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A. V. ROE CANADA LIMITED
MALTON - ONTARIO

**RESEARCH & DEVELOPMENT** (AIRFRAME)

PROJECT ARROW ESCAPE SYSTEM

REPORT No. RD.84.B

FILE No.:

No. OF SHEETS 22

TITLE:

# SPECIFICATION FOR ROCKET SLED TESTING OF THE ARROW ESCAPE SYSTEM

Classification cancelled/changed to UNCLASSIFIED

by authority of ..... (date) .....

..... (signature)

CHECKED: G. Grossmith

APPROVED: E. J. Lynch

DATE: Sept 10/57

SECRET
UNCLASSIFIED

PREPARED BY E.J. Lynch & G. Grossmith

DATE September 10th, 1957

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1.0 TITLE

Specification for Rocket Sled Testing of Avro Arrow Escape System.

2.0 SUMMARY

This specification is intended to form the technical basis of a contract for the engineering responsibility, materials and services necessary to complete the track site phase of a rocket sled test program, intended to prove the adequacy of the escape system of the Avro Arrow Aircraft. Its issue does not itself establish such a contract, nor a declaration of intent to enter into a contract. The security classification of this document is "Secret".

## 3.0 GENERAL INFORMATION

### 3.1 Object And Scope Of Test Program

The object of the test program referred to herein is to demonstrate the effectiveness of the complete escape system of the aircraft. This object may be regarded as sufficiently realised if the tests show that, under all conditions prescribed:-

(a) The emergency canopy opening system functions satisfactorily without causing hazard to the crew.

(b) The crew ejection system functions correctly, with safe and satisfactory separation of the dummy crew members from the aircraft and its services.

(c) The post-separation performance of the ejection seats and personal equipment of the crew members is such that the latter pass safely clear of the aircraft structure without either suffering injury or being subjected to unacceptable accelerations, and, having regard to the available knowledge of the seat characteristics, without apparent danger of subsequent mishap.

The possible need for escape system development in order to achieve this object is acknowledged. Such development would be the responsibility of Avro Aircraft Limited, and suitable modifications may be made from time to time to the test vehicle and other equipment, as well as to the test program.

### 3.2 The Aircraft And Applicable Specifications

The Avro Arrow Aircraft is a supersonic two-place fighter, with the navigator's cockpit aft of the pilot's cockpit. A general view of the front fuselage area of the aircraft wooden mock-up is shown in Figure (1). It is being produced under a contract between Avro Aircraft Limited, and the Canadian Government, and the technical requirements are those contained in the Model Specification, which fairly closely defines the physical nature of the escape system.

3.2 The Aircraft And Applicable Specifications (Continued)

The test requirements for the systems are those defined by U.S.A.F. A.R.D.C. Manual 80-1 (Handbook of Instructions for Aircraft Designers), of which the applicable paragraph is number 6.115. Since flight demonstrations of the escape system are impracticable, it is necessary to resort to Rocket Sled Testing.

3.3 Preliminary Investigations

In January 1957, a visit was paid by an Avro group to W.A.D.C. at Dayton, Ohio, in order to learn the current attitude and practices of the U.S.A.F. with respect to escape system development and testing. These subjects were discussed with Mr. A.B. Nutt, Chief of Special Projects Branch of the Aircraft Laboratory, and his staff. Preliminary data was also obtained concerning the "SMART" track at Hurricane Mesa. This was followed in March by visits to the tracks at Edwards Air Force Base, N.O.T.S. China Lake and Hurricane Mesa, during which the facilities were inspected and the technical feasibility of carrying out the Avro program was discussed. As a result of this tour, the conclusion was reached that there exists no basic technical requirement for the selection of any particular one of these three tracks.

3.4 Track Selection

The selection of a suitable test track will primarily be the responsibility of Avro Aircraft Limited. It is acknowledged however, that interested firms should be afforded the opportunity, as part of their proposal, to recommend a track which may suit their particular method of operations.

3.5 Responsibility For Track Provision

Responsibility for the arrangements under which the selected track, and the facilities normally provided by the track authorities, are made available to Avro Aircraft Limited, will be assumed by the Royal Canadian Air Force.

## 4.0 SERVICES DESIRED OF THE SUB-CONTRACTOR

### 4.1 Summary

The services desired are as follows:-

(a) Engineering assistance, on a consulting basis, with the design of a rocket sled vehicle, and the design of sled-borne instrument installations and actuation devices, by Avro Aircraft Limited.

(b) Supply of all dummy aircrew and aircrew instrumentation, as specified herein.

(c) Supply of all rocket motors and/or propellants as required.

(d) Necessary assistance to track personnel in setting up and conducting test runs.

(e) Technical liaison with Avro Aircraft Limited.

(f) Supply of special devices.

(g) Necessary repair, maintenance, modification and replacement of all items, and installation of replacement items supplied by Avro Aircraft Limited.

(h) All necessary assistance with data reduction and the preparation of interim reports.

(i) Preparation and submission of a final report.

The services listed above are further discussed in the following paragraphs.

### 4.2 Consulting Assistance

The detailed design and drawing of the sled test vehicle will be performed at Avro Aircraft Limited by Avro personnel. In order to make good the lack of previous specific experience at Avro in the field of sled design, the sub-contractor is to send to Avro an engineer whose previous experience and calibre

4.2 Consulting Assistance (Continued)

fit him to share the design leadership for the project, together with such other engineers whose specialised knowledge and experience are necessitated from time to time, as may be agreed. Such proprietary knowledge as may be desirable for the proper carrying out of the sled design shall be made fully available to Avro Aircraft Limited, for its private purposes, under this section.

4.3 Dummy Aircrew

To cater for the test program as specified in section 6, the sub-contractor is to supply anthropomorphic dummies as required. Provision must be made to salvage ejected dummies, and to repair or replace damaged appendages when economical. The general requirements for the anthropomorphic dummies supplied shall be as nearly as possible as follows,

(a) General: Height 6' 1" Weight 200 lb.

(b) Motions Of The Appendages (In Degrees)

NECK

Forward Flexion.....60
Backward Flexion.....60
Lateral Flexion.....40
Rotation.....70

UPPER ARM

Forward Flexion At Shoulder.....180
Backward Flexion At Shoulder..... 60
Lateral (Outward Only).....135
Rotation..... 90

FOREARM

Flexion At Elbow (Forward Only).....145
Rotation Of Wrist..... 90

4.3 Dummy Aircrew (Continued)

(b) (Continued)

SHOULDER

Upward Flexion.....40
Forward Flexion.....20
Backward Flexion.....20

CHEST (Relative To Pelvis)

Forward.....40
Backward.....20
Lateral.....45
Rotation.....45

HAND

Forward Flexion At Hip.....90
Backward Flexion At Wrist.....60
Finger Flexion.....Fit Functional Hands

UPPER LEG

Forward Flexion At Hip.....145
Backward Flexion At Hip..... 45
Lateral Flexion At Hip (Outward Only).... 70
Rotation..... 90

LOWER LEG

Backward Flexion At Knee.....135

FOOT

Forward Flexion At Ankle.....30
Backward Flexion At Ankle.....75
Lateral Flexion At Ankle.....15

(c) Principal Dimensions (In Inches)

Sitting Height (Seat To Top Of Head).....38
Shoulder Height (Standing).....60
Shoulder Height (Sitting).....25
Elbow Rest Height (Seat To Bottom Of Elbow).....11
Knee Height (Sitting).....23
Buttock-Knee Length (Sitting).....25
Shoulder-Elbow Length (Elbow Flexed).....15

(d) Weight Distribution

The weights and weight distributions of all members shall duplicate as nearly as possible the properties of a male human pilot of similar dimensions.

4.4 Rocket Motors And/Or Propellants

It is desired that the designated sub-contractor shall assume the responsibility of procuring motors or propellants of the type and quantity specified by Avro Aircraft. In addition, this item shall include all storage and handling of same in so far as these services are not provided by the track authorities. It is expected that if intervention by military authority is required to allocate or expedite motors or propellants, the necessary action can be initiated by the R.C.A.F. upon request via Avro Aircraft Limited.

4.5 Preparation And Conduct Of Tests

This item is intended to cover co-ordination of material deliveries to the test, inspection and preparation of the track for test, collaboration with track personnel in setting up and calibrating sled-to-fixed station telemetry apparatus, assistance with the operation of land-based equipment where necessary; inspection, measurement and recording of all pertinent evidence upon completion of each test run, and recovery of all re-usable or salvagable equipment for future use.

4.6 Liaison With Avro Aircraft Limited

In the track phases, an Avro engineering representative will be constantly assigned to liaison with the sub-contractor, and, together with the sub-contractor, will carry out liaison with the track authorities and others, as may be expedient. At this stage, communication from the test site to Avro Aircraft Limited, will normally be via the Avro engineering representative. Notice will be required in advance of all test firings so as to permit time for arranging the attendance of witnesses, and acknowledgement will be necessary before proceeding.

4.7 Instrumentation And Special Devices

It is expected that the track facility will provide all land-based cameras and telemetry receiving equipment, as well as a system for indicating the passage of a device, on the sled vehicle, past a series of fixed points on the track. The measurements and observations required are specified in the section of this document entitled "Technical Data", and Avro Aircraft Limited will supply or rent from the sub-contractor all sled-borne transducers cameras, transmitters and/or recorders necessary. The design, supply and installation of instrumentation and transmitting equipment in the dummy aircrew is to be the responsibility of the sub-contractor. The sub-contractor is required to record the signals with an accuracy that shall represent good experimental practice and be subject to the approval of Avro Aircraft Limited. This section further covers the supply of replacement instrumentation items and the repair of damaged instrumentation items, as necessary, to complete the program.

It is required that the cockpit will be pressurized for two of the high speed runs and the sub-contractor shall supply stored compressed air to the figures quoted in Section 7.6 of Technical Data. The pressurisation system will be included in the sled as manufactured by Avro Aircraft Limited.

All special trackside devices required to initiate events on the sled are to be supplied by the sub-contractor, but the sled-borne systems operated thereby will be supplied by Avro Aircraft Limited.

4.8 Repairs, Maintenance, Modifications And Replacements

Equipment of every kind shall be repaired and maintained in good order as may be required, to ensure continued and satisfactory operation, whenever such action would represent proper economy. Otherwise, such equipment may be replaced. Modifications to aircraft structure or equipment specified by Avro, or repairs occasioned by test damage, are to be carried out as needed. Equipment other than instrumentation originally provided by Avro will be replaced by Avro when necessary.

4.9 Reports And Data Reduction

All engineering materials and assistance necessary to reduce data and prepare reports are required for:-

(a) An advance statement in detail of all preparation and arrangements proposed for the test program proper, including full procedural and data recording details.

(b) Essential, and especially requested, immediate results for each track test.

(c) A final report, co-ordinating all the previously issued reports and completing the presentation of all data obtained.

Item (a) is to be submitted not later than four weeks before the first test run, and item (c) within three months after the completion of the test program. All reports are to be submitted directly to Avro Aircraft Limited in reproducible form. Each shall be issued and signed by a responsible official of the sub-contracting company.

4.10 General Conditions

All technical questions, and the disposition of all damaged material, shall at all times be the subject of Avro Aircraft Limited discretion.

No material, the cost of which has been charged to Avro Aircraft Limited, shall be disposed of except as prescribed by Avro. The sub-contractor shall undertake to use practices and materials of good - commercial quality throughout all phases of the contract, suited to the purposes intended, and shall indemnify Avro Aircraft Limited, against all consequences of his neglect in such matters.

No data acquired by the sub-contractor out of this document, or as a result of the proposed contract, or as a result of tests conducted under such a contract, shall be revealed to any third party except with prior consent in writing from Avro Aircraft Limited.

The sub-contractor shall provide to Avro Aircraft Limited a complete set of drawings covering modifications and repairs to the test vehicle and dummy aircrew, and instrumentation of the dummy aircrew.

All communications with Avro Aircraft Limited concerning the subject test program shall be addressed to the Procurement Manager, unless they are of a purely non-contractual character, in which case they shall be addressed to the Chief Ground Test Engineer.

4.11 Amendments

The possible necessity for modifications to portions of the escape system, or of basic alterations in the type of system employed, and for consequent changes to the vehicle and/or the test program, shall be recognised. Such changes shall not affect the general intentions of the original contract, but shall be the subject of negotiation in each case.

5.0 SERVICES TO BE PROVIDED BY AVRO AIRCRAFT LIMITED

5.1 Engineering Materials

This company will provide all engineering drawings for the test specimen, vehicle, instrumentation and systems necessary for the proper execution of the sub-contractor's work.

5.2 Engineering Liaison

An engineering representative of Avro Aircraft Limited will provide liaison with the sub-contractor and with the track authorities as already described in paragraph 4.4.

5.3 Technical Assistance

This company will provide, for the program, a crew to assist with the installation and servicing of the ejection seats.

5.4 Witnessing Of Tests

Avro Aircraft Limited engineering representatives will witness the performance of all tests conducted by the sub-contractor.

5.5 Non-Engineering Materials

This company will supply the following:—

(a) Rocket sled vehicle, complete with fixed sled-borne instrumentation installations, actuating devices, water brakes, slippers of sufficient quantity for the test program and provision for mounting propulsion units.

(b) Ejection seats, suitably coloured and marked, in quantities sufficient for the test program.

(c) Seat and canopy actuating cartridges, in quantities sufficient for the test program.

(d) Clothing, suitably coloured and marked, and personal equipment.

(e) Spare canopies and linkage items, as required.

(f) Spare gas system parts, as required.

(g) Spare manufactured structural parts, as required for repair purposes.

Transportation and insurance in transit will be provided for these items, to the point of delivery to the sub-contractor.

6.0 TEST PROGRAM

As presently forseen, the test program will consist of five runs, one at low speed, one at intermediate speed, and three at high speed. These speeds are defined as 150, 490 and 700K (E.A.S.) respectively. In each case both dummy aircrew members will be ejected in sequence, and their respective canopies will be opened by the emergency systems. It is anticipated that the cockpit will be pressurized in two of the high speed runs.

6.0 TEST PROGRAM (Continued)

Prior to the dispatch of the test specimen to the sub-contractor, ejection tests will have been carried out at Avro Aircraft Limited, with the vehicle stationary and no repetition of this test will be required at the track site for Avro purposes. It is recognized that it may be desirable to conduct one run using the accelerating impulse only, without ejections, in order to establish the drag co-efficient variations with speed over the entire range.

7.0 TECHNICAL DATA

7.1 Drawings

No drawings are issued with this specification, which is issued in conjunction with report RD.84.A, including a full set of drawings such as would be required for an initial assessment of the task of designing the sled vehicle. Drawings of the Avro designed vehicle will be supplied when available.

7.2 Extent And Construction Of Components Supplied

7.2.1 Fuselage Test Specimen

(a) Front fuselage structure, including ramps, windscreen and nacelles from Stn. 120 to Stn. 255.

NOTE: The cockpit floor and tranverse bulkheads are of aluminum alloy sheet. The outer fuselage skins are of magnesium, and all stiffeners are of aluminum alloy. The nacelles are constructed of aluminum alloy throughout. All construction is by means of rivets or other fasteners, except for one or two reinforcing members on the bulkheads, which are metal-bonded.

7.2 Extent And Construction Of Components Supplied (Continued)

7.2.1 Fuselage Test Specimen (Continued)

(b) Pilot and navigator canopies and seals, complete with normal and emergency actuating mechanisms, and seal inflation piping.

(c) Ejection seats (operating charges supplied separately).

(d) Control mechanisms, such as stick, rudder and radar units, or suitable mock-ups, as would be deemed necessary for compliance with the ejection path clearance requirements.

(e) Dummy nose section forward of Stn. 120 of suitable construction to withstand the track test conditions.

(f) Dummy centre fuselage section to fair in the front fuselage test specimen of suitable design and construction to mount propellants.

7.2.2 Test Vehicle

Details not yet established.

7.3 Operation And Maintenance Of Canopy Locking And Opening Systems

7.3.1 Locking

The locking and actuating mechanisms are shown schematically in Figure 2. Five latches (17) are mounted on one canopy half, and are connected by link rods. Their key-hole slots engage mushroom studs on the other canopy half. Forward motion of the lever (13) engages the latches, and finally disengages the lever itself from the latching arrangements.

7.3.2 Normal Opening

The latches are first disengaged by pulling handle (13) down and aft. A micro-switch, thus actuated, normally operates a solenoid valve to deflate the canopy seals. The normal electric actuator (14) is then operated via a selector switch.

7.3.3 Emergency Opening Without Ejection

Either by operation of handle (12) inside the cockpit, or by pulling on cable (9) from outside, the sear is withdrawn from firing unit (4), which is a cartridge-operated gas generator. Gas due to this firing passes to the latch-operating jack (5), actuating the push-rod (6) and the bell-crank (7) to disengage the latches. Motion of the push-rod (6) allows the gas pressure to be sequenced from the jack (5) to the emergency canopy-operating jack (1), and the action of this jack, through the linkage, shears a pin in the rod-end of the normal actuator (14), and opens the canopies.

The emergency opening action goes further than the normal action, and results finally in removal of the sear (11) from the seat ejection gun. The striker is restrained, however, by the presence of a safety pin connected to cable (16).

7.3.4 Emergency Escape

Either by pulling the face blind handle (8), or by operating an alternative control (not shown), mounted on the seat pan, the sear is removed from the firing unit (4) and the sequence described in para. 7.3.3 is initiated. At the same time, the safety pin attached to cable (16) is removed, so that upon completion of the canopy-opening action, the ejection seat is fired.

7.3.5 Safety

Cartridges shall not be placed in the chambers of the firing units or the ejection seat guns until the last possible moment before firing. If any work is subsequently necessary in the cockpit, all safety pins, with prominent warning notices attached, must be inserted in such a way as to prevent accidental firings, before such work is commenced, and must remain until all such work is finished. If the cockpit is to be left unattended at any time when the cartridges are in the chambers, the safety pins and warning signs must be fitted.

7.3.6 Inspection And Replacements

All cables and moving parts shall be inspected frequently for wear and proper operation, and lubricated and replaced as necessary. After each firing of the canopy mechanism, the following should be replaced:-

(a) Normal actuator shear pin.

(b) Flexible hoses from latch operating jacks to emergency operating jacks.

(c) Copper rings in latch operating jack.

(d) Any mechanism parts worn or damaged.

7.3.7 Cleaning

All parts of the gas system (i.e. firing unit, gas piping, latch jack, and emergency actuating jack) must be dismantled as promptly as possible after each firing, and cleaned of all corrosive deposits by boiling in water. The parts must then be thoroughly dried.

7.4 Operation And Maintenance Of Ejection Seats

The ejection seat presently specified for these tests will be the Martin Baker Mk. C.5. It is anticipated that at a later date a detailed brochure will be available on the operation and maintenance features of this seat. The ejection gun is permanently mounted in the aircraft, and acts as the guide rail for the ejection seat. The ejection seat is installed in the aircraft, and locked to the ejection gun guide rails.

7.5 Operating Times, And Required Period Of Uniform Sled Velocity

For the test program as outlined in section 6.0, the maximum required period of uniform sled velocity will be for the 700 knots E.A.S. runs. A breakdown of this estimated time for the complete sequence is as follows:-

(1) Navigator's canopy opening time with air loads tending to close.....0.5 seconds

(11) Navigator's seat ejection and clearance.....0.3 seconds

(111) Pilot's canopy opening time, with air loads tending to close.....0.5 seconds

(1V) Pilot's seat ejection and clearance.....0.3 seconds

TOTAL 1.6 seconds

As the above figures are based on mean data presently available, a total of 2 seconds for uniform sled velocity is thought to be necessary, in order to ensure that the first ejection is completed up to the separation stage, before the second is commenced.

7.6 Cockpit Pressures And Leak Rate

As previously stated in Sect. 6.0, in two of the high speed runs the cockpit will be pressurized. The pressure to be supplied will be 5.75 p.s.i. above ambient pressure. The estimated cockpit volume is 127 cu. ft. The total estimated leak rate is 50 to 75 standard C.F.M.

7.7 Measurements And Observations Required

The sub-contractor will be required to record and produce data as specified herein, correlated with time on a common basis, for each of the following functions, in each test run.

7.7.1 Motion Of Test Vehicle

A continuous record of signals is required for the longitudinal acceleration and decelerations of the test vehicle. A record of distance travelled versus time originating from the magnetic pick-ups provided at the track is also required.

7.7.2 Emergency Canopy Opening

Signals must be recorded to show the instants of initiation of the escape process for the pilot and the navigator, and these signals must be separately recognisable for each crew member. Continuous records of the gas pressures at two points in each canopy system are required. Continuous records are required of strains at about 12 locations on the canopy and cockpit structure, and of the pressures in the two cockpits, and of the angular displacements of the four canopies. In addition, cine-photography records are required of the latch and opening mechanism action, for each cockpit.

7.7.3 Crew Ejection

A continuous record is required of the distance travelled by each seat from its starting point, independently of land-based camera records, for the first eight feet of travel only. Accelerations of each test dummy are to be recorded continuously during the test runs, for the following motions. Three accelerometers placed at the heart location, to record the upward, downward and lateral movements of the test dummies. One accelerometer placed in the upper chest or neck, with its distance from the heart location rigidly fixed, to record the pitch of the dummies. One accelerometer placed in the head to record the pitch of the head relative to the body. All instruments are to be located in the plane of symmetry of the test dummy. The total dynamic pressure is to be continuously recorded, at the centre of the chest area, outside the suit, and in the forward facing direction, as well as the pressure inside the flatable portion of the suit. Cine-photography records are required to show leg motions of the dummy aircrew at the beginning of the ejection process, as well as the clearance or lack of clearance around the legs during the process. Land-based "metric range" photography will be required to yield as accurately as possible a record of the position of a target mark at the heart location, seen in side elevation, together with the orientation of the seat in pitch. It is expected that it will be possible to deduce whether or not the crew members would have cleared the fin of the aircraft from these records, as well as to observe the flight of the seats and their occupants until they reach the ground. A photographic record in the fore and aft plane to record the sideways travel of the dummy and seat after ejection is required.

7.7.4 General

Still photographs are required of the completed vehicle on the track, and to illustrate the dummy occupants and their equipment as installed for test, as well as to illustrate all mechanisms, for test purposes. Examinations of the seat dummies, clothing, equipment and the vehicle are to be made in situ, where appropriate and the observations are to be recorded by photography as well as in writing. The ambient temperature, barometric pressure, wind velocity and wind direction are to be recorded for each test run. The temperatures of the cartridges at the time of firing should be closely estimated, since they may be significantly heated by the sun after the cockpits are closed.

The names, ranks or titles, and affiliations of all witnesses present must be recorded for each run.

8.0 TIME SCHEDULE:

October 11th, 1957 — All bids to be received

November 1st, 1957 — Authority to proceed to be issued to sub-contractor and design of vehicle to begin.

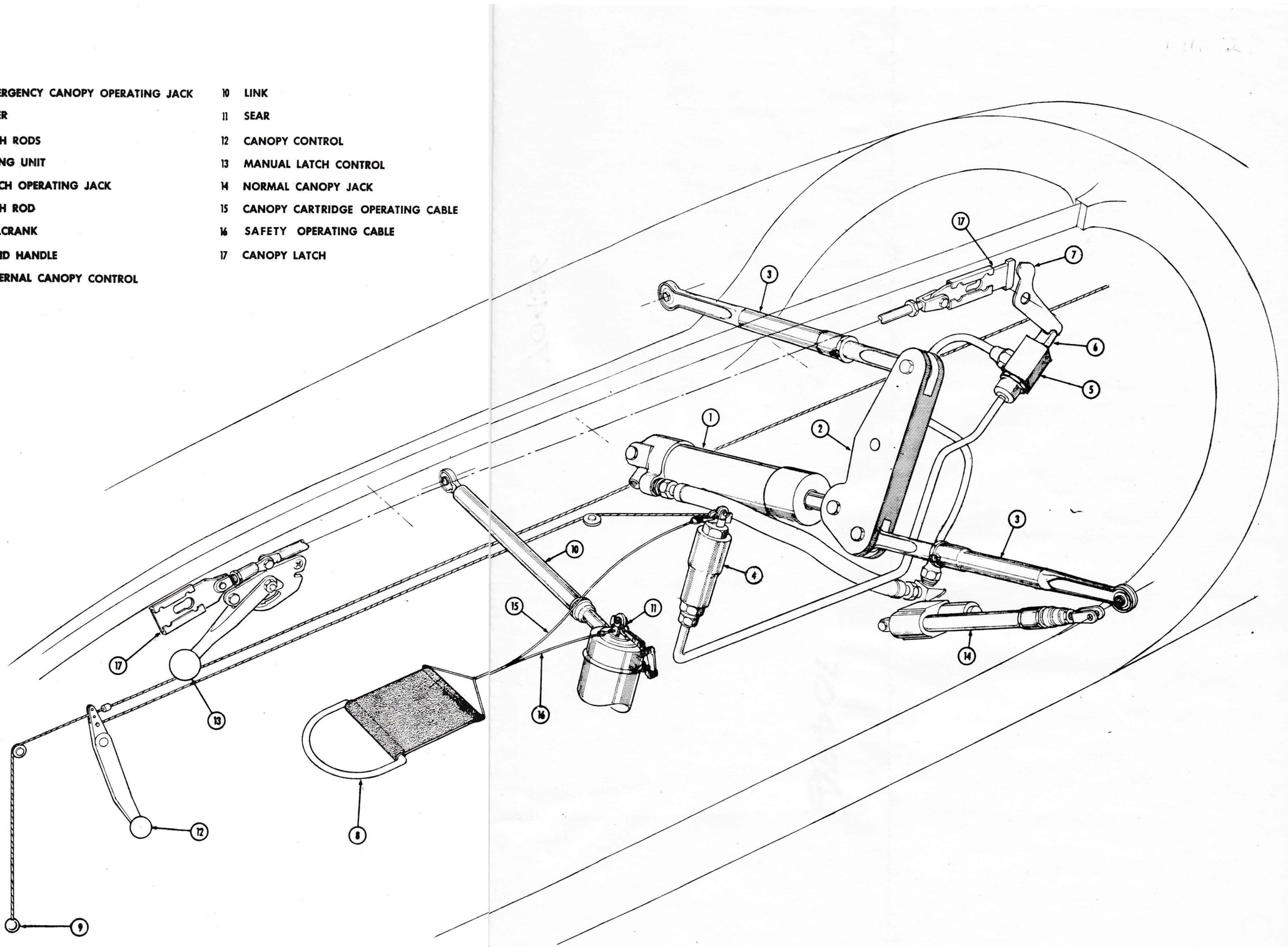
February 1st, 1958 — Front Fuselage component to be available for incorporation into vehicle.

May 1st, 1958 — Vehicle to be completed and tested, as necessary.

May 15th, 1958 — Vehicle to arrive at test track.

June 1st, 1958 — First Test Run

1 EMERGENCY CANOPY OPERATING JACK
2 IDLER
3 PUSH RODS
4 FIRING UNIT
5 LATCH OPERATING JACK
6 PUSH ROD
7 BELLCRANK
8 BLIND HANDLE
9 EXTERNAL CANOPY CONTROL
10 LINK
11 SEAR
12 CANOPY CONTROL
13 MANUAL LATCH CONTROL
14 NORMAL CANOPY JACK
15 CANOPY CARTRIDGE OPERATING CABLE
16 SAFETY OPERATING CABLE
17 CANOPY LATCH

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**CF-105 COCKPIT CANOPY ACTUATING MECHANISM**


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