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TITLE

BLACK BRANT DATA BOOKLET CCI-28 & 38.: ANNEX C TO OPERATIONAL REQUIREMENTS NO.: PRE-FLIGHT DATA JET SEEDING VEHICLE

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CARDE BLACK BRANT

DATA BOOKLET CCI-28 & 38

ANNEX C

to

Operational Requirement No. ____

PRE-FLIGHT DATA

JET SEEDING VEHICLE

ANNEX C

to

Operational Requirement No. ____

PRE-FLIGHT DATA

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ANNEX C

To Operational Requirement No. ____

PRE-FLIGHT DATA OF THE JET SEEDING VEHICLE

ABSTRACT

Two Black Brant I, (CC I 28 and 38), rocket vehicles with jet seeding nose cones are to be launched at Fort Churchill, Manitoba.

The rocket vehicles with the seeding experiment and the CARDE supplied ground charging system, are described. The aerodynamic data, predicted zero wind performance and general details of the rocket vehicle are presented to provide pre-launch information for use in preparations for the rocket launching.

LIST OF FIGURES

TABLE OF CONTENTS

Page

1.0 INTRODUCTION

The 'Jet Seeding' programme is part of the CARDE programme for research into the composition of the upper atmosphere. The jet seeding rocket vehicle is a system devised to titrate the upper atmosphere for atomic oxygen. The method to be used in this test is to continually vent, (Jet Seed), nitric oxide over an altitude range of 95 to 105 km and to record any chemical energy released by the reaction of the NO + O, on ground based instrumentation.

This report describes the test objective, the rocket vehicle and the ground charging system that will be used for the experiment. This report also gives the performance for an 80° zero wind launch and vehicle data for the first test of the overall system, in order that preperations for firing can be completed.

2.0 TEST OBJECTIVE

The objective in the firing of the second and third CARDE 'Jet Seeding' vehicles is to carry out a series of experiments into the composition of the upper atmosphere over Fort Churchill, Manitoba.

The main areas in the test objective are:

i) To determine whether the expected reaction does occur using ground based instrumentation and visual observation.

ii) To check the operation of the jet seeding system by inflight monitoring.

iii)To record rocket engine pressure.

iv) To obtain trajectories of a) the complete vehicle to separation b) the separated nose cone and if possible c) the engine with fins.

Because of the low energy released by the expected nitric oxide and atomic oxygen reaction, a night firing, without moon, aurora, and no cloud in the direction of the seeding altitude, is requested.

3.0 THE ROCKET VEHICLE

3.1 General

The rocket vehicle allocated to the seeding experiment is a Black Brant I. The complete vehicle, see Fig. 1, comprises a nose cone specially developed for the seeding programme, the 15KS25000 rocket engine and the BB I tail assembly.

To satisfy the basic seeding experiment, the nose cone must be separated from the engine at the time of gas seeding. Separation of the nose cone from the engine with fins is initiated by a clock timed switch soon after burn out of the rocket engine. Inertia switches delay arming of the clock timer until burn out. This separation technique was used by CARDE with success in a seeding experiment at Fort Churchill in Sept. 1960, and at Wallops Island in Nov. 1962.

The act of separation initiates power to a sequence timer for the flash bulb trajectory system. This system, to enable visual tracking by the ground instrumentation crew, also provides a method for recording trajectories using the star background as a reference by photographs from two separated camera sites.

The nose cone is provided with instrumentation and telemetry so that the operation of the vehicle system can be monitored in flight.

3.2 Rocket Vehicle Data

The configuration of the rocket vehicle from launch till nose cone separation is shown in Fig. 1. Other vehicle data is given in Table I. The weight variation versus burning time and c.g. versus time are presented in Figs. 23 and 24 and Table II.

The pitch and roll inertia versus burning time are given in Figs. 25 and 26 and Table II.

4.0 SEPARATED NOSE CONE

4.1 General

The separated nose cone as illustrated in Figs. 2 and 8 has a ballast section between station 0-32, the conical pressure vessel between station 32-67 and a conical and cylindrical fairing from station 67 to 102 containing the instrumentation, telemetry, timers, arming switches and flash bulb system. The adaptor for the external charging system is mounted on the conical section at station 75.

The separated nose cone is aerodynamically stabilized by the flow around the cone and the cylindrical afterbody. The lower $C_D A/w$ of the separated cone relative to the engine with fins and drag brakes, ensures separation of the engine from the seeded cloud.

4.2 Nitric Oxide Gas System

The main part of the nitric oxide gas system is an AISI 4340 pressure vessel containing the 30 lb. of gas. The remaining components include the gas charging adaptor, the dump and control valve, check valve, jet pipe with nozzle, clock timers, inertia arming switches, explosive valve, pressure transducer and pressure switch. The complete system is shown diagrammatically in Fig. 3.

A nominal operating pressure of 3,500 psi is used in the gas system; the pressure vessel has been proof tested to 6,000 psi. The charging of the nitric oxide is described in Section 11.0.

The gas is released by an explosive operated valve that is controlled by the clock timer set for X+ 84 secs. Inertia switches are used to delay arming of the clock timer system until burn out of the rocket. The explosive valve uses a McCormick Selph Squib, described in Section 6.0.

The data for nitric oxide seeding is given in Tables VI and VII; the pressure variation from initiation is given in Fig. 35.

4.3 Rocket Instrumentation

The instrumentation within the rocket vehicles, see Fig. 9, is to monitor the functioning of the rocket vehicle system. The transducers used and their functions are as follows:-

i) Nitric Oxide Pressure Transducer

Continual in flight monitoring of the nitric oxide pressure.

ii) Nitric Oxide Pressure Switch

A switch operated by the gas pressure dropping to 750 psi; back up to continuous pressure monitoring.

iii) Rocket Engine Pressure Transducer.

To provide statistical data of the rocket engine performance.

iv) Clock Timer

In addition to its main functions, to initiate separation and gas release, the safe positions of the clock timer switch are monitored.

v) Flash Bulb Sequence Timer

To monitor the initiation of each flash bulb.

vi) Separation Switch

To monitor physical separation of the nose cone from the engine.

4.4 Airborne Telemetry System

The airborne telemetry system, see Fig. 9, is a three channel FM/FM system operating on a carrier frequency of 219.5 mc/sec. The transmitter is an Advanced Electronics T-2A with an output power of 2 watts. The sub-carrier centre frequencies and their functions are:

i) 3.9 Kc/sec. Engine pressure, switched by separation to monitor flash bulbs and pressure switch.

ii) 3.0 Kc/sec. Monitor clock timer switch positions.

iii) 2.3 Kc/sec. Nitric oxide pressure.

4.5 Umbilical Plug

The umbilical plug with 25 conductors is used for monitoring of the vehicle gas system and to provide external power for the check out of telemetry. Final switching to internal power is achieved by the release of a switching relay.

Release of the umbilical from the rocket is automatic upon vehicle motion.

4.6 Separated Nose Cone Data

The configuration of the separated nose cone is shown in Fig. 2. The data relevant to the separated nose cone is given in Tables VIII and IX.

5.0 ROCKET ENGINE WITH FINS

5.1 General

After separation of the nose cone, the engine with fins coasts upwards but will be separated from the seeded cloud by its high C_DA/w relative to the nose cone.

The rocket engine with fins includesthe drag brake section, see Fig. 5.

5.2 Drag Brake Section and Clamping Ring

The drag brake section is attached to the engine casing by flat head screws and attached to the separating nose cone by a marmon type clamping ring with two explosive bolts. For convenience in general handling, the clamping ring is held in position by flat head screws. These screws are removed after installation of the explosive bolts at a time consistent with safety. The explosive bolts use a No. 8 Electric Blasting Cap, described in Section 6.0. As the clamping ring is released, drag brakes are inclined to the flow to increase the differential drag acceleration between the nose cone and engine with fins. The effect of the drag brakes is negligible when the dynamic pressure acts on the head end of the engine.

5.3 Rocket Engine

The rocket engine for the Black Brant I rocket vehicle is the 15KS25000 with a nozzle to suit the BB I tail assembly, see Fig. 4. The total impulse of the engine at sea level is 380,000 lb. sec. with a 15.5 seconds nominal burning time. Sea level and trajectory corrected thrust-time curves are shown in Fig. 17.

The igniter for the engine, shown in Fig. 6, comprises a flame tube and the main igniter charge attached to the head end of the engine.

The electrical initiator for the igniter is a McCormick Selph Squib, described in Section 6.0.

5.4 Tail Assembly

The tail assembly for the Black Brant I rocket vehicle comprises three swept back delta fins and a centre support casting. The basic fin is made up of a sparred and ribbed core for the steel skins. The skin is covered with an asbestos reinforced phenolic, 'Durestos', and the leading edge capped with a stainless steel cuff.

5.5 Rocket Engine With Fins Data

The configuration of the rocket engine with fins is shown in Fig. 5. The data relevant to the burnt engine with fin is:

Length, inch	218.63
Body dia., inch	17.2
Fins	see 4.2
Weight, lb.	709
Centre of gravity, inch	231.5
Pitch inertia, slugs ft^2	790
Propellant weight, lb.	1770
Propellant specific impulse, sec.	213.9
Total impulse, S.L., lb. sec.	380,000

6.0 EXPLOSIVE TYPE COMPONENTS, INITIATION & SAFETY SYSTEMS

6.1 Explosive Category

The explosive type components and their categories are:-

i)	Rocket engine propellant	1760 lb.	Class B
ii)	Rocket engine igniter and flame tube	1 lb.	Class B
iii)	Rocket engine squib, see Fig. 37		Class C
iv)	Explosive bolt, see Fig. 38		Class C
v)	Explosive valve, see Fig. 39		Class C

6.2 Initiation and Safety Systems

6.2.1 Rocket Engine Firing Circuit

The McCormick Selph M-32 squib, shown in Fig. 37, has a resistance of 0.3 ohm and requires a minimum current of 2.0 amps for satisfactory ignition. The initiation and safety of the rocket engine is a range responsibility.

6.2.2 Explosive Bolts and Valves

The initiation and safety circuits for the explosive bolts and valves is shown in Fig. 40. The units involved comprise the clock timers, inertia switches in parallel, the explosives, power supply and shorting plugs. The McCormick Selph M - 76 squib for the explosive valve is inserted into the nozzle prior to assembly of the nose cone to the engine. The No. 8 blasting caps are assembled to the clamping ring prior to assembly of nose cone to the rocket engine. A shorting plug is fitted across the firing lines and to open power lines. The clock timers are located so that the safe position of the 'G' weight can be seen through an access door opening. Monitor of continuity through the normally closed side of the clock timer switches indicates open circuit. Monitor of continuity, using special meter, through normally open side of clock timer switches indicates open circuit on clock timer switch. Monitor of continuity, using special meter, through inertia switches indicate safety of firing lines. Arming of the explosive circuits is done by removal of the shorting plug and replacement by an arming plug. The access door is bolted in position. The safe side of the clock timer switches is monitored on the 3.0 Kc/sec. V.C.O. of the telemetry system.

7.0 STABILITY

7.1 General

The stability derivatives have been determined using Ref. 1, 2, 3, 5, 6, 7 and 9. The c.g. of the various components have been obtained from vehicle check out data and sections 4.6 and 5.5 . The basic lift slope data is referred to the cross sectional area A_B.

7.2 Complete Rocket Vehicle

The slope of the coefficient of lift at zero angle of attack over the Mach No. range for i) the nose cone and afterbody, is shown in Fig. 13 ii) the tail assembly, is shown in Fig. 14 and iii) the complete vehicle in Fig. 10. Centre of pressure over the Mach No. range is shown in Figs. 12, 13 and 14. Tabulated data is given in Tables II and III.

7.3 Separated Nose Cone

The slope of the coefficient of lift at zero angle of attack over the Mach No. range from 3-6 for the separated nose cone is shown in Fig. 31. The centre of pressure over the Mach No. range of 3-6 is shown in Fig. 31. Tabulated data is presented in Tables VIII and IX.

7.4 Rocket Engine with Fins

No data is given for the engine with fins because of the unpredictable nature of the motions.

7.5 Undamped Pitching Frequencies

The undamped pitching frequencies of the complete vehicle is shown as a function of time in Fig.29.

8.0 DYNAMIC STABILITY

8.1 General

Damping derivative for the complete vehicle and nose cone have been determined using Ref. 5. The results are shown in Figs. 16 and 30 and Tables III and IX.

9.0 DRAG

9.1 General

The wave, friction and base drag coefficients were estimated using references 4, 6 and 8. The total drag coefficients for an 80° zero wind launch as a function of Mach No. for the complete vehicle, separated nose cone and engine with fins are shown in Figs. 11, 30 and 32. The source of this data, when considered with the trajectory is given in Figs. 33 and 34. Tabulated data is predicted in Tables III, V and IX.

10.0 PERFORMANCE

10.1 General

The performance of the planned rocket vehicle, separated nose cone and engine with fins has been estimated for an 80° zero wind launch from a flat plan.

The results are shown in the following:-

a) Acceleration versus time .... Fig. 18

b) Velocity versus time .... " 19

c) Altitude versus time .... " 20

d) Altitude versus range .... " 21

e) Mach No. versus time .... " 22

f) Dynamic pressure versus time .... " 27

g) Reynolds No./ft versus time .... " 28

h) Undamped pitching frequency versus time ..... " 29

i) Trajectory data complete vehicle .... Table 10

j) Trajectory data separated nose cone .... " 11

11.0 NITRIC OXIDE GAS SYSTEM

11.1 General

The nitric oxide charging system, see Fig. 36 and Tables VI and VII, is the means by which the complete gas system can be purged, evacuated and charged. In the event of a cancellation of the firing, a dump cycle is included to transfer gas from the pressure vessel back to the gas bottles and the excess to atmosphere. The system includes the rocket vehicle gas system, control valves, pressure transducers and a control system that can be operated remotely.

The main part of the charging system, carried on a trailer, comprises storage bottles, gas manifold, high pressure pump, purifier, control valves and trailer control console.

The compressed gas is transferred to the rocket vehicle, by steel and flexible piping through an automatic disconnect to the rocket vehicle system. The pressure in the rocket pressure vessel is monitored during pumping by use of the rocket instrumentation and check out leads passing through the umbilical plug to the remotely located control console.

11.2 High Pressure System

The high pressure nitric oxide gas system includes twenty nitric oxide gas bottles (Size 1A), initially charged to a pressure of 750 psi, a manifold to collect the gas from the selected bottles, a purifier to absorb NO_2 and water, a 'Micronic' filter, the high pressure pump, after-cooler, control valves, rocket pressure vessel and pressure transducers.

The cycle used is that, after purging and evacuation of the complete gas system up to the standard storage bottles, the manual valves on the size 1A bottles are opened to fill the complete system. The equilibrium pressure is approx. 650 psi. With the control valve open for charging, the diaphragm pump is started remotely and the pumping pressure is monitored continuously. The charging rate is low, approx. 90 minutes to obtain a pressure of 3,500 psi, and the pumping cycle is stopped at the required pressure using the remote controls. For safety there are two automatic pressure control devices, i) a pressure switch that cuts the power to the pump motor at a pressure of 4200 psi and ii) a 4,500 psi pressure relief valve.

The low pressure system from the manifold through the purifier and inlet to the pump is exposed to a maximum pressure of 750 psi from the size 1A bottles. The low pressure system has been tested at 1500 psi.

The high pressure system from the outlet of the pump through the control valves, piping to the automatic disconnect and rocket pressure vessel could be exposed to a maximum pressure of 4,200 psi. The minimum burst pressure of the system is 9,000 psi, in the tank. The complete system has been tested to 4,200 psi. The tank has been tested to 6,000 psi.

11.3 Purifier and Filter

The nitric oxide purifier is a container designed to pass the gas at low velocity through 10 lb. of 'Ascarite' or 'Caroxite'. A 'Micronic' filter is fitted to the outlet of the purifier to collect any solid particles.

11.4 High Pressure Pump

The high pressure pump is a Corblin A2C350 single stage diaphragm compressor capable of compressing gas to a pressure of 5,000 psi. The main feature of the pump is the compression chamber fitted with inlet and outlet check valves and the diaphragm. The diaphragm separates the gas from the pulsing fluid to avoid gas contamination. The pulsing fluid is driven by a piston operating in the fluid chamber and driven by a crank. The pulsing fluid (Pydraul 60) is nominally non-reactive with nitric oxide.

The compressor is driven by a $7\frac{1}{2}$ HP electric motor operating on 220 or 440 Volts, 3 phase.

11.5 After-Cooler

An after-cooler for the compressed gas uses water that is circulated around the outlet pipe and cylinder head. The after-cooler system is mounted in the trailer and comprises a 20 gallon tank and circulating pump. The circulating pump is driven by a $\frac{1}{2}$ HP electric motor operating on 110 Volts. Approx. 100 lb. of ice is used to increase the after-cooling of the gas.

11.6 Control Valves

The main control valves for the system are three solenoid piloted servo valves that operate on a 50 psi nitrogen supply. The nitrogen supply with regulator valve is mounted in the trailer.

11.7 Automatic Disconnect

To ensure that dumping of the nitric oxide to atmosphere is the absolute minimum, a high pressure hose connection to the rocket vehicle up till launch, is required. The automatic disconnect was devised so that, after the gas has been charged through the unit and the pressure in the charging line stabilized, the nose is automatically disconnected by vehicle motion.

11.8 Rocket Vehicle Dump Valve

An electrically operated dump valve is included in the rocket vehicle system to provide a by-pass of the high pressure check valve. This dump valve is used when a firing has been cancelled. A manual valve also by-passes the check valve. It is used in purging the tank and as a back-up to the electrical dump valve.

11.9 High Pressure Transducer

A high pressure transducer is mounted on the rocket vehicle pressure vessel and monitor leads pass through the umbilical plug to the remotely located control console.

11.10 System Control

There are two control consoles for operation of the nitric oxide charging systems -

i) Trailer Mounted Console

To control the purging and evacuation cycles. To check out main pumping system.

ii) Remote Console

To remotely control and monitor the charging cycle. To initiate the dumping cycle.

11.11 Auxiliary Systems

A vacuum pump to evacuate the charging lines and pressure vessel is mounted in the trailer. The pump is driven by a 1 HP electric motor operating on 110 V.

Nitrogen bottles are carried in the trailer to provide power for the solenoid piloted servo valves and for use in the purging and evacuation cycle.

11.12 Dry Ice Trap

A dry ice trap is provided at the outlet of the pump to freeze out any NO_2 present in the gas. Approximately 100 pounds of dry ice is required for a single charging. Heat transfer with the trap is maintained by the use of alcohol or acetone.

11.13 Purging and Evacuation Cycle

After installation of the rocket onto the launcher, the purging and evacuation is initiated from the trailer adjacent to the launcher. This cycle requires that all lines, including the pressure vessel, previously exposed to air or water, are purged and evacuated repeatedly to remove the maximum amount of free oxygen that would otherwise convert some of the nitric oxide to nitrogen dioxide. (The presence of NO_2 is undesirable for the seeding experiment and every attempt is made to keep it to a minimum). The aim of the purging and evacuation cycle is the evacuation of all gas lines up to the nitric oxide bottle.

11.14 Charging Cycle

Charging takes place with the vehicle horizontal.

The nitric oxide is manually bled into the system through the purifier until the pressure of the gas bottles and tank are stabilized. (Approx. 650 psi).

The nitric oxide charging cycle is then initiated at a remote location (approx. 100 yds) from the launcher and controlled by the remote control console.

After a pressure of 3,500 psi is attained within the tank, the pump is stopped (approx. 30 lb. of gas). The high pressure gas in the charging line up to the check valve on the pressure tank is then vented back through the by-pass valve to the gas bottles. The pressure should stabilize at approx. 400 psi. All valves between the nitric oxide bottles and rocket vehicle are then closed. The rocket firing initiates the automatic disconnect. The quantity of gas vented to atmosphere from the 400 psi line is negligible.

11.15 Dumping Cycle

In the event that a firing is cancelled, assumed at X-10 sec., the dumping cycle will be required.

The dumping cycle is initiated from the remotely located console by opening control valves to vent the high pressure gas in the tank back to the gas bottles. An equilibrium pressure of approx. 650 psi within the gas bottles and tank should be attained. Operation of the by-pass valve and flow control valve, closes the nitric oside bottle line. Operation of the vent valve releases the gas at 650 psi to the atmosphere. The weight of nitric oxide vented during the dump cycle is approximately 7 lb.

Should the electrically operated valve fail, the manual by-pass valve may be used to dump the tank.

11.16 Shut Down Cycle

After a firing or a dump cycle, nitric oxide gas is left in the lines between the gas bottles and the control valve. The gas bottle valves are closed manually and the nitric oxide in the lines purged from the system using nitrogen.

11.17 Gas Hazards

Nitric oxide mixed with air oxidizes to nitrogen dioxide, which in the presence of water forms nitrous and nitric acids; the products are highly toxic. The hazards require that the charging operation is carried out remotely. Operations that require manual control of the nitric oxide system will be performed by CARDE personnel wearing breathing apparatus and protective gloves. It is strongly recommended that after charging has begun no one approach the trailer closer than 100 feet unless wearing the breathing apparatus. In the event that a large quantity of gas is dumped to atmosphere, hazardous conditions may exist for 200 ft. downwind of the trailer.

The hazardous conditions that can be obtained from nitric oxide mixed with air is given in Appendix "A".

12.0 ORDER OF EVENTS IN PREPARATION & FIRING

Time	Operation
T- 1 Day	Physical inspection of motors and all associated stores.
	Install nozzle and fin assembly.
	Check of firing circuit.
	Activate batteries.
	Assemble nose cone.
	Test nose cone instrumentation.
	Mount nose cone on motor.

Hrs. Min. Secs.	
T-4 - 30 - 00	Black Brant on launcher.
4 - 20 - 00	Horizontal instrumentation check.
4 - 00 - 00	Purge and evacuate pressure vessel.
2 - 55 - 00	Arm vehicle.

Hrs. Min. Secs.	
T-2 - 45 - 00	Start water pump, open manifold, set control box to "remote". Clear Area.
2 - 30 - 00	Open flow valve - begin charging operation.
	Dangerous Conditions Exist on Pad from this Time on
2 - 25 - 00	Begin pumping.
0 - 55 - 00	Pumping complete.
0 - 45 - 00	Elevate (nominal 80°) and set azimuth (to be determined).
0 - 20 - 00	Vertical instrument check.
0 - 08 - 00	Turn on external power.
0 - 05 - 00	Station checks (to be listed).
0 - 03 - 00	Turn to internal power.
0 - 00 - 30	Time count by seconds starts.
0 - 00 - 00	Fire.
T+0 - 00 - 20	Nose cone separation
0 - 01 - 24	Start of gas release (310,000 ft).
0 - 03 - 00	Time count by seconds ends.
	Time count by tens begins, continue until impact. (Approx. T+ 346 secs. at 62.7 nautical miles 381,000 ft).

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Table I

Jet Seeding Vehicle Data

Weights and Centers of Gravity (Nominal)

Item	Weight lb	C. of G. Station in.
Nose cone and payload	423.6	57.76
Stabilizer Assembly	186.8	304.20
Motor (unburnt)	2263.5	203.99
Motor (burnt)	493.5	211.63
Complete Vehicle (unburnt)	2873	188.97
Complete Vehicle (burnt)	1103	168.29

Dimensions

Length overall	320.67 in.
Body cross-section area	1.614 ft^2.
Body diameter	17.2 in. = 1.433 ft.
Plan form area	40.7 ft^2.
Nozzle exit area	0.76 ft^2.
Nozzle throat area	0.148 ft^2.
Fin semi span	39.0 in.
Fin root chord	46.2 in.
Fin tip chord (nominal)	4.7 in.
Fin sweep back leading edge	52.7°
Fin sweep back trailing edge	0°
Drag brake area (total)	0.36 ft^2.

Performance Summary

Total impulse (sea level)	380,000 lb-sec.
Nominal burning time	15.5 sec.
Maximum velocity	5,350 ft/sec.
Time at burnout	19 sec.
Altitude at burnout	55,900 ft.
Maximum acceleration *	15.2 g's
Time at separation	20 sec.
Altitude at separation	60,900 ft.
Velocity at separation	5,182 ft/sec.
Nominal (zero wind) launch angle	80°

* Measured aboard vehicle.

Table II

Time Dependent Data

Jet Seeding Vehicle

Time	Thrust (Sea Level) lb.	Thrust (Actual) lb.	Mass lb.	X_{c_g} inches	Pitch Inertia Slug-Ft^2	Roll Inertia Slug-Ft^2
0	29,100	29,100	2,874	188.93	3,839	36.5
1	26,600	26,609	2,743	188.31	3,751	36.1
2	26,200	26,238	2,619	187.67	3,668	35.8
3	26,200	26,280	2,496	186.97	3,585	35.2
4	25,900	26,030	2,374	186.21	3,502	34.6
5	25,800	25,998	2,253	185.37	3,420	33.8
6	25,600	25,882	2,132	184.43	3,336	33.0
7	25,400	25,785	2,012	183.39	3,253	32.0
8	25,000	25,486	1,894	182.24	3,169	30.9
9	24,800	25,384	1,777	180.95	3,086	29.7
10	24,400	25.097	1,662	179.50	3,002	28.5
11	24,000	24,810	1,548	177.85	2,916	27.2
12	23,500	24,424	1,436	175.98	2,831	25.8
13	22,500	23,538	1,328	173.88	2,747	24.3
14	19,000	19,970	1,231	171.67	2,668	22.9
15	10,000	10,648	1,163	169.91	2,611	21.9
16	4,800	5,146	1,128	168.92	2,581	21.4
17	2,300	2,472	1,112	168.44	2,567	21.1
18	600	657	1,105	168.23	2,561	21.0
19	0	8	1,104	168.20	2,560	21.0
20	0	0	1,104	168.20	2,560	21.0

EXIT AREA = 0.76 ft^2.

Table III

Aerodynamic Data

Jet Seeding Vehicle

Mach Number	C_D	$C_{d_{\alpha=90°}}$	C_{L_α}	X_{c_p} (inches)	$C_{L_{\alpha_1}}$	$X_{c_{p_1}}$ (inches)	$C_{L_{\alpha_2}}$	$X_{c_{p_2}}$ (inches)	C_{m_q}
0	0.313	1.20	22.40	291.9	0.86	48.0	21.54	301.6	1956
0.5	0.201	1.35	23.02	285.3	1.52	54.5	21.50	301.6	2069
0.8	0.252	1.82	24.05	283.8	1.81	58.3	22.24	302.1	2151
0.9	0.299	1.83	24.52	283.7	1.91	59.8	22.61	302.6	2228
1.0	0.462	1.80	24.98	284.0	1.98	61.2	23.00	303.2	2304
1.1	0.585	1.73	25.32	284.4	2.05	62.6	23.27	303.9	2357
1.2	0.546	1.66	24.56	283.9	2.12	64.0	22.44	304.7	2308
1.3	0.514	1.58	23.08	283.1	2.17	65.4	20.91	305.7	2214
1.5	0.462	1.47	20.65	279.4	2.28	68.0	18.37	305.6	2026
2.0	0.371	1.28	16.62	270.5	2.46	74.3	14.16	304.6	1596
2.5	0.311	1.19	13.70	261.6	2.59	79.8	11.11	304.0	1301
3.0	0.274	1.13	11.88	252.5	2.77	84.7	9.11	303.6	1105
3.5	0.247	1.10	10.63	242.2	3.03	88.8	7.60	303.3	978
4.0	0.226	1.07	9.85	233.0	3.27	92.2	6.58	303.0	879
4.5	0.209	1.05	9.20	226.1	3.40	95.2	5.80	302.8	796
5.0	0.196	1.03	8.69	220.4	3.48	97.4	5.21	302.6	744
5.5	0.188	1.02	8.27	216.1	3.51	99.1	4.76	302.4	689
6.0	0.181	1.01	7.93	212.9	3.50	100.0	4.43	302.2	654
6.5	0.175	1.01	7.62	209.8	3.49	100.6	4.13	302.0	628
7.0	0.171	1.01	7.33	206.2	3.49	100.9	3.84	301.9	608
Ref. Area-Ft^2	1.614	40.7	1.614	-	1.614	-	1.614	-	1.614

REFERENCE LENGTH: $\bar{C}$ = 17.2 ins = 1.433 ft.

Table IV

C_L Versus Mach Number and Angle of Attack

Jet Seeding Vehicle

Mach No.	ANGLE OF ATTACK								
	0°	5°	10°	15°	20°	25°	30°	35°	40°
0	0	2.184	4.807	7.822	11.145	14.673	18.281	21.839	25.216
.5	0	2.238	4.916	7.985	11.361	14.943	18.616	22.798	25.768
.8	0	2.328	5.095	8.254	11.732	15.398	19.400	23.491	27.693
.9	0	2.369	5.177	8.380	11.910	15.749	19.877	24.261	28.787
1.0	0	2.409	5.258	8.503	12.096	16.056	20.439	25.167	30.505
1.1	0	2.439	5.317	8.599	12.253	16.387	20.966	26.449	31.764
1.2	0	2.372	5.184	8.404	12.038	16.296	21.142	26.773	31.576
1.3	0	2.243	4.927	8.030	11.610	15.797	21.012	26.318	30.703
1.5	0	2.031	4.505	7.425	11.006	15.574	20.661	25.050	28.918
2.0	0	1.679	3.816	6.591	10.585	14.710	18.508	21.719	24.357
2.5	0	1.425	3.343	6.252	9.846	13.142	16.034	18.624	20.874
3.0	0	1.267	3.101	6.068	9.070	11.743	14.229	16.567	18.614
3.5	0	1.159	2.988	5.765	8.313	10.686	12.982	15.154	17.217
4.0	0	1.093	3.023	5.487	7.712	9.919	12.118	14.308	16.303
4.5	0	1.040	2.965	5.165	7.222	9.325	11.516	13.632	15.562
5.0	0	1.001	2.885	4.879	6.833	8.903	11.036	13.103	14.982
5.5	0	.973	2.804	4.627	6.496	8.572	10.663	12.670	14.448
6.0	0	.955	2.708	4.434	6.269	8.293	10.343	12.312	14.100
6.5	0	.939	2.615	4.252	6.075	8.064	10.067	12.001	13.764
7.0	0	.929	2.515	4.101	5.896	7.843	9.816	11.715	13.466

Table V

C_D Versus Mach Number and Angle of Attack

Jet Seeding Vehicle

Mach Number	ANGLE OF ATTACK 0°	5°	10°	15°	20°	25°	30°	35°	40°
0	.313	.321	.366	.481	.694	1.038	1.545	2.244	3.168
.5	.201	.209	.254	.369	.582	.926	1.435	2.141	3.089
.8	.252	.260	.305	.420	.634	.986	1.528	2.324	3.474
.9	.299	.307	.352	.467	.678	1.044	1.614	2.476	3.734
1.0	.462	.470	.515	.630	.848	1.222	1.832	2.776	4.284
1.1	.585	.593	.638	.754	.975	1.369	2.015	3.133	4.690
1.2	.546	.554	.599	.715	.941	1.362	2.074	3.266	4.747
1.3	.514	.522	.567	.684	.918	1.349	2.152	3.332	4.759
1.5	.462	.470	.516	.634	.890	1.408	2.258	3.327	4.682
2.0	.371	.379	.425	.559	.897	1.435	2.160	3.047	4.107
2.5	.311	.319	.367	.530	.865	1.336	1.938	2.700	3.646
3.0	.274	.282	.333	.514	.814	1.219	1.755	2.457	3.334
3.5	.247	.255	.311	.488	.755	1.124	1.626	2.288	3.161
4.0	.226	.234	.298	.462	.702	1.047	1.528	2.187	3.038
4.5	.209	.217	.284	.434	.658	.989	1.466	2.109	2.942
5.0	.196	.204	.271	.410	.624	.950	1.417	2.048	2.867
5.5	.188	.197	.263	.393	.597	.922	1.382	2.002	2.806
6.0	.181	.190	.254	.378	.579	.898	1.351	1.962	2.754
6.5	.175	.184	.246	.364	.565	.879	1.326	1.929	2.715
7.0	.171	.180	.240	.355	.553	.863	1.305	1.902	2.685

Table VI

Details on Nitric Oxide Load

Nominal Pressure	3500 psi
Nominal Temperature	$500^{o}R = 40^{o}F = 4.5^{o}C$
Volume	$2800\ in^3 = 1.620\ ft^3$
Critical Pressure	940.8 psi
Critical Temperature	$324.6^{o}R$
Gas Constant	51.5 ft-lbs/lb^{o}R
Reduced Pressure	3.72
Reduced Temperature	1.540
Compressibility Factor	0.838
Density	$23.36\ lb/ft^3$
Mass	37.84 lb = 17.17 kg
Initial Mass Flux	1.61×10^4 lb/sec ft^2
Nozzle Diameter	0.226 in
Initial Flow Rate	4.48 lb/sec = 2.035 kg/sec

Table VII

Nitric Oxide Dump

Time sec	Altitude km	Mass Flow Rate kg/sec	Seeding Rate kg/km	Seeded Mass kg	Pressure psi
84	94.48	2.035	2.340	0	3,500
86	96.22	1.322	1.550	3.08	2,280
88	97.90	.991	1.190	5.30	1,750
90	99.55	.826	1.017	7.14	1,360
92	101.15	.685	.864	8.61	1,065
94	102.72	.571	.739	9.82	825
96	104.24	.476	.632	10.92	640
98	105.73	.395	.539	11.83	495
100	107.18	.330	.462	12.61	380
102	108.59	.275	.396	13.25	300
104	109.96	.228	.338	13.82	230
94.8	103.33	.533	.698	10.26	750

Table VIII

SEPARATING NOSE CONE DATA

Weight (with gas)	395.00 lb.
Station of Center of Gravity	54.62 inches
Roll inertia	2.05 slug/ft^2
Pitch inertia	59.9 slug/ft^2
Overall length	102.04 inches
Cone semi apex angle	5.73 degrees
Diameter	17.2 inches
Cross sectional area	1.614 ft^2
Planform area	7.05 ft^2
Gas pressure (nominal)	3500 psi
Gas Temperature (nominal)	500°R (40°F)
Tank Volume	2800 in^3
Weight of gas	37.75 lb.
Nozzle diameter	0.226 in.
Start dump at	84 sec.
Altitude at start	310,000 ft.
Initial dumping rate	4.48 lb/sec.
Peak altitude	437,000 ft.
Time to peak	172.7 sec.
Impact range	387,000 ft.
Time to impact	350 sec.

Table IX

Aerodynamic Data

Jet Seeding Vehicle

Separated Nose Cone

Mach Number	C_D (Wave drag) only	$C_{d_{\alpha=90^\circ}}$	C_{L_α}	X_{c_p} (inches)	C_{m_q}
3.0	.1129	See Curve for Complete Vehicle	2.293	63.47	1.188
3.5	.0924		2.284	63.26	1.128
4.0	.0751		2.269	63.15	1.094
4.5	.0646		2.245	63.18	1.087
5.0	.0572		2.224	63.28	1.103
5.5	.0518		2.207	63.29	1.099
6.0	.0471		2.194	63.19	1.066
Ref. Area-Ft^2	1.614	7.05	1.614	-	1.614

Table X

Trajectory Data

Jet Seeding Vehicle

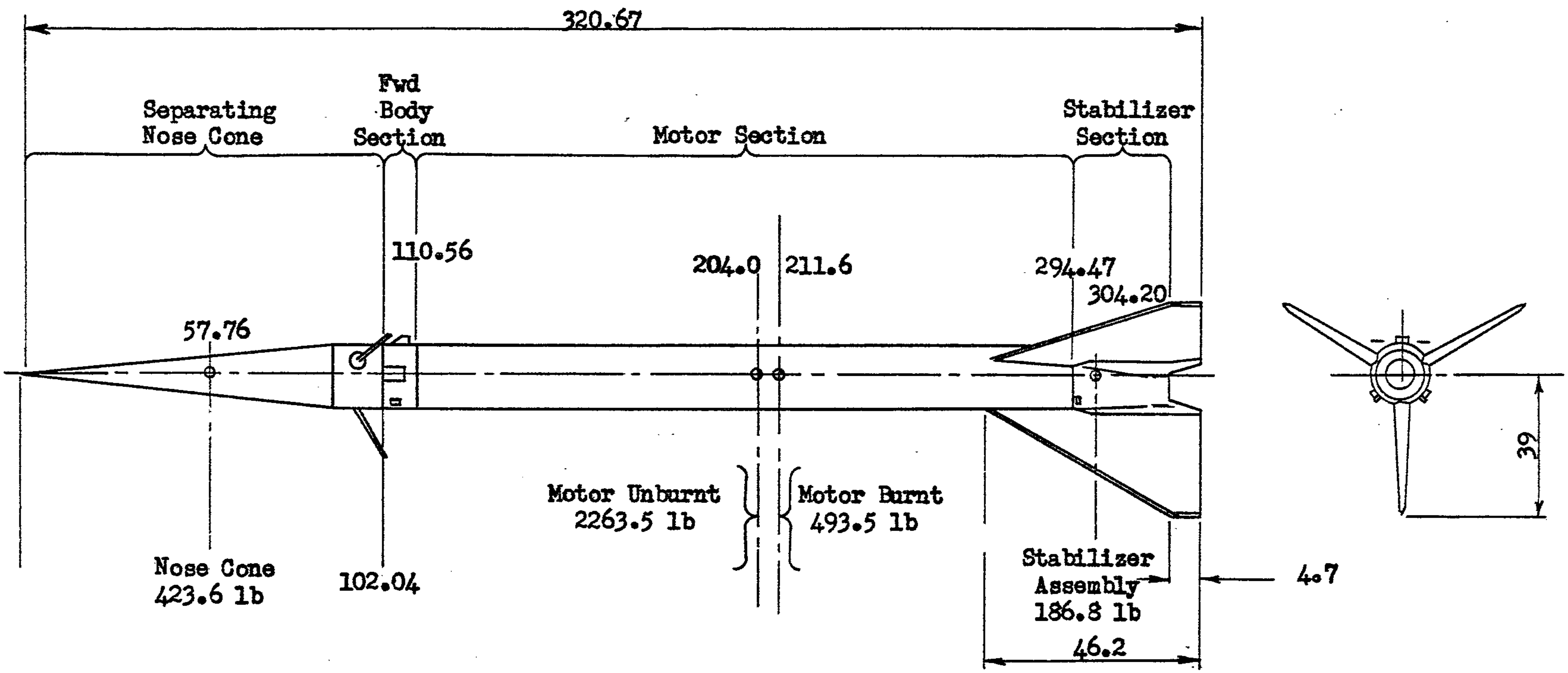
Time sec	Altitude ft	Range ft	Velocity ft/sec	Dynamic Pressure lb/ft^2	Mach Number	Reynolds Number per foot length 1/ft	Undamped Pitching Frequency cps
0	0	0	0	0	0	0	0
1	139	37	288	74	.26	1.83×10^6	.39
2	554	147	573	300	.52	3.7×10^6	.89
3	1,252	332	870	950	.78	5.4×10^6	1.44
4	2,241	594	1,177	1,620	1.06	7.2×10^6	1.97
5	3,526	934	1,484	2,380	1.34	8.7×10^6	2.27
6	5,085	1,355	1,803	3,330	1.63	1.02×10^7	2.48
7	7,045	1,867	2,135	4,350	1.94	1.15×10^7	2.62
8	9,275	2,458	2,481	5,460	2.28	1.26×10^7	2.69
9	11,846	3,139	2,843	6,650	2.66	1.35×10^7	2.72
10	14,776	3,916	3,223	7,770	3.05	1.43×10^7	2.73
11	18,084	4,792	3,624	8,800	3.48	1.46×10^7	2.68
12	21,786	5,774	4,042	9,730	3.93	1.47×10^7	2.62
13	25,906	6,865	4,488	10,400	4.42	1.46×10^7	2.53
14	30,450	8,070	4,920	10,520	4.93	1.40×10^7	2.42
15	35,350	9,368	5,224	9,750	5.32	1.25×10^7	2.27
16	40,450	10,720	5,337	8,060	5.50	1.03×10^7	2.05
17	45,613	12,088	5,351	6,340	5.49	8.0×10^6	1.83
18	50,764	13,453	5,314	4,910	5.47	6.3×10^6	1.62
19	55,865	14,805	5,246	3,780	5.42	4.9×10^6	1.43
20	60,901	16,140	5,182	2,940	5.36	3.9×10^6	1.27

Table XI

Trajectory Data

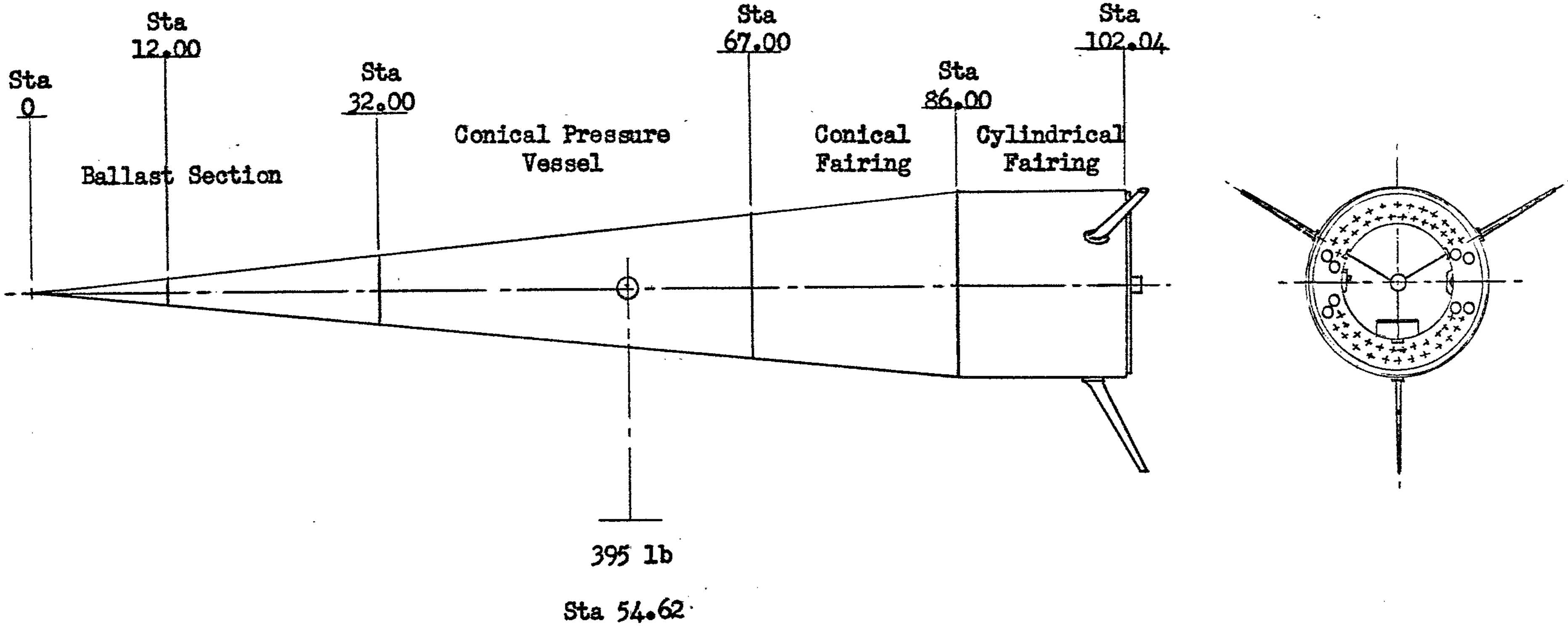
Jet Seeding Vehicle

Time	Altitude ft.	Altitude km	Range ft.	Range km.	Vertical Velocity ft/sec	Vertical Velocity km/sec
20	60,901	18.57	16,140	4.92	5,006	1.526
30	108,731	33.15	28,815	8.79	4,595	1.401
40	153,065	46.67	40,564	12.37	4,274	1.303
50	194,195	59.21	51,894	15.82	3,952	1.205
60	232,105	70.76	63,224	19.28	3,630	1.107
70	266,795	81.34	74,554	22.73	3,308	1.009
80	298,265	90.93	85,884	26.18	2,986	.910
84	309,951	94.48	90,416	27.57	2,857	.871
86	315,601	96.22	92,682	28.26	2,793	.852
88	321,123	97.90	94,948	28.95	2,728	.832
90	326,515	99.55	97,214	29.64	2,664	.812
92	331,779	101.15	99,480	30.33	2,600	.793
94	336,913	102.72	101,746	31.02	2,535	.773
96	341,919	104.24	104,012	31.71	2,471	.753
98	346,797	105.73	106,278	32.40	2,406	.734
100	351,454	107.18	108,544	33.09	2,342	.714
102	356,165	108.59	110,810	33.78	2,278	.695
104	360,655	109.96	113,076	34.47	2,213	.675
106	365,017	111.29	115,342	35.17	2,149	.655
108	369,251	112.58	117,608	35.86	2,084	.635
110	373,355	113.83	119,874	36.55	2,020	.616
120	391,945	119.50	131,204	40.00	1,698	.518
130	407,315	124.18	142,534	43.46	1,376	.420
140	419,465	127.89	153,864	46.91	1,054	.321



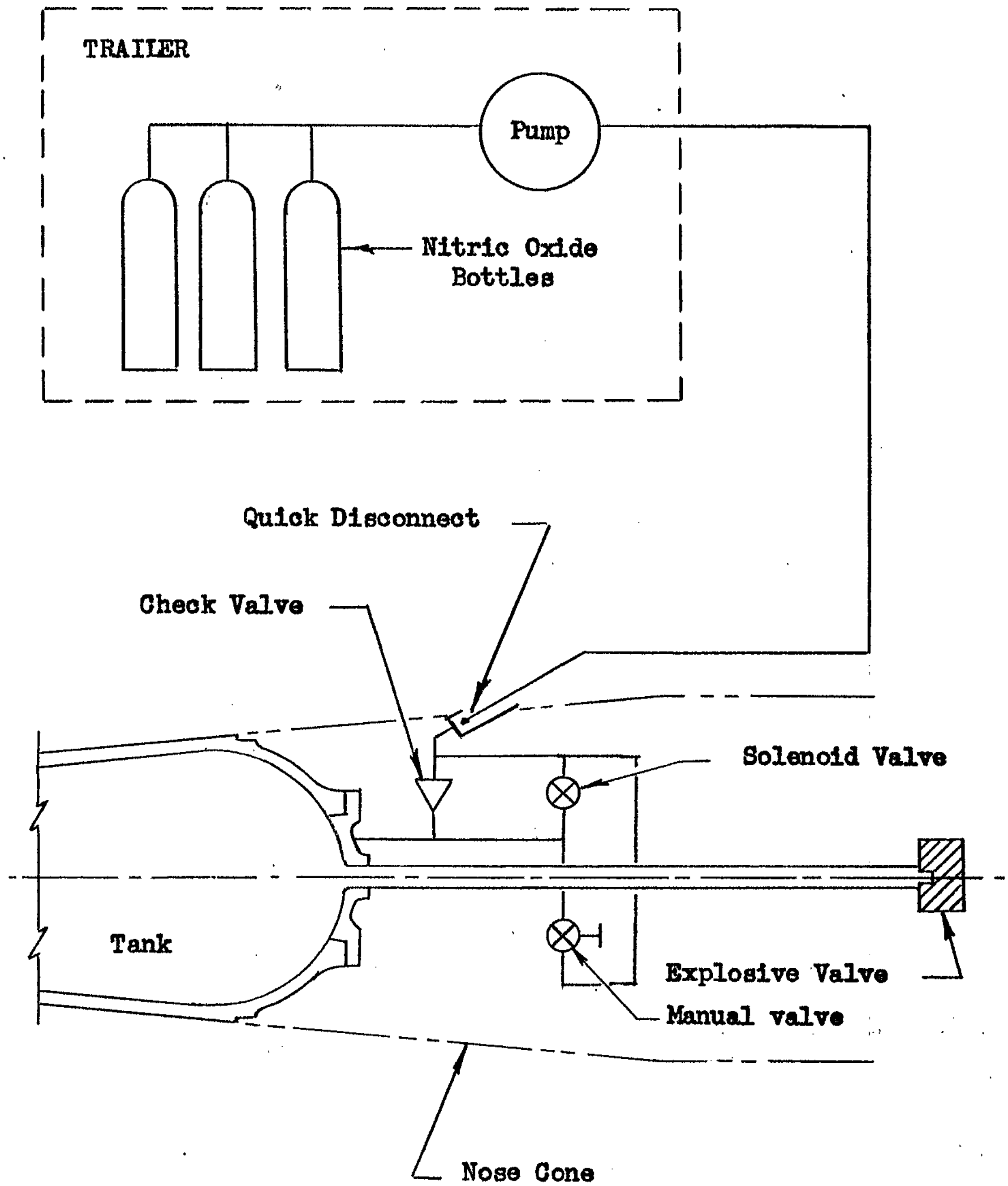
Jet Seeding Vehicle Configuration

Figure 1



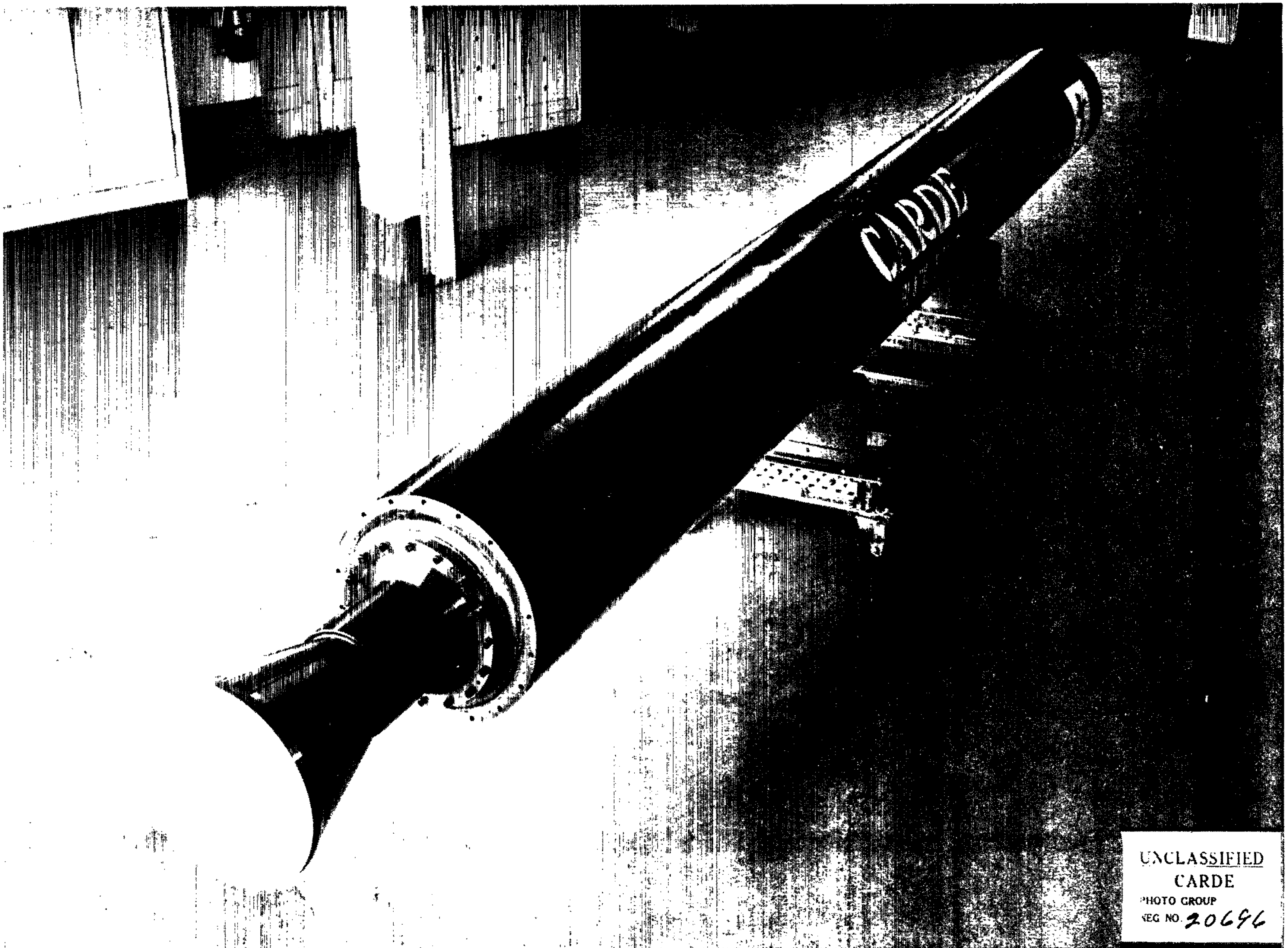
Jet Seeding Nose Cone

Figure 2



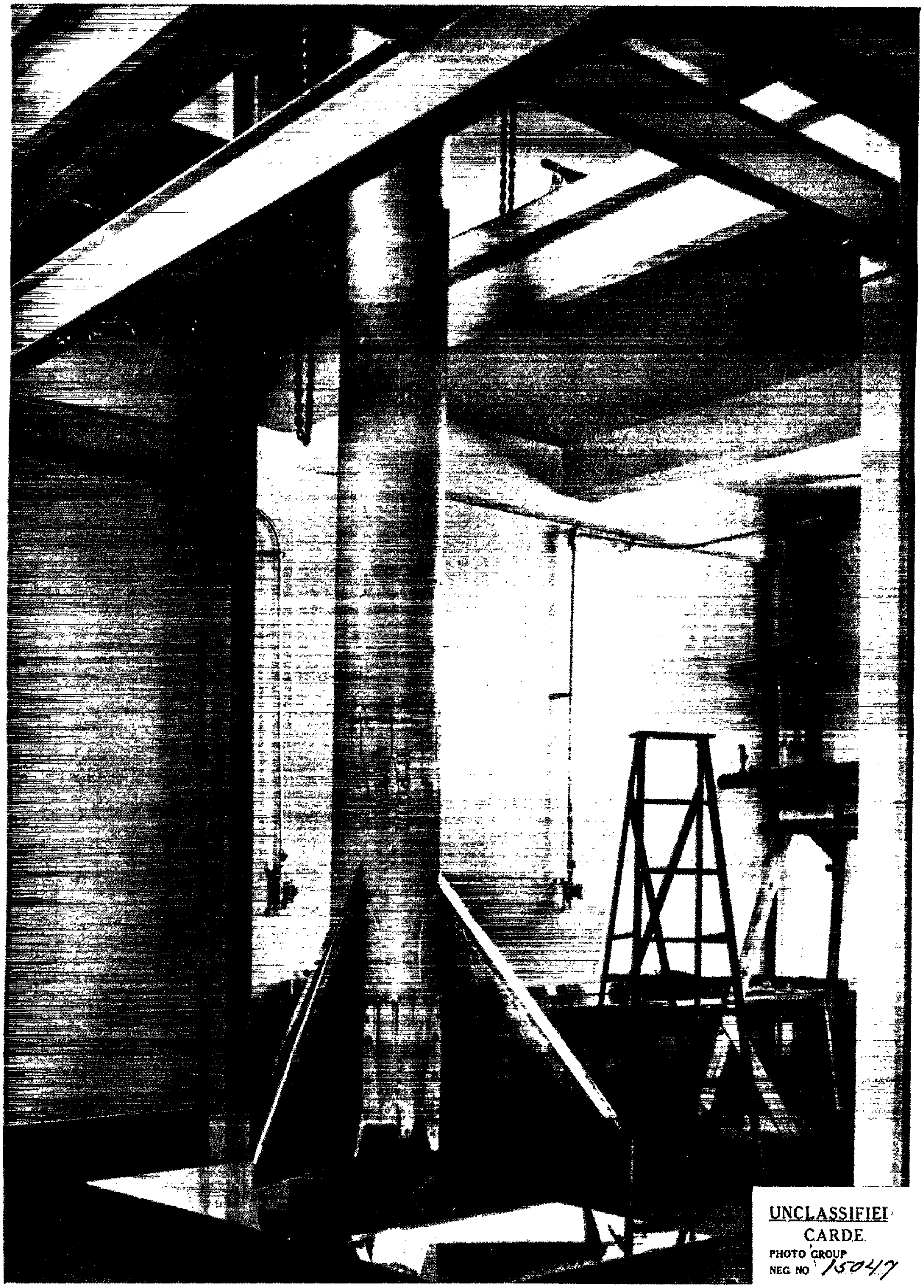
Charging System

Figure 3



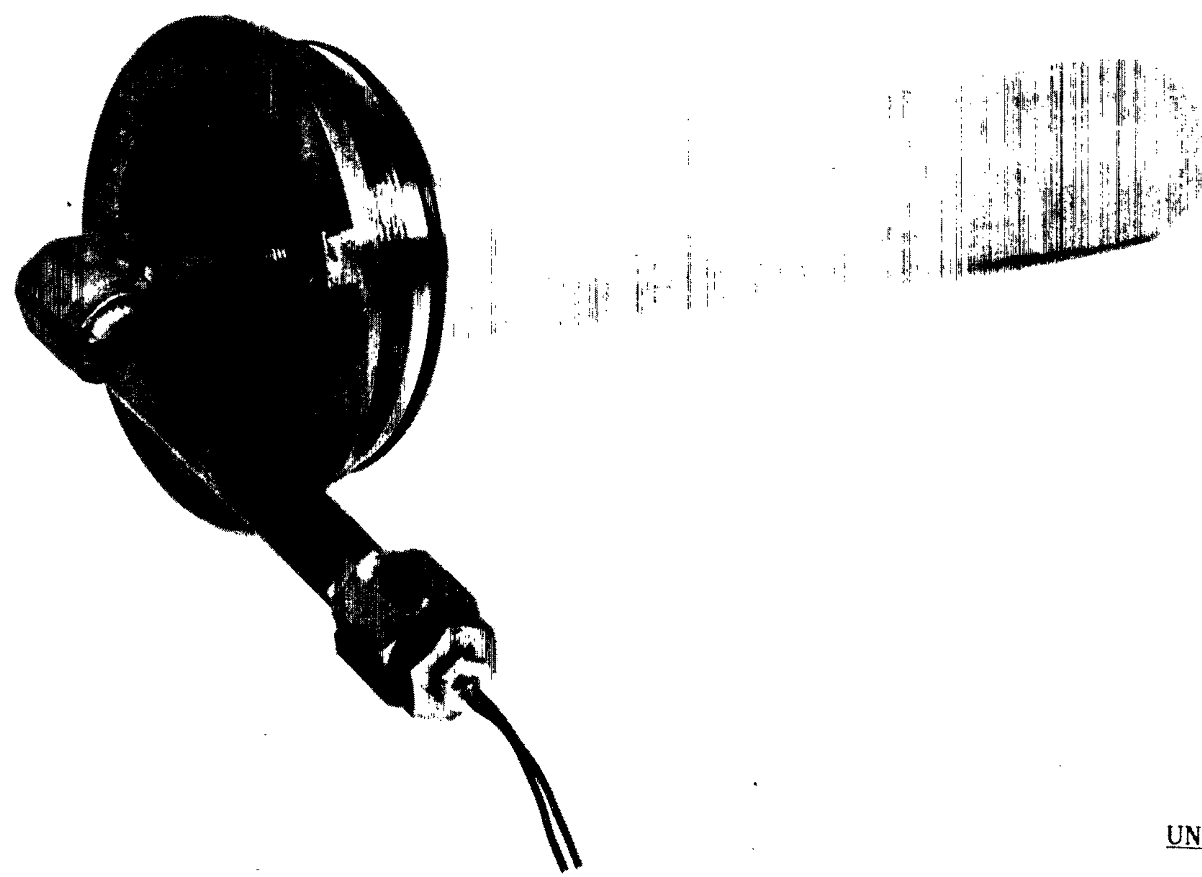
Black Brant I Rocket Motor

Figure 4



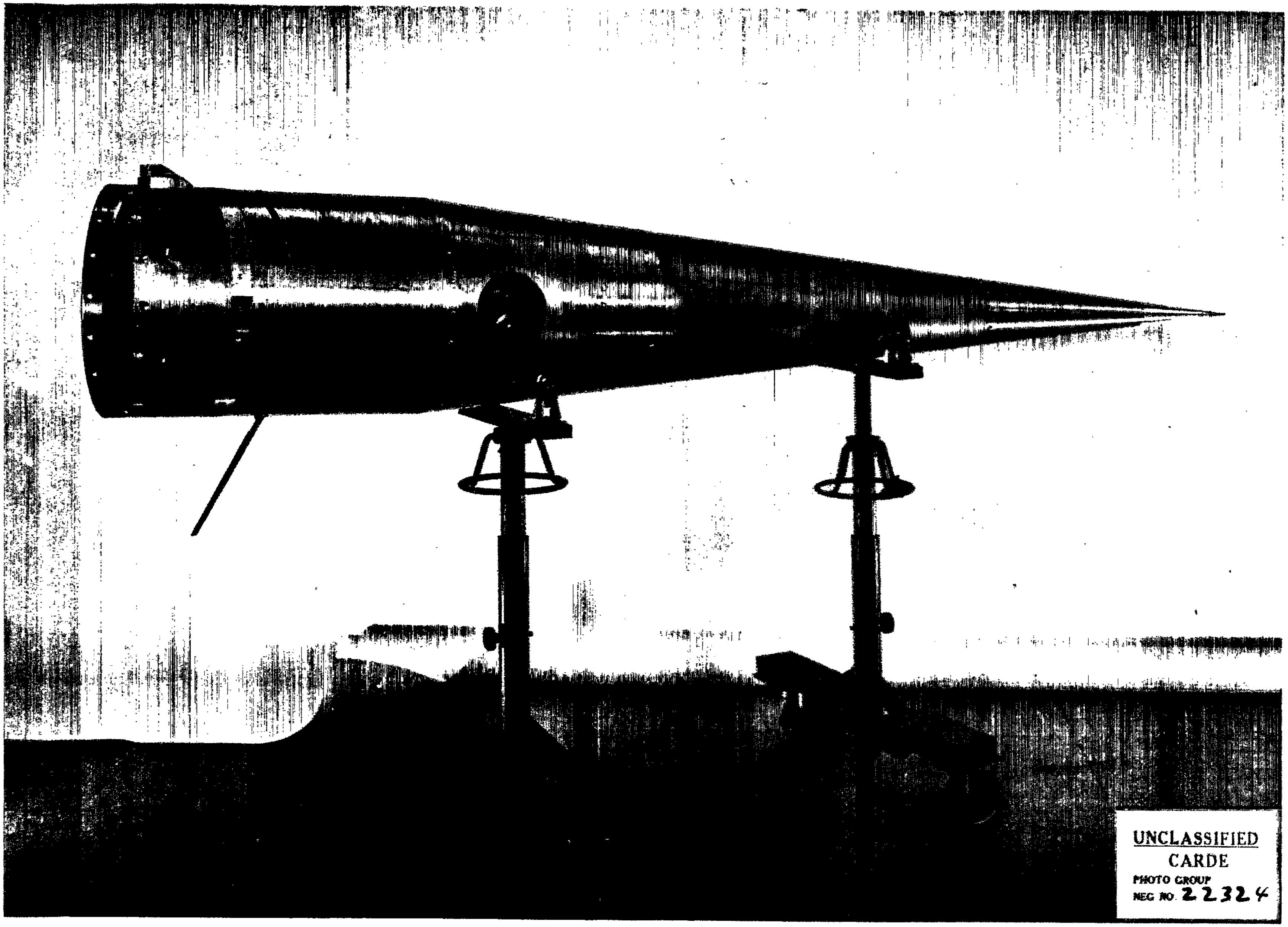
Black Brant I Fin Assembly Mounted on the Engine Casing

Figure 5



Black Brant I Igniter

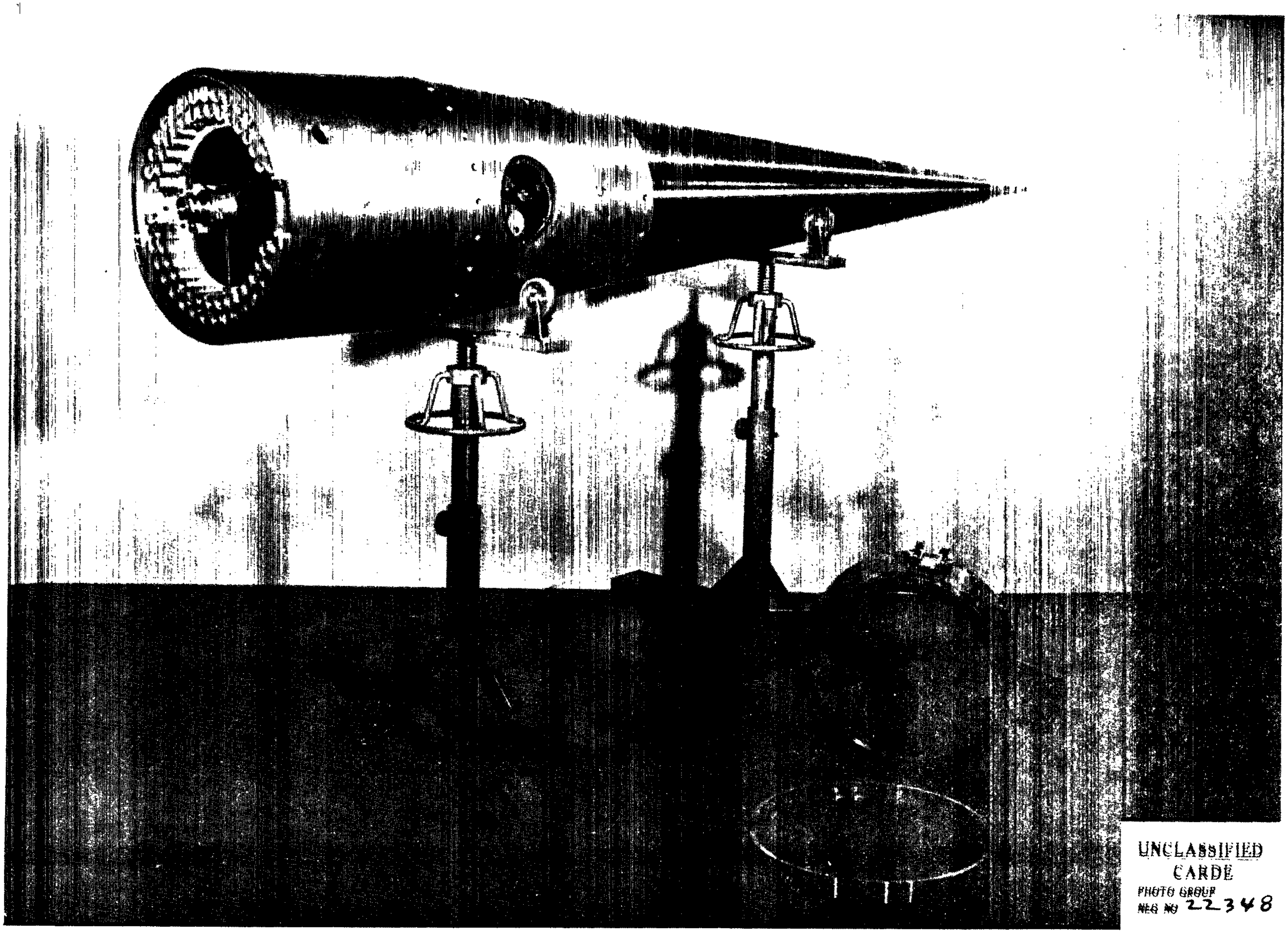
Figure 6



Complete Nose Cone

Jet Seeding Vehicle

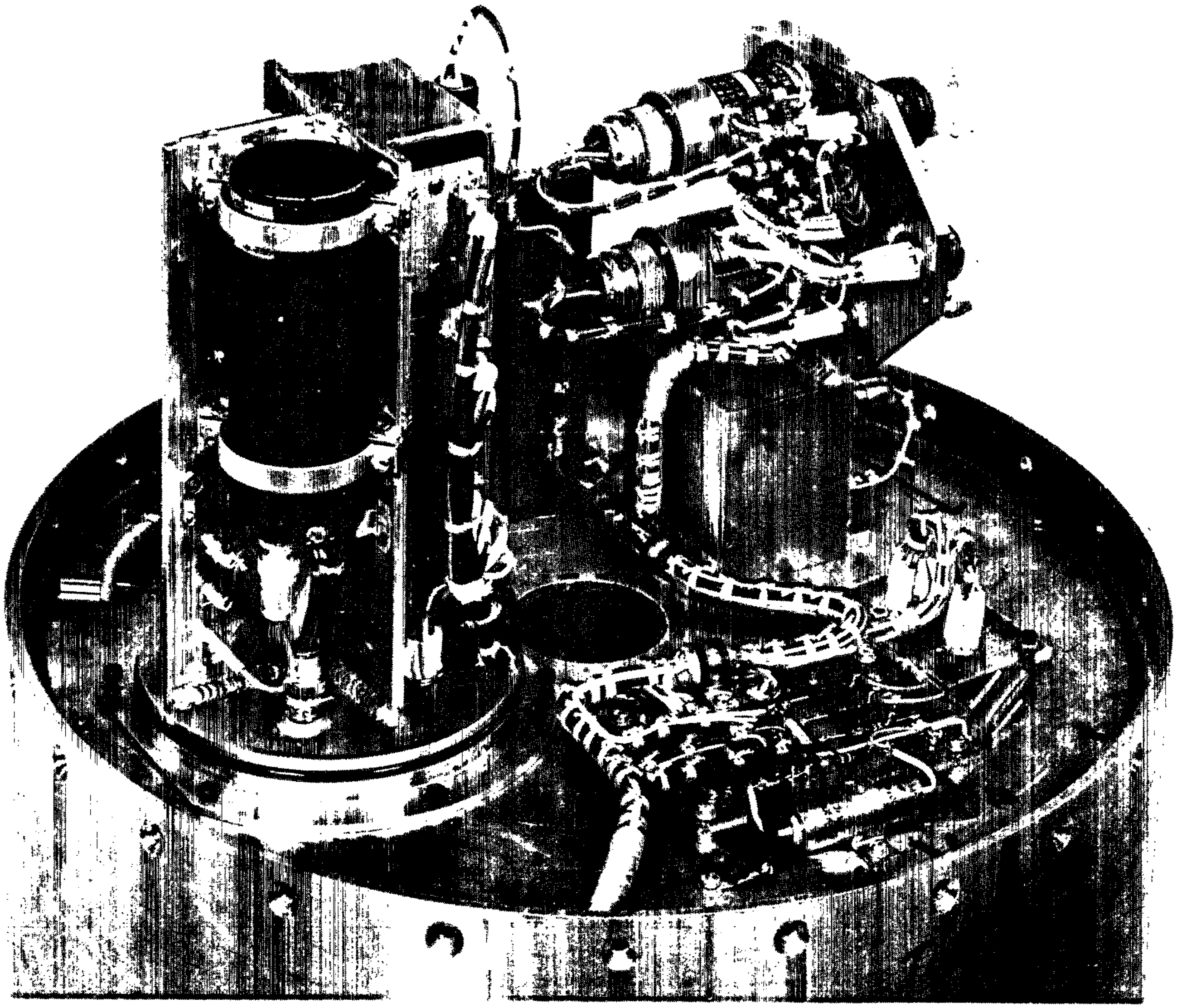
Figure 7



Separating Nose Cone

Jet Seeding Vehicle

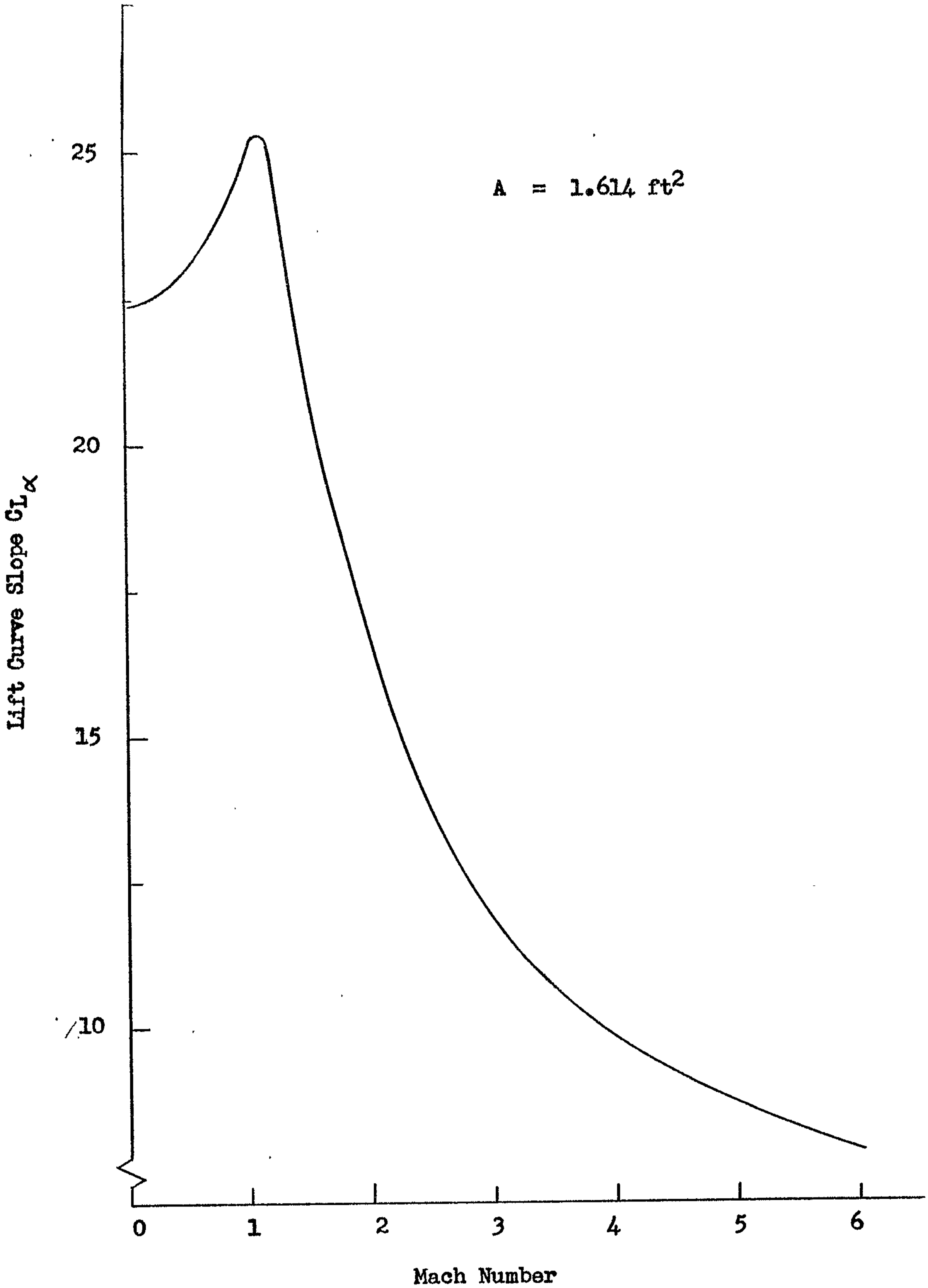
Figure 8



Telemetry and Timers

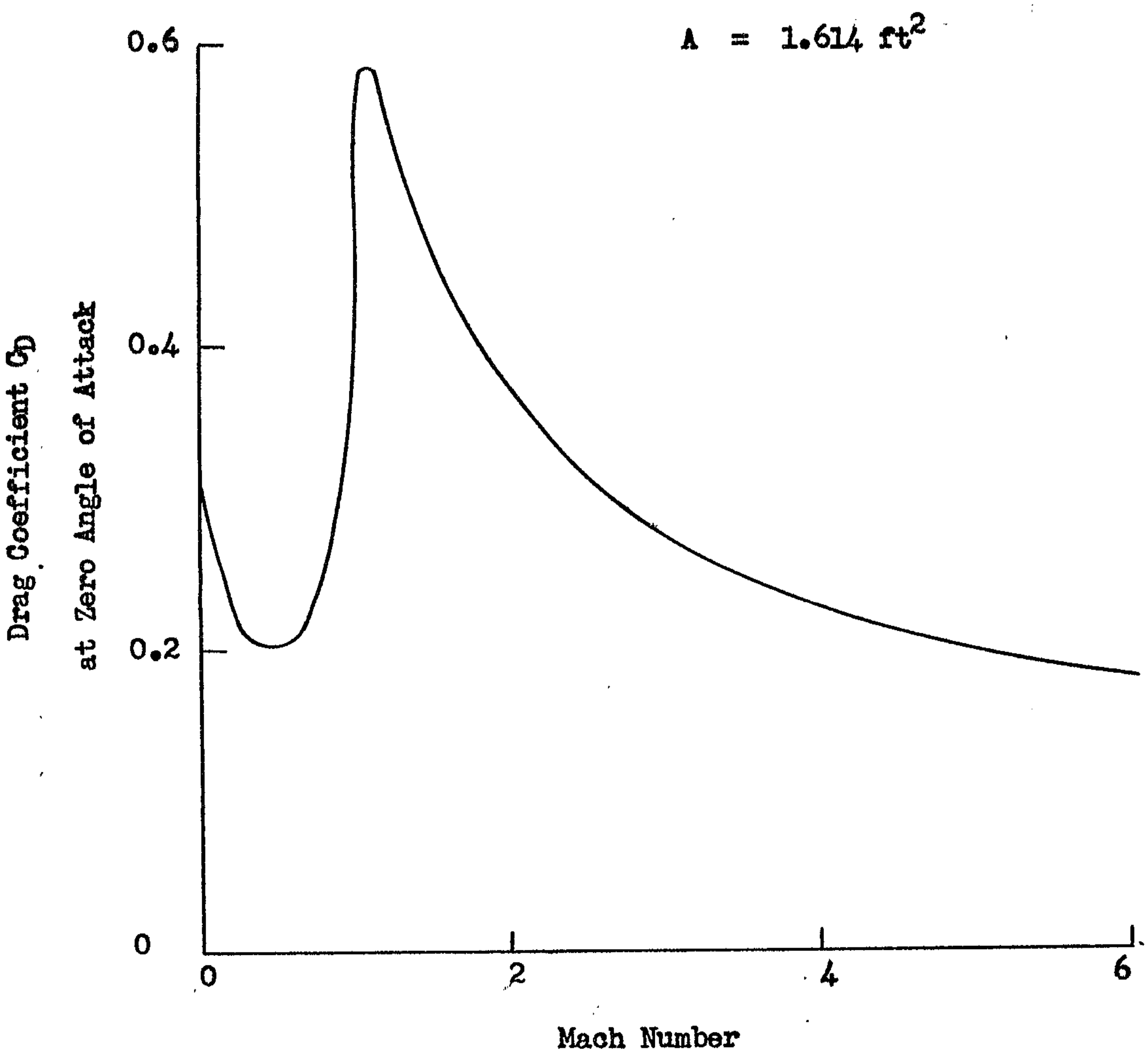
Jet Seeding Vehicle

Figure 9



Lift Curve Slope Versus Mach Number

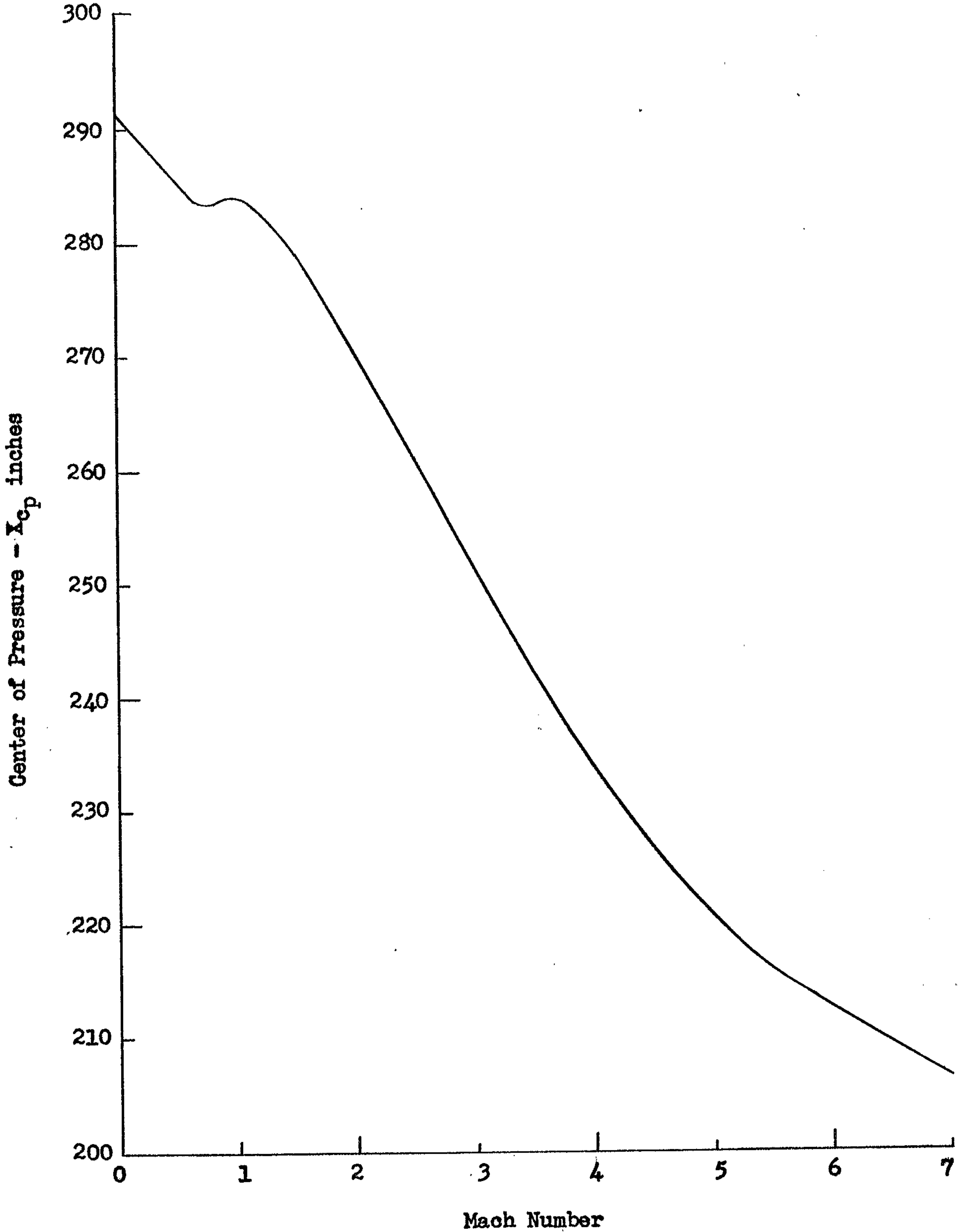
Figure 10



Drag Coefficient Versus Mach Number

Jet Seeding Vehicle

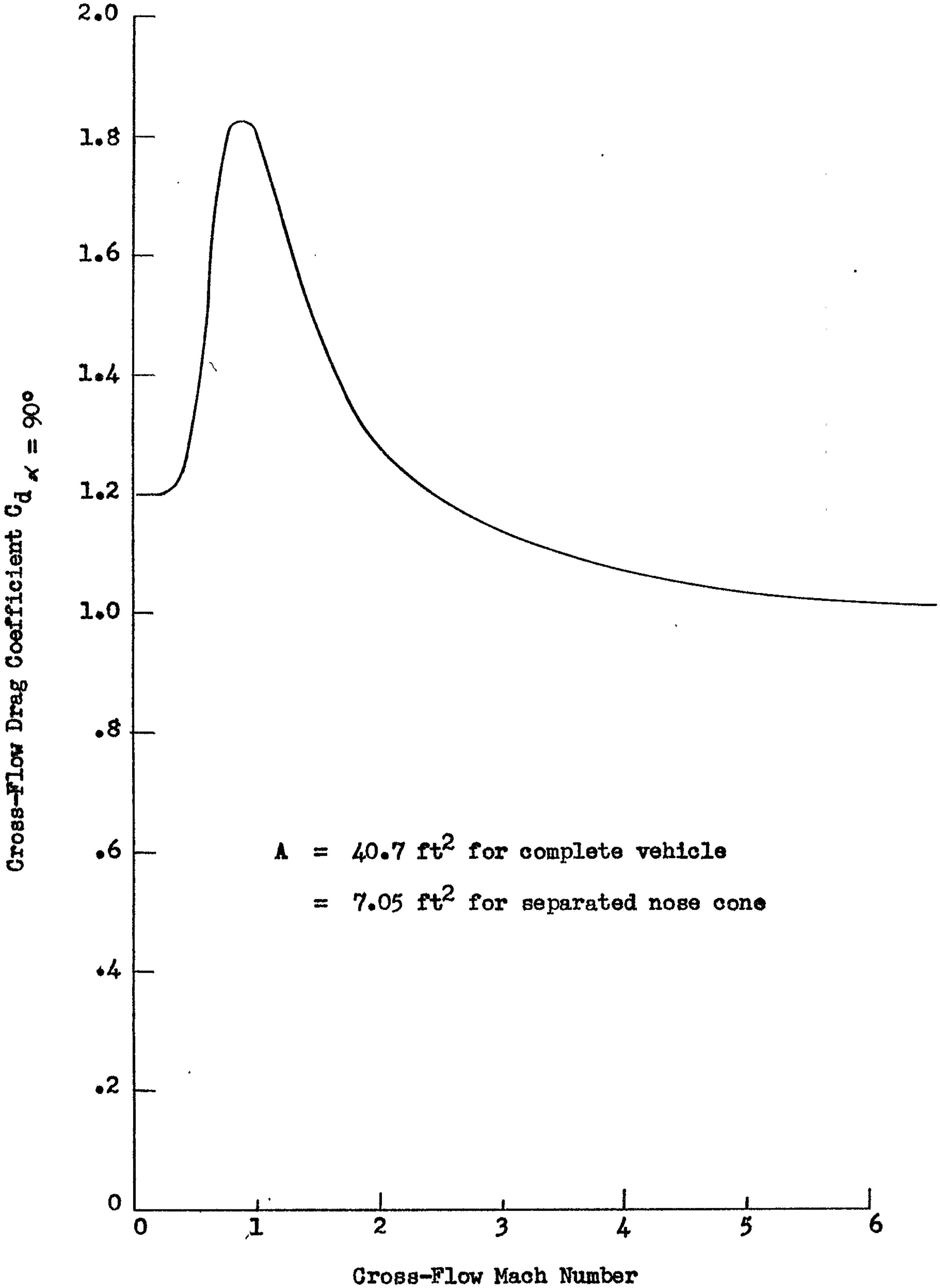
Figure 11



Center of Pressure Versus Mach Number

Jet Seeding Vehicle

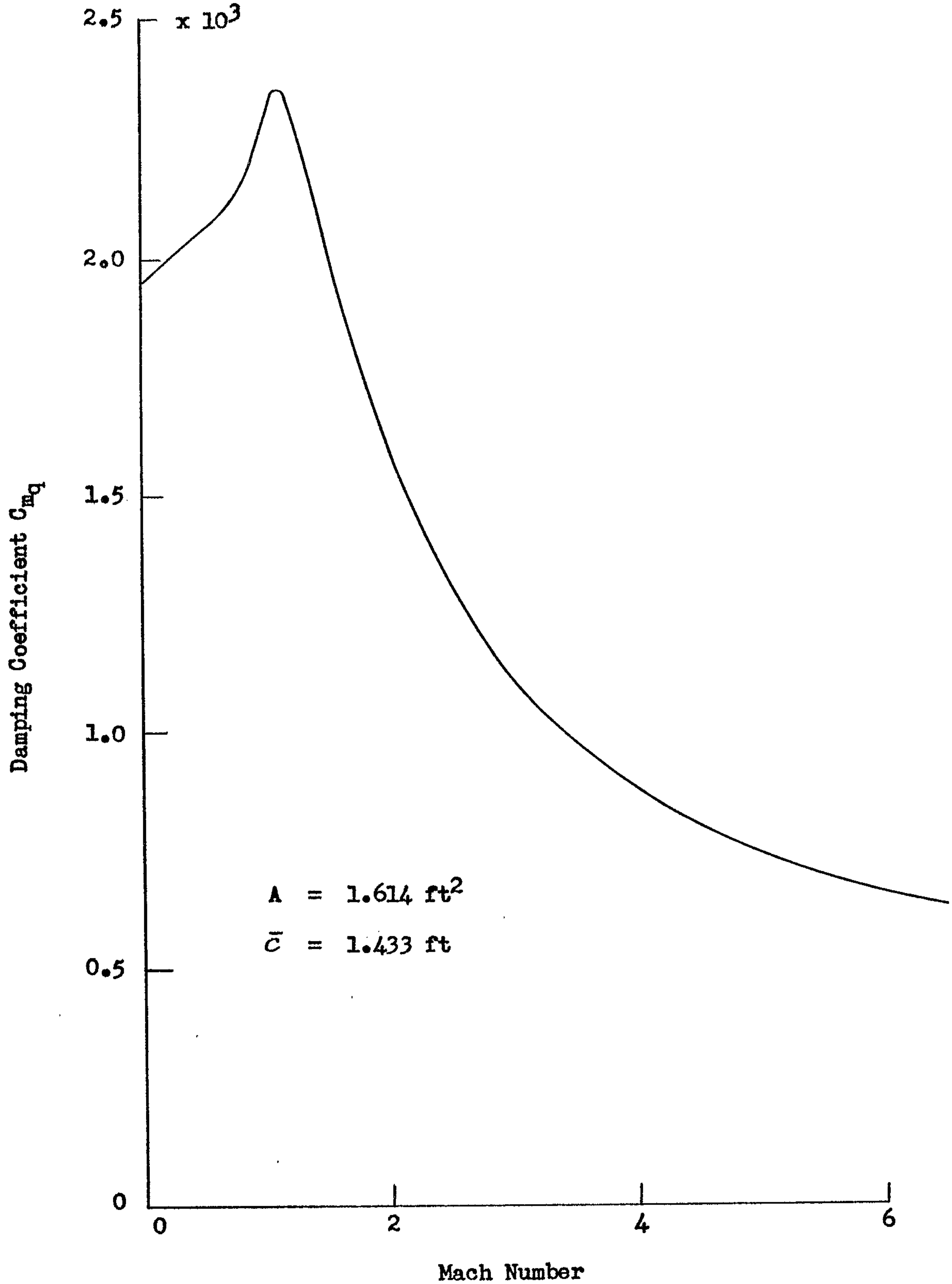
Figure 12



Cross-Flow Drag Coefficient Versus Mach Number

Jet Seeding Vehicle

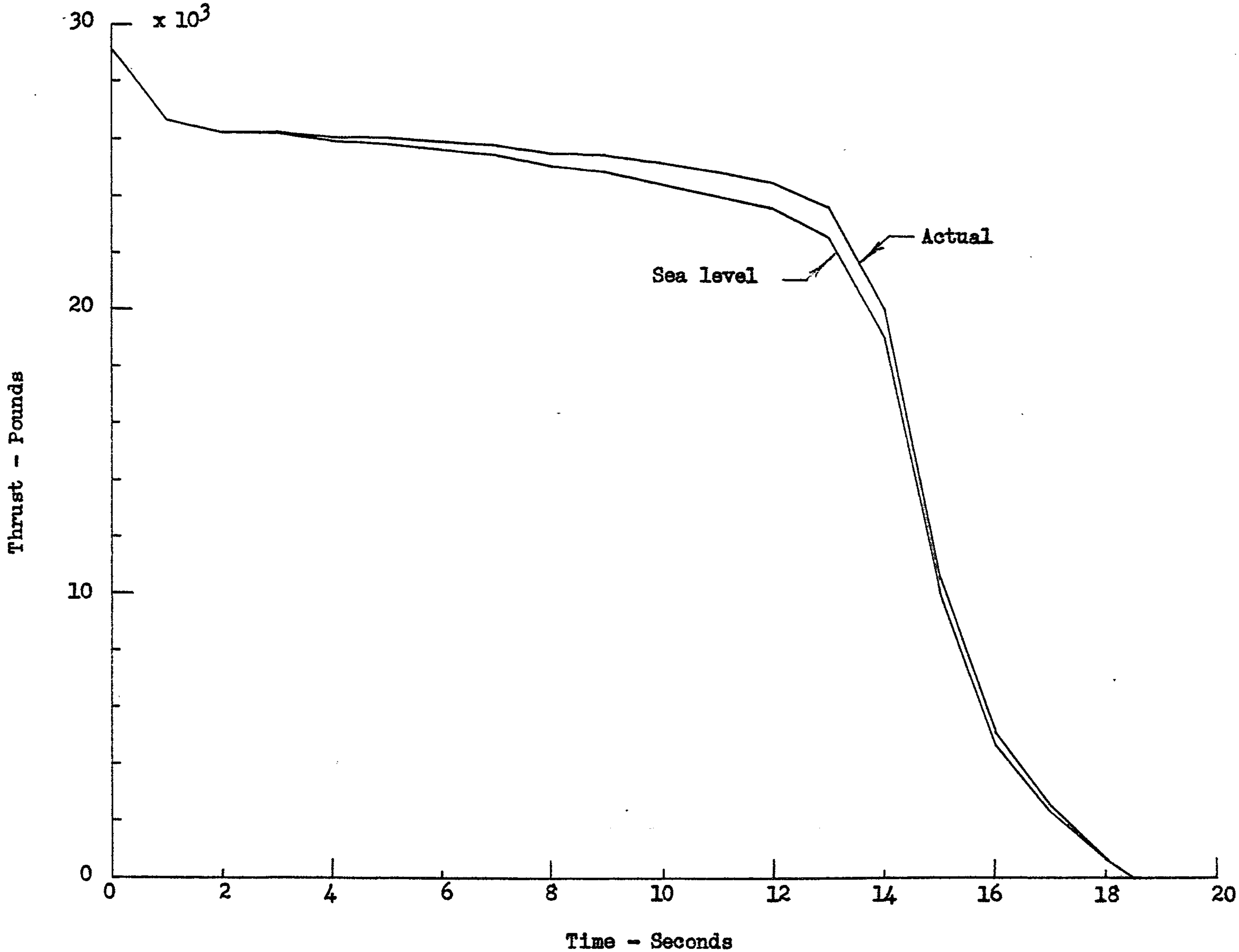
Figure 15



Damping Coefficient Versus Mach Number

Jet Seeding Vehicle

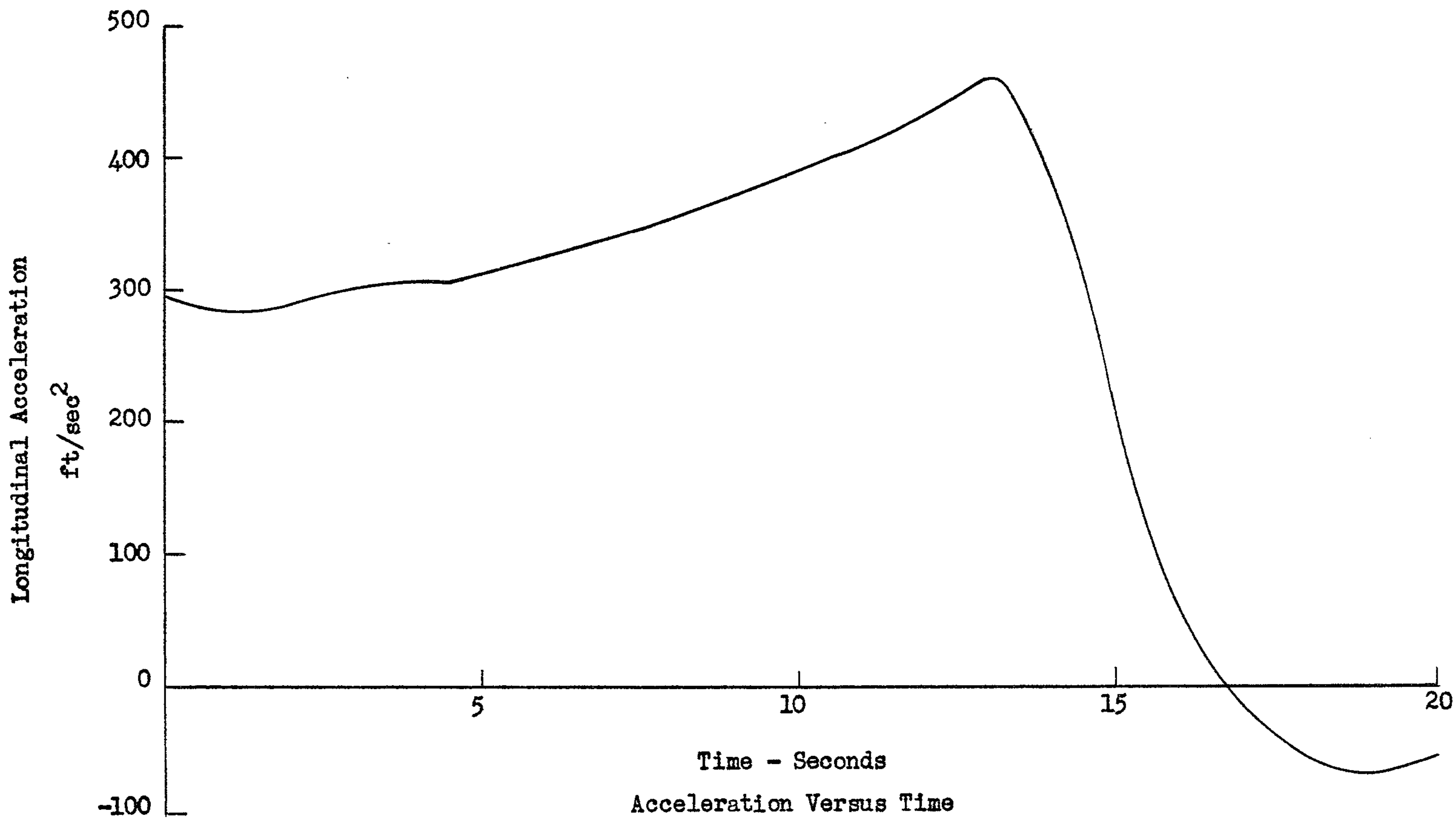
Figure 16



Thrust Versus Time

Jet Seeding Vehicle

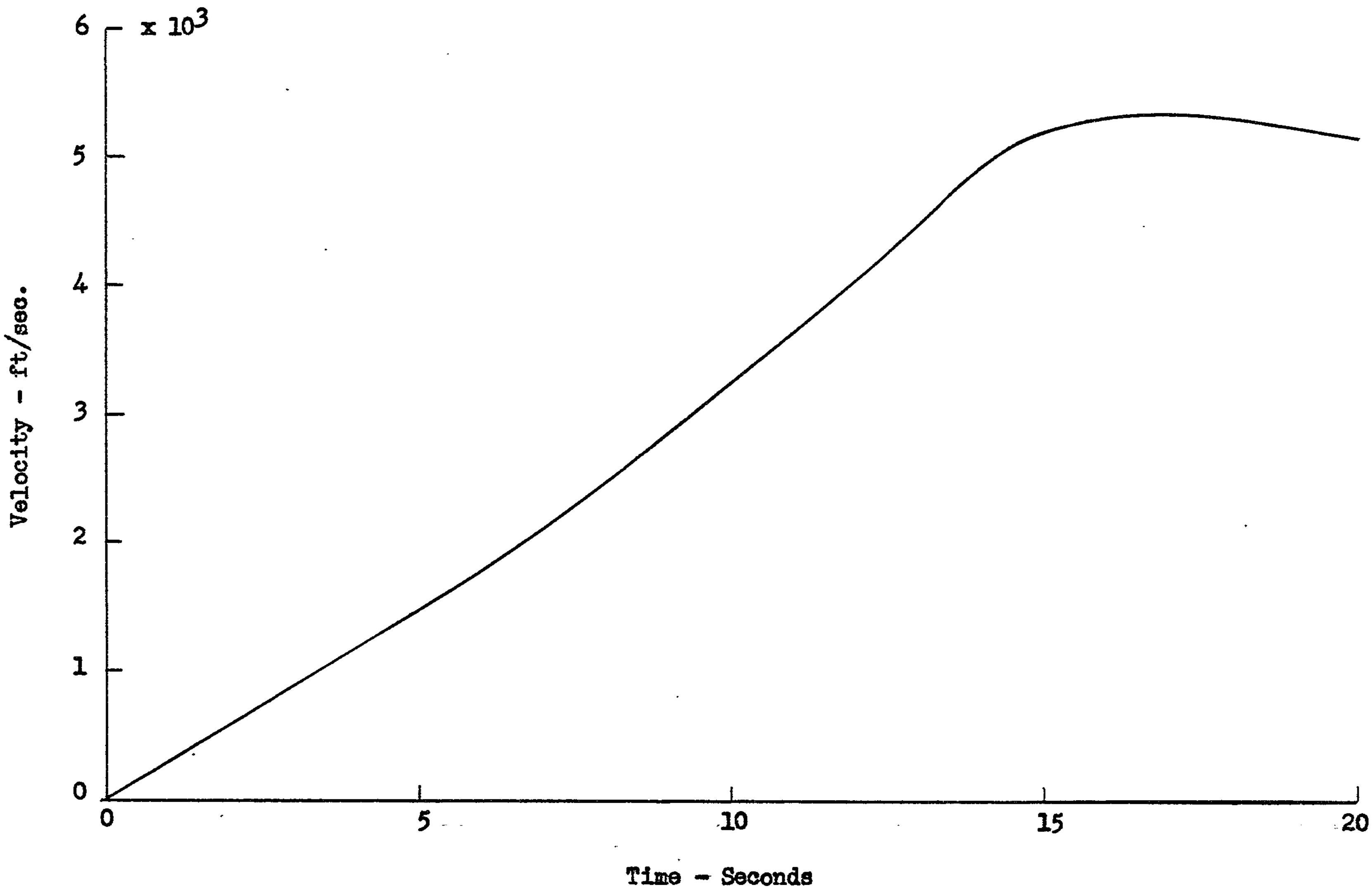
Figure 17



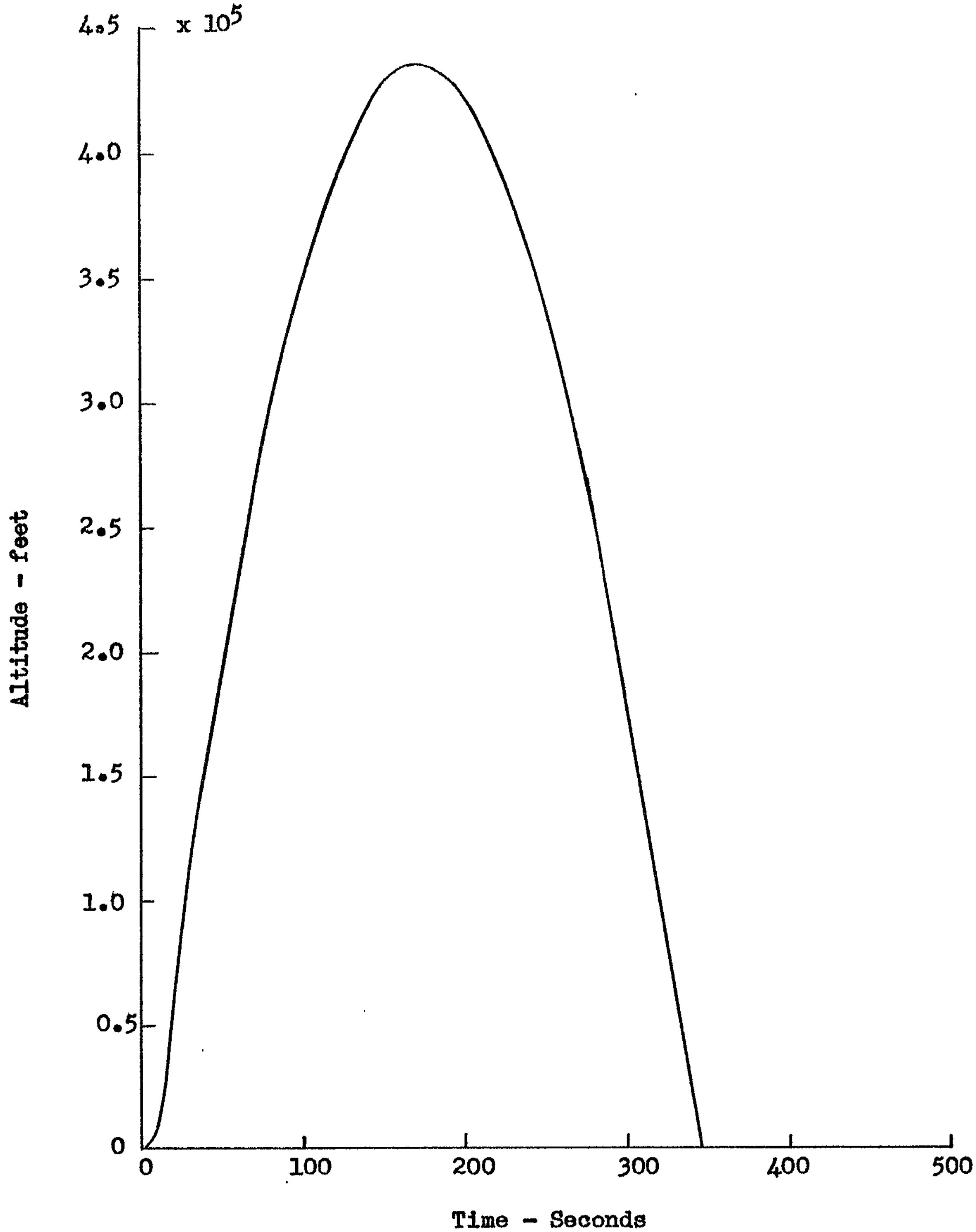
Acceleration Versus Time

Jet Seeding Vehicle

Figure 18



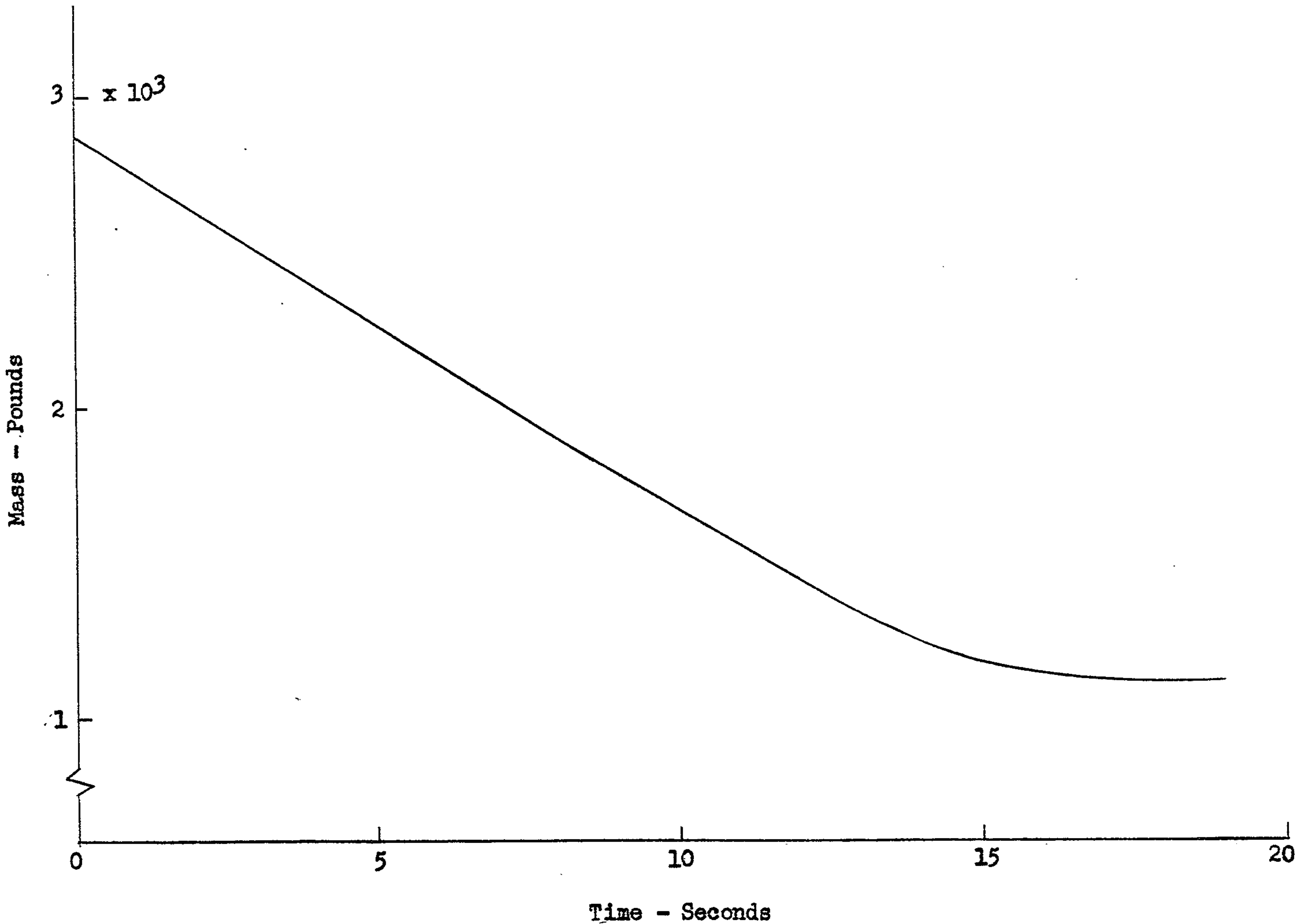
Velocity Versus Time
Jet Seeding Vehicle
Figure 19



Altitude Versus Time

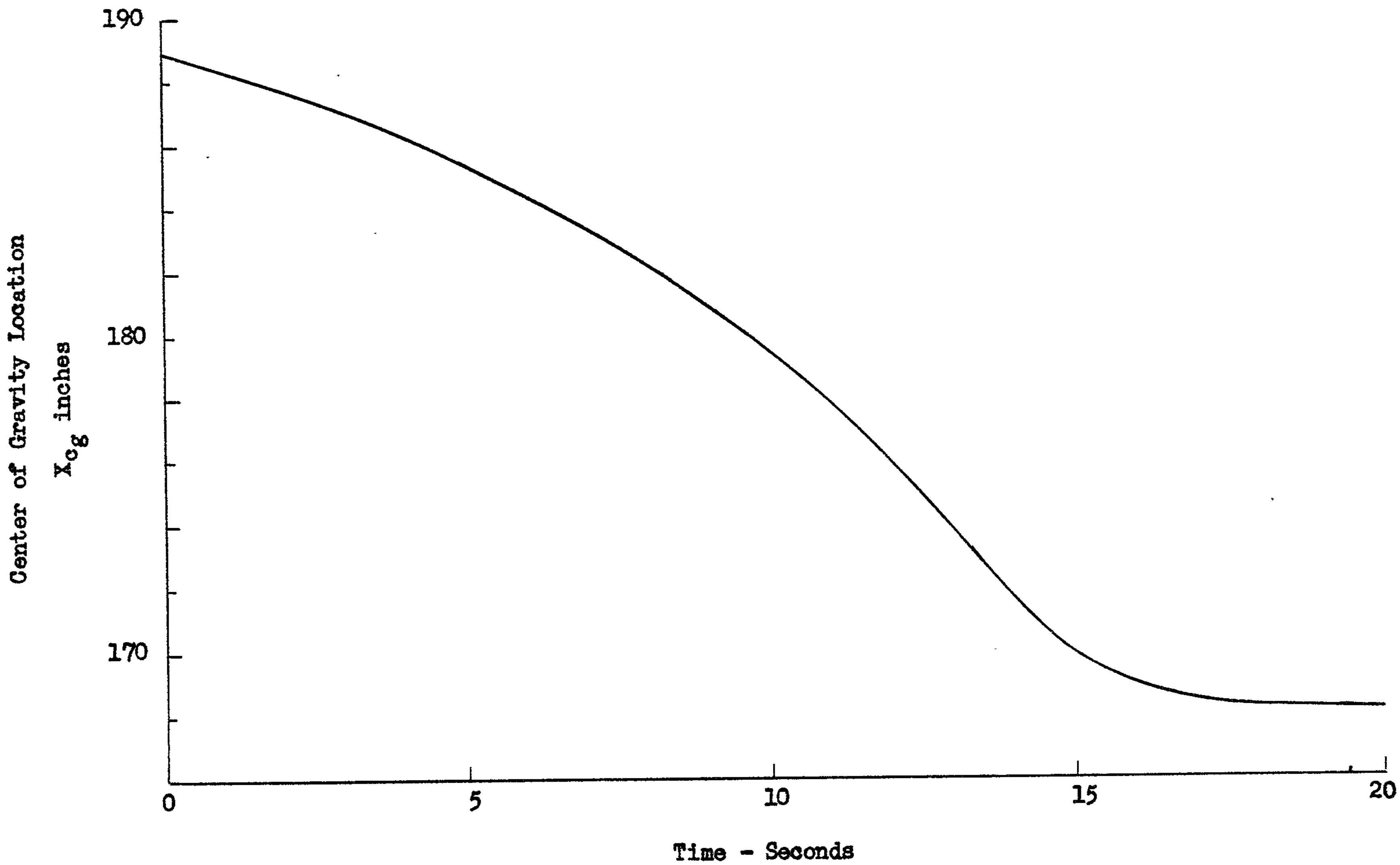
Jet Seeding Vehicle

Figure 20



Mass Versus Time

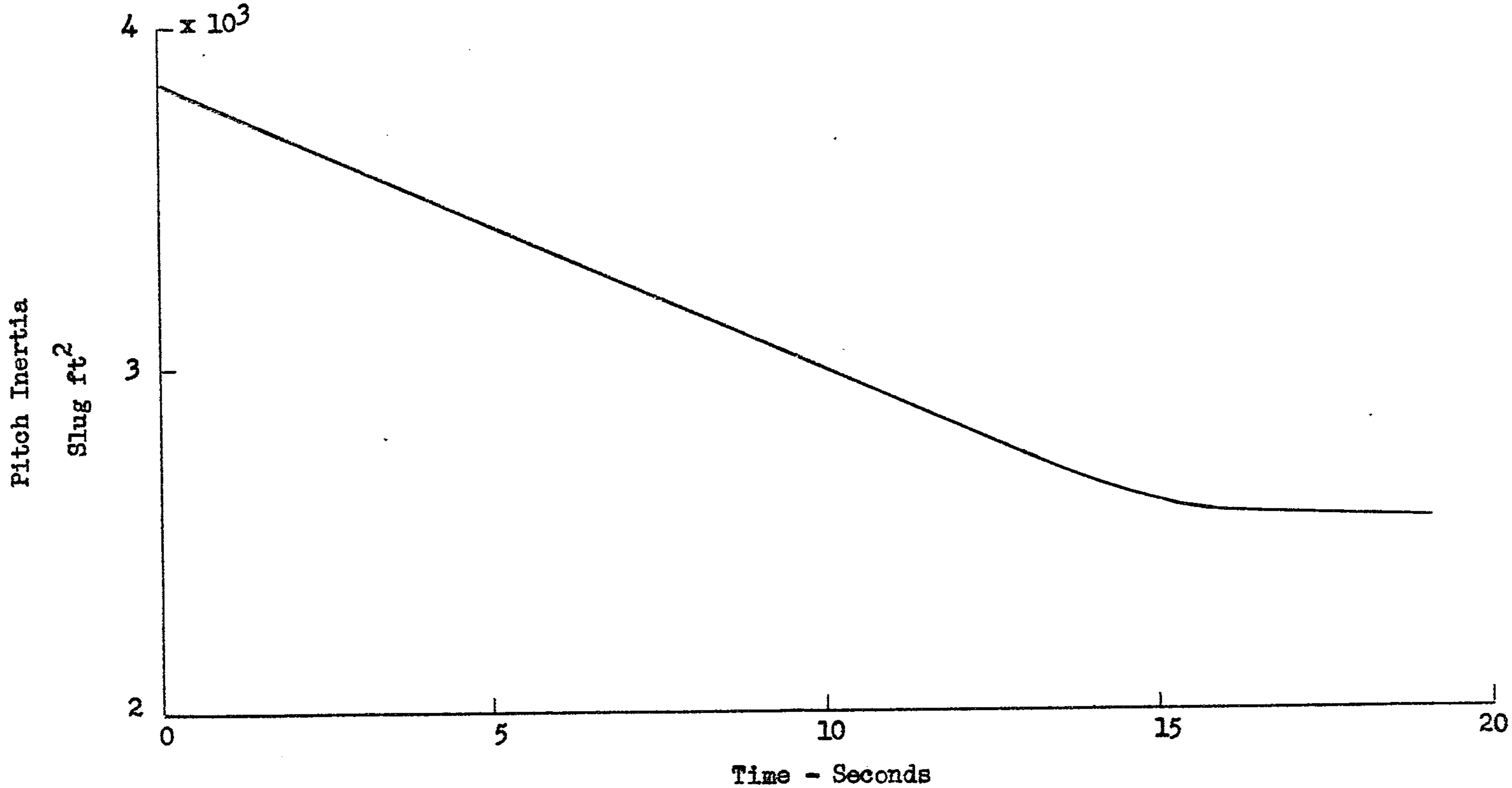
Jet Seeding Vehicle
Figure 23



X_{cg} Versus Time

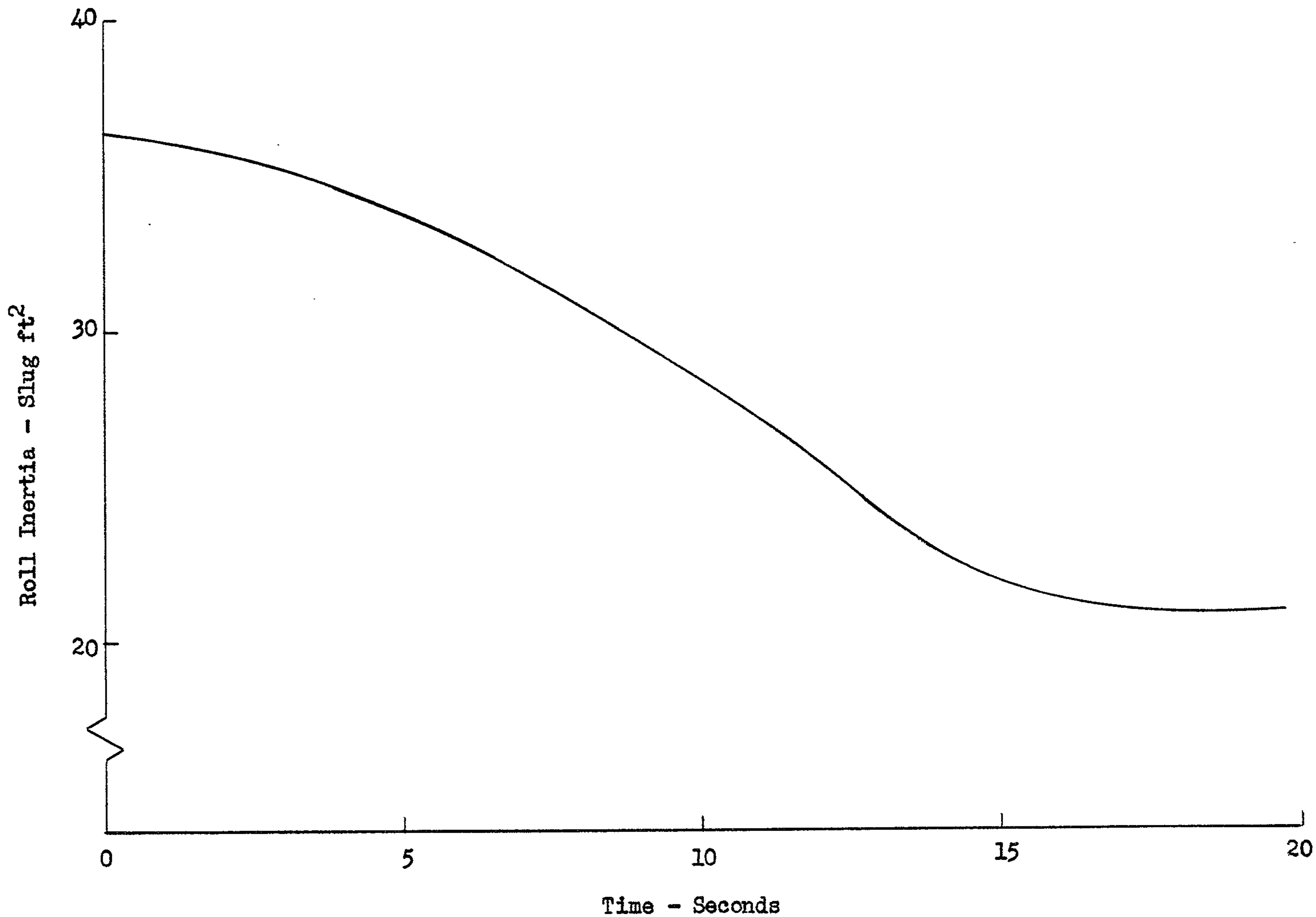
Jet Seeding Vehicle

Figure 24



Pitch Inertia Versus Time - Jet Seeding Vehicle

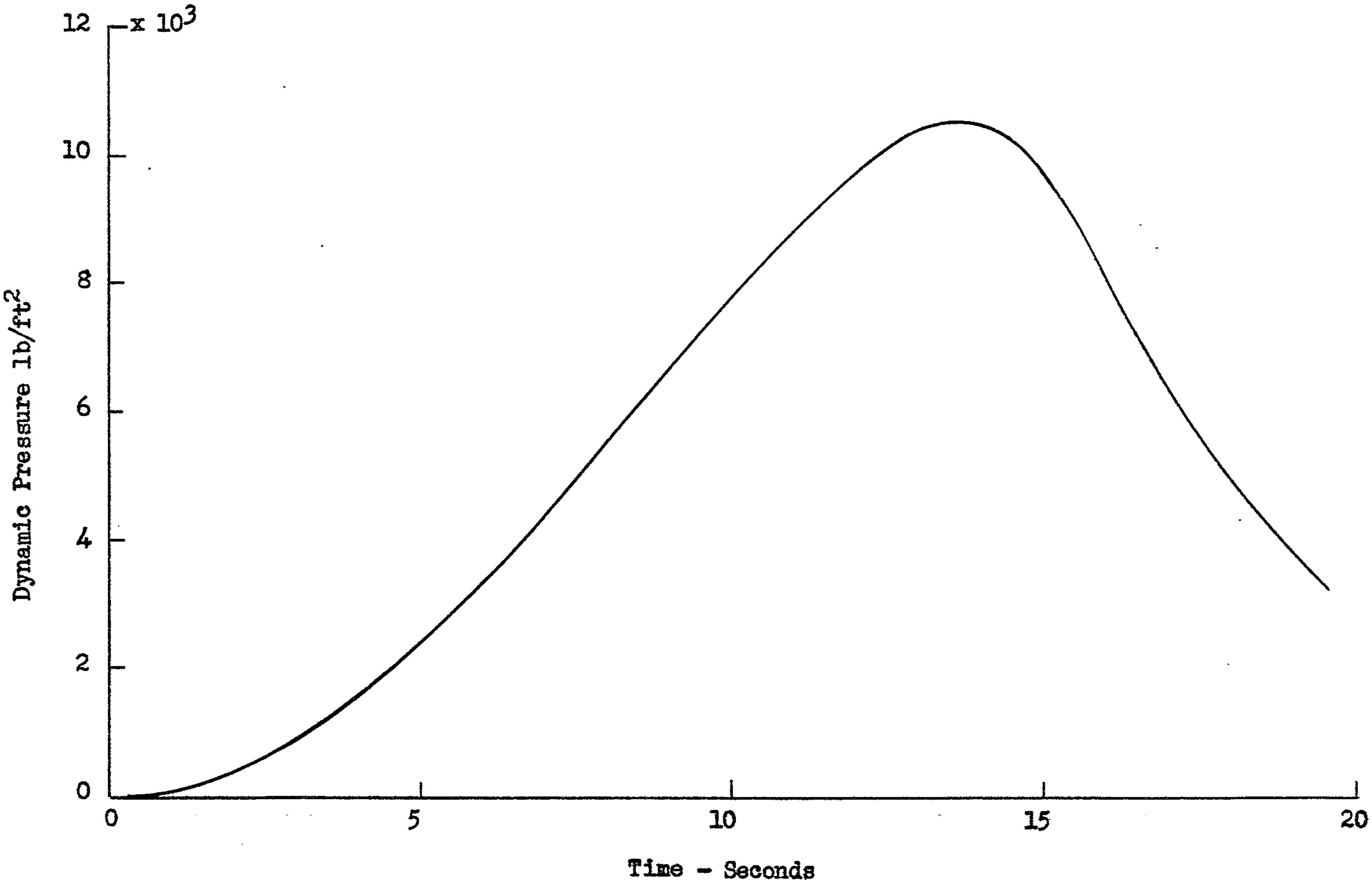
Figure 25



Roll Inertia Versus Time

Jet Seeding Vehicle

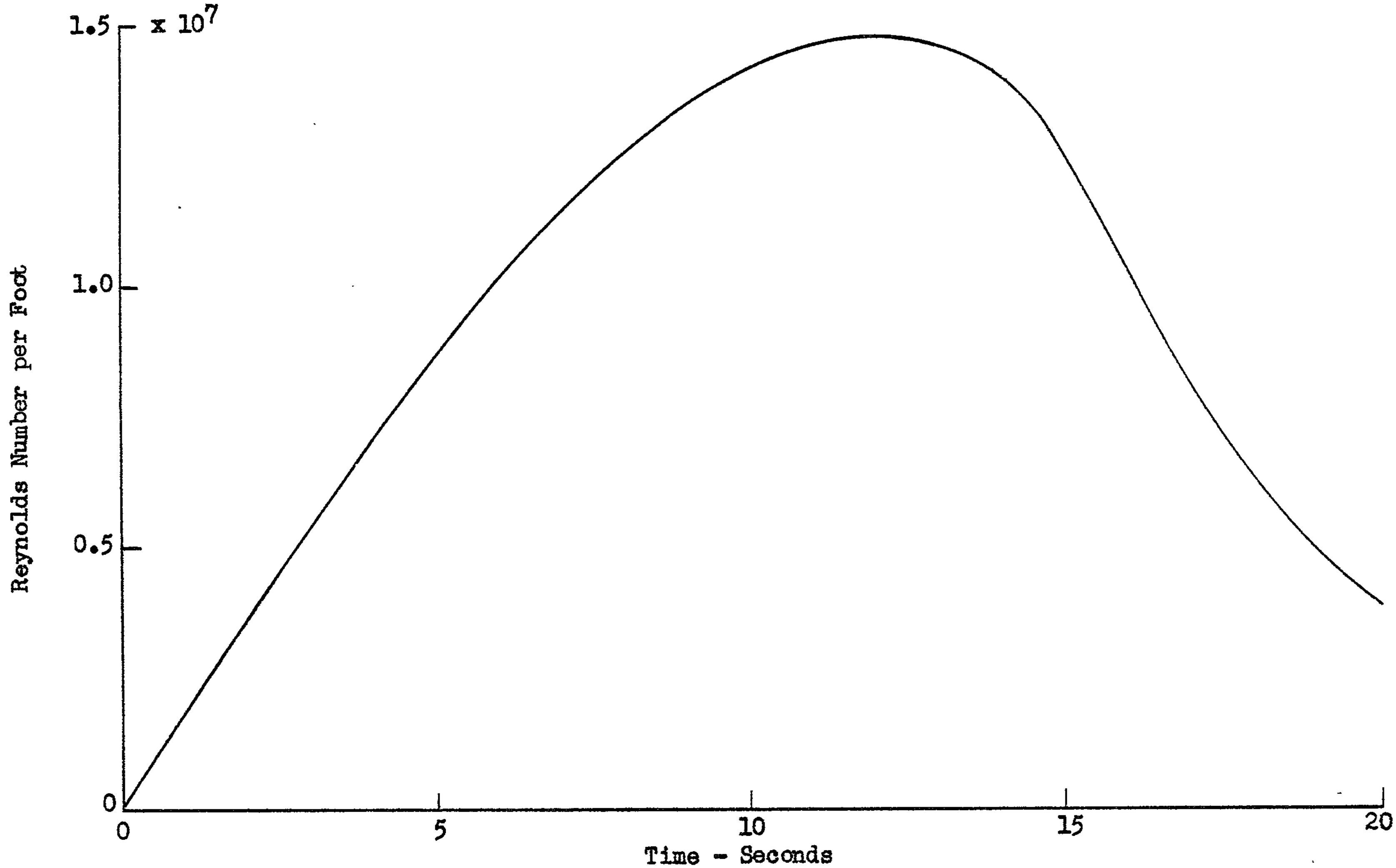
Figure 26



Dynamic Pressure Versus Time

Jet Seeding Vehicle

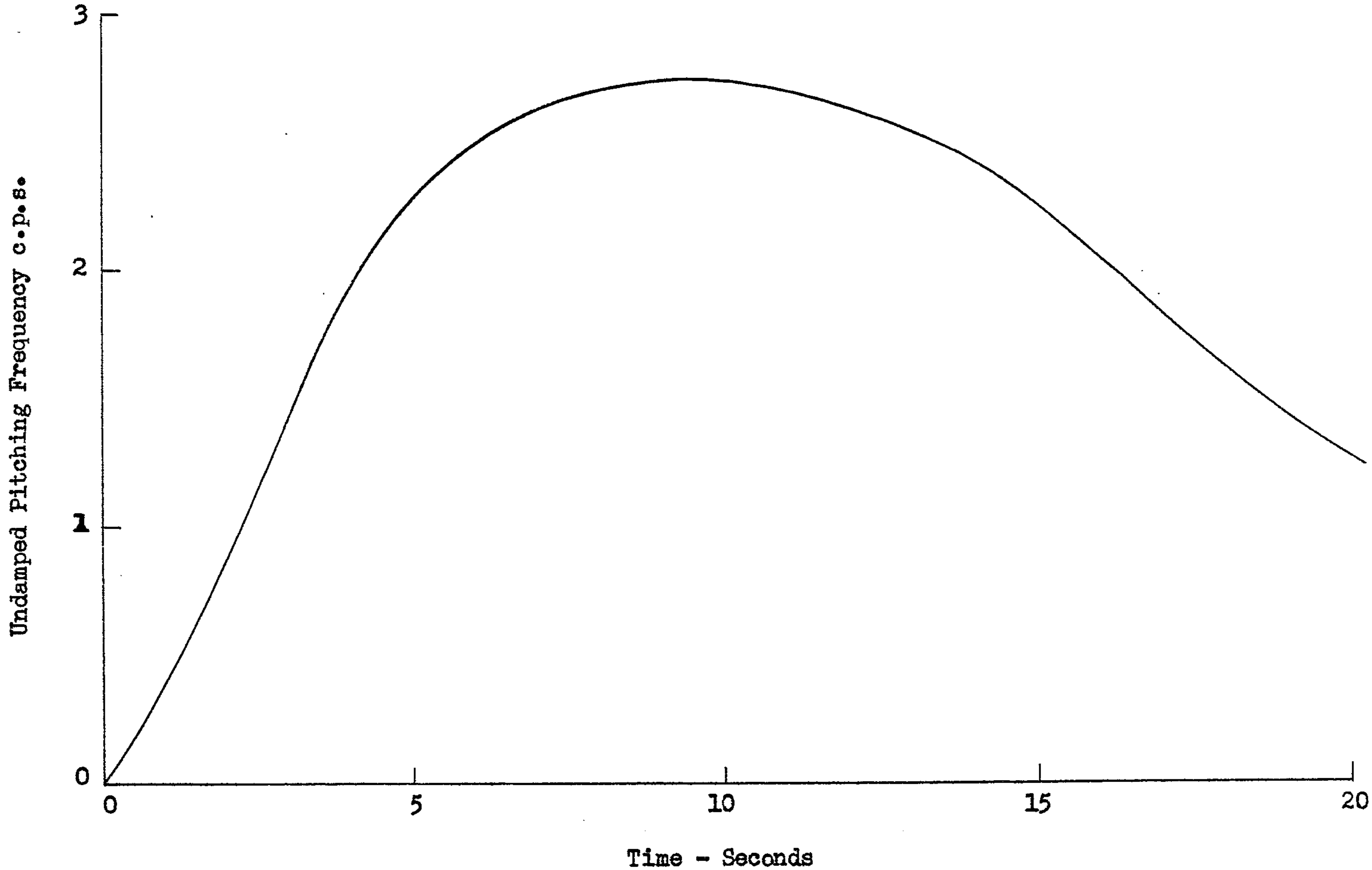
Figure 27



Reynolds Number per Foot Versus Time

Jet Seeding Vehicle

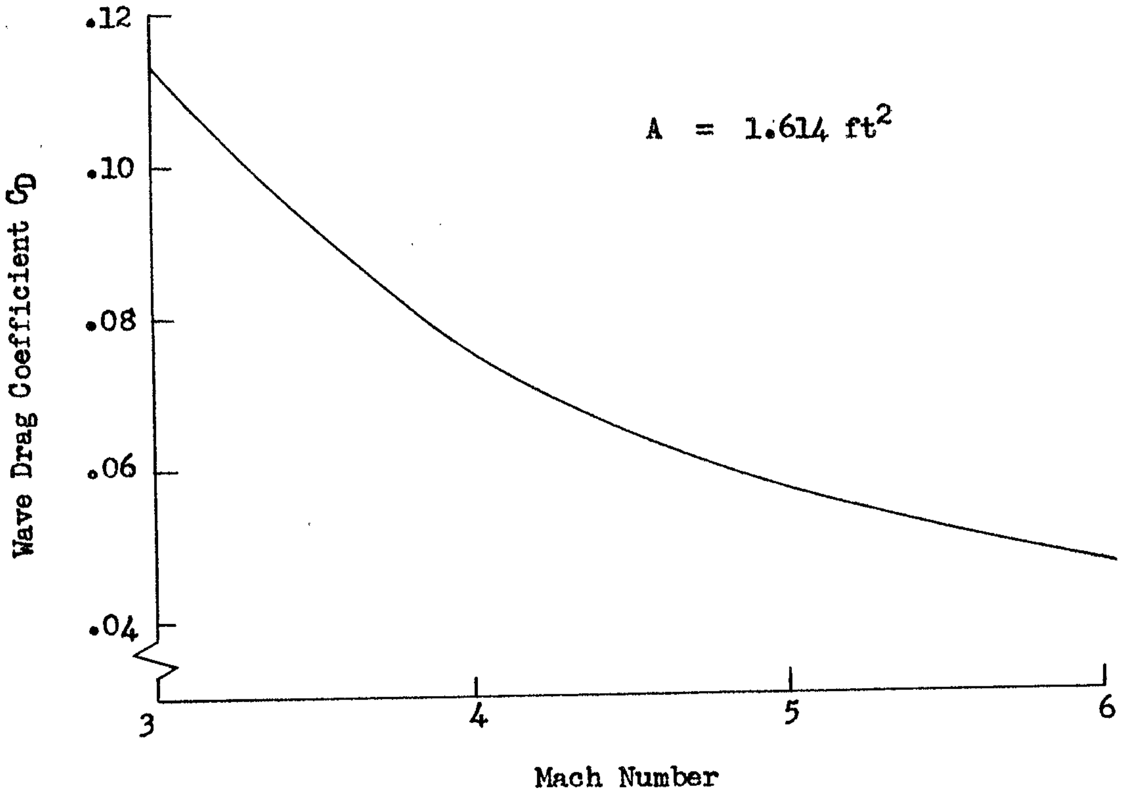
Figure 28

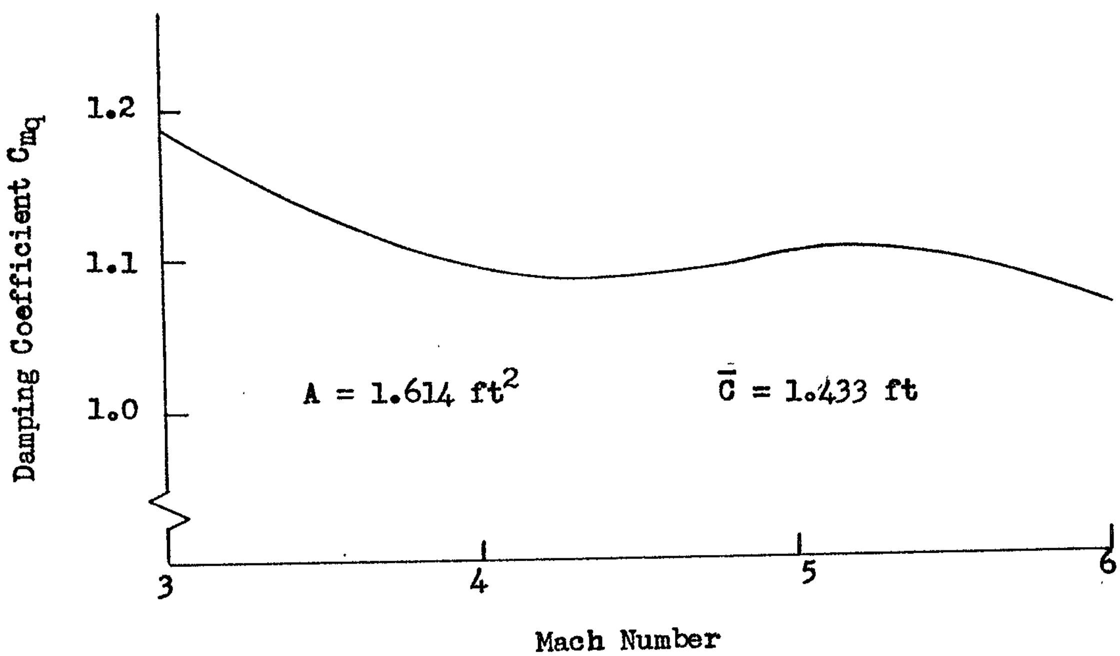


Undamped Pitching Frequency Versus Time

Jet Seeding Vehicle

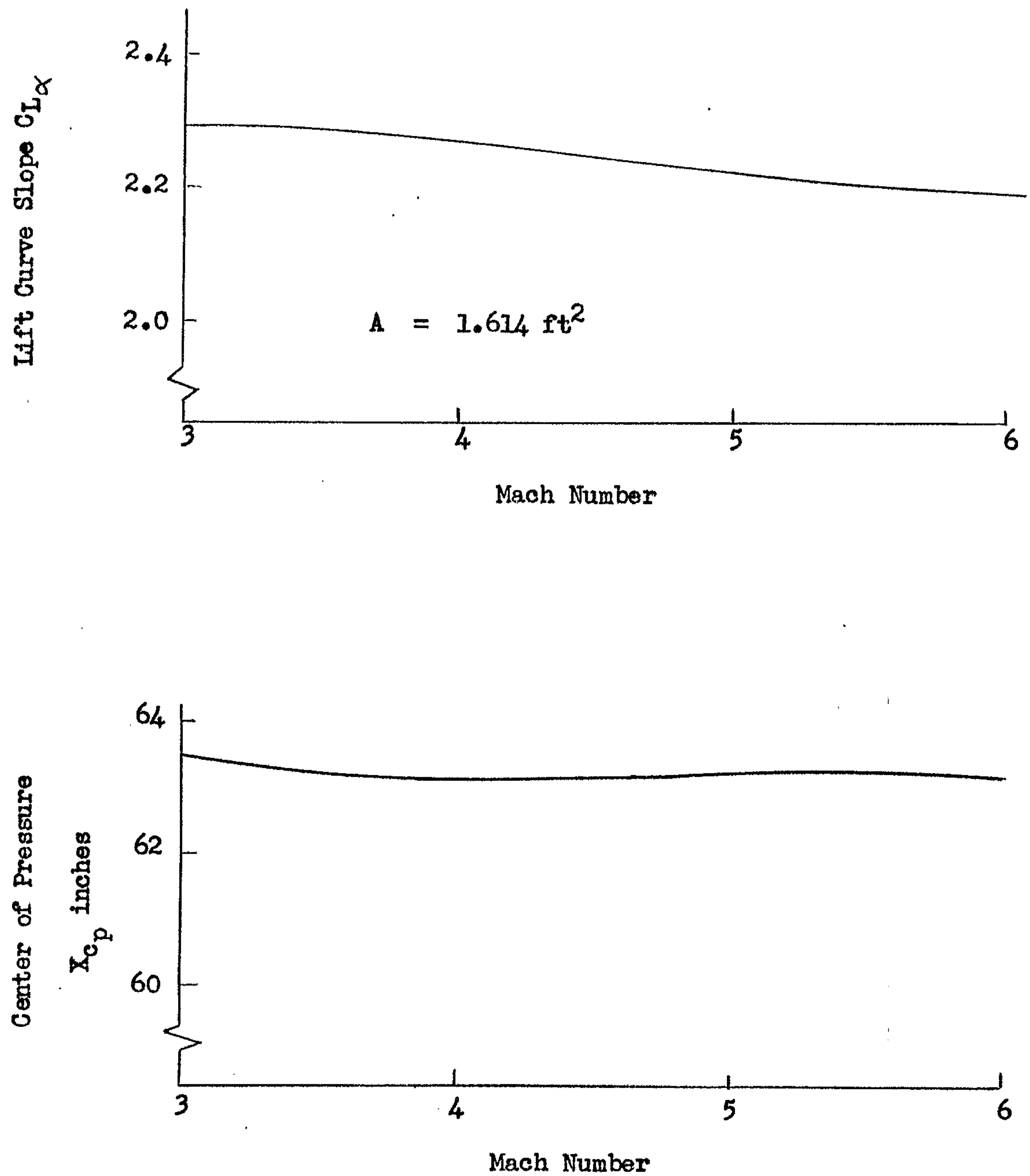
Figure 29





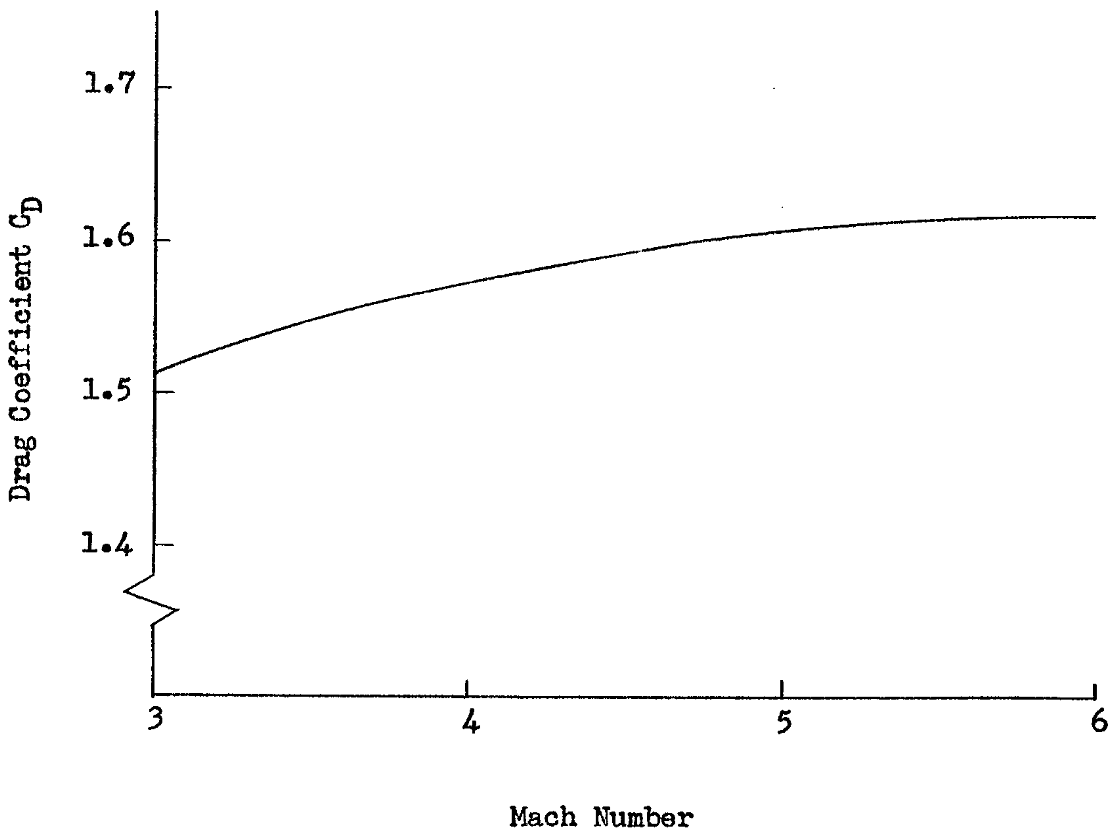
Aerodynamic Coefficients of Separated Nose Cone
Versus Mach Number (1)

Figure 30



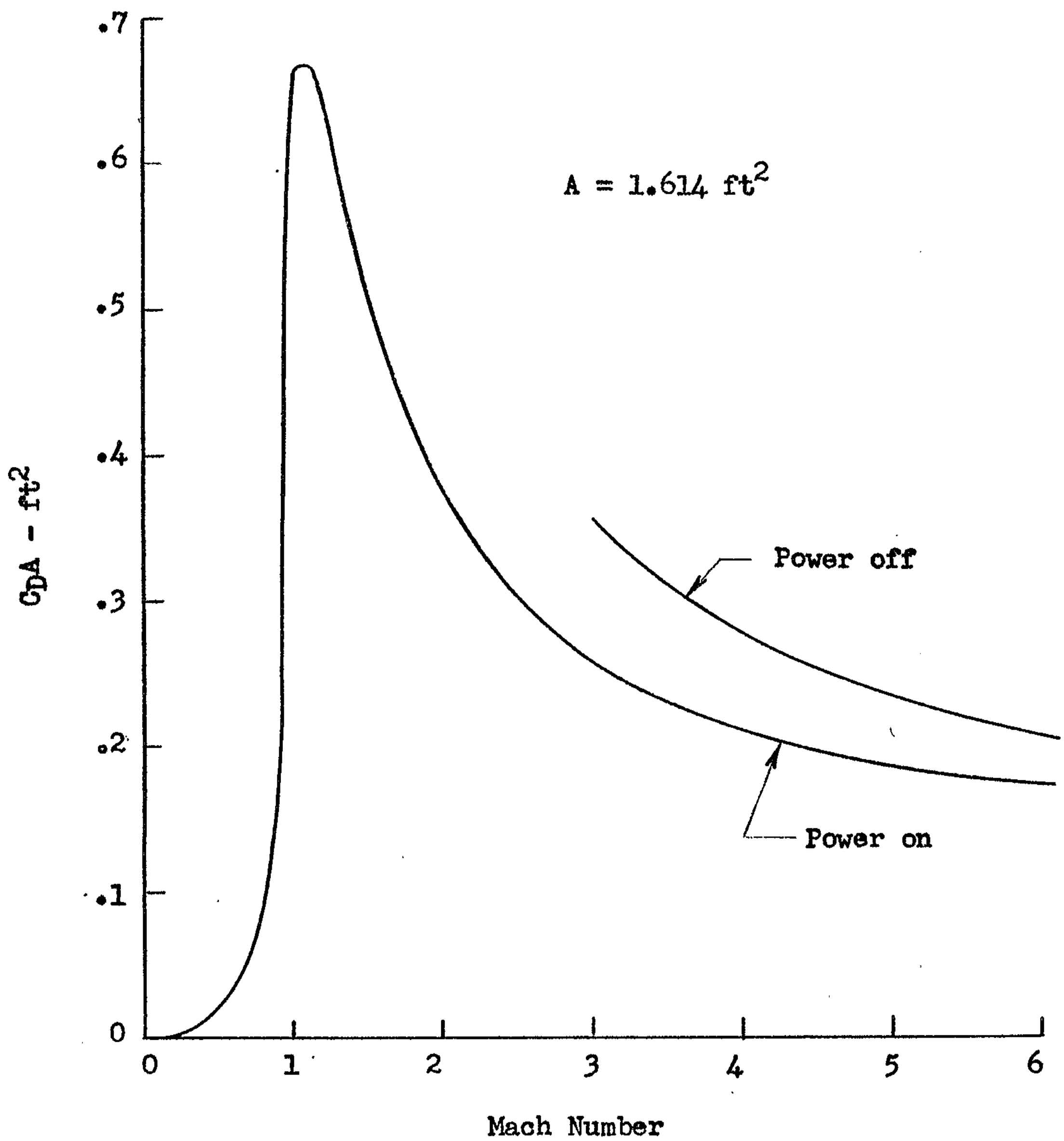
Aerodynamic Coefficients of
Seperated Nose Cone
Versus Mach Number (2)

Figure 31



Drag Coefficient of Separated Engine
versus Mach Number

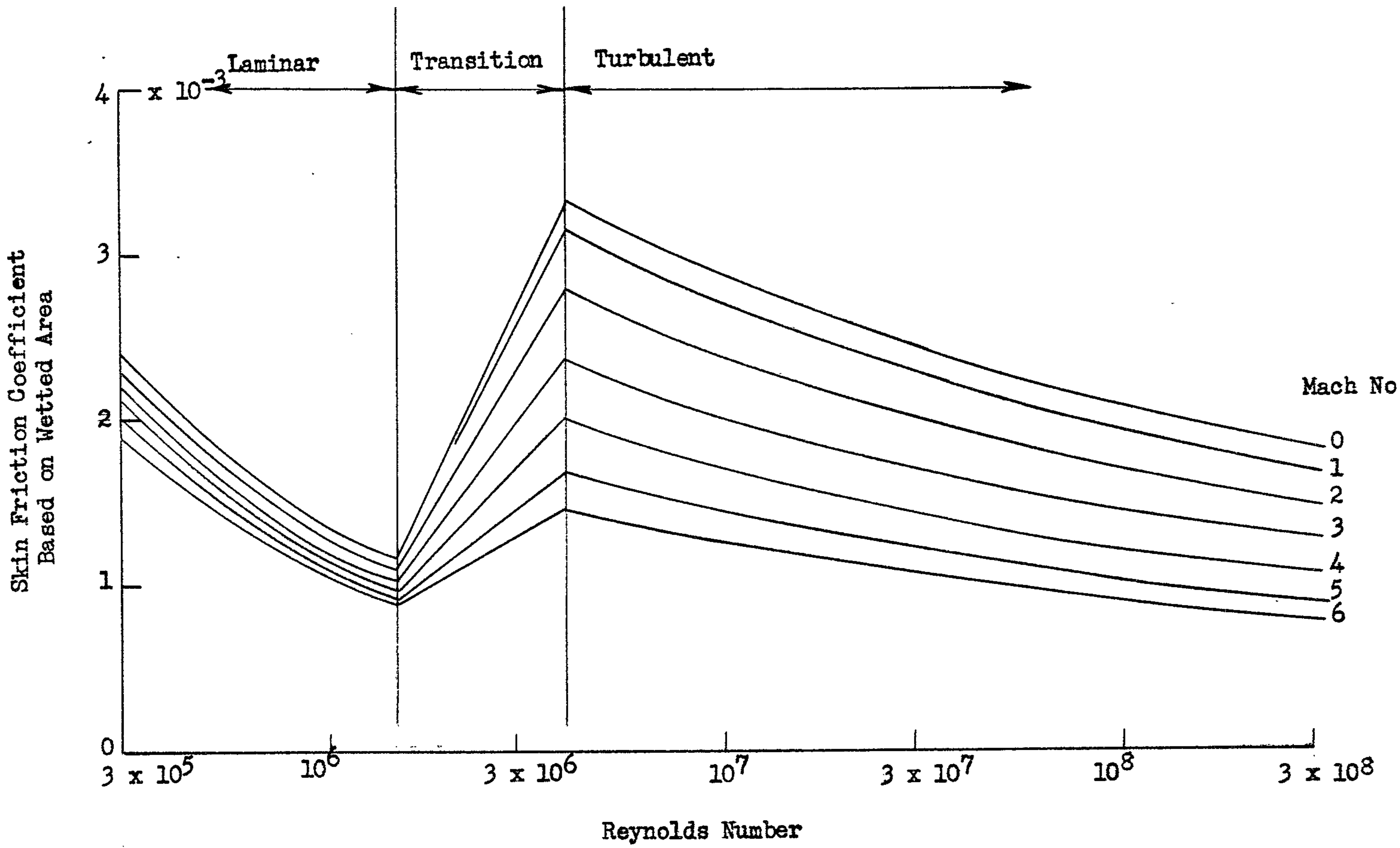
Figure 32



Wave Drag Coefficient Versus Mach Number

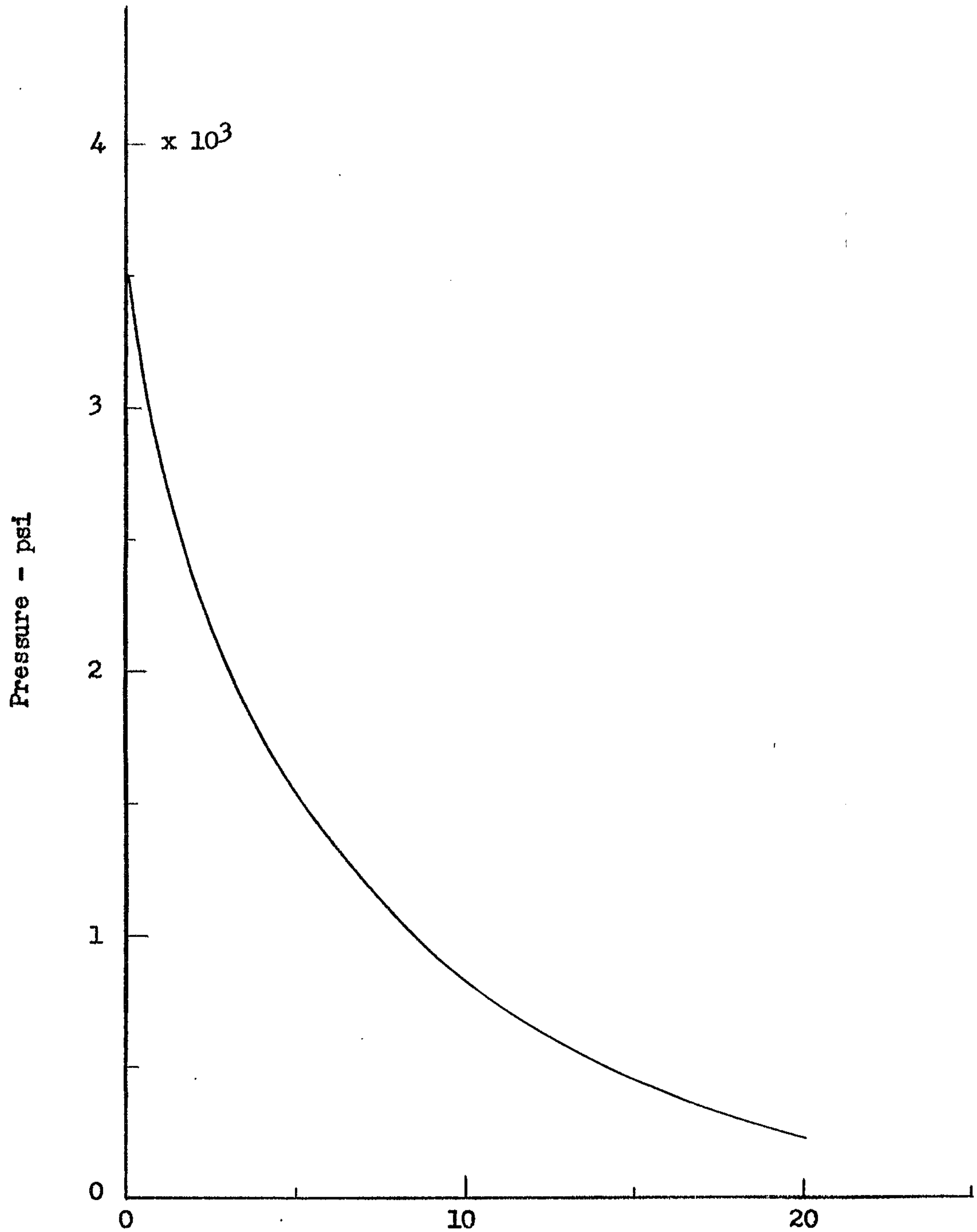
Jet Seeding Vehicle

Figure 33



Skin Friction Coefficient as a Function of
Mach Number and Reynolds Number

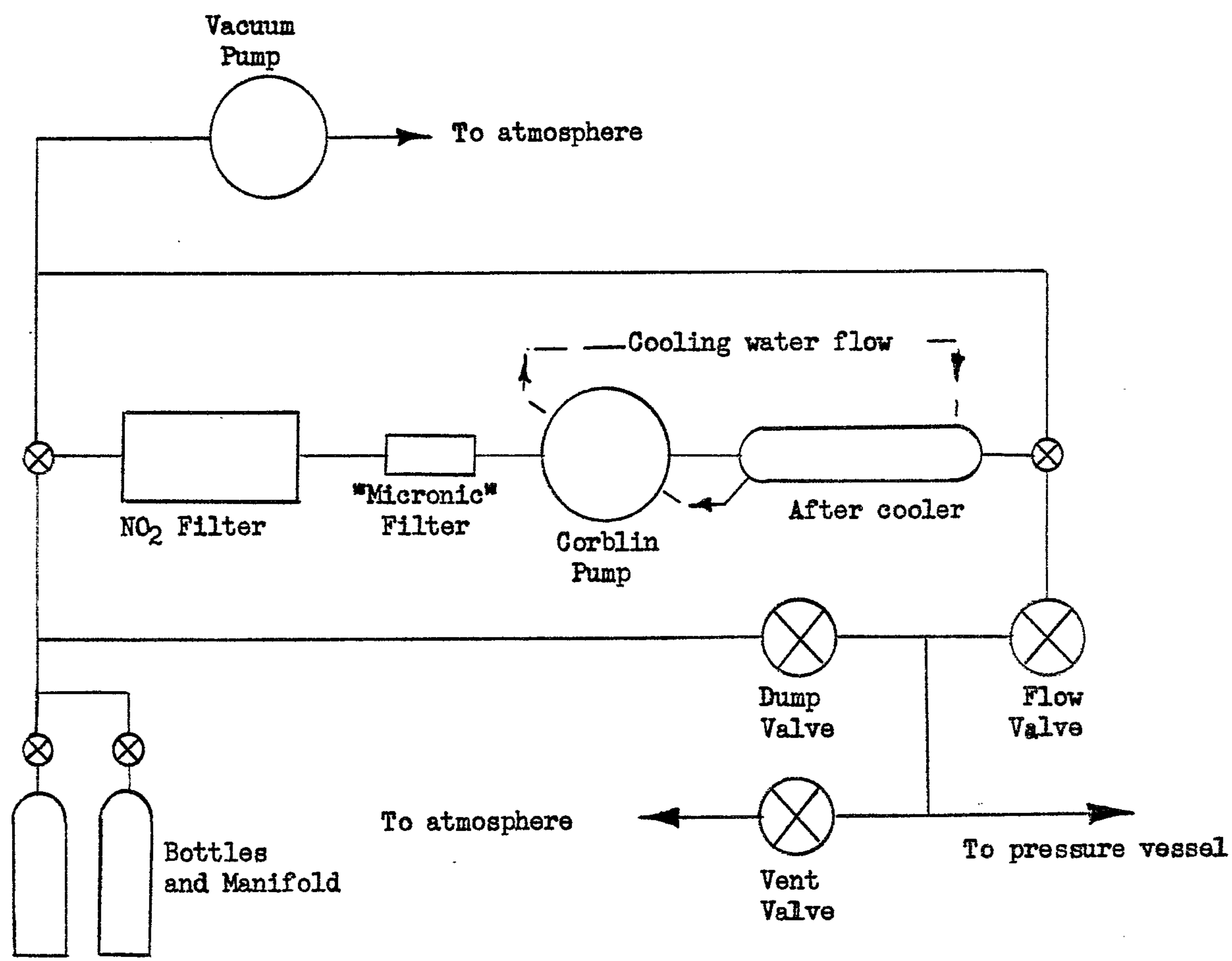
Figure 34



Time (in Seconds) After 84 seconds

Pressure versus Time During Nitric Oxide Dump

Figure 35



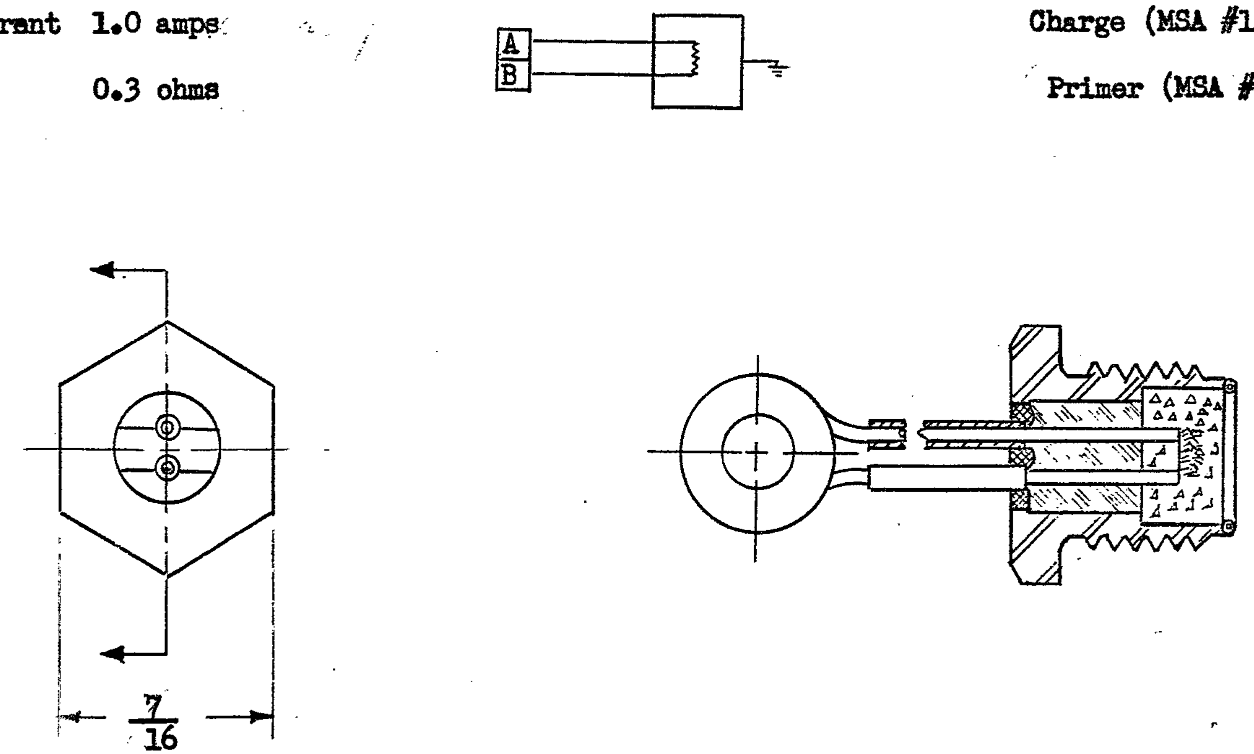
Nitric Oxide Charging System

Figure 36

Firing current	5 amps (recommended) 2 amps (min.)
No fire current	1.0 amps
Resistance	0.3 ohms

Charge (MSA #147) 120 mg

Primer (MSA #26 Bead)

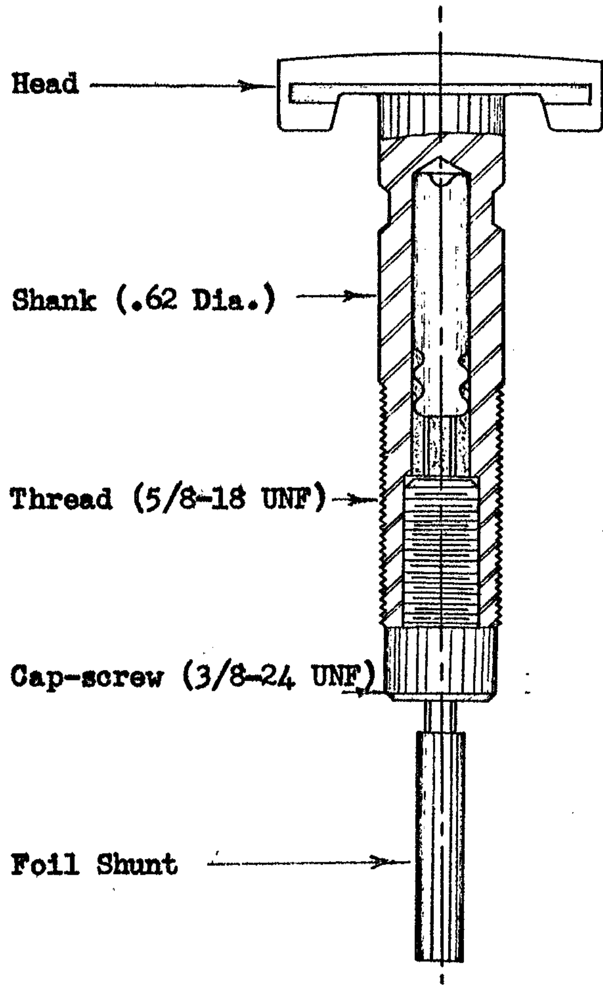


Rocket Engine Squib

(M-32 Mod. V)

Figure 37

Actual Size



No. 8 Electric Blasting

Cap

(CIL Dwg. No. A-14320)

2.75	GRS	40-20-40 loose charge
3	GRS	lead azide
.6	GRS	P.E.T.N.

Resistance 1-2 ohms

Sure fire current 0.6 amp

No fire current 0.1 (?) amp

Test current .015 amp

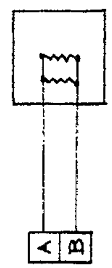
Explosive Bolt

Figure 38

Firing current 2 amps min.

No-fire current 0.8 amp max.

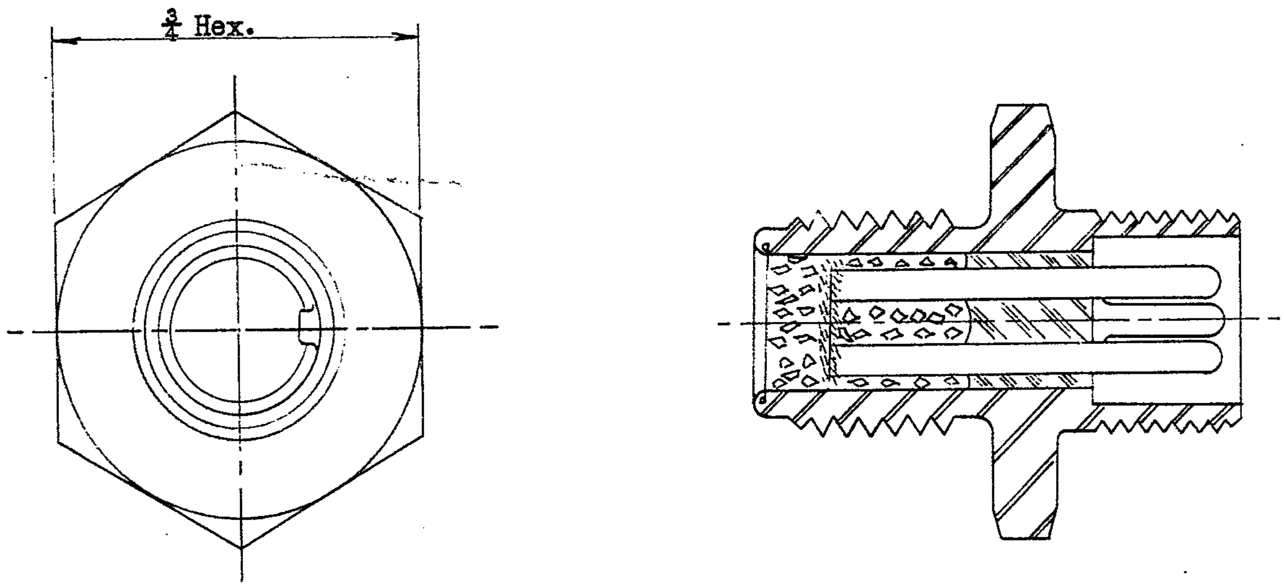
Resistance 1.0 ohm



<u>Charge</u>

Igniter (MSA #131) 450 mg

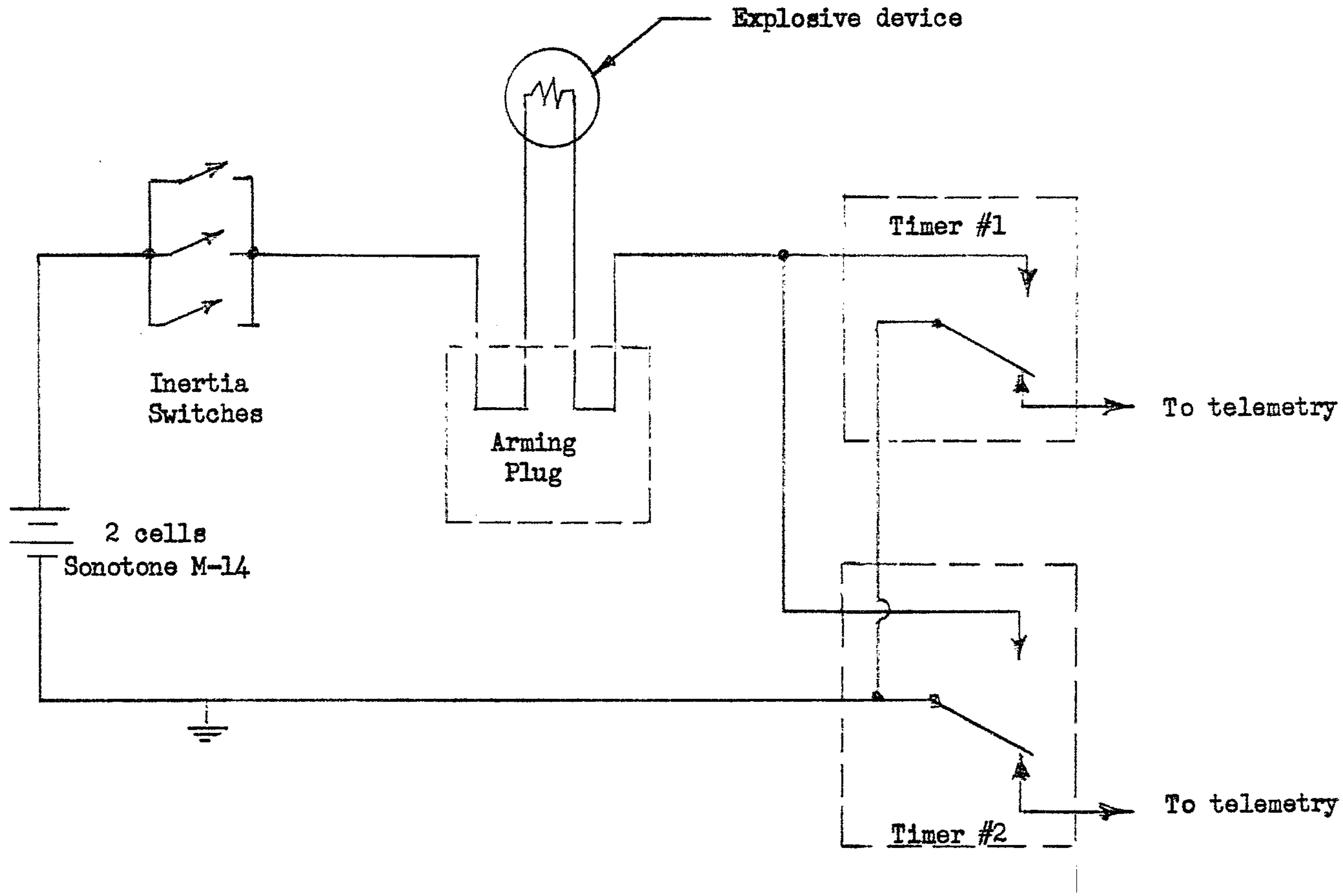
Primer (MSA #26) 50 mg



Explosive Valve Pressure Cartridge

(M-76 Mod. I)

Figure 39



Firing Circuit
Jet Seeding Vehicle
Figure 40

APPENDIX "A"

NITRIC OXIDE TOXICITY (1)

TOXICITY

Nitric oxide is an extremely toxic gas. It is rapidly converted by the oxygen of the air to nitrogen dioxide (NO_2). Thus, in most cases of exposure to nitric oxide, the individual is being actually exposed to NO_2. The recommended (American Conference of Governmental Industrial Hygienists) maximum acceptable concentration of NO_2 in air is 5 p.p.m.

The greatest hazard of exposure to NO_2 comes from the fact that its serious effects are not felt until several hours after the exposure in spite of the fact that dangerous amounts may be breathed before any real discomfort occurs. Edema may not develop up to 72 hours. In most cases the period between exposure and the onset of edema is practically free of symptoms.

Exposure to higher concentrations (60-150 p.p.m.) causes immediate irritation of the nose and throat, coughing, nausea, choking, headache, shortness of breath, and restlessness. Edema may develop within 6-24 hours after such exposure. Concentrations of 100-150 p.p.m. are dangerous for exposures of 30-60 minutes and concentrations of 200-700 p.p.m. may be fatal after even very short exposures.

Chronic exposure to low concentrations may cause chronic irritation of the respiratory tract, with cough, headache, loss of weight, loss of appetite, dyspepsia, corrosion of the teeth, and gradual loss of strength.

FIRST AID SUGGESTIONS

Anyone exposed to dangerous concentrations of nitric oxide (rapidly converted to NO_2 by the oxygen of the air) or overcome by gas should be placed immediately in the care of a physician. Prior to the physician's arrival, first aid should be started. Those presented herein are believed to be common practice in industry. Their adoption in any specific case should be subject to the prior endorsement of a competent medical advisor.

a) Persons suspected to exposure to dangerous concentrations of the gas should be given bed rest for 24 hours and kept under observation during this period because of the dangers of developing edema.

b) Anyone suffering from nitric oxide poisoning should be given 100% oxygen if breathing has not stopped or 100% oxygen with artificial respiration, manual or otherwise, if breathing has stopped. No one who has been exposed to nitric oxide should be allowed to move until permitted to do so by the attending physician.

c) If the person collapses after exposure, he should be moved to fresh air and kept warm. The victim should be laid face down with his head and chest lower than his hips to improve drainage of fluid from the lugs. The body can be inclined to about a 15 or 20 degree angle. Artificial respiration should be started right away. If possible, oxygen should be administered simultaneously with an inhalator or resuscitator.

d) The chances of developing edema will be considerably reduced if oxygen is administered with an exhalation back-pressure of 2-2.5 inches of water. If the oxygen is bubbled through ethyl alcohol as it is administered, any frothing likely in the lugs will be lessened.

c) If a person exposed to nitric oxide commences to cough, has difficulty breathing, or feels slightly fatigued, he should be given oxygen immediately. A physician should be called. If it is necessary to move the victim, he should be carried on a stretcher. In no case should he be allowed activity.

(1) Matheson Gas Data Book. pp 319-320.