FACILITY FORM 602

N65-19866
(ACCESSION NUMBER)

22
(PAGES)

CR-57472
(NASA CR OR TMX OR AD NUMBER)

1
(THRU)

(CODE)

32
(CATEGORY)

[redacted]

GPO PRICE $ ______

OTS PRICE(S) $ ______

Hard copy (HC) $1.00

Microfiche (MF) $0.50

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

Rq A 27424

No. 63-434

AERODYNAMIC FACILITIES

SECTION 373

Internal Memorandum CP-5

EXPERIMENTAL DATA ON WIND-INDUCED VIBRATIONS OF A PARABOLOIDAL REFLECTOR ANTENNA MODEL

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January, 1963

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ABSTRACT

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The steady-wind induced oscillations of a series of simplified models of a paraboloidal reflector antenna, located adjacent to a ground plane, have been recorded. The models, designed primarily for steady-state wind load measurement, consisted essentially of a single lumped-parameter system. The data are in the form of oscillograph recordings of the three moments in the support staff, at approximately the ground-plane level, and were obtained over the range of reflector azimuth and elevation angles for several reflector-surface geometries. This Memorandum presents samples of the data and the descriptions and calibrations necessary for further analysis. The complete original data will be made available for inspection on request.

AUTHOR

I. INTRODUCTION

A number of large paraboloidal reflector antennas have been designed and built and are providing satisfactory operation. The possibility of wind-induced vibrations or oscillations arises in the design of such installations. Although very little design information on this subject has come to the author's attention, experience indicates that this phenomenon is not a major problem on existing installations.

Wind-induced vibrations on paraboloidal reflector antenna installations may be categorized into three types:

1. Independent (although possibly coupled) transverse vibration of one or more individual structural members in a steady wind.

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2. The response of a major portion or the complete structure to wind gusts.

3. Vibration of major portions of the installation in a steady wind.

While each type of vibration may be attributed to a different aerodynamic phenomenon, the first usually occurs under different weather conditions than the latter two.

Several existing installations have reported problems attributed to the first category. Vibration of the structural members usually occurs in mild, steady winds and leads to the description of a "singing" structure. Such vibrations are the result of the periodic shedding of vortices at relatively low Reynolds numbers. This phenomenon is most pronounced on round cross-section members and has not been reported as a problem on structural channels, I's or T's. Any resulting damage appears to occur as fatigue failures at the column end attachments. Several published papers (e.g., Ref. 1) report investigations of the cause of this type of vibration and present correlations of the results which should be adequate for engineering design use.

In order to design a structure for wind gust loads, three types of information are needed:

a. The velocity magnitude, direction, relative scale size, and frequency of the gusts must be estimated. These gusts are usually superimposed upon steady winds and are somewhat random in nature. Local terrain features, such as mountains, may exert a great influence on the nature of the gusts.

A limited amount of published experimental information, mostly for flat, uniform terrain, is available.

b. The forces on the structure resulting from these gusts must be estimated. Some evidence is available to indicate that this relationship may not be identical to that of forces due to steady winds. However, to date, no established techniques are available for making reduced-scale tests of this relationship.

c. The response of a structure to such nonsteady forces is primarily a structural problem, particularly with regard to natural frequency and internal damping. Rather lengthy mathematical methods are yielding some results.

Problems in this second category have arisen with bridge structures, as summarized in Ref. 2.

It has been demonstrated in aircraft and missile aerodynamics that smooth, steady winds can, in some circumstances, produce significant oscillatory loads. The experimental data described in this Memorandum fall into category 3.

These data were obtained as a by-product of a wind-tunnel test planned to obtain data on the steady loads produced by wind. No attempt was made to follow the customary dynamic model-similarity laws. Because of this fact, and the labor involved in working with oscillograph-recorded dynamic data, the material has received little more than a cursory examination. No other equally applicable data have come to the author's attention. This Memorandum presents descriptions, calibrations, and samples of the material for further evaluation of the results.

II. TEST DESCRIPTION

Reference 3 briefly describes the wind-tunnel facility, model configurations tested, types of data obtained, and nomenclature used. All models consisted of 18-in. aperture diameter paraboloidal reflectors, spin-formed from 1/8-in. sheet copper. These reflectors were mounted on the permanently installed wind-tunnel balance by means of a segmented-wheel pitch mechanism and a round steel staff. The top member of this balance, a cast-iron channel section, was estimated to weigh 2000 lb and therefore was considered a rigid fixed base.

Figure 1 shows a typical model, as mounted in the wind tunnel ready for testing. The tubular windshield surrounding the round support staff is mounted to the tunnel floor, physically isolated from the model components. Figures 2 and 3 show a model and its mounting components in the absence of the windshield and tunnel floor and present some typical dimensions.

The dynamic data obtained consisted of the two bending and one torsional moments in the support staff. Figure 2 shows the strain gages from which the data were obtained and their locations. The output from these three sets of gages was recorded directly on a CEC oscillograph for a 3-sec interval for approximately half the combinations of model attitude and configuration otherwise tested.

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All dynamic load data were obtained at a tunnel dynamic pressure of 95 lb/ft^2, corresponding to an air speed of 282 ft/sec. The tunnel operated at approximately sea-level standard conditions, yielding a Reynolds number based on the antenna aperture diameter of 2.7×10^6.

Calibrations of the oscillograph trace deflections were obtained by comparing their time-average values with the loads obtained concurrently from the external balance. The external balance results were transferred appropriately, and a three-dimensional RMS linear curve fit was used to evaluate the comparisons. Identifying the deflections (in millimeters) of the three (sometimes concurrent) traces on the oscillograph records as top (T), middle (M), and bottom (B) under no-wind-load conditions, the curve fit showed the responses to pitch moment (P), roll moment (R), and yaw moment (Y) to be as tabulated below:

$$\frac{\partial P}{\partial B} = -24.7 \text{ in.-lb/mm*}$$

$$\frac{\partial P}{\partial M} = +4.8 \text{ in.-lb/mm}$$

$$\frac{\partial P}{\partial T} = +11.3 \text{ in.-lb/mm}$$

$$\frac{\partial R}{\partial B} = +0.1 \text{ in.-lb/mm}$$

$$\frac{\partial R}{\partial M} = +32.3 \text{ in.lb/mm*}$$

$$\frac{\partial R}{\partial T} = -19.4 \text{ in.-lb/mm}$$

$$\frac{\partial Y}{\partial B} = +\ 2.0 \text{ in.-lb/mm}$$

$$\frac{\partial Y}{\partial M} = +\ 3.5 \text{ in.-lb/mm}$$

$$\frac{\partial Y}{\partial T} = -\ 2.17 \text{ in.-lb/mm*}$$

where the moments (in in.-lb model scale) are defined about the center of the support shaft, 9.41 in. below the antenna elevation center of rotation (1.15 in. above the physical tunnel floor). The values marked with an asterisk (*) were used for the sample data presented in this Memorandum; the meaning of the other values will be discussed later.

The natural frequency and damping of the model under no-wind-load conditions were recorded by "twanging" the model. Figures 4 through 8 summarize this model calibration obtained only for a single configuration at 0- and 90-deg elevation angles. Yaw moment data are presented for zero elevation angle only; trace calibration interactions and, possibly, energy transfers make the remaining traces practically impossible to analyze.

III. DISCUSSION

As indicated previously, the purpose of this Memorandum is to point out the existence of a particular set of experimental data and to provide the descriptions necessary for further evaluation. The applicability of these data to any particular installation is left to the reader's judgment. During the test, the wind-tunnel model was observed to vibrate on the order of 1 in. at the reflector edges in several angular attitudes.

Because of the by-product nature of this phase of the wind-tunnel test, the conventional aeroelastic testing procedures were not followed. Specifically, no attempt was made to record aeroelastic damping or to vary the parameters of mass distribution, model stiffness, etc. With the exception of the air-off natural frequency-damping data presented in Fig. 4 through 8, the records consist exclusively of dynamic moment data due to a steady uniform 282 ft/sec wind with relatively low turbulence.

The scatter of the experimental points shown in Fig. 4 through 8 is indicative of the repeatability observed throughout these data. The symbols in these Figures represent consecutive "twangs" of the model, with arbitrary adjustments of the time-scale "zero." The reason for the unmistakable break in these damping curves is unknown. Because this break is always in the same direction, it cannot be attributed to energy transfer between modes; neither does it seem likely that there was frictional slippage in the model or its supports.

The trace deflection calibrations presented in the preceding Section show that the three data output channels did not respond as exclusively, each to its designated moment component, as could be desired. Particularly in the case of yaw moment, the slightly predominant interaction of pitch moment makes the trace analysis difficult. In the case of the yaw natural frequency and damping (Fig. 6), proper relations in beat-note frequencies substantiate the values presented. The calibrations of yaw moment should be applied to the dynamic data with caution.

Figures 9 and 10 present the peak-to-peak amplitude of the oscillatory component of pitch and roll moment for two simple configurations. Also shown, for comparison, are faired curves of one-half of the comparable time-average moments, computed from external balance data about the comparable moment center.

It is significant to note that, in the case of pitch moment for this model, the peak-to-peak oscillatory load component is approximately equal to half of the steady load but occurs at a noncoincident-model angular attitude.

Figure 11 presents a copy of the oscillograph trace data used in Fig. 9 and 10. This sample represents one of the 800 records made for various model configurations and attitudes. The original records or copies will be made available to qualified parties on an unclassified nonproprietary basis.

SUMMARY

A quantity of data on the steady-wind-caused dynamic oscillations of a model paraboloidal reflector antenna is available. Because of questionable simulation of the dynamic model scaling parameters and the labor involved, the bulk of the data has not been reduced beyond the original oscillograph trace form.

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1. Weaver, Jr., W. "Wind-Induced Vibrations in Antenna Members", Journal of the Engineering Mechanics Division, Proceedings of American Society of Civil Engineers, February, 1961, pp. 141.

2. Steinman, D. B. "Suspension Bridges: The Aerodynamic Problem and Its Solution", American Scientist, July 1954, pp. 397.

3. Fox, N. L. and B. Dayman, Jr., "Preliminary Report on Paraboloidal Reflector Antenna Wind Tunnel Tests", Internal Memorandum JPL CP-3, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, February 28, 1962.

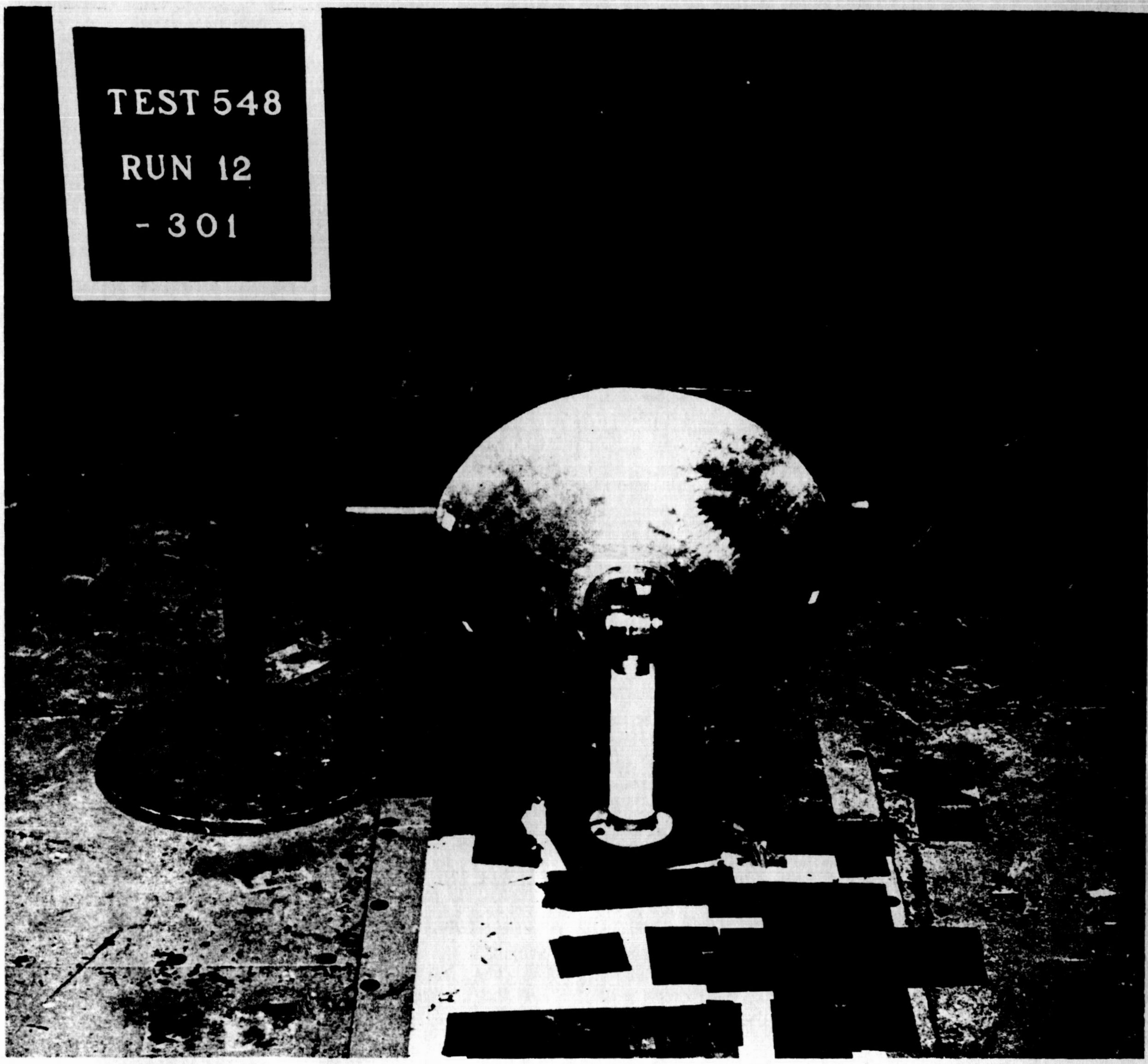

Fig. 1. A typical paraboloidal reflector antenna model configuration as tested in the wind tunnel

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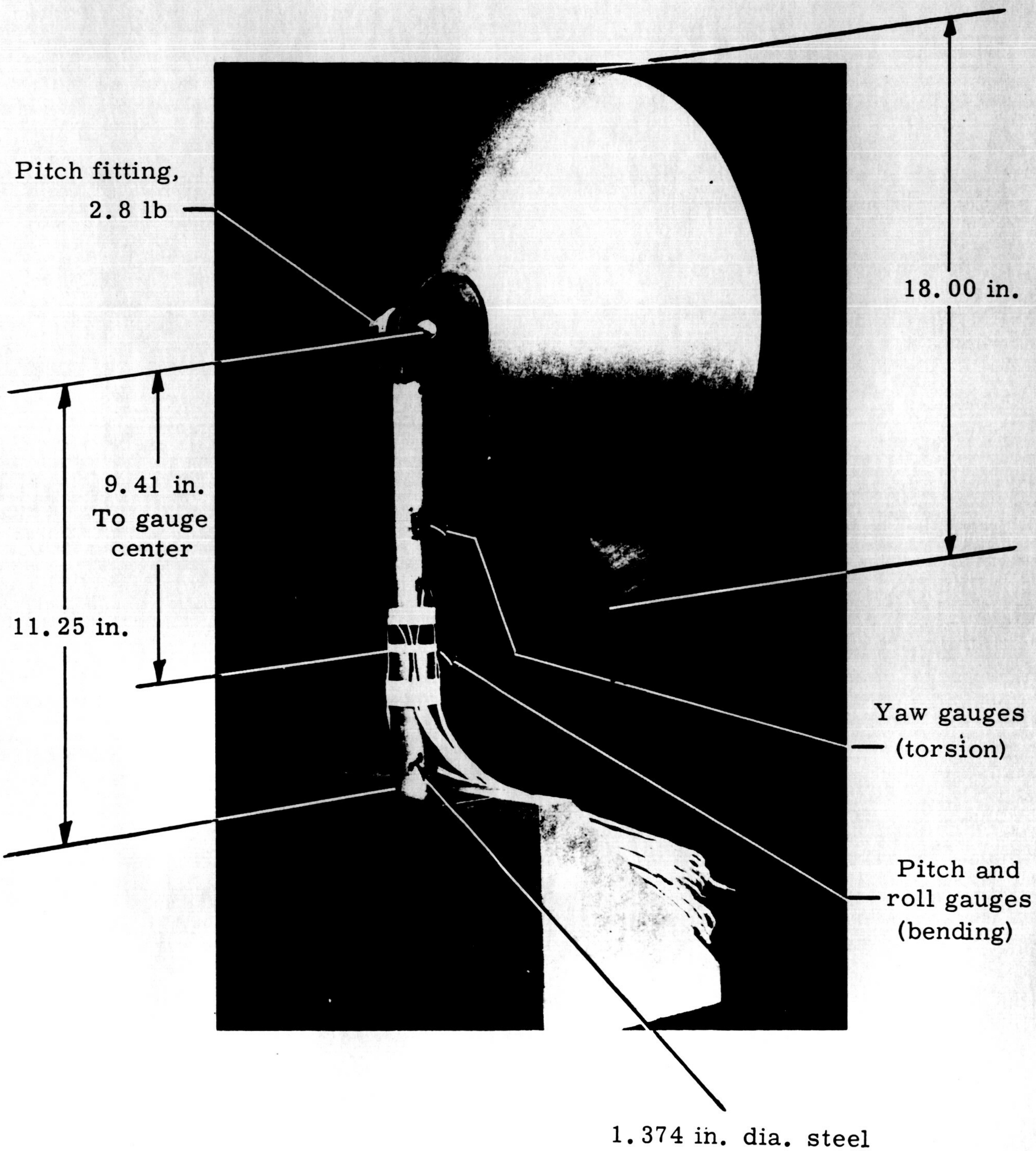

Fig. 2. Salon photograph of antenna model, rear view, showing model geometry

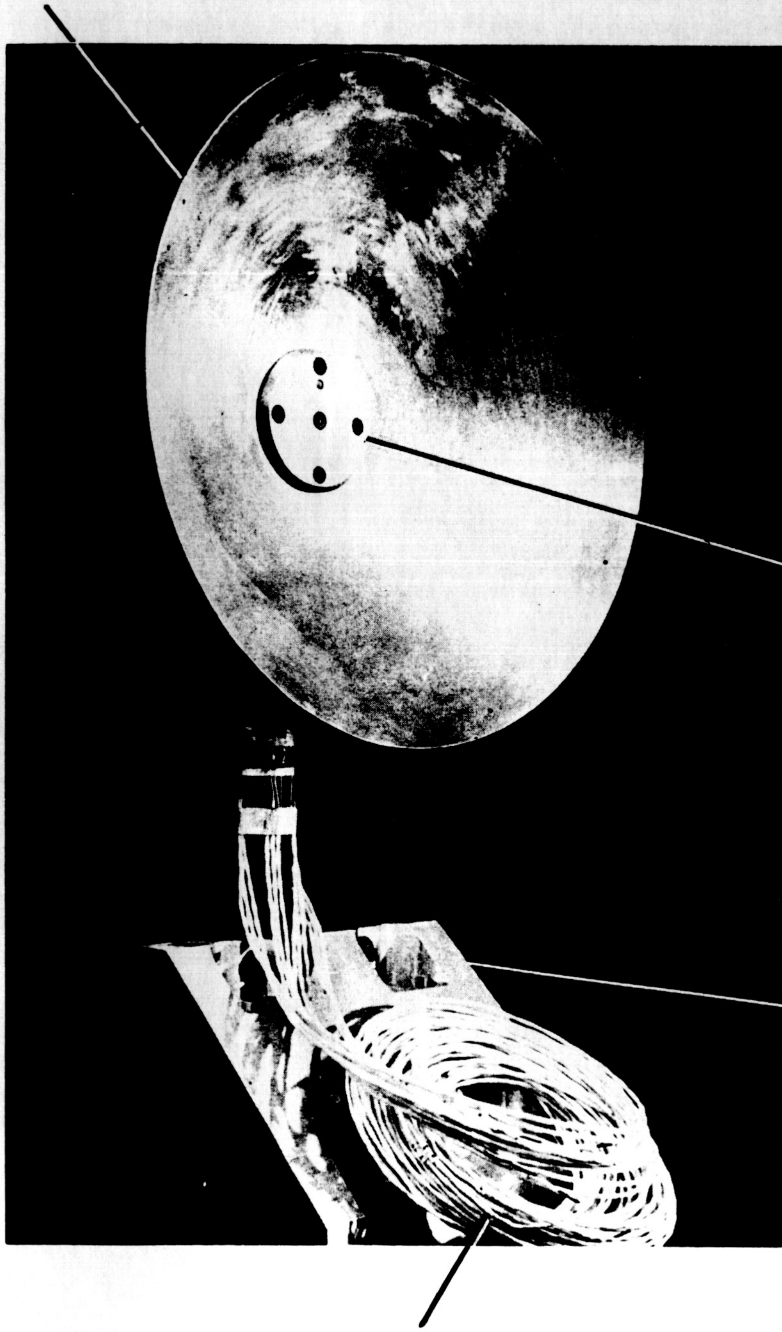

Fig. 3. Salon photograph of antenna model, front view, showing model geometry, Reflector geometry given for configuration 101

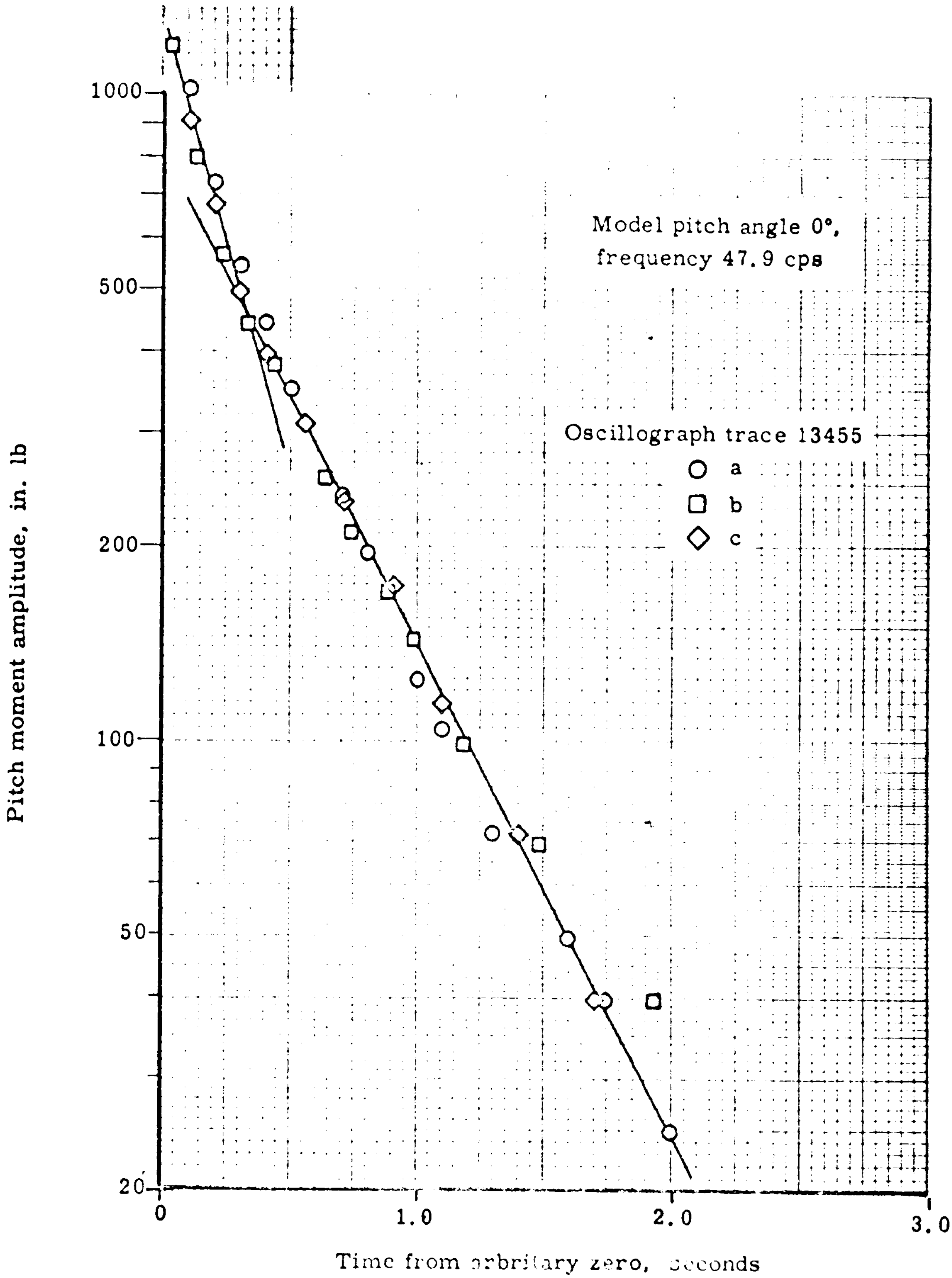

Fig. 4. Pitch moment damping

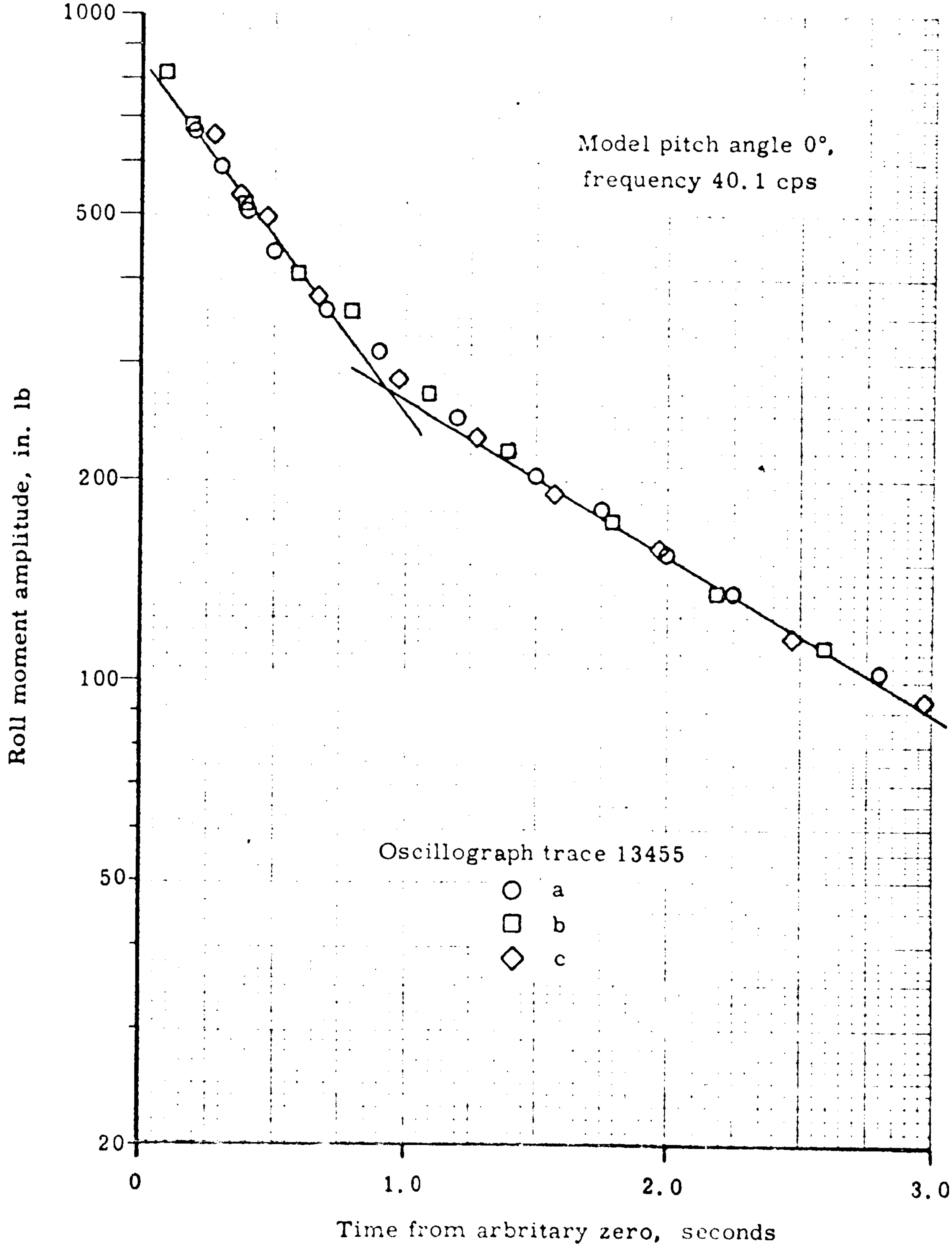

Fig. 5. Roll moment damping

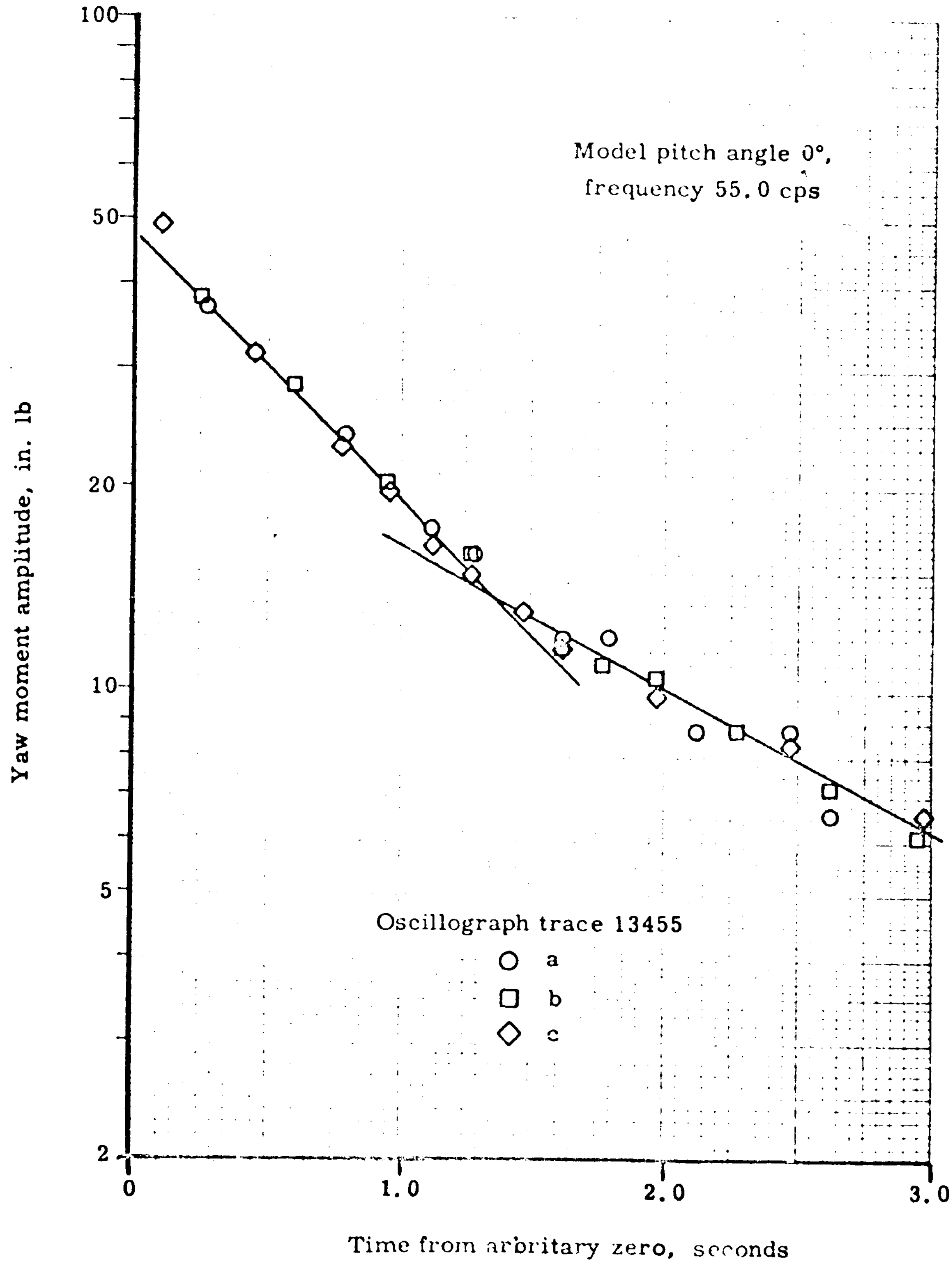

Fig. 6. Yaw moment damping

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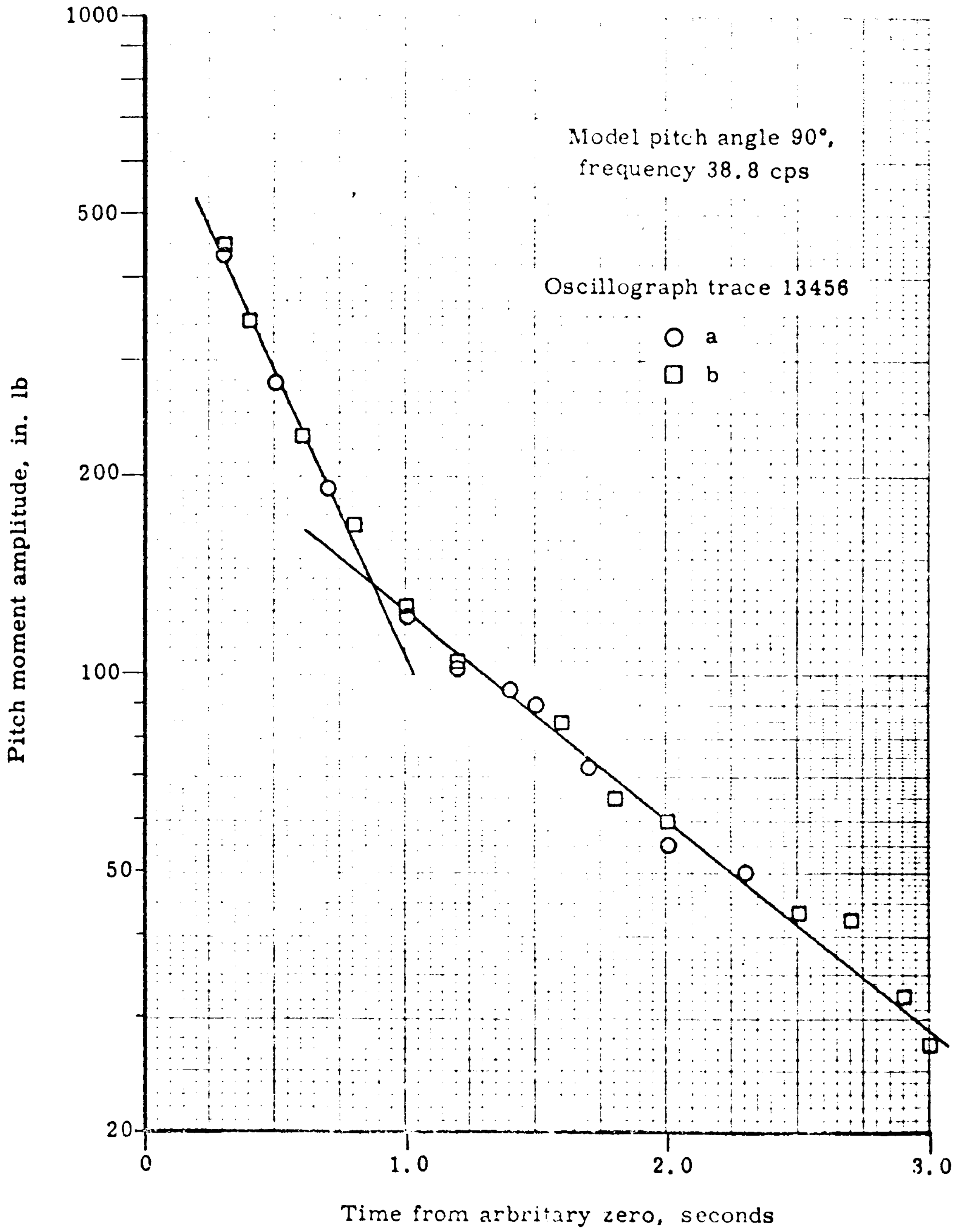

Fig. 7. Pitch moment damping

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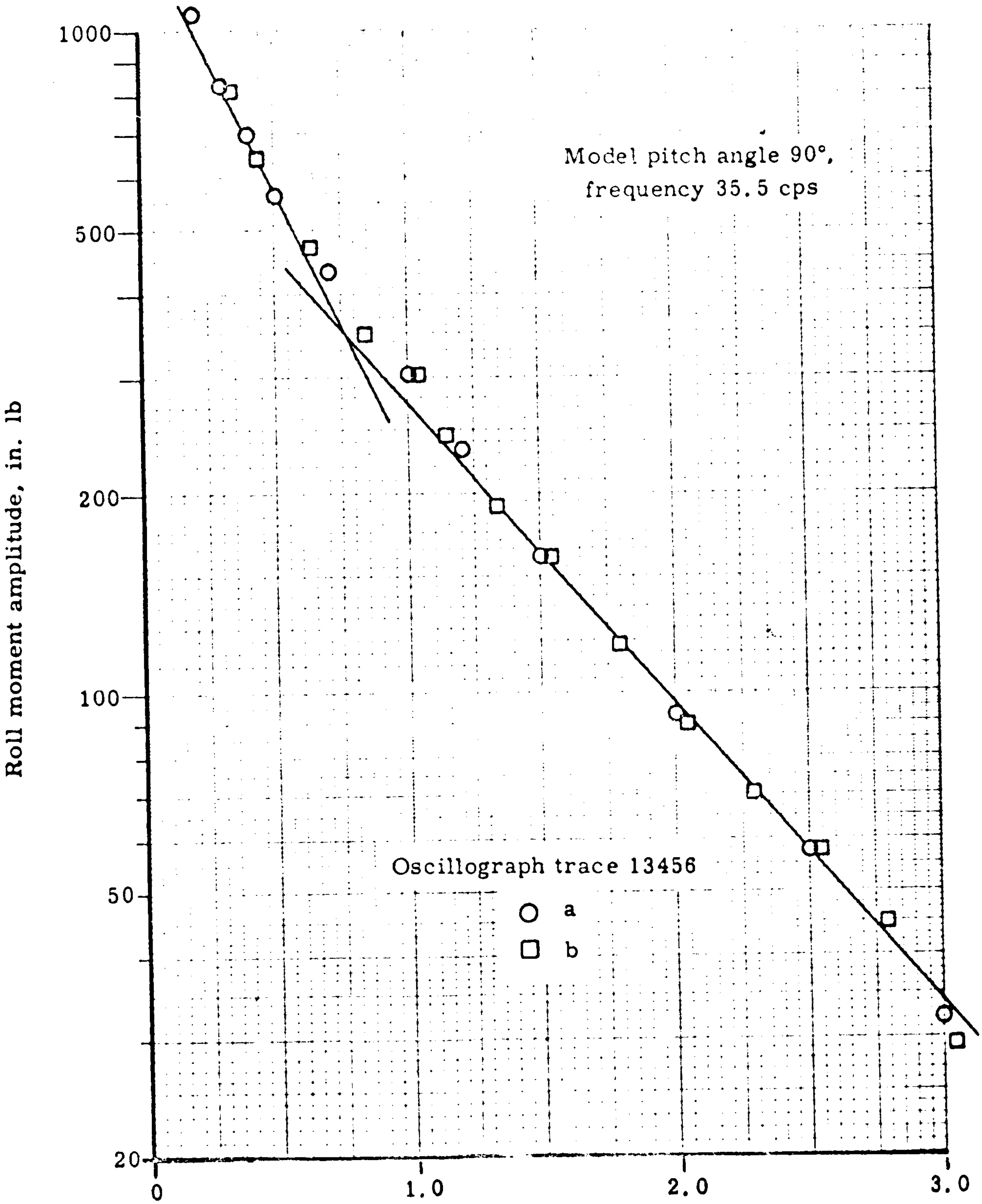

Fig. 8. Roll moment damping

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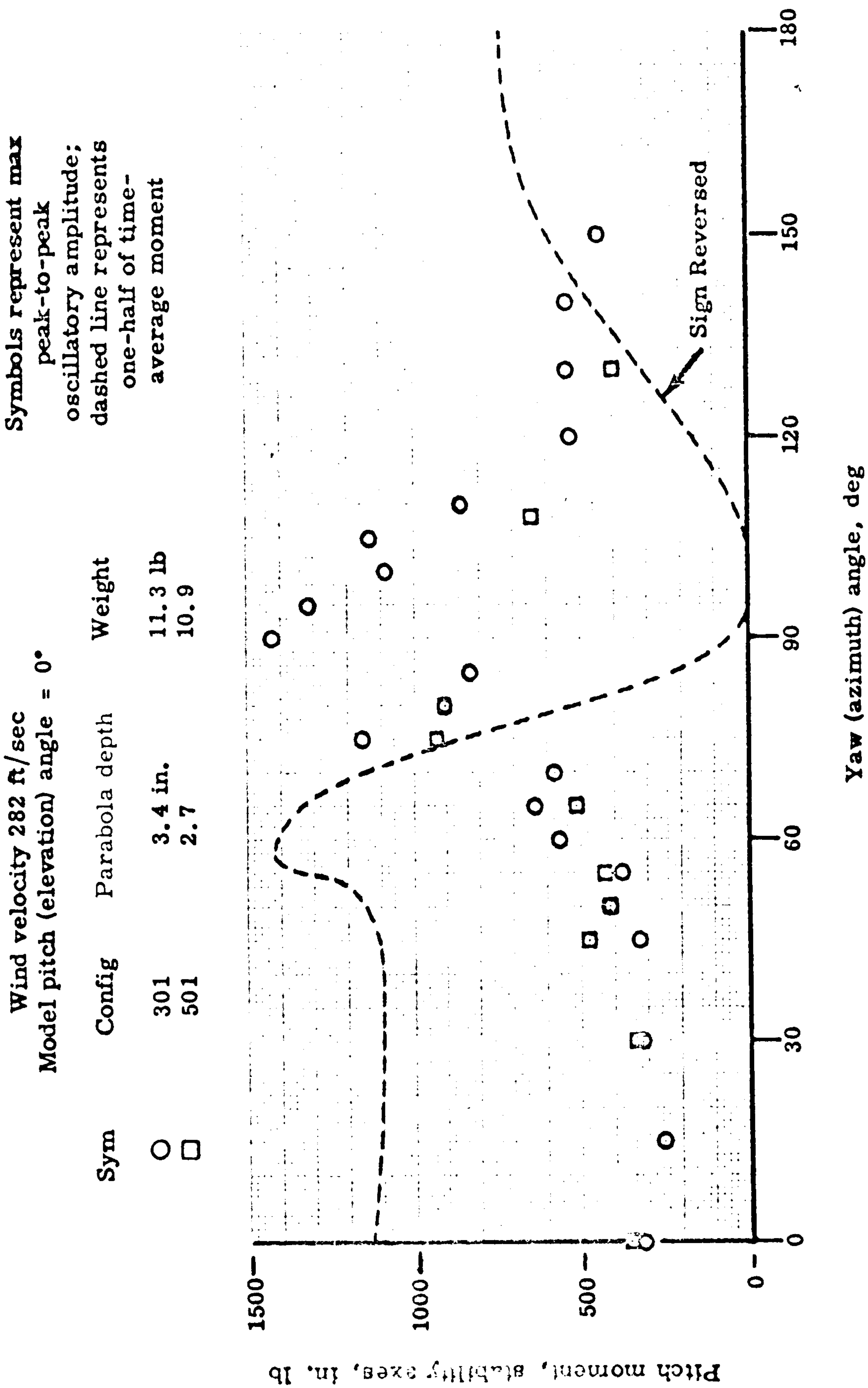

Fig. 9. Comparison of oscillatory to steady pitch moment amplitude

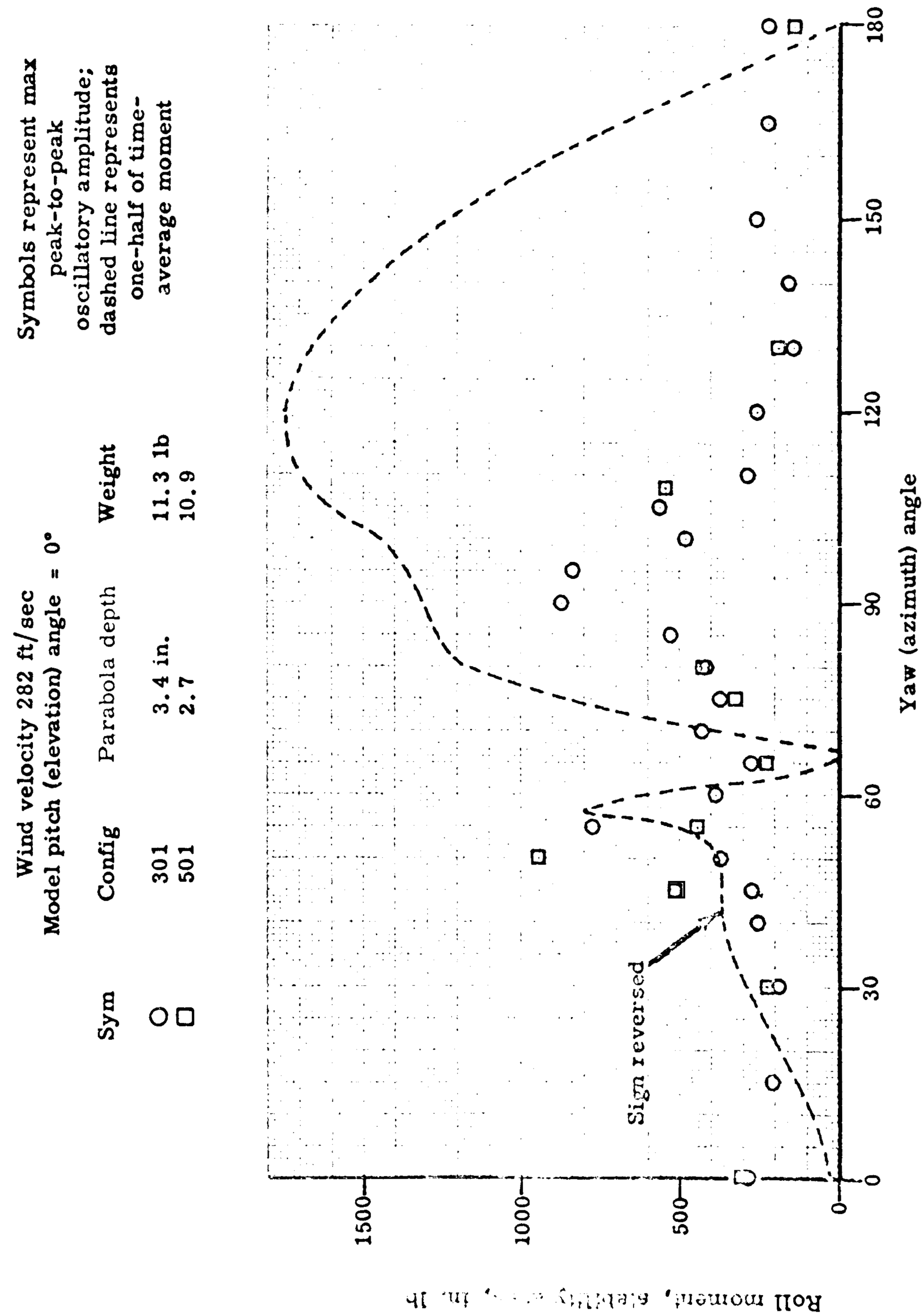

Fig. 10. Comparison of oscillatory to roll moment amplitude

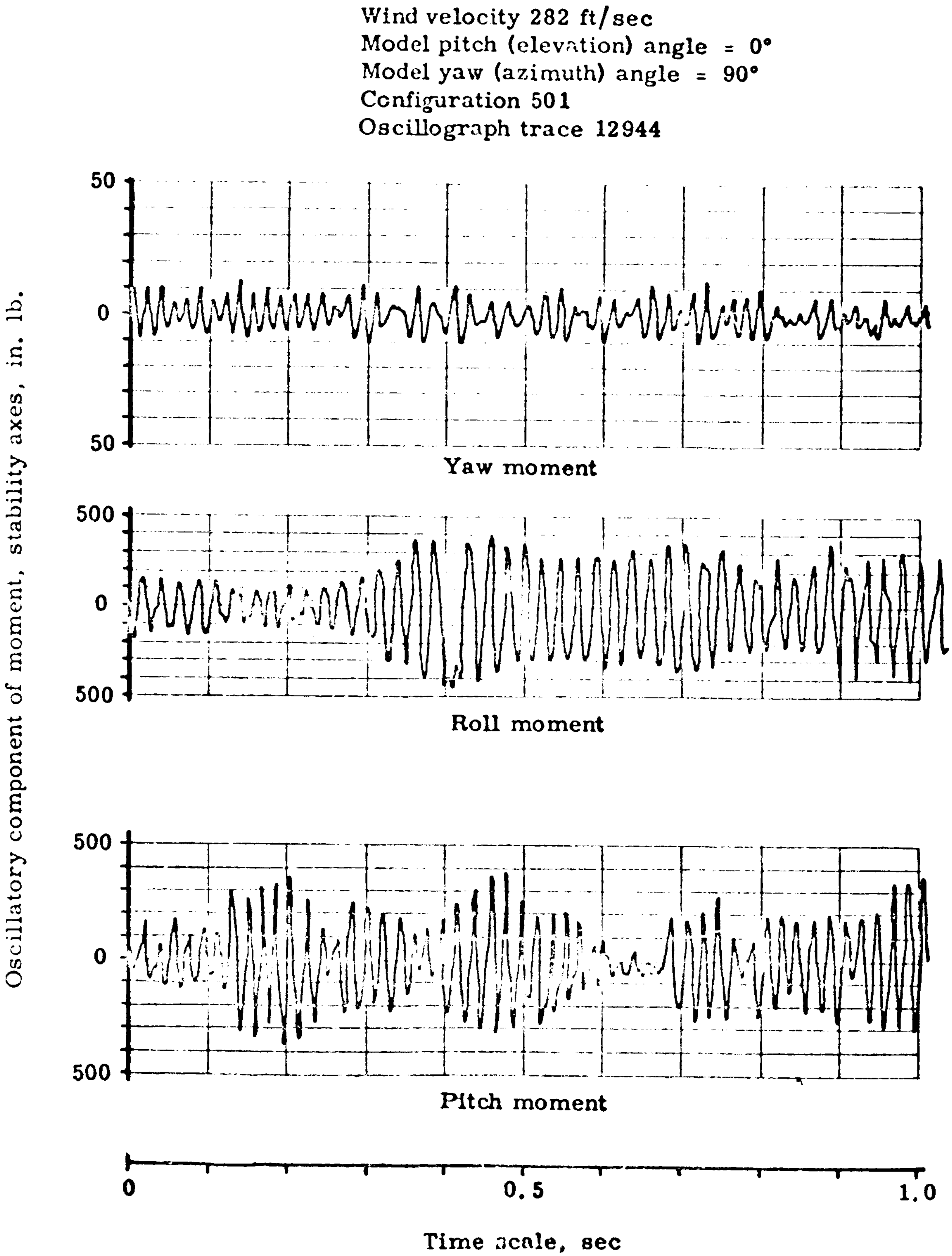

Fig. 11. Sample, oscillograph traces