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ARROW ESCAPE SYSTEM
PROPOSALS FOR ROCKET-SLED TESTS
OF THE ARROW ESCAPE SYSTEM
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Report No.: QCX Auro CF105 RD-83

Has been: Downgraded to: As per letter 1463 (AC) 95/0043

De-Classified

By: (Name)

(Dept)

Date: JAN 9 1996

B.J. Petzinger
Deputy Coordinator
Access to Information and Privacy

Signature

A. V. ROE CANADA LIMITED
MALTON - ONTARIO

RESEARCH & DEVELOPMENT (AIRFRAME)

REPORT No. RD. 83 Iss. 2

SHEET No. _____

PROJECT

ARROW ESCAPE SYSTEM

DATE May 9th, 1957

PREPARED BY E.J. Lynch

UNCLASSIFIED
UNLIMITED

PROPOSALS FOR ROCKET-SLED TESTS OF
THE ARROW ESCAPE SYSTEM

Prepared by:

E. J. Lynch

Chief Ground Test Engineer

May 9th, 1957.



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RESEARCH & DEVELOPMENT (AIRFRAME)

REPORT NO. RD. 83 Iss.2

SHEET NO. 1 of 10

DATE May 9th, 1957

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ARROW ESCAPE SYSTEM

PREPARED BY E.J. Lynch

1.0 TITLE

Proposals for Rocket Sled Tests of the Arrow Escape System.

2.0 SUMMARY

This report sets out the proposals of Avro Aircraft, Ltd., for ground proof testing of the Arrow aircraft escape system, by means of, and to the extent permitted by, rocket sled tests. It covers both action to be taken by Avro and action to be expected of the R.C.A.F. Approximate cost and time schedules are included.



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3.0 INTRODUCTION

3.1 The object of the test programme referred to herein is to demonstrate, as fully as possible within the limitations of rocket sled tests, that the mechanisms for emergency canopy opening and crew ejection function properly, and that the crew members are safely separated from the aircraft, and ejected clear of the aircraft structure, over a full range of aircraft speeds.

3.2 Arising out of the requirements of A.R.D.C. Manual 80-1 (U.S.A.F.) (Ref: 9.1) and the relevant specification MIL-E-9426A (Ref: 9.2) the above objectives are to be demonstrated by a minimum of three rocket sled runs, namely at minimum safe flying speed, maximum practicable speed, and an intermediate speed corresponding to a dynamic pressure mid-way between the other two cases. It is regarded as impracticable to demonstrate the escape system properly in flight tests. *what is to be done about sled conditions??*

3.3 It is to be recognized that when the sled velocities used in track testing are chosen to give a dynamic pressure equivalent to a flight speed at altitude, the mach number in the test is too low, and the flow patterns may be unrepresentative. Nevertheless, track testing is the most practicable form of functional demonstration for the escape system.

3.4 In the course of investigations into the feasibility of rocket sled testing of the Arrow escape system, visits were paid in February and March 1957, to the Aircraft Laboratory, W.A.D.C., Dayton, Ohio, to Edwards A.F.B., California, The Naval Ordnance Test Station at China Lake, California, and to the U.S.A.F. track belonging to W.A.D.C. at Hurricane Mesa, Utah. The three facilities mentioned are the only facilities known which would possibly accommodate the Avro tests, and full opportunity for inspection of them was afforded. Consultations were also held with the Coleman Engineering Co. Inc., in Los Angeles, regarding the possibility of their designing and constructing a sled vehicle for Avro.

This company operates the U.S.A.F. facility at Hurricane Mesa, under contract to W.A.D.C. and has enjoyed almost exclusive responsibility for the design of vehicles used there, although it is by no means the only company which can provide design and construction service.

3.5 While it is recognized that there may be developments which will alter the nature of the ejection seats and other items of equipment concerned with the escape process, this report is necessarily written, at the present issue, on the assumption that the aircraft will be equipped with Martin-Baker seats, and that presently standard personal equipment will be used by the crew.



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4.0 MATERIAL AND FACILITIES REQUIRED4.1 Test Vehicle

The test vehicle must include a representation of aircraft structure from the nose boom back to a station a few feet behind the navigator's bulkhead. The cockpit section will have to be true aircraft structure, although the radar nose could be simulated structure, sufficiently strong to withstand the loads experienced during testing, provided that the cockpit front bulkhead were adequately supported.

It may be convenient to incorporate this structure into an integral vehicle containing the propulsion motors and the water brakes, in which case a rather heavy sub-structure will have to be incorporated. Alternatively, the aircraft structure may be mounted on slippers (runners), using a relatively light sub-structure, or perhaps only a little reinforcement, and pushed by a rocket propelled locomotive; which would incorporate the brakes as well. In this case a draw bar would be necessary to decelerate the test vehicle.

With solid propellant rockets, either method is equally feasible. A separate locomotive normally leads to a greater total weight to be accelerated and braked, but there is the advantage that the locomotive is afterwards available for other purposes. Propulsion motors are readily available in many varieties, but there appears to be no existing locomotive of sufficient performance to suit the Arrow tests.

The space required for fuel, oxidant and pressure storage tanks for a liquid rocket engine is much too great to permit an internal installation, and a separate locomotive is a necessity in this case. At some test sites, there are existing liquid-fuelled vehicles (not necessarily useable as locomotives) of sufficient performance for the Arrow tests, and it is probable that locomotives will be available at all otherwise feasible sites by the time the tests can be run. Costs are much lower for liquid fuels, although the initial cost of a liquid-fuelled locomotive is comparatively high.

4.2 Equipment

At all the facilities visited, it was recommended that an allowance of two new seats and two new dummy aircrew be planned for each test run proposed. However, this recommendation was based upon experience confined to seat types which do not have a "zero altitude" escape potential, and it is proposed that in the present case, provision be made for seats and dummies at only half the full quantity for the low speed and medium speed tests, but at the full quantity for the high speed tests.



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4.2 (Continued)

Complete clothing and personal equipment (e.g. parachutes, oxygen masks, etc.) should be allowed for each new dummy. It is to be expected that repairs will be necessary for all items, on this basis. Minor repairs will not present a problem at any of the sites under consideration, and spare components for the dummies should be available at short notice. It may be desirable to provide for additional seats, on an optional basis, so as to avoid the possibility of delay, if extra units are needed.

4.3 Instrumentation

Instrumentation is required to reveal the behaviour of the emergency canopy-opening mechanism, the loads imposed upon the mechanism, the velocities and accelerations of the ejected items, and the behaviour of the ejected items after separation from the aircraft. Miscellaneous transducers and sled-borne cameras will be used for all such observations, except observation of the ejection path outside the aircraft, and in addition some strain gauges will be used to obtain information on structural stresses resulting from the escape procedures. The transducer and strain gauge signals will be telemetered to a fixed station, and the number of telemetry channels available will restrict the number of strain gauges which can be used. Fixed cameras at a distance from the track will enable the ejection path to be measured with accuracy, including post-separation velocities and accelerations, and others will provide for general recording of the action.

4.4 Consumable Items

Reference has already been made to the need for a generous supply of seats, dummy aircrew, clothing and equipment. Irrespective of the number of seats obtained, complete sets of cartridges will be needed for every firing. Propellants will have to be provided, either as solid-fuel rocket motors, or as liquid fuel, oxidant, and pressurizing gas in bulk. It must be expected that the canopies will be damaged to some extent in the high speed runs, and some spares will therefore be necessary.

4.5 Track

A contract will have to be arranged for the use of the test track, selected by Avro. Only three tracks are known on which it will be technically feasible to perform the work required.

These are the W.A.D.C. aircraft laboratory track at Hurricane Mesa, Utah (Project SMART), the U.S.A.F. track at Edwards Air Force Base, Edwards, California, and the U.S. Navy Ordnance Test Station track at China Lake, California, (Project SNORT).



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4.5 (Continued)

The first is operated on contract by a civilian firm, Coleman Engineering Co. Inc., whose head office is in Los Angeles. The other two are operated directly by civilian employees of the military establishments where they are located. The use of all three tracks includes the use of fixed instrumentation, such as the land-based cameras and telemetry receiving stations, as well as delivery of continuous trace records and films, and a rough analysis of the ejection path. Minor repairs can be catered for to varying degrees, and accounting methods differ in respect of this service. Separately from the use of the track, it is customary to sub-contract to a civilian firm such supporting work as is needed, e.g. provision for maintenance of the vehicle, replacement of damaged instrumentation, major repair or modification work, detailed analysis of results and formal reporting.

5.0 TEST PROGRAMME

In the experience of the authorities who have been consulted, the number of test runs actually performed in a programme is apt to be from $1\frac{1}{2}$ to 2 times as great as originally anticipated, because of failures, modifications and the need for additional information. In addition, it may be expected that calibration runs will be necessary to establish the thrust scheduling necessary to achieve the desired sustained speed. Subject to such reservations, a preliminary programme may be set down as follows:

Test #	1	2	3	4	5
E.A.S. (Knots)	150	490	700	700	700
Cockpit Pressurized	No	No	No	Yes	Yes
First Crew Member Ejected	Nav.	Nav.	Nav.	Nav.	Pilot
Last Crew Member Ejected	Pilot	Pilot	Pilot	Pilot	Nav.

In formulating this programme, it has been assumed that all air loads have a net opening effect on the canopy mechanism, that the normal escape sequence would be navigator first, and that the main effect of cockpit pressurization would be to increase the destructive potential of the air loads upon the canopy. The speeds selected are in accordance with paragraph 3.2.



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DATE May 9th, 1957PREPARED BY E.J. Lynch6.0 RECOMMENDED ACTION6.1 General

It is assumed that it is the intention of the R.C.A.F. to provide, without cost to the Company, the facilities of the track selected, which arrangement will be on a basis similar to that available to U.S. contractors engaged on U.S. Military Contracts. It is further noted that it is the wish of the R.C.A.F. Institute of Aviation Medicine to supply clothing and personal equipment for the dummy aircrew (Ref. 9.3). Accordingly it will be proposed formally that the R.C.A.F. assume these obligations, and that Avro Aircraft Ltd., assume the remainder.

6.2 Action Proposed by Avro Aircraft Ltd.

The Company proposes to carry out the following:-

1. Construction of a front fuselage with all essential structure, including the canopies and their mechanisms, but without irrelevant systems, and without a radar nose.
2. Procurement of ten ejection seats on a firm basis, with provision for a further eight if needed.
3. Procurement of twenty sets of seat cartridges (each set being sufficient for one firing of one seat).
4. Provision of three spare sets of canopies, and vulnerable linkage details.
5. Procurement from civilian firms of proposals for a contract, as described in item 6. The firms to be approached are Coleman Engineering Co. Inc., of Los Angeles, the Hunter-Bristol Corporation of Bristol, Pennsylvania, and Century Engineers, Inc., of Los Angeles. All of these firms have had previous experience of the same nature, and the first two are widely recommended. It is proposed that these firms be allowed full discretion in the preliminary stage to suggest a particular choice of one of the three tracks already mentioned, subject to the acceptance of the proposed programme by the track authorities in question. The choice of track dictates to a considerable extent the magnitudes of the maximum acceleration and deceleration required of the vehicle, so that for a particular vehicle configuration, the track choice may not be easily variable. The availability of liquid-fuelled locomotives at the several tracks at the time when the tests are to be run is a question which could not be answered definitely when the matter was investigated in March 1957, but may be expected to become progressively clarified during the period of the proposed negotiations.



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6.2 (Continued)

5. As previously pointed out, the use of such a locomotive may be an important economic factor. Finally there is the consideration that the Coleman Engineering Co. enjoys a virtual monopoly of contracts such as that proposed, for test programmes run at the SMART track. Since there is no decisive technical factor requiring the choice of that track, it is regarded as highly desirable, from the economic point of view, to leave the choice of track as free as possible, so as to provide a realistic basis for competitive proposals. - providing
6. *we get the man out of sand track.* Allocation of a contract, based upon proposals as described above, to cover:-
- Design and construction of a suitable sled vehicle including a simulated radar nose, plus a locomotive if that should be necessary. Avro to supply an aircraft front fuselage, and such stressing reports as may be required.
 - Design, supply and assembly of all sled-borne instrumentation, and devices for initiating ejection action.
 - Supply of all dummy aircrew necessary for the programme.
 - Supply of all rocket motors and/or propellants required.
 - Necessary assistance to the track personnel in setting up and conducting test runs.
 - Technical liaison with Avro Aircraft Ltd.
 - Necessary repair, maintenance, modification and replacement of all items, except the replacement of such items (e.g. seats) as will be supplied by Avro.
 - All necessary assistance with data reduction, and the preparation of interim reports.
 - Preparation and submission of a final report.

6.3 Action Requested of the R.C.A.F

It is proposed to ask the R.C.A.F. for:-

- Specific approval of the courses of action proposed throughout this report.



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6.3 (Continued)

2. Confirmation that the R.C.A.F. will supply clothing and personal equipment for dummy aircrew in the quantities necessary for the programme and contingencies described herein, and without charge to Avro.
3. Contractual authority, as may be necessary, for the supply of a front fuselage and ejection seats by Avro Aircraft Ltd.
4. Provision of a track facility, to be recommended later by Avro Aircraft Ltd., including the services normally provided by the track selected, without charge to Avro.
5. Expedition of security clearances for Avro personnel at the chosen track for all phases of the programme.
6. Expedition of rocket motor and/or propellant supplies, in the event that intervention by military authorities is needed for that purpose.

It is expected, of course, that the test programme and any required development of the escape system will be conducted in collaboration with the R.C.A.F. Institute of Aviation Medicine and other branches, and that R.C.A.F. witnesses will attend some or all of the firings.



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9.0 REFERENCES

- 9.1 U.S.A.F. A.R.D.C. Manual 8C-1 "Handbook of Instructions for Aircraft Designers", section 6, paragraph 6.115.
- 9.2 MIL-E-9426A - General Specification for Escape System Testing - Ejection Seat Type - Ground and Flight Tests.
- 9.3 Minutes of the 33rd meeting of the Arrow Development Co-ordinating Committee held on March 20th, 1957 - Item 13 - decision 48, para. b., sub-para. a.

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