14p. Ots: $1.60 ph, $0.80 mf.

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PARAGLIDER RECOVERY SYSTEMS

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For Presentation at IAS Meeting
on Man's Progress in the Conquest of Space

St. Louis, Missouri
April 30, May 1-2, 1962

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The flexible-wing concept, which may be as old as the pterodactyl and was given serious consideration by Leonardo Da Vinci, was apparently ignored by the Wright Brothers, Glen Curtiss, and others whose rigid-wing structures followed established bridge and roof-truss design. Today's airplanes have evolved from these early rigid-wing designs. The thin cantilever wings of modern high-speed airplanes are not completely rigid, but they are elastic rather than flexible. They can not be folded up like a balloon or parachute.

In 1945 it occurred to the writer that if we could discover how to make flexible wings that could be packaged and deployed somewhat like a parachute, such wings would have many new applications as well as replacing some parachutes and rigid wings. Previous uses of flexible materials in aerodynamic surfaces - parachutes, kites, boat sails, and wind mills - were reviewed, and some crude experiments were performed with gliders and kites. Before the end of 1948, the device now generally called a paraglider was evolved and developed sufficiently to merit a patent application[1]. The study was continued privately as time permitted, and in 1954 a short paper on the subject[2] was presented to an audience of about 50 Reserve Air Force Officers. This paper was given rather wide distribution, although it suffers from lack of the many kite and glider demonstrations of the original presentation. Little serious interest was shown by the aeronautical community, however, until about a year after Sputnik I. In December 1958 the flexible-wing concept was presented to the Langley Committee on General Aerodynamics with the aid of the hurriedly prepared charts shown in figure 1, faithfully reproduced here for historical purposes.

Of the many configurations and applications shown in figure 1, it was decided that the two-lobe, single-curvature, suspended-load design that had already shown much promise[1,2] should be investigated as a possible reentry glider. While preliminary work of this nature, which is reported in references 3 to 7, was in progress, information pertaining to other applications was requested. The parawing was shown to be a very effective high-lift device for aircraft[8]. It was demonstrated as a wing for a powered aircraft and an air-drop glider, both radio controlled[9]. It was considered for the recovery of rocket boosters[10], and for the terminal glide and landing of manned space capsules[11]. And to support such applications, basic information on pressure distribution was obtained[12,13]. The aerospace industry, particularly Ryan, North American, and Goodyear, has also contributed paraglider information and has made feasibility studies of the recovery of boosters and space vehicles by paraglider. These studies indicated that such recoveries were feasible.

Because NASA work on flexible wings prior to 1961, including Langley Film L-593, was well received at the January 1961 New York IAS Meeting, it was thought that a brief mention of NASA work done since then and continuing, in addition to that listed in the references, might be of interest. Langley Film L-688 shows some of this work.

A wide range of wing geometric variables is being investigated with static wind-tunnel setups such as those shown in figure 2. Line loads and complete glider static forces and moments are determined by the setup of figure 3. Stability and control characteristics of gliders in flight are determined by tests of remote-control models, such as are shown in figures 4 and 5. Space capsule (fig. 4) and booster (fig. 5) models were flown in the full-scale tunnel and also by radio control after being dropped from a helicopter. Deployment of the folded wings after dropping was an important part of the investigation by the Outdoor Test Unit of the Recovery Systems Branch at Langley.

In figure 6 is shown a propeller-powered model being flown in the full-scale tunnel, and in figure 7 is a roughly similar gas-powered radio-controlled model with which some impressive flight demonstrations were made. Figure 8 is a static wind-tunnel model for force test in the 7- by 10-foot wind tunnel, and figure 9 is the Ryan Aircraft being statically tested in the Langley full-scale tunnel.

The glider shown in figure 10 just after lift-off by a helicopter is 50 feet long and has 32-inch-diameter inflated fabric tubes at the leading edges and keel. It has been towed to an altitude of several hundred feet and released for free glide with weights of about 700, 1,300, and 1,900 pounds with the small capsule shown. A standard sized Mercury Capsule will be used next, and weight progressively increased.

In figure 11 is shown a glider built and flown by the NASA Flight Center at Edwards Air Force Base, California. This glider has been towed to altitude and then released for glide and landing.

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10. Hatch, Howard G., Jr., and McGowan, William A.: An Analytical Investigation of the Loads, Temperatures, and Ranges Obtained During the Recovery of Rocket Boosters by Means of a Parawing. NASA TN D-1003, 1961.

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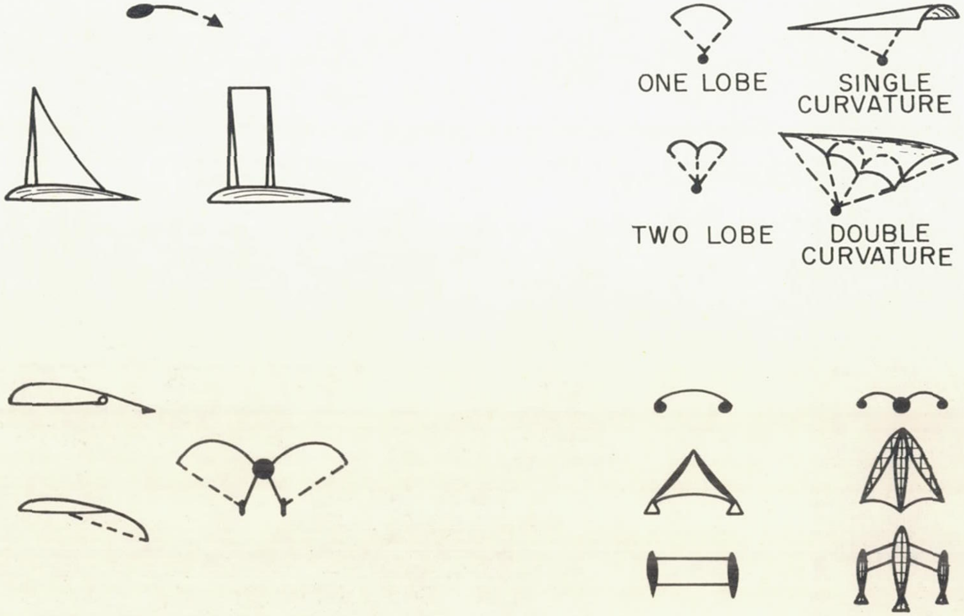
13. Fournier, Paul G., and Bell, B. Ann: Transonic Pressure Distributions on Three Rigid Wings Simulating Paragliders With Varied Canopy Curvature and Leading-Edge Sweep. NASA TN D-1009, 1961.

WHY A MEMBRANE WING ?

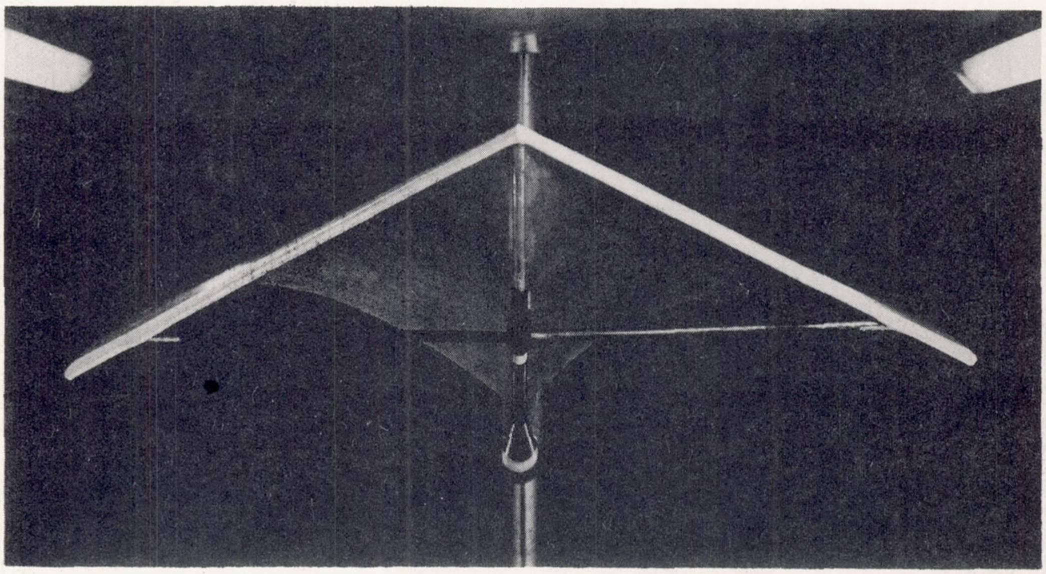
1. VERY LIGHT WING WEIGHT PER UNIT AREA MAKES POSSIBLE VERY LOW WING LOADING
2. ABILITY TO BE ROLLED UP OR FOLDED LIKE A PARACHUTE
3. RADIATION FROM BOTH SURFACES REDUCES AERODYNAMIC HEATING AND FLEXIBILITY REDUCES THERMAL STRESS
4. VERY THIN WINGS REDUCE WAVE DRAG AT HIGH SPEED

1. REENTRY
2. SPACE SHIP LANDING
3. SOLAR SAILING
4. HIGH ALTITUDE CRUISE (POSSIBLY DISSOCIATED OXYGEN PROPULSION)
5. PERSONNEL AND/OR CARGO GLIDING PARACHUTE AS SUBSTITUTE FOR CONVENTIONAL PARACHUTE
6. WINGS FOR STOL (COULD BE ROADABLE)
7. LANDING AID FOR CONVENTIONAL AIRPLANE (LIFT ADVANTAGE OVER DRAG)



NASA

Figure 1.- Flexible-wing concept as presented to Langley Committee on General Aerodynamics, December 19, 1958.



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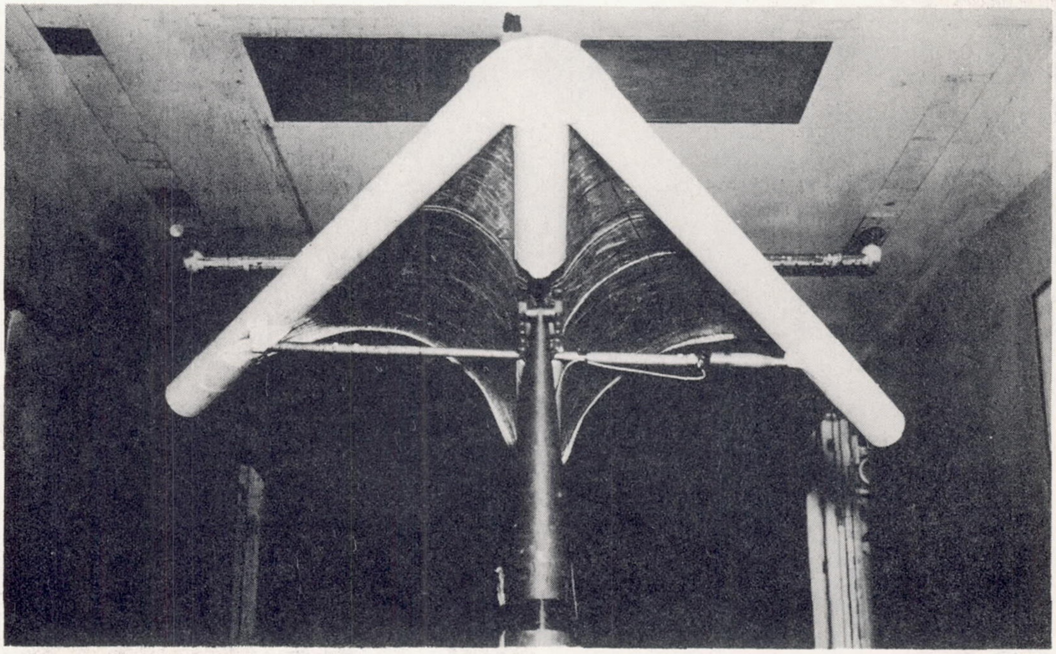

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Figure 2.- Typical wind-tunnel setup for systematic investigation of the effect of wing geometry on the static aerodynamic characteristics of flexible wings.

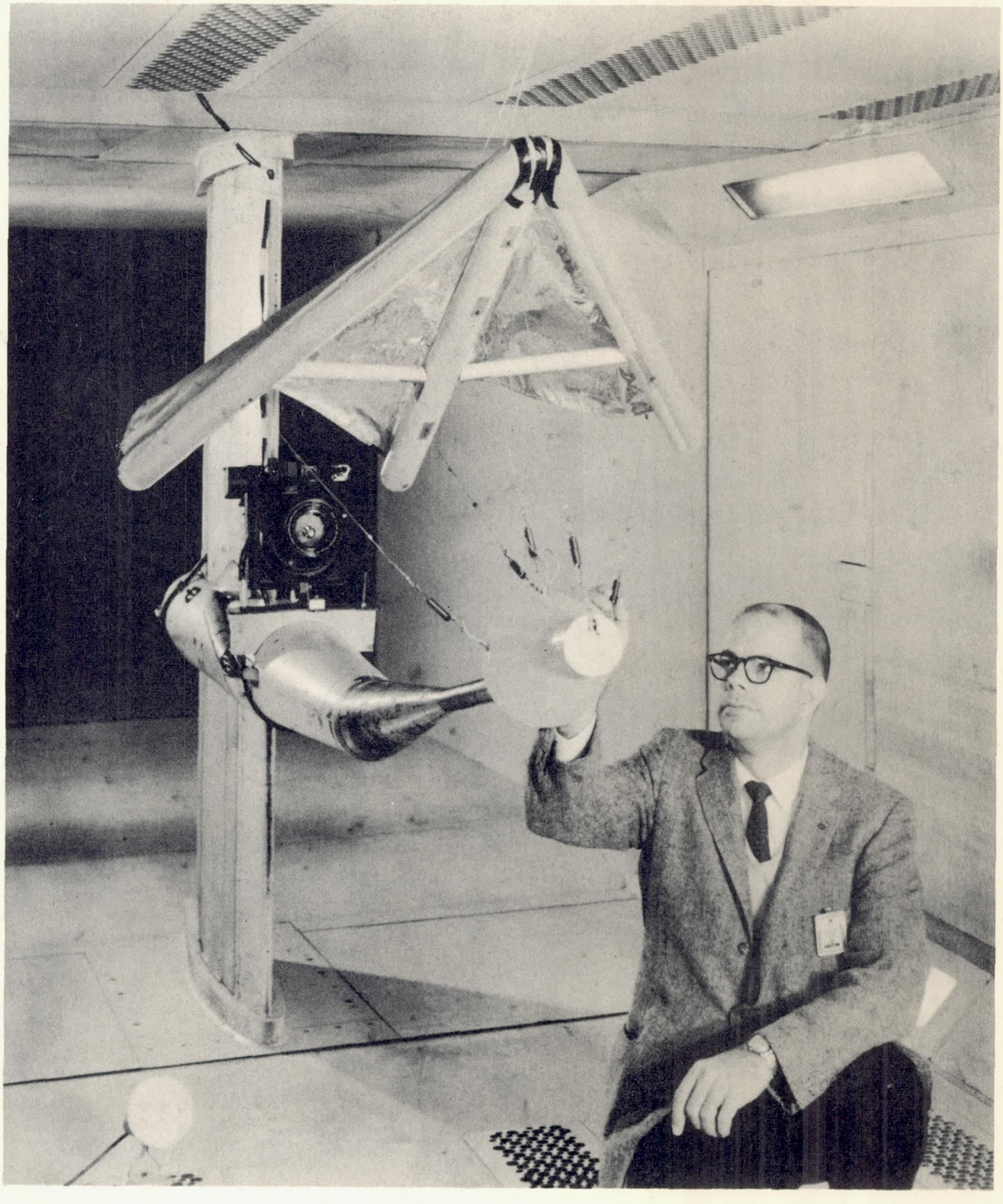

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Figure 3.- Wind-tunnel setup for determination of line loads and complete glider static aerodynamic characteristics.

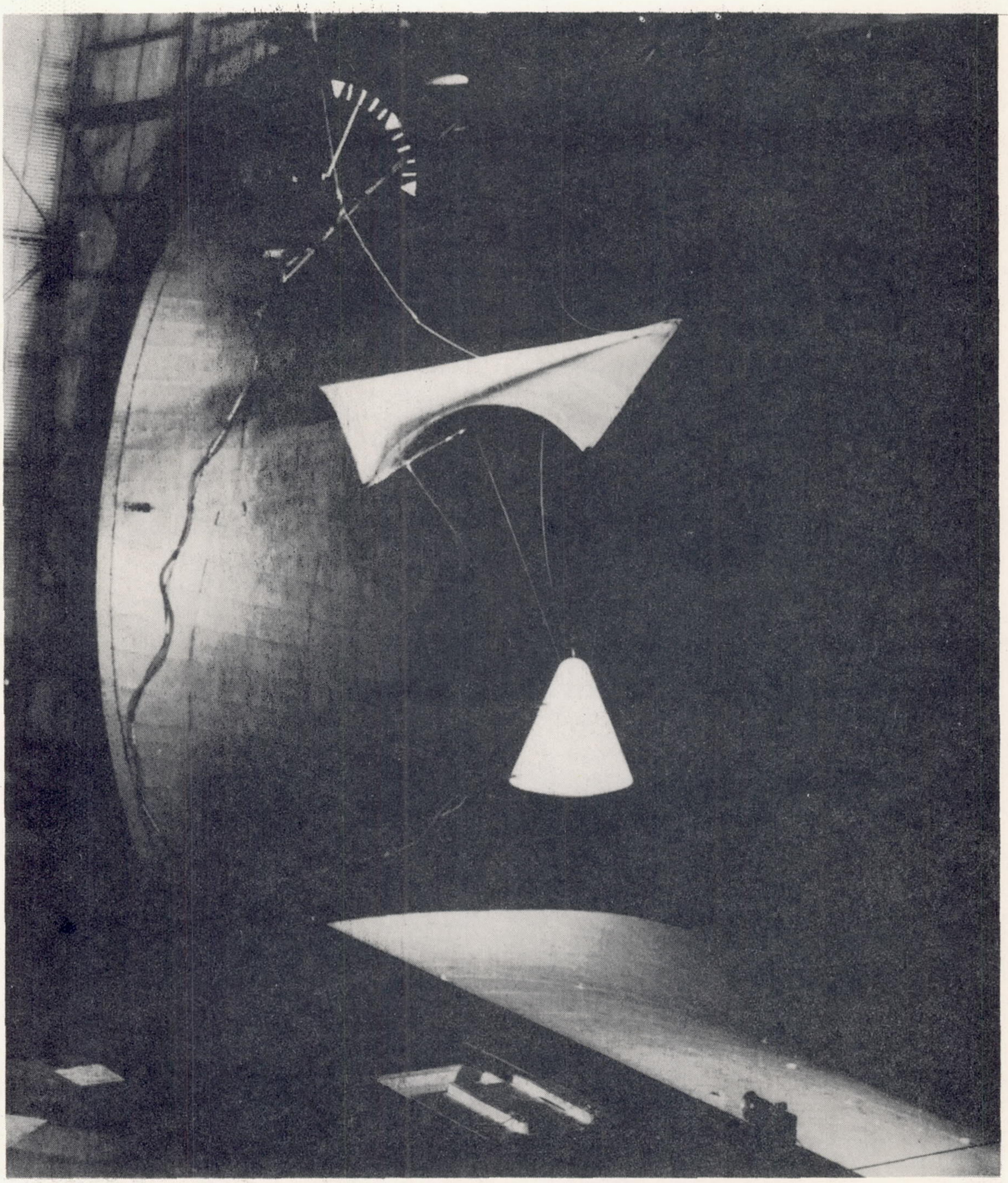

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Figure 4.- Remote-controlled model of a paraglider recovery system for space capsules, shown flying in the Langley full-scale wind tunnel.

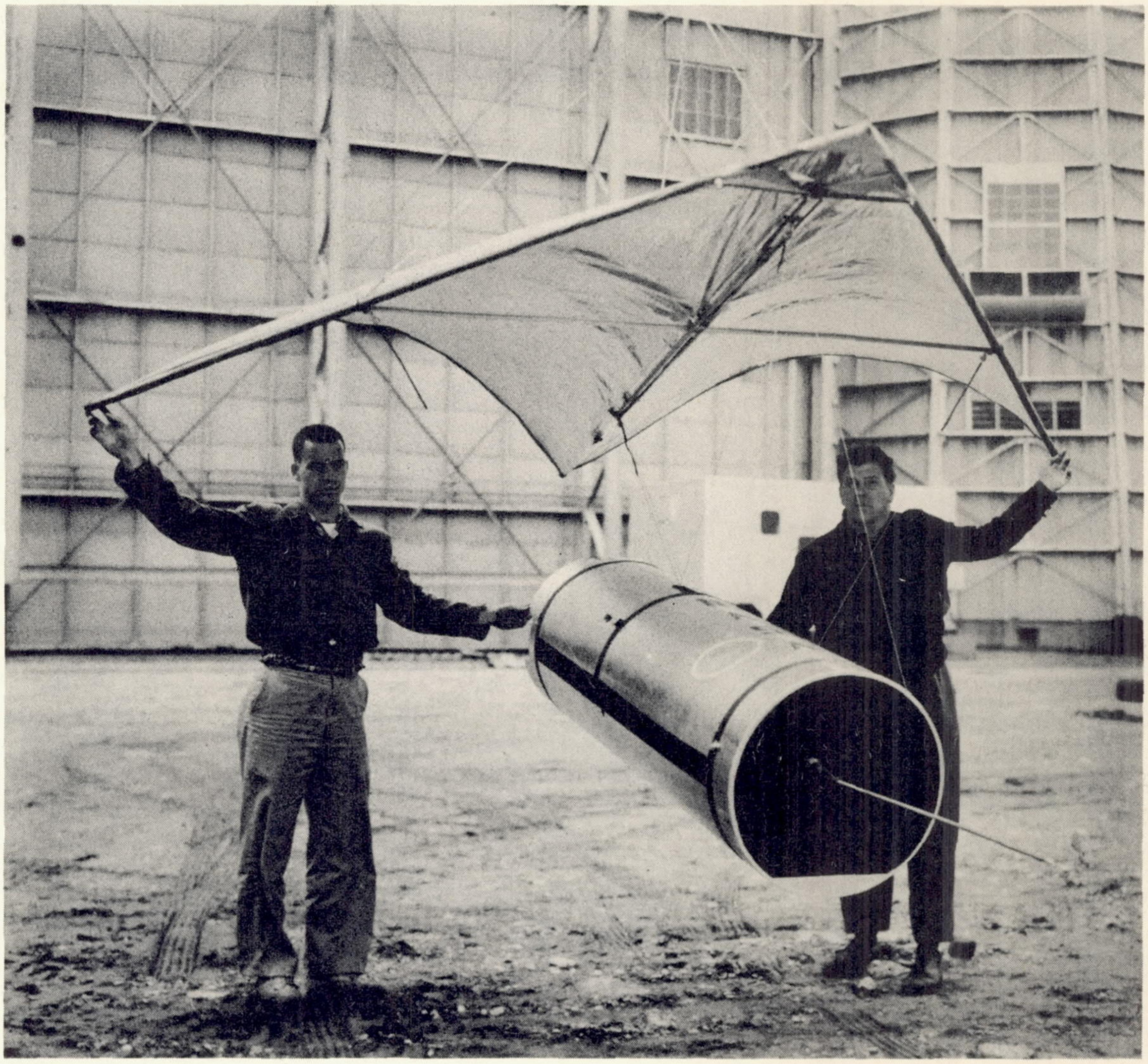

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Figure 5.- Paraglider booster-recovery model that was radio-controlled after drop from a helicopter by the Langley Recovery Systems Branch.

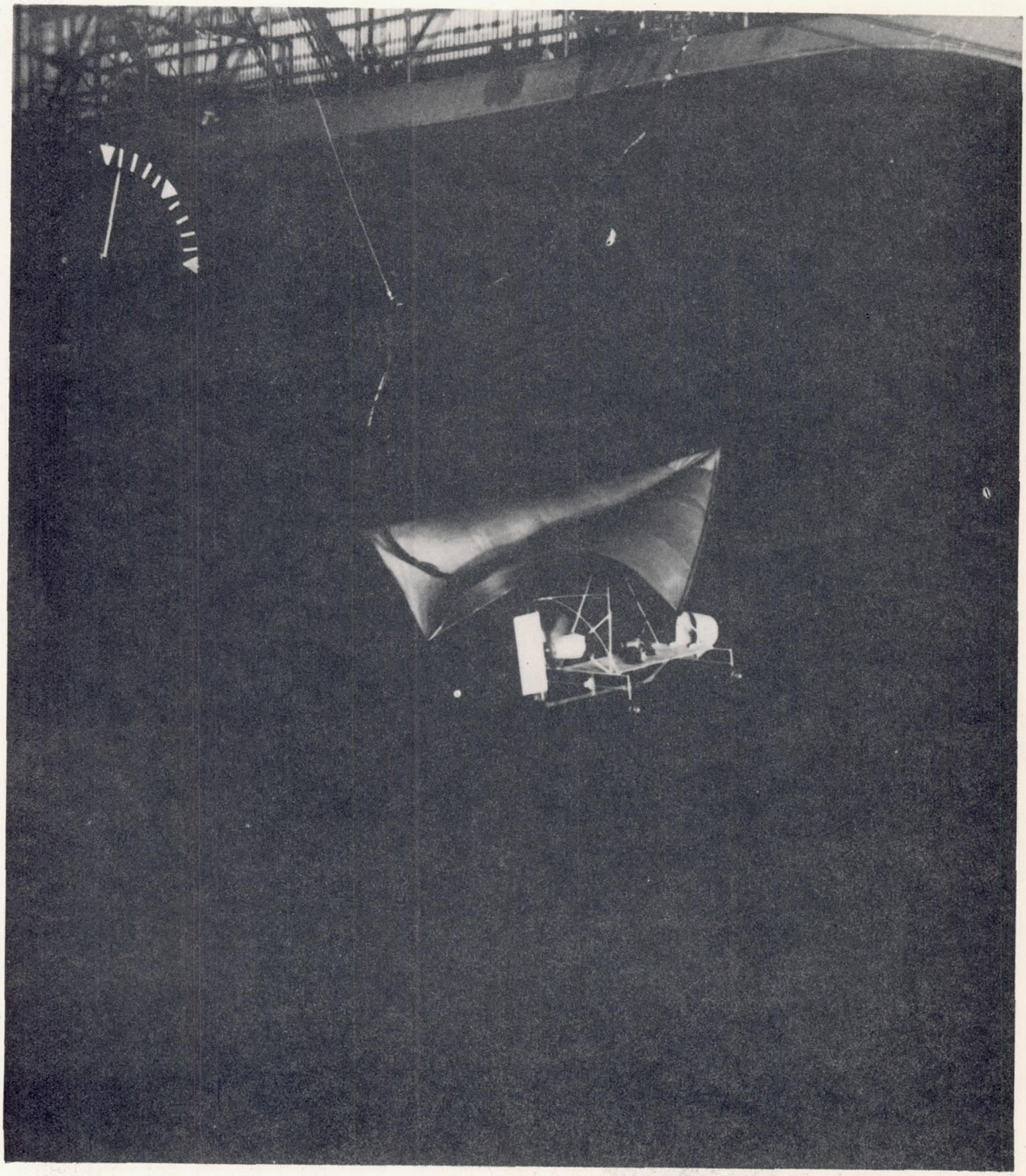

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Figure 6.- Remote-controlled model of a manned flexible-wing vehicle flying the Langley full-scale wind tunnel.

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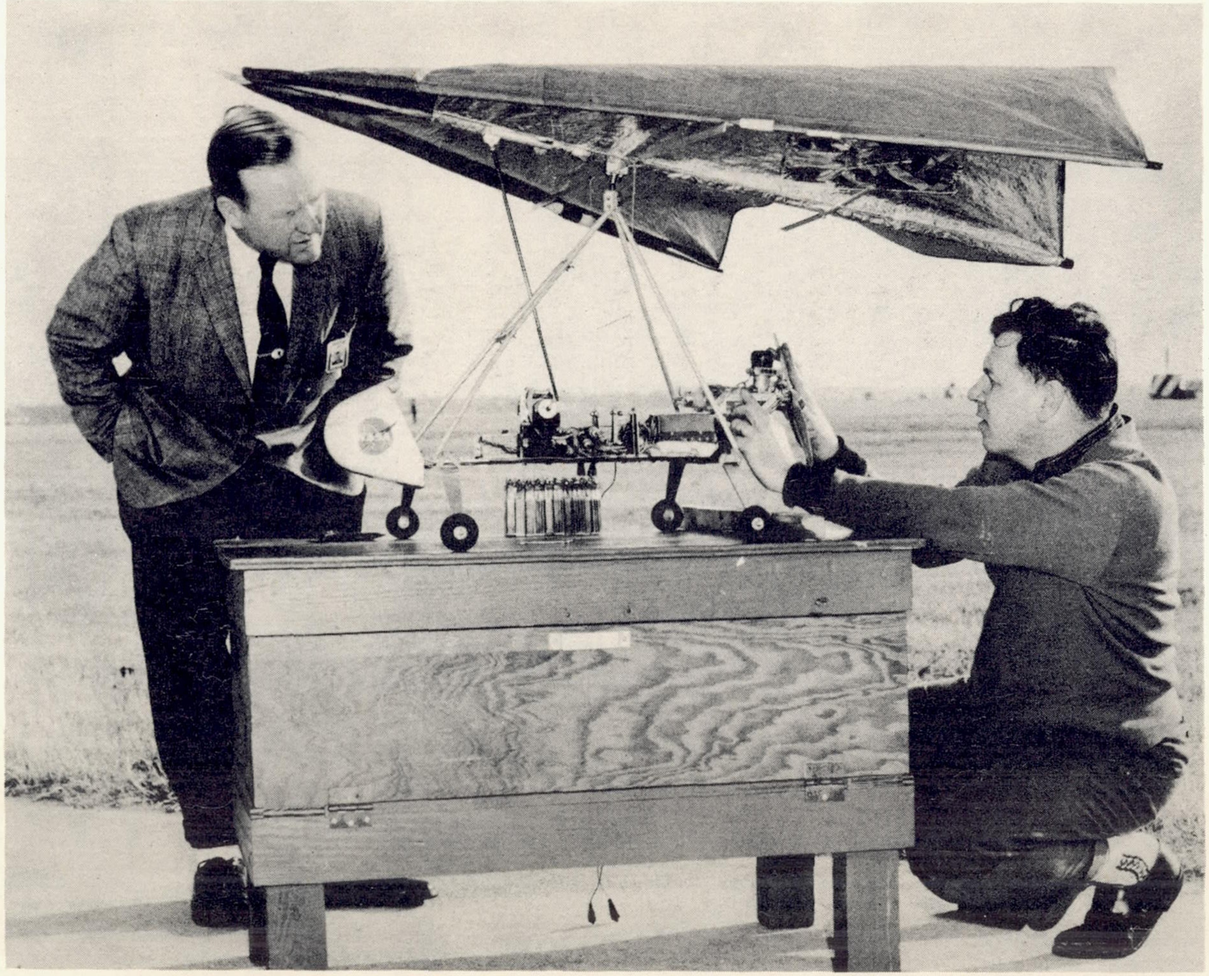

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Figure 7.- Radio-controlled gas-powered model of a manned flexible-wing vehicle being prepared for flight by the Langley Recovery Systems Branch.

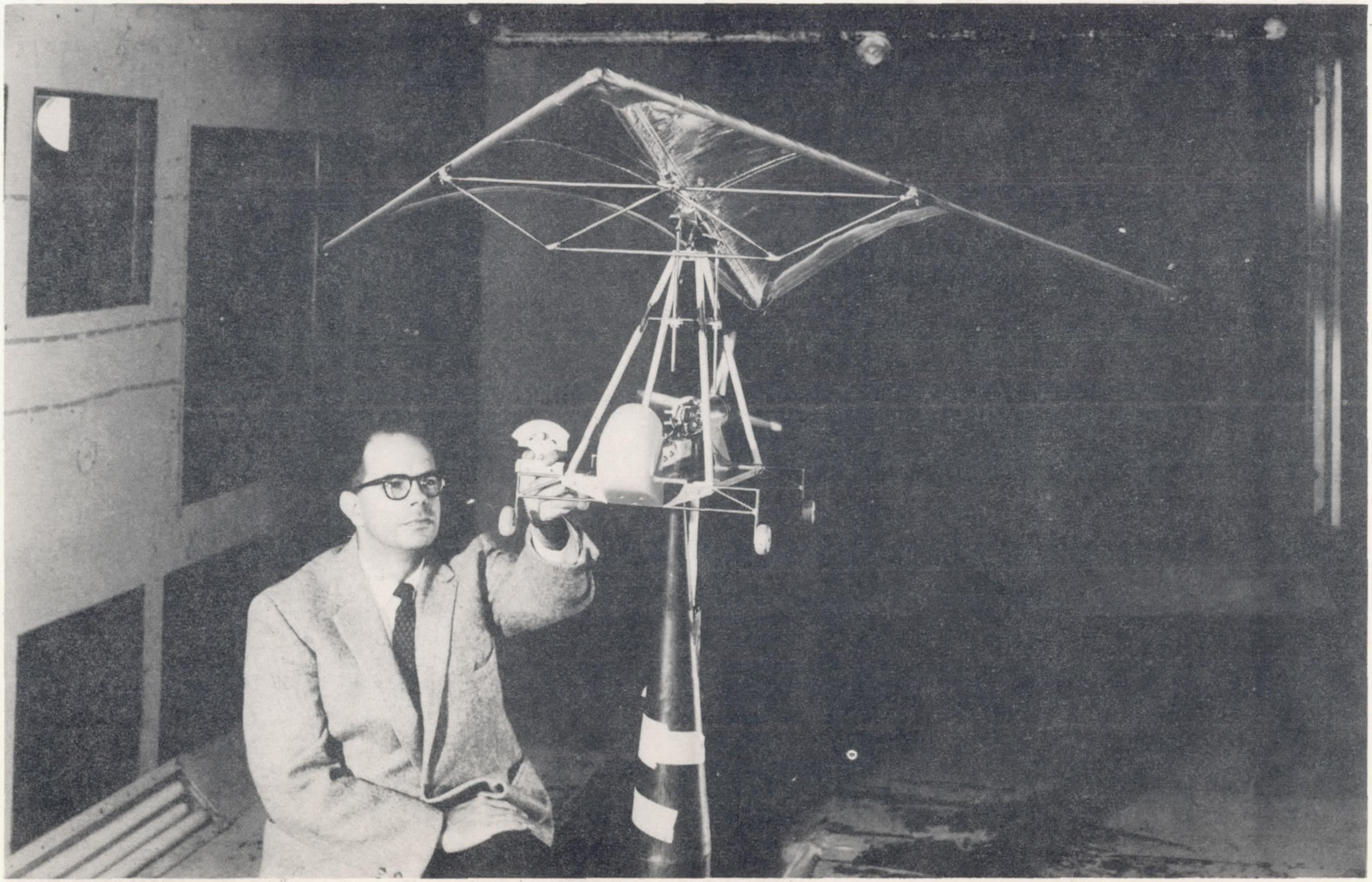

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Figure 8.- Static wind-tunnel model of a manned flexible-wing vehicle in a Langley 7- by 10-foot tunnel.

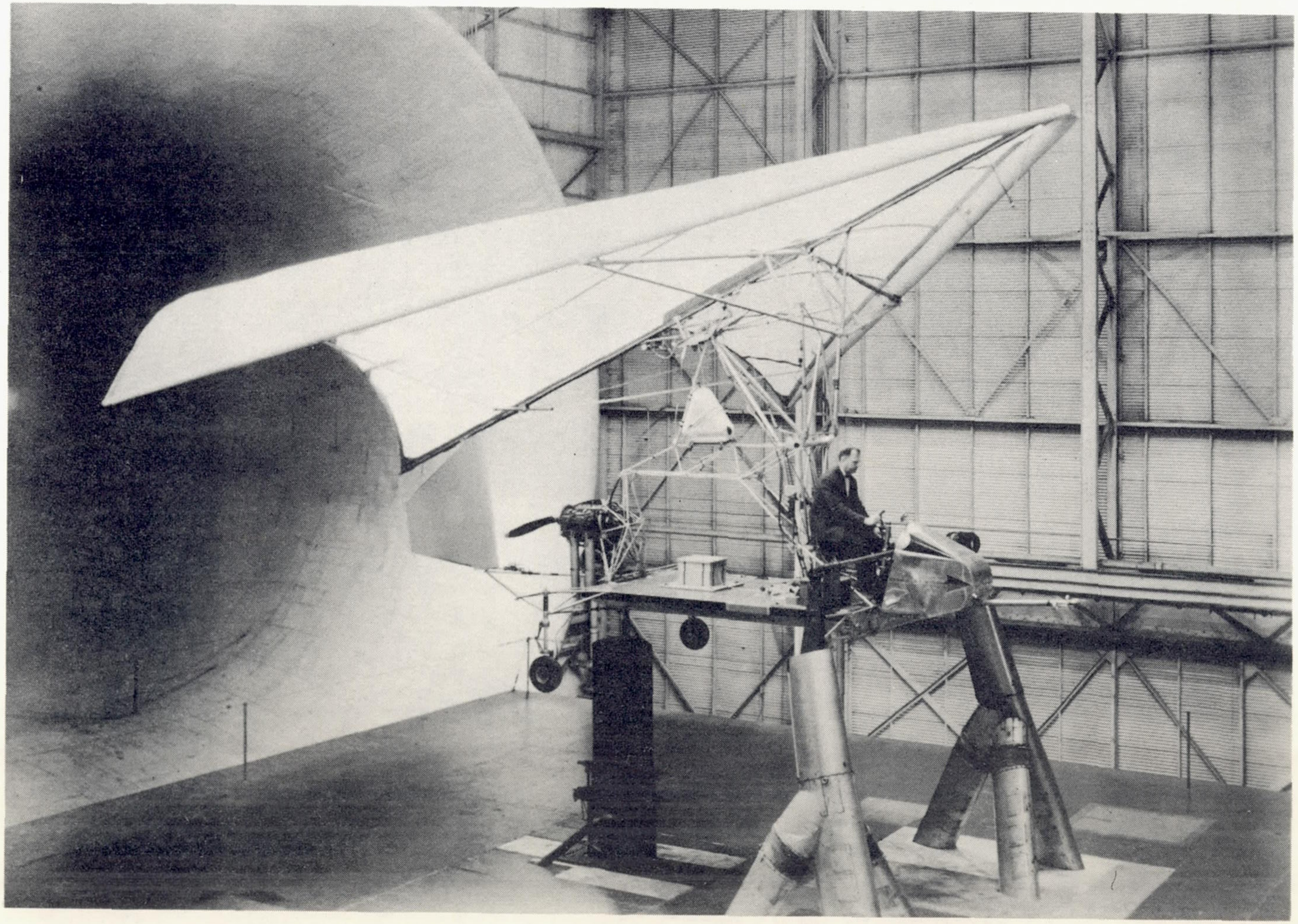

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Figure 9.- Ryan flexible-wing vehicle setup for force tests in the Langley full-scale wind tunnel.

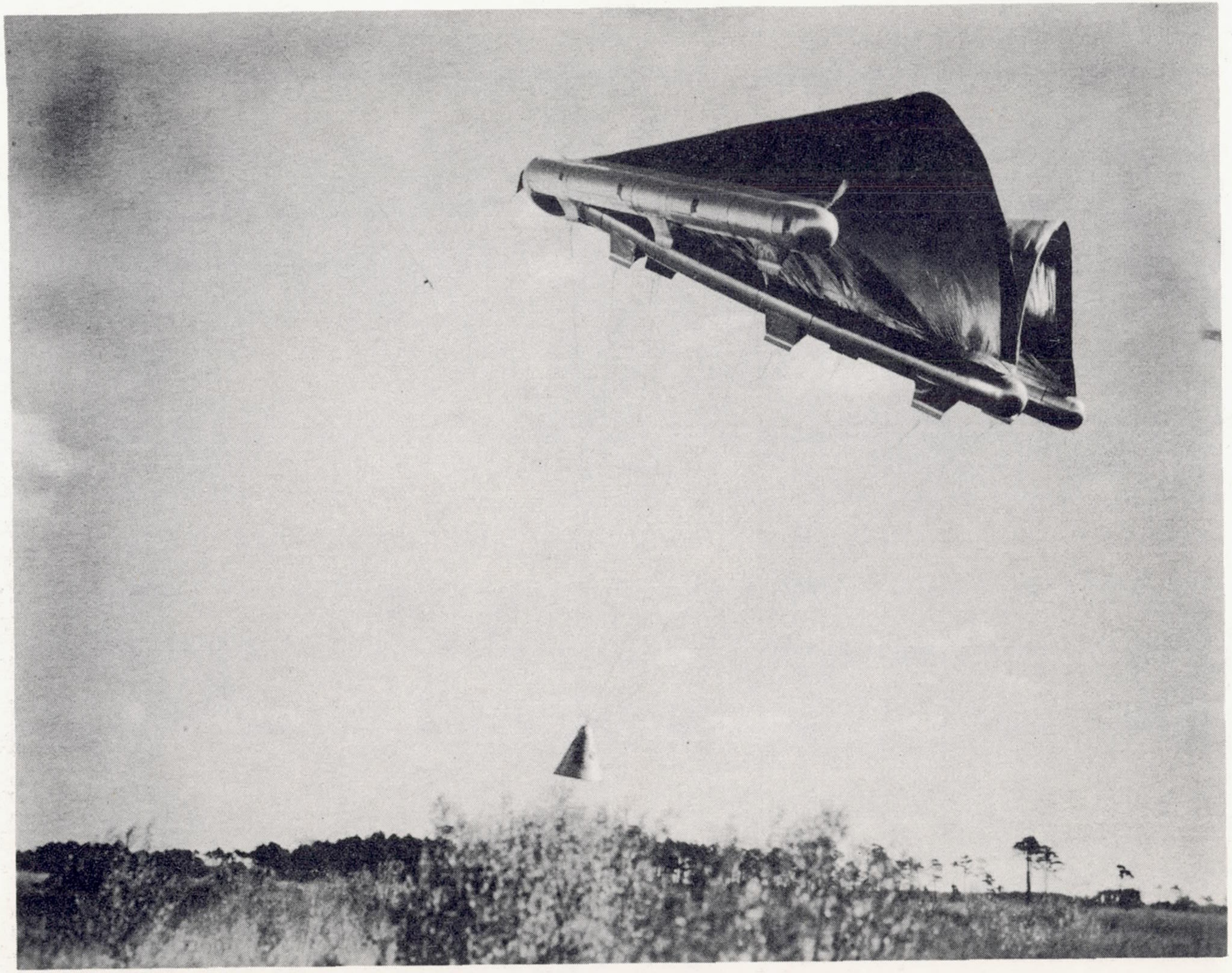

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Figure 10.- Fifty-foot inflated-frame paraglider immediately after lift-off by a helicopter.

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Figure 11.- Paraglider research vehicle built and flown at NASA Flight Research Center, Edwards, California.

1

LOADING CONDITIONS VERSUS TIME OF FLIGHT

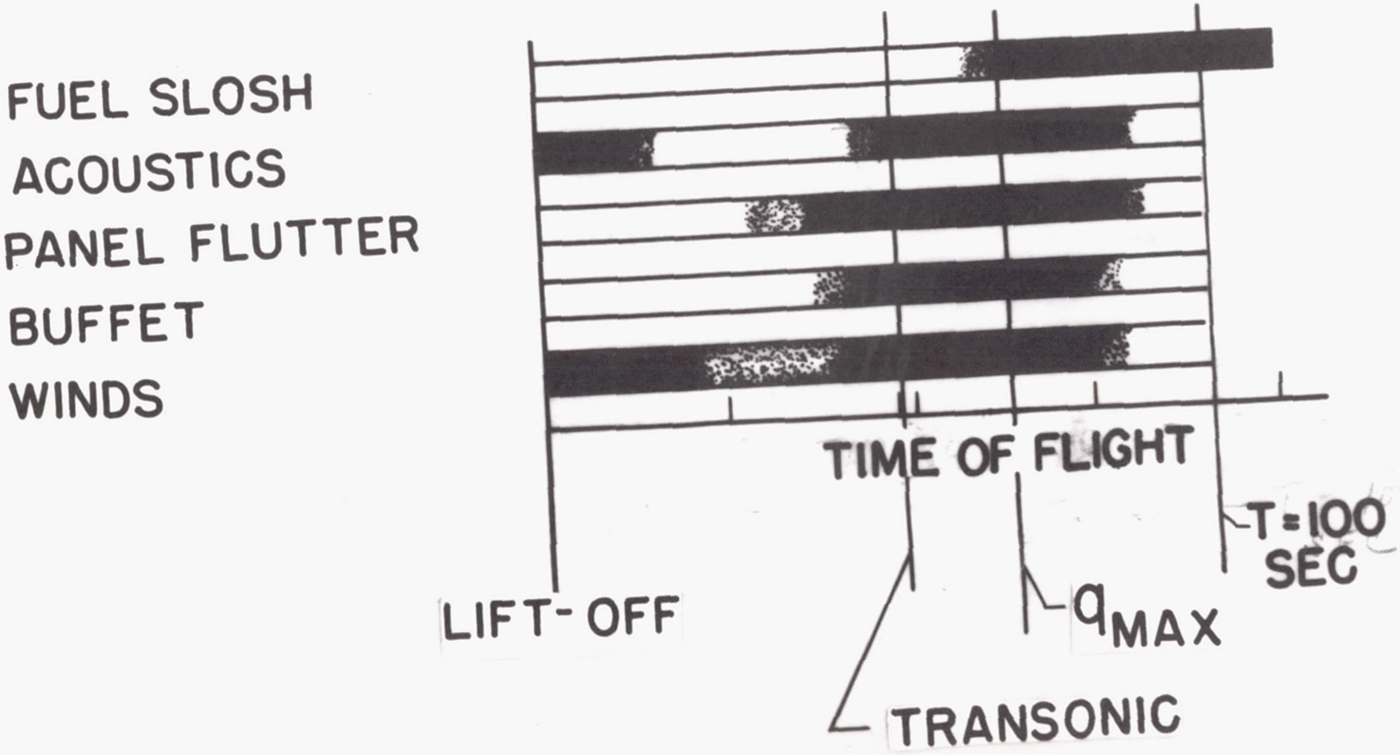

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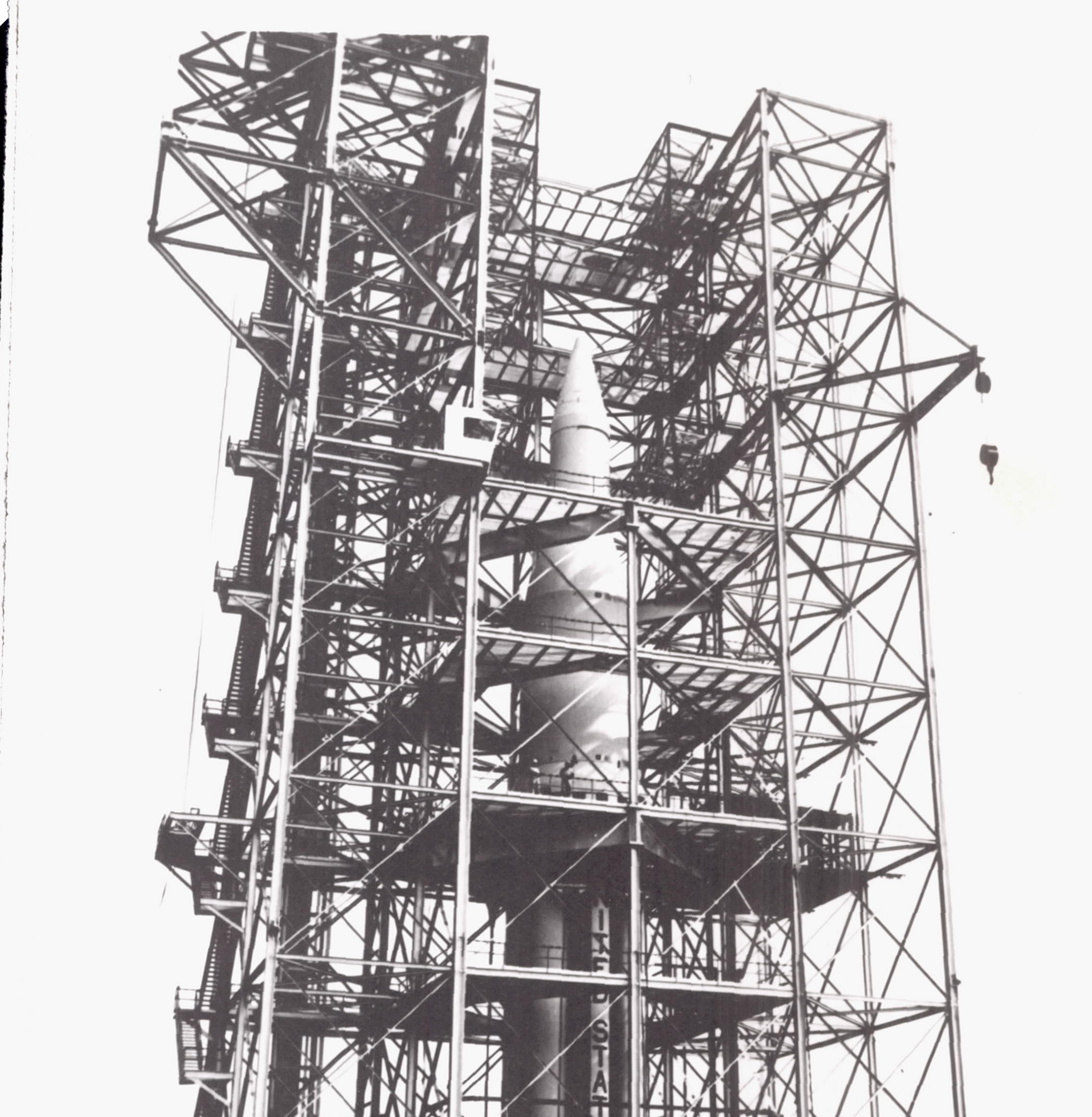
FIG-1 RHODE 4/2-3/62

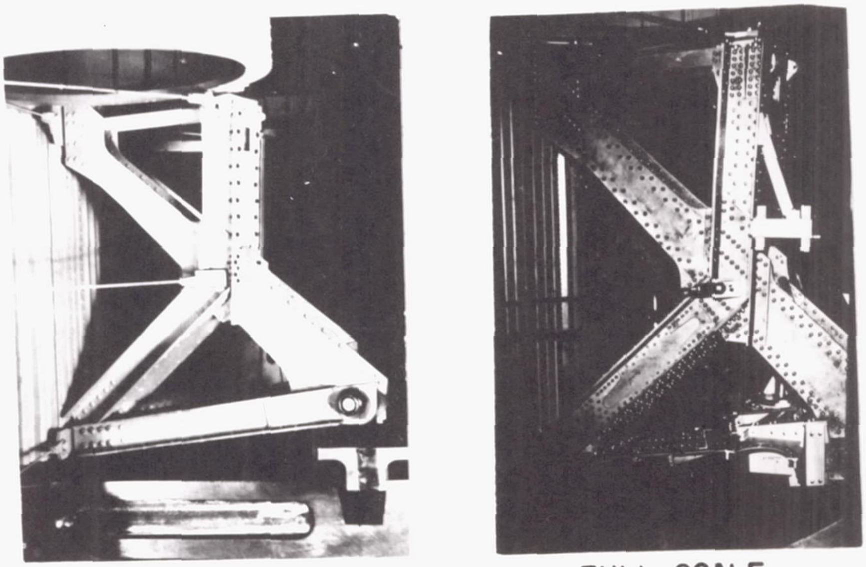
ARS - Phoenix Ariz



8

3.75" X 5.00"

SATURN CONSTRUCTION DETAILS



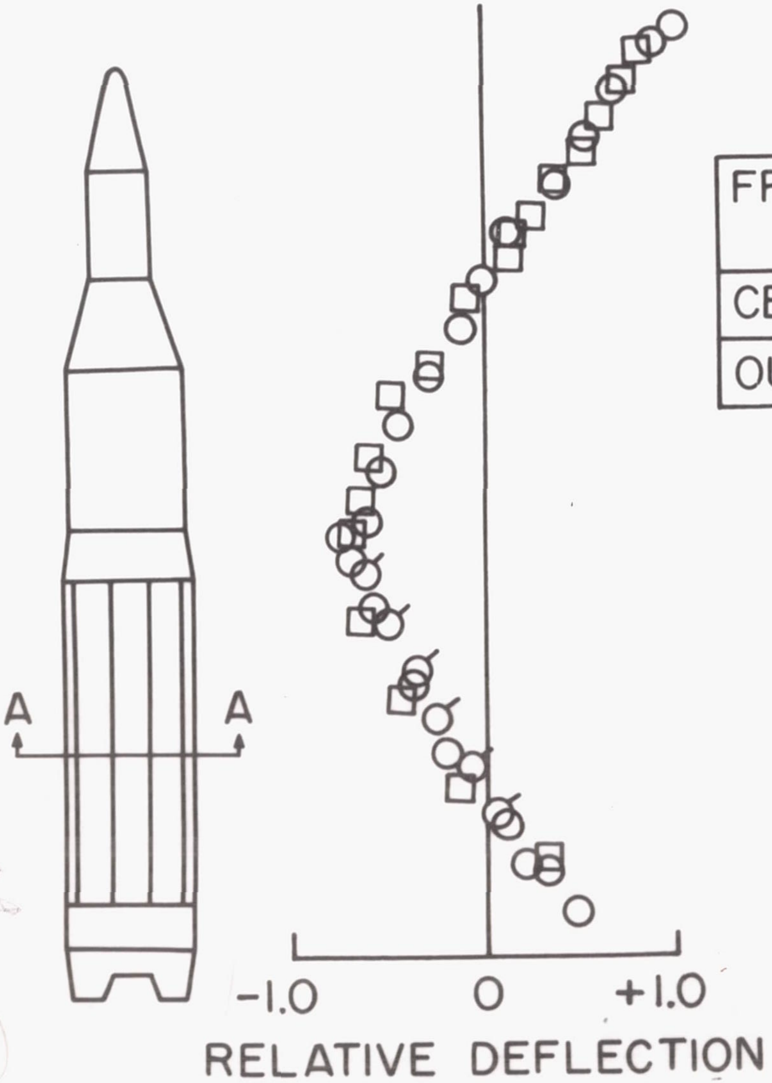
MODEL

FULL SCALE

~~Mixson Fig. 2~~

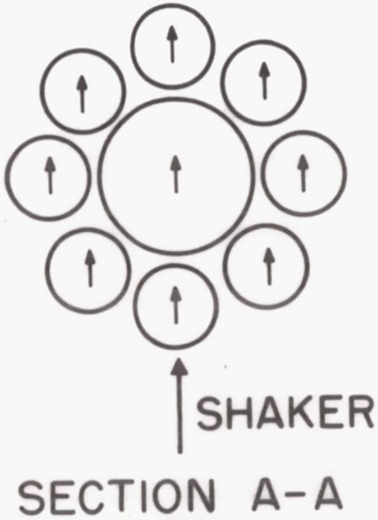
FIRST VIBRATION MODE

MAX Q WEIGHT



	1/5 SCALE MODEL	FULL SCALE (SAD-1)
FREQUENCY, CPS	2.6	2.83
CENTERLINE	○	□
OUTER TANK	σ	

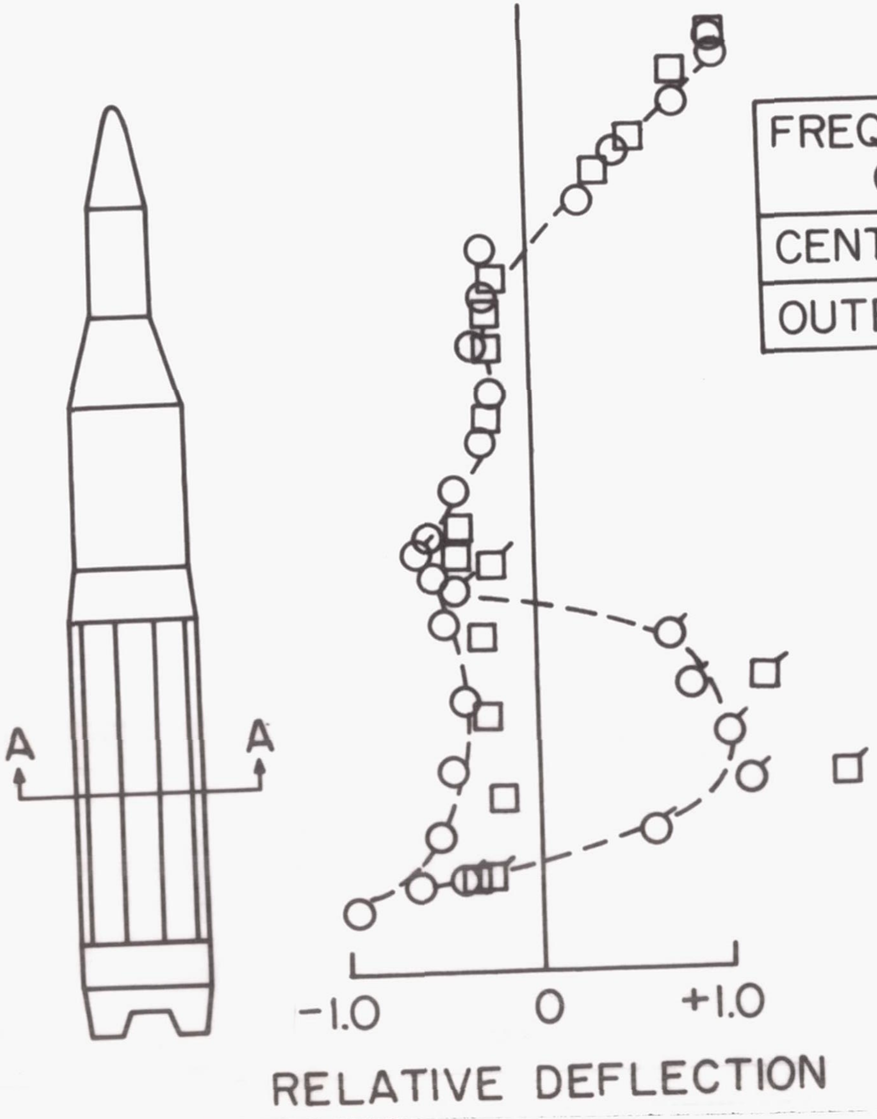
↑ DIRECTION OF MOTION



4

SECOND VIBRATION MODE
MAX Q WEIGHT

	1/5 SCALE MODEL	FULL SCALE (SAD-1)
FREQUENCY, CPS	5.20	5.68
CENTERLINE	○	□
OUTER TANK	○ˊ	□ˊ



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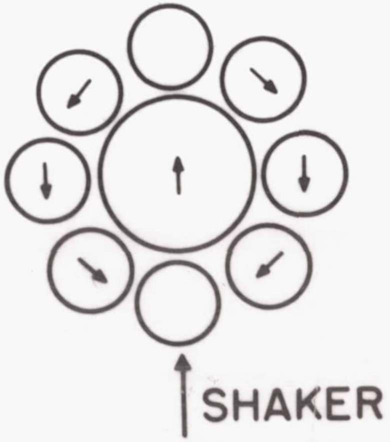
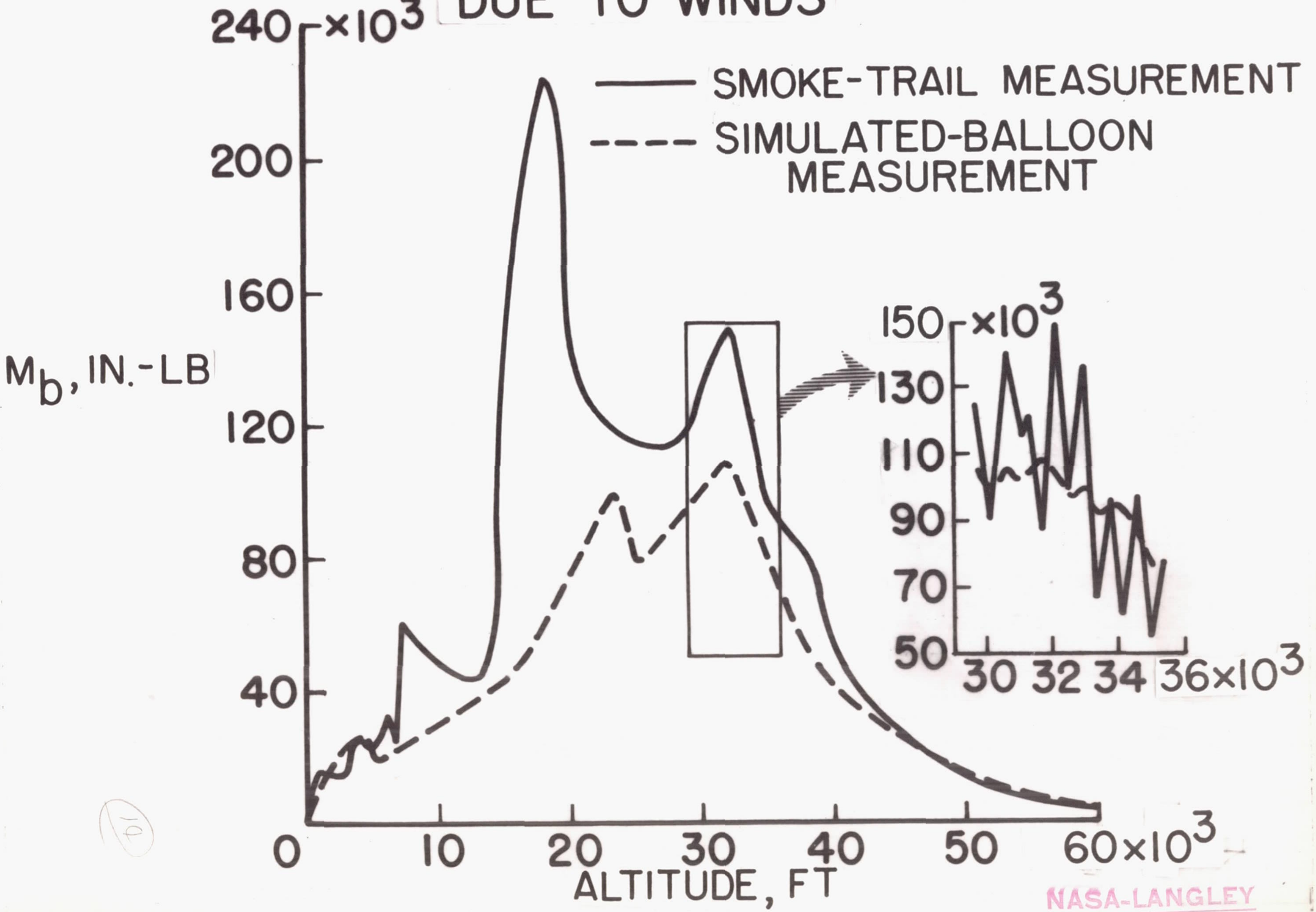


SECTION A-A

BENDING-MOMENT ENVELOPE DUE TO WINDS



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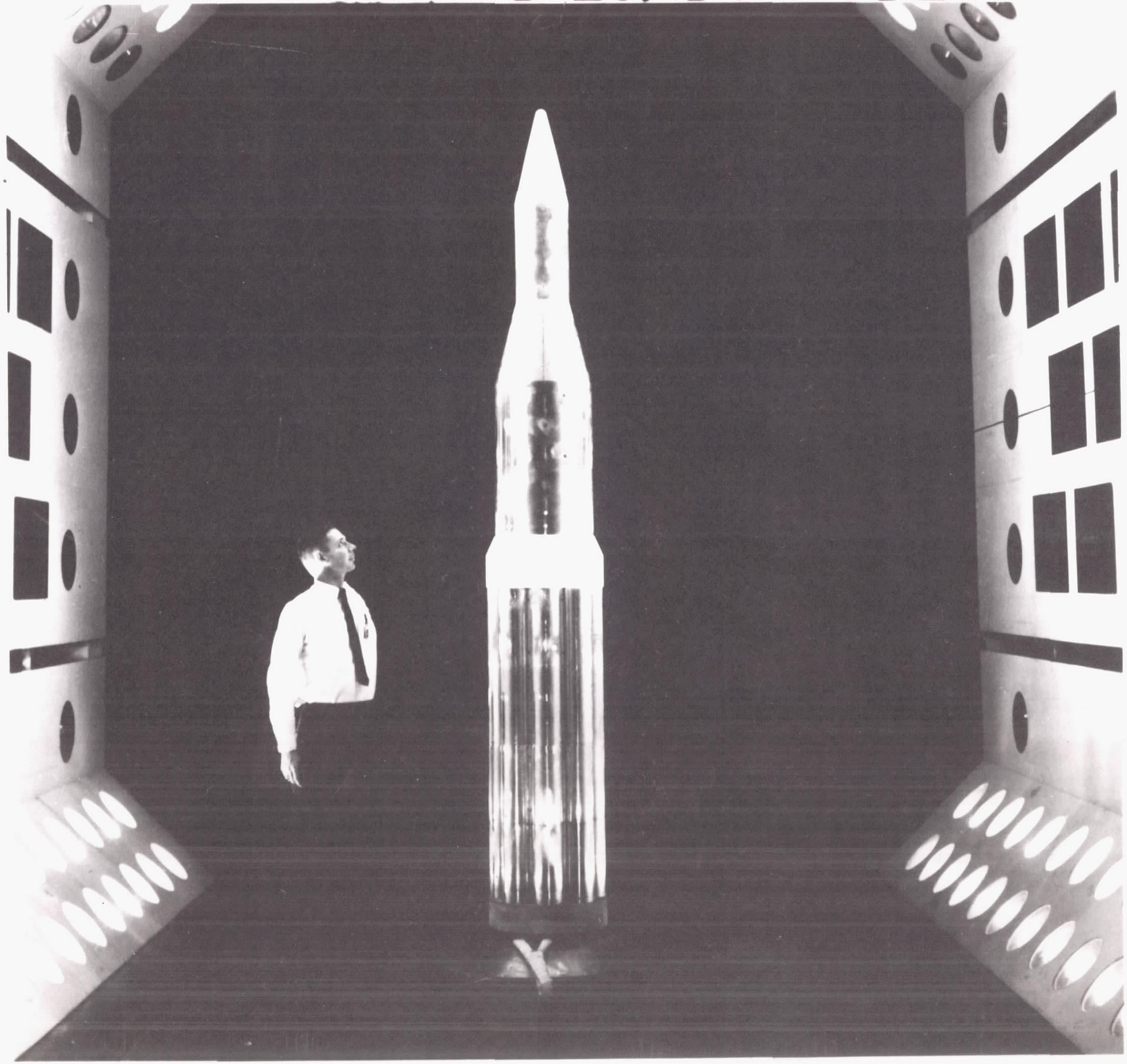
GROUND-WIND-LOADS MODEL



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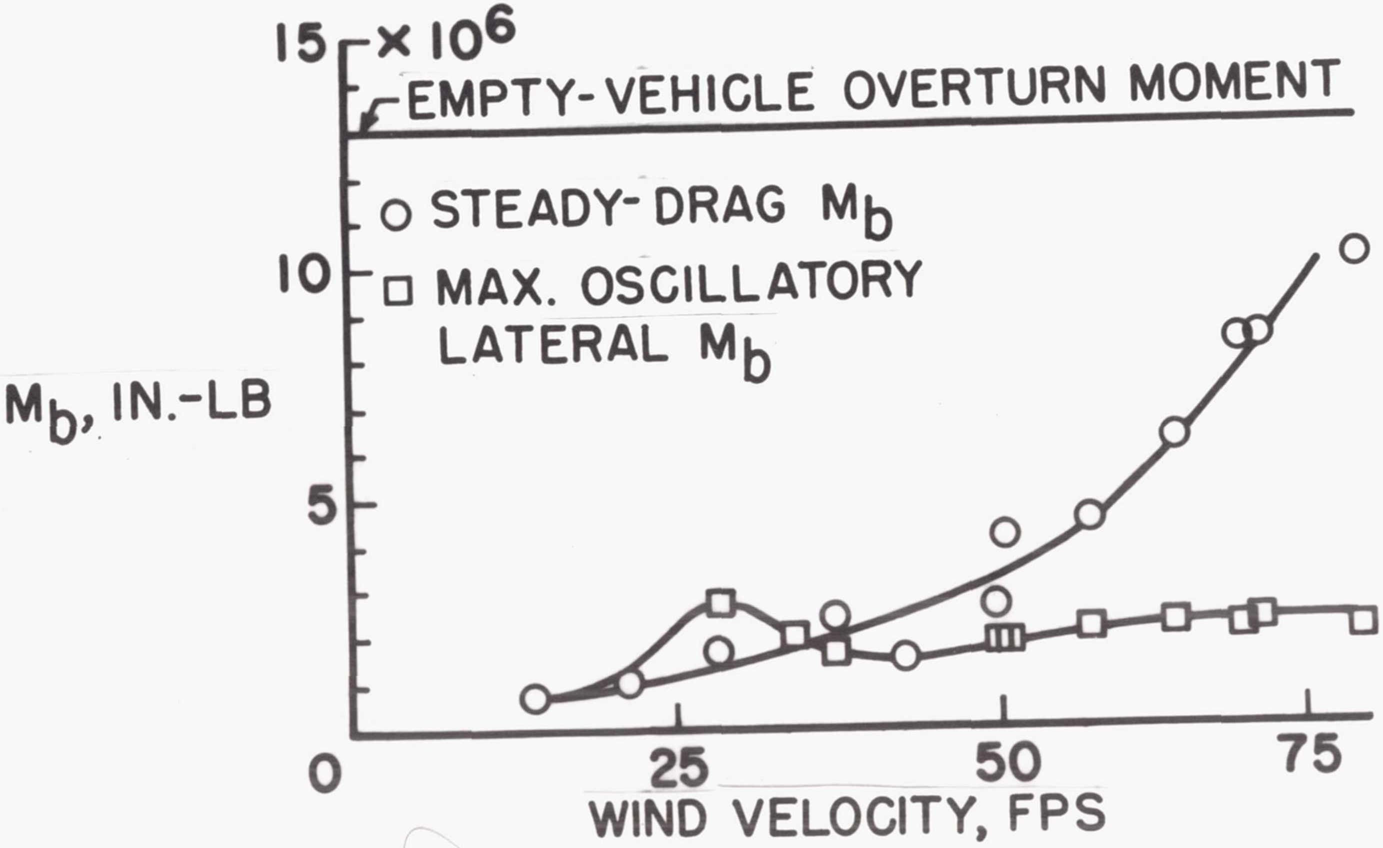
SATURN GROUND-WIND INDUCED LOADS



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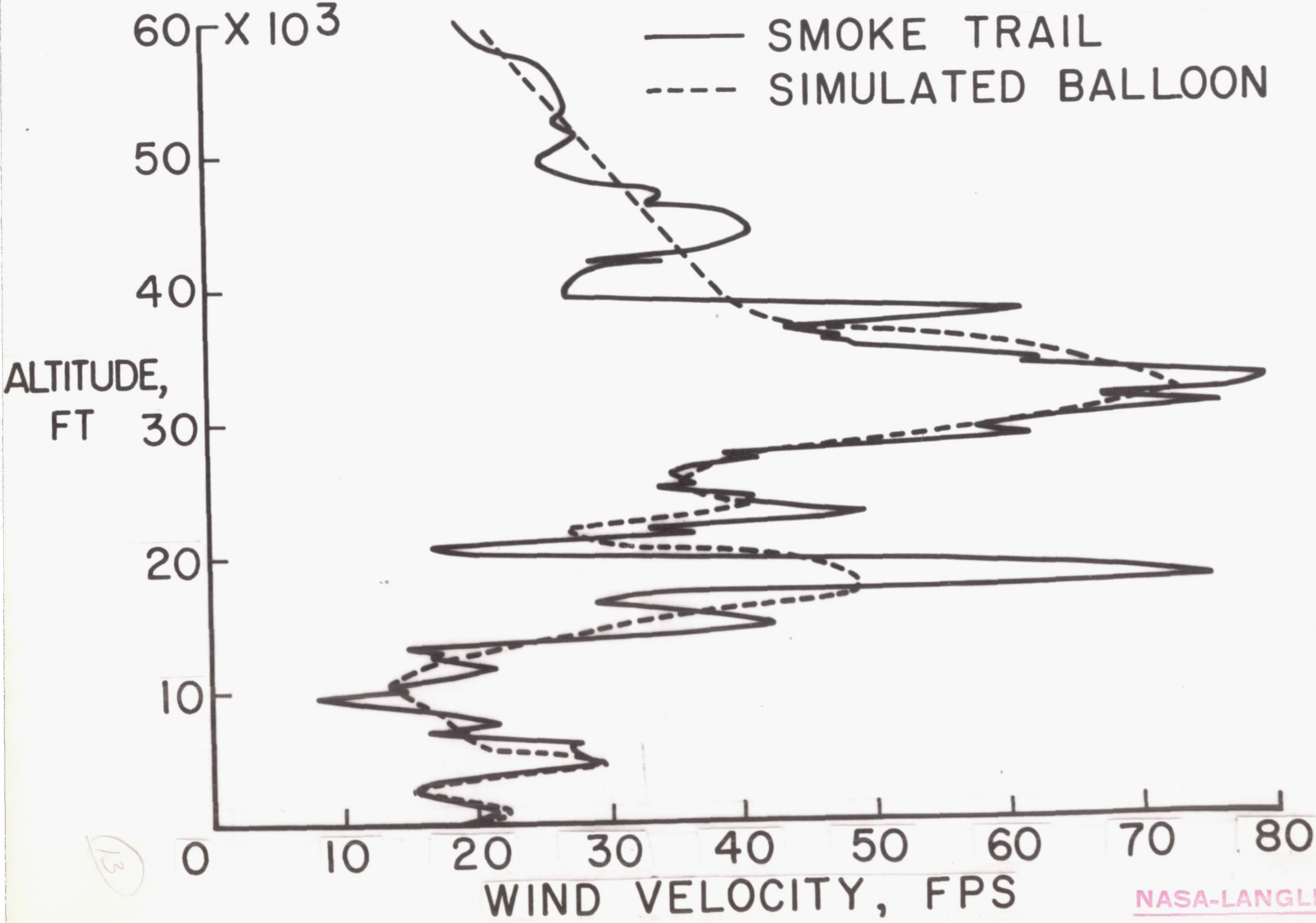
(12)

WIND-VELOCITY MEASUREMENTS



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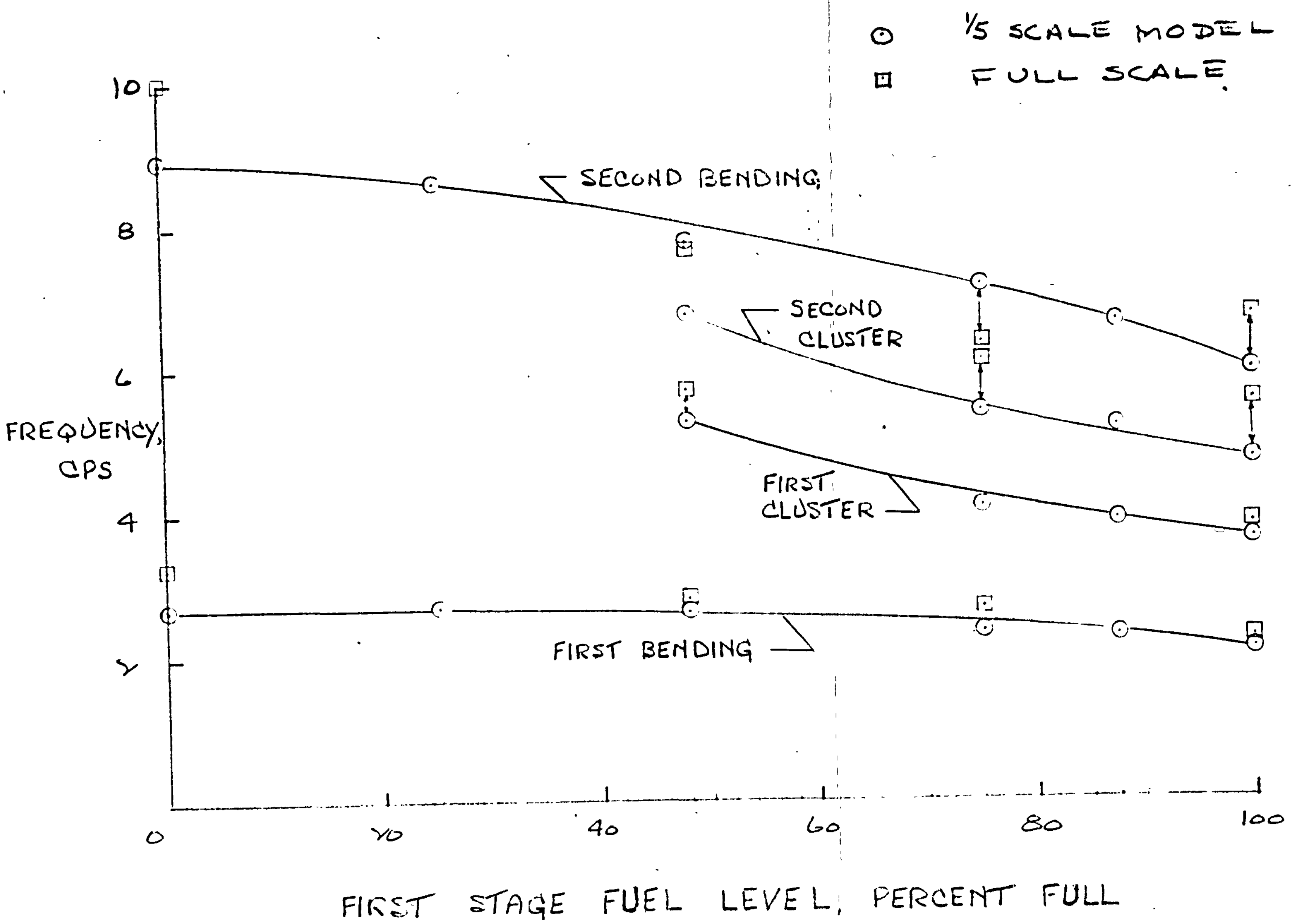
COMPARISON OF MODEL AND FULL SCALE FREQUENCIES



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RAINEY

NASA-LANGLEY

RLH-000

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and other
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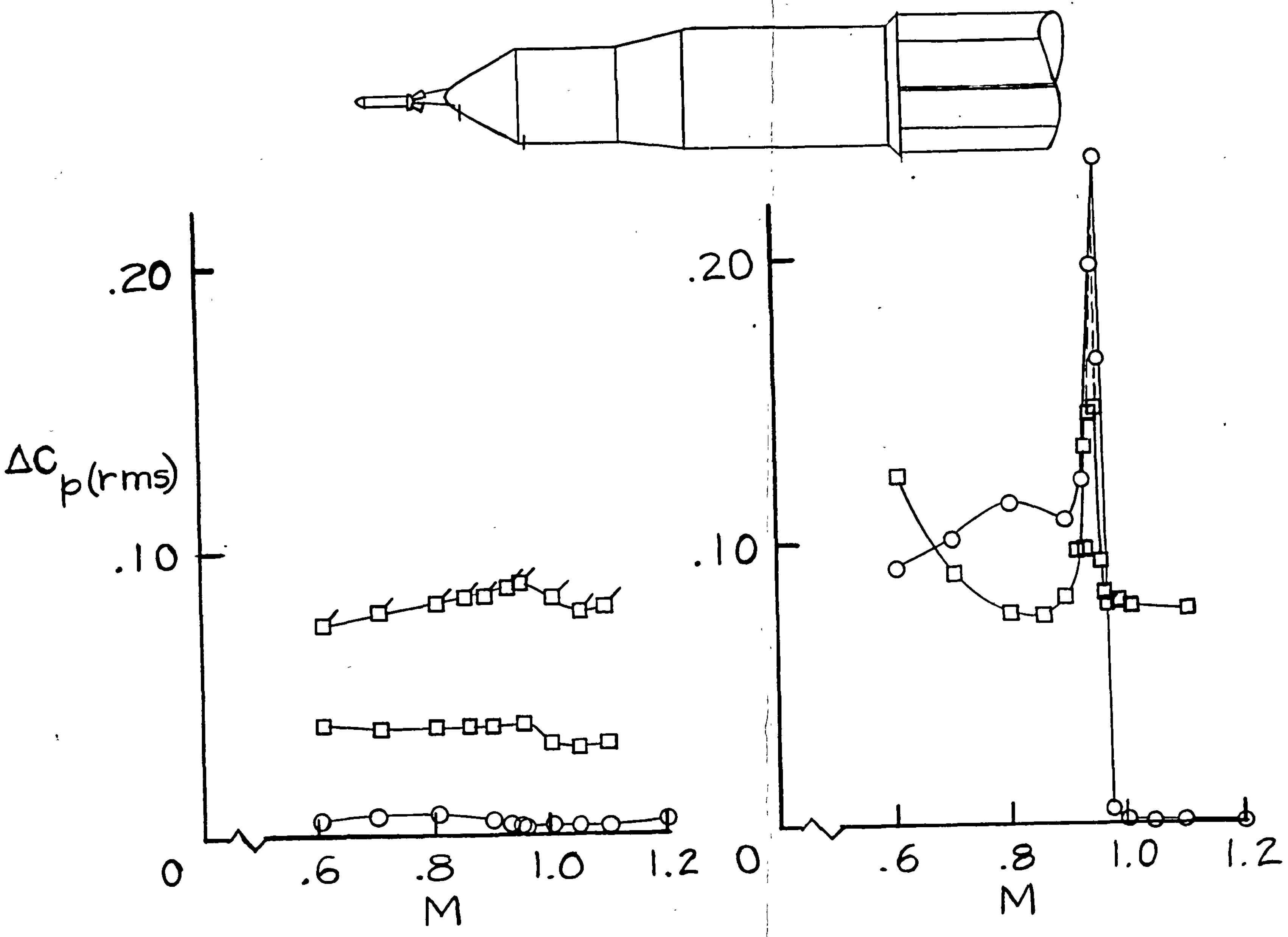
for title



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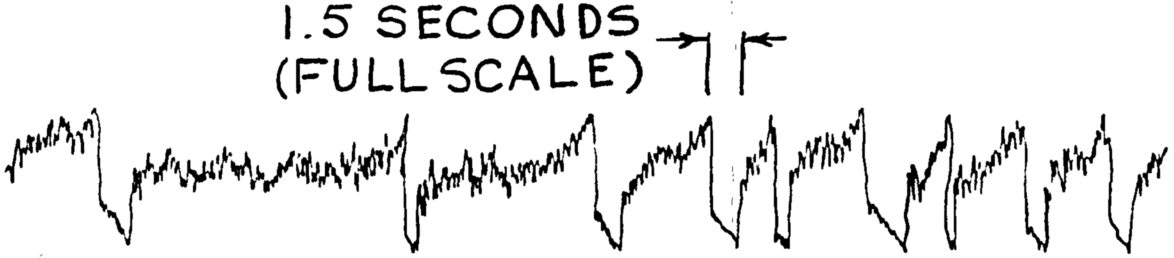
Title to be added

8-PERCENT MODEL IN FREON



1.6-PERCENT MODEL IN FREON

(8)

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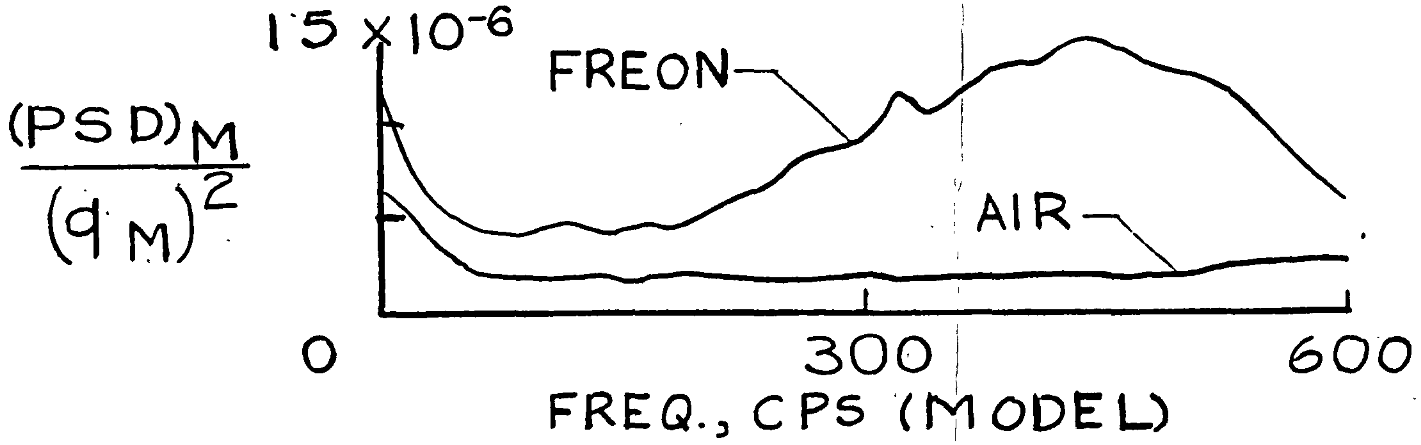
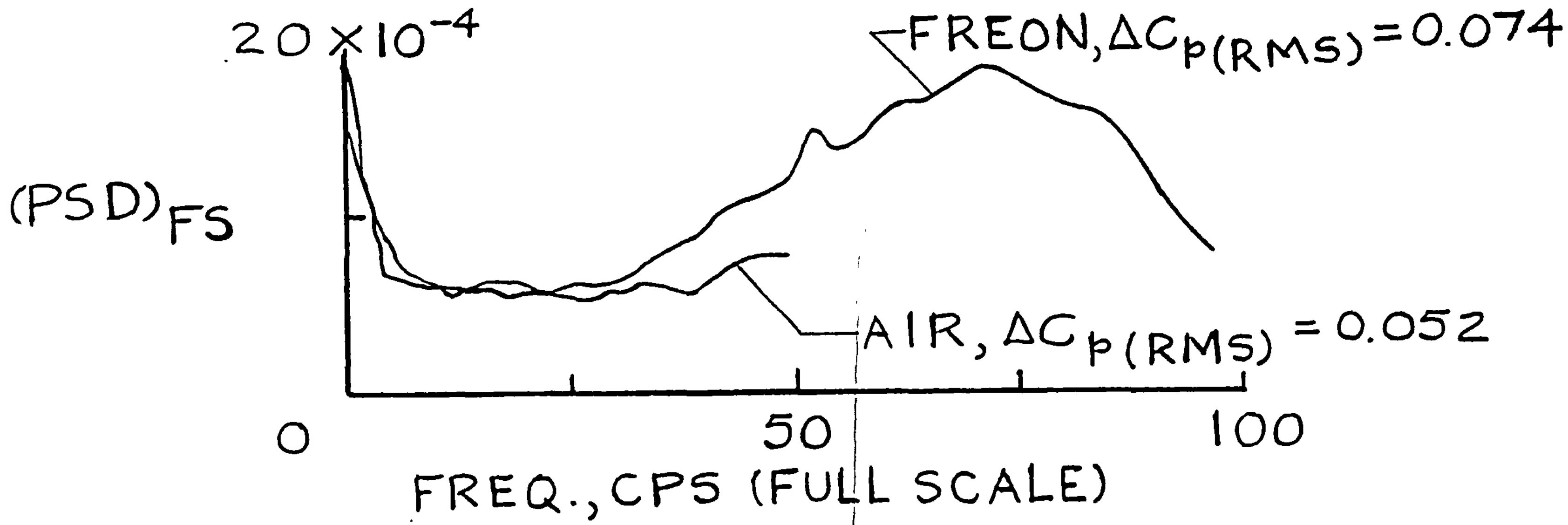
title to be added



$$(PSD)_{FS} = (PSD)_M \left(\frac{q_{FS}}{q_M}\right)^2 \left(\frac{D_{FS}}{D_M}\right) \left(\frac{V_M}{V_{FS}}\right) ; \quad f_{FS} = f_M \left(\frac{D_M}{D_{FS}}\right) \left(\frac{V_{FS}}{V_M}\right)$$



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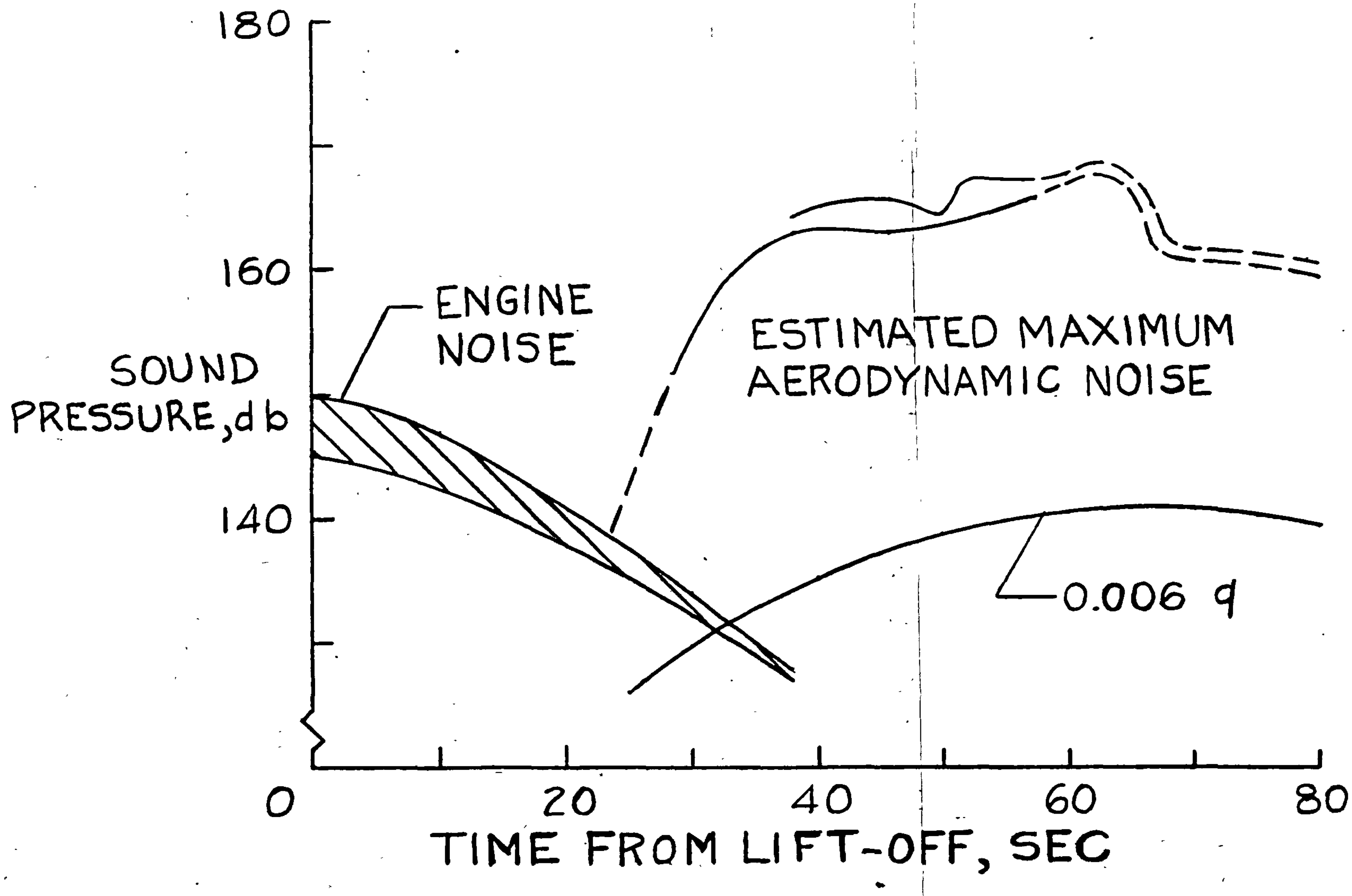

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