent Material for Windscreen and Canopy	May 1958
72/SYSTEM 12/166	Control Surpass Position Indicator Design	May 1958
72/SYSTEM 13/139	A Proposal for an Antenna Range System	May 1958
72/SYSTEM 13/179	Report on Interim ASTRA	May 1958
72/SYSTEM 13/192	Post Installation Check of the APX-25A	May 1958
72/SYSTEM 13/193	Post Installation Check of the ARC-52	May 1958
72/SYSTEM 13/194	Post Installation Check of the Radio Compass System	May 1958
72/SYSTEM 13/195	Post Installation Check of the AIC-10A	May 1958
72/SYSTEM 15/161	q_c Actuator System - Investigation for ARROW 2	May 1958
72/SYSTEM 15/172	Schematic - Flying Controls	May 1958
72/SYSTEM 15/190	Evaluation of Control Valves and Elevator, Aileron and Rudder Control Systems	May 1958
72/SYSTEM 17/141	Long Range Fuel Capacities - ARROW 2	April 1958
72/SYSTEM 18/171	Equipment Pressurizing System	May 1958
72/SYSTEM 18/185	Production Test Procedures - Low Pressure Pneumatics	May 1958
72/SYSTEM 19/163	Schematic Drawing - Aircraft 25201 Landing Gear	April 1958
72/SYSTEM 19/188	Schematic - ARROW 2 Wheel Brakes (less anti-skid)	May 1958

Report No.	Description	Issued
72/SYSTEM 19/202	Permissible Main Landing Gear Wheel Weight	June 1958
72/SYSTEM 21/176	Schematic - Oxygen System	May 1958
72/SYSTEM 21/182	Production Test Procedures - Oxygen System	May 1958
72/SYSTEM 22/137	Proposed Mass Flow Controller	April 1958
72/SYSTEM 22/144	Modification of the Mass Flow Controller Theory to the Precept of Compass Flow Guidance by the Rotor	April 1958
72/SYSTEM 24/205	Development Program for the ARROW Escape System	June 1958
72/SYSTEM 24/210	The Requirement for "Linked" Crew Escape from the ARROW	June 1958
72/SYSTEM 25.157	Aircraft 25206 - Engine Installation - Internal Ground Test	April 1958
72/SYSTEM 26/165	Installation of Genie Missiles in the AVRO ARROW	April 1958
72/SYSTEM 31/186	Drag Chute System - Schematic - ARROW 2	May 1958
72/SYSTEM 32/173	Schematic - Flying Controls Hydraulics - Aircraft 25206, 25207, 25208	May 1958
72/SYSTEM 32/169	Investigation of Revised Flying Control Booster Hydraulic Circuits	May 1958
72/SYSTEM 32/209	Influences of Hydraulic Stiffness, on Response of Flying Control Hydraulic Circuits	June 1958

30.12 EQUIPMENT DESIGN REPORTS - Airborne and Ground Equipment - Maintenance, Reliability

Report No.	Description	Issued
72/GEQ/8	ARROW 2 Design Study in Engine Ground Run-Up and Testing	May 1958
72/GEQ/10	Requirement for Air Conditioner and Generator A.C. and D.C.	May 1958
72/GEQ/11	Proposal for the Ground Support Equipment Demonstration and Evaluation Conference	April 1958
72/GEQ/12	Starting Unit Requirements	May 1958
72/GEQ/13	An Investigation of the Need for an All-Weather Trailer, Aircraft Water Supply	May 1958
72/GEQ/14	Proposal for Intrim Type Test Console	June 1958
72/GEQ/15	ARROW - Operating Instructions for 4,000 psi Hydraulic Test Stand	June 1958
70/AIREQ 25/2	ARROW - Valve, Shut-Off Temperature Control	April 1958
71/AIREQ/2	ARROW 1 -Rework of Compensators - Aircraft 25201	May 1958
71/AIREQ 18/3	ARROW 1 - Relative Wind Sensor and Pitot Static Boom	June 1958
72/AIREQ 25/2	ARROW 2 - Gear Box Drive System	April 1958
72/AIREQ 32/3	ARROW 3 - Flying Control Valves	April 1958
70/MAINT/00/3	ARROW Maintenance Instructions - Use of Pre-Load (P.L.I.) Washers	June 1958
71/MAINT 24/1	ARROW Maintenance Instructions - Ejection Seats	May 1958
71/MAINT 25/4	ARROW Maintenance Instructions - J75 Engine Preservation and De-Preservation	May 1958

Report No.	Description	Issued
72/MAINT 00/2	An Introduction to the Personnel Requirements Data Study	June 1958
70/REL 00/2	A New System for Recording, Utilization Data on Aircraft Equipment	May 1958
71/REL 25/2	ARROW - Pneumatic Starter - J75 Engines	April 1958

30.13 GENERAL TECHNICAL DESIGN REPORTS

Report No.	Description	Issued
72/INT AERO/12	Improvement of Subsonic Cruise for ARROW 2 By means of an Expandable Ejector Insert	April 1958
72/INT AERO/13	Performance Calculations at Subsonic Cruise for ARROW 2 with 3 Ejectors of Small Throat Diameter Ratio	April 1958
72/INT AERO/14	Distortion of Pressure Recovery at Compressor Face	May 1958
72/INT AERO/15	Anti-Icing on Intake Lips	May 1958
72/INT AERO/16	Deterioration of Propulsion System Thrust	May 1958
71-2/AERO DATA/9	Effect of C.G. and Weight Change on δ_e	May 1958
71/AERO DATA/11	Elevator Hinge Moment Under Various 'g' Loadings	June 1958
71/ELASTICS/4	Rear Spar Deflected Shapes for Induced Control Surfaces Bending Under 8" Elastic Loading Cases	April 1958
71/ELASTICS/6	Flexibility of Aircraft With Fully Effective Structure	May 1958
72/ELASTICS/7	Effects of Spanwise Free Thermal Stresses on Wing Torsional Stiffness	May 1958

Report No.	Description	Issued
71/STAB/28	Short Period Oscillation of the Elastic Aircraft	April 1958
71/STAB/29	Flight Measurements of Control Surfaces Duty Cycles	May 1958
71/STAB/31	Digital Computation Method of Analysis of Lateral Motion with Moving Lateral Controls	May 1958
71/STAB/37	Digital Computation Response Prediction in Seven Degrees of Freedom	June 1958
72/STAB/35	Trim Angles: All Weights and C.G. Positions	June 1958
72/STAB/36	Trim Angles at W=47,000 lb. and C.G. = 29c	June 1958
72/STAB/38	Elevator Angle to Train at M=0.5 Based on High Reynolds Number Wind Tunnel Tests	June 1958
GEN/STAB/1	A Note on the Instability of Digital Solutions for Differential Equations	June 1958
72/LOADS/13	Loads on External Tanks	April 1958
72/LOADS/14	Air Loads Due to Jet Nozzle Extension	April 1958
71-2/LOADS/16	Aerodynamic Pressures on the Wing Fuel Tanks	April 1958
71-2/LOADS/20	Investigation of the Elevator Load using Wind Tunnel Values of C_m, C_L and C_h	June 1958
72/LOADS/17	Preliminary Load Analysis-Ejector Nozzle	April 1958
72/LOADS/18	Incremental Air Loads For the Symmetric Aircraft in Symmetric Manoeuvres	April 1958
72/LOADS/19	Documents Tabled at the Meeting on May 8, 1958 on Subject of Structural Integrity of ARROW	May 1958

Report No.	Description	Issued
70/COMP A/19	Aircraft Manoeuvres (Zoom)	April 1958
70/COMP D/2	Stable Numerical Procedure For Temperature Determination	April 1958
70/THERMO/31	An Analytical Solution of Steady Static Temperature Distribution in Joints	June 1958
70/THERMO/24	An Extract Solution for Temperature Response in an Insulated Slab	April 1958
70/THERMO/26	Acceleration and its Effects on Thermal Stresses	April 1958
71/THERMO/11	ARROW 1 Fuel Temperature	May 1958
71/THERMO/27	Instrumentation for Aircraft 25201	April 1958
72/THERMO/23	Fuel Temperatures	May 1958
72/THERMO/28	Parachute Temperatures	May 1958
72/THERMO/30	Transient Fuel Temperature at Engine Inlet - ARROW 2	June 1958
70/SIMUL/14	General Information on the ARROW Flight Simulator	April 1958
70/TACTICS/9	Schematic Proposal for a Study of the Mass Raid Problem	April 1958
72/TACTICS/10	Effect of Steering Loop Gains on the Interceptor of the ARROW.	June 1958
70/TACTICS/11	Seeker Lock-On Range Requirements For the Sparrow 1242D Missile	June 1958
70/TACTICS/12	Information Requirements in Support of Part 7 of the Co-Ordinating Contractors Statement of Work	June 1958
71/ENG PUB/9	Report on Accident to AVRO ARROW 1 25201 at Malton	June 1958