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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2079

EXPERIMENTS IN EXTERNAL NOISE REDUCTION OF LIGHT AIRPLANES

By Leo L. Beranek, Fred S. Elwell, John P. Roberts
and C. Fayette Taylor

Aeronautical Research Foundation



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EXPERIMENTS IN EXTERNAL NOISE REDUCTION OF LIGHT AIRPLANES

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SUMMARY

The present work is part of a program, the objective of which is to find practicable ways of reducing the external noise level of light airplanes in order to make them less objectionable to persons on the ground.

This report covers noise measurements on standard light airplanes and on similar airplanes equipped with engine mufflers, propeller reduction gears, and propellers with various numbers of blades and blade shapes.

Tests were made with a standard Stinson Voyager 165 airplane and a similar airplane modified with a geared engine, with exhaust silencers, and with propellers varying in number of blades from two to eight. These tests included sound-level recordings of take-offs and of overhead flights at 100- and 500-foot altitude. They also included analyses of sound-frequency components with the airplane on the ground from a distance of 50 feet and at various positions around the airplane.

Similar sound-level readings for take-offs and overhead flight and from various angles around the grounded airplane were also made on a standard Piper Cub J-3 airplane and a Cub modified with an engine exhaust silencer and a four-bladed propeller, driven by means of vee-belts, at the same reduction ratio (0.632) as the modified Stinson.

In general, it was demonstrated that significant reduction in the external noise level of light airplanes can be achieved without basic changes in airplane structure and without serious sacrifices in performance. The noise levels with the best combinations tested were, in the opinion of staff and observers, probably lower than is essential to eliminate most public objection to such airplanes on account of their noise characteristics.

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The results confirmed previous work insofar as reductions in noise level were found to result from muffling the engine and from reducing propeller tip speed and blade loading. This result was obtained even when the experimental airplanes were operated at considerably higher power output than that of the standard airplanes.

With a given tip speed and engine-power output, it was found that increasing the number of propeller blades (except for the change from two to three blades) tended to decrease the noise level under all flight conditions.

With four-bladed propellers adjusted to absorb the same power in flight, changes in blade design, principally blade width, had little effect on the sound levels in flight, although narrow blades produced more noise on take-off, probably due to higher engine speed which these blades allowed early in the take-off run.

Changes in blade angle showed increasing sound level as the blade angle was increased at a given tip speed, because of the increased power required.

Ground tests showed that the over-all level decreased with increasing number of blades up to six, but here the eight-bladed propeller was not significantly quieter than the six-bladed propeller. The components of sound plotted with relation to angular position around the airplane showed quite different patterns for each propeller-engine combination.

In the performance tests the modified Cub was superior and the modified Stinson only slightly inferior, at comparable engine powers, to the standard airplanes.

INTRODUCTION

One of the factors that limits the usefulness of light airplanes is the fact that many, if not most, airports and flying fields are at considerable distances from the population centers which they serve. An important reason that airports and flying fields are thus located is objection on the part of home owners to having such fields close to their houses. Since this objection appears to be based principally on noise, it would appear that reduction in the external noise level of light airplanes might be very effective in securing public acceptance of flying fields for such airplanes reasonably close to residential areas.

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Experiments by the National Advisory Committee for Aeronautics (references 1 to 5) have already shown that it is possible to make significant reductions in the external noise of airplanes by the use of propellers operating at low tip speeds and low blade loading, together with engine mufflers.

The present study was designed to supplement the NACA work in a number of ways. One important objective was to make continuous sound records of both standard and modified airplanes during the entire take-off run and during approach and departure in overhead flight.

Another objective of the present study was to determine whether external noise levels of representative light airplanes could be effectively reduced without alterations in their structures or power plants which would involve large increases in weight and costs, or serious impairment of performance. Particularly, it was desired to avoid changes in propeller diameter which would require increased landing-gear heights, and to avoid changes in engines or propellers which would seriously shorten the take-off run.

A third objective of the present study was to obtain information concerning the effect on external noise level of progressive changes in the number of propeller blades, in blade design, and in blade-angle setting.

The experiments reported herewith were conducted during the years 1948-49 by the Aeronautical Research Foundation under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

Design of airplane modifications, propellers, and silencers was carried out under the direction of Professor Otto C. Koppen of the Massachusetts Institute of Technology. The project was under the general direction of Dr. Lynn L. Bollinger, Executive Director of the Foundation.

The following individuals and organizations generously contributed equipment and assistance on this project: Aircooled Motors, Inc., loan of experimental geared engine; Goodyear Aircraft Corporation, gift of castering landing gear for experimental Stinson airplane; Lycoming Division, The Aviation Corporation, gift of engine for experimental Cub airplane; Maxim Silencer Co., gift of silencers for experimental Stinson; Sensenich Brothers, provision of all experimental propellers at cost; Stinson Aircraft Division, Consolidated Vultee Aircraft Corporation, gift of Stinson airplane for experiments; Mr. William Piper, President of Piper Aircraft Corporation, gift of castering gear for experimental Cub; Mr. Joseph Garside, President of Wiggins Airways, use of his company's shops and facilities.

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DESCRIPTION OF APPARATUS

The apparatus used in this study can be divided into four categories, as follows: The airplanes used together with their power plants, propellers and propeller hubs, the sound-measuring and sound-recording equipment, and the flight-control apparatus.

Airplanes and Their Power Plants

The airplanes used were the following:

(1) A standard 1948 Stinson Voyager 165, equipped with a Franklin six-cylinder, direct-drive engine, rated at 165 horsepower at 2800 crankshaft rpm. This airplane was used as received from the manufacturer. A similar airplane is illustrated in figure 1. Blade-form curves for the propeller (Sensenich Skyblade) are shown in figure 2.

(2) A 1946 Stinson Voyager 150 equipped as follows:

Engine:
Experimental geared Franklin, rated at 180 horsepower at 3050 crankshaft rpm. (At 2800 rpm this engine delivers 170 hp.)

Gear Box (part of engine):
Planetary, 0.632-to-1 ratio.

Exhaust system:
Two Maxim Silencers, connected to standard exhaust manifolds. A cross-sectional drawing of one of these silencers is shown in figure 3, and figure 4 shows photographs of the mufflers as mounted on the airplane. Other data concerning these silencers are as follows: Weight, each 12 pounds; supporting brackets, 2.5 pounds; back pressure measured in pipe between engine and muffler, 4 inches of Hg at 2900 rpm, full throttle.

Photographs of this airplane with various propellers are shown in figure 5.

(3) A standard Cub J-3, equipped with a Continental four-cylinder, direct-drive engine, rated at 65 horsepower at 2300 rpm. This familiar type is illustrated in figure 6. It was used to furnish a basis of comparison, with respect to sound levels, with airplane 4.

(4) A modified Cub J-3 airplane, shown in figure 7, essentially the same as a standard 1940 J-3, except for a new and larger vertical fin and rudder, and a complete new engine mount and cowling. The engine

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used in this airplane was a Lycoming four-cylinder, direct-drive, rated at 108 horsepower at 2600 crankshaft rpm. This engine was modified with the special vee-belt propeller drive illustrated in figure 8.

As shown in figure 8, the drive included a small pulley mounted on the forward end of the engine crankshaft and a larger pulley mounted on an external stationary shaft fastened to the engine crankcase. The upper pulley turned on two antifriction, grease-packed bearings located inside the pulley.

Ten Goodyear rubber vee-belts with steel cable cores were used. These belts were each 42 inches in length and 3/8 inch in width. The nominal speed ratio of this combination is 0.632 to 1. An eccentric arrangement in each upper shaft bracket provided means for adjusting the belt tension.

Before using this vee-belt drive in flight, it was necessary to subject it to endurance tests on the ground. These tests are reported in the appendix.

Another special feature of this airplane was its exhaust system. This was of the ejector type. An assembly drawing of this arrangement is shown in figure 9. It was developed by Professor Otto C. Koppen of the Massachusetts Institute of Technology for the dual purpose of silencing the exhaust and insuring proper engine cooling under all normal conditions of operation, including the ground tests.

As shown in figure 9, the exhaust ejector consists of a cylindrical tube open at both ends. This tube is attached to the fuselage with its forward end communicating with the engine compartment and its rear end open to the atmosphere. The engine exhaust manifolds are arranged so as to discharge into a single nozzle which is so located with respect to the tube as to act as an ejector, drawing air from the engine compartment. This compartment has no other exit, and the engine baffles are so arranged that air entering the cooling-air inlet openings and passing over the engine is finally ejected through the ejector tube.

Silencing of the exhaust is assisted by a perforated metal lining within the ejector tube. Between this lining and the outer shell Johns Manville "Flex Blanket" is inserted, so that the arrangement acts as an effective sound absorber. This arrangement was found to furnish adequate air circulation to keep cylinder temperatures well below specified limits, even for continuous running on the ground during the tests of the vee-belt drive. Back-pressure and weight data are as follows: Back pressure, measured in pipe between engine and nozzle, 10 inches of Hg at 2500 rpm, full throttle; weight, 9 pounds.

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Propellers and Propeller Hubs

Airplane 1, the Standard 1948 Stinson Voyager 165, was first equipped with a Sensenich two-position Skyblade two-bladed propeller (similar to that shown in figures 1 and 2). This propeller was set in cruising pitch for all flight noise tests herein reported. It was not used in the take-off tests. Hereafter the combination of this airplane and propeller will be referred to as the standard Stinson configuration 1.

Airplane 2, the modified Stinson Voyager 150, was equipped with eight different propeller arrangements during these tests. These propellers are identified in table I which also includes all other configurations used in this study.

The propellers used for configurations 2A through 2G were made up with special wooden blades assembled in one of two "hub adapters." These adapters, in turn, were mounted on a conventional 10-spline, steel propeller hub, normally used with fixed-pitch, wooden propellers.

The purpose of the adapters was solely that of experimental variation. They made it possible to assemble propellers with various numbers of blades, styles of blade, and variable blade-angle settings. The eight-bladed adapter was used for the two-, four-, and eight-bladed combinations, configurations 2A, 2D, 2E, 2F, and 2G.

The six-bladed adapter, similar to the eight-bladed adapter, was used for the three- and six-bladed combinations, configurations 2B and 2C, respectively.

The propeller blades used with the above adapters were of "medium," "thin," and "wide" types (see blade-form curves of figs. 10, 11, and 12, respectively). Photographs of these blade types assembled on the airplane have already been shown (see fig. 5).

These blade types combined with the hub adapters made available configurations 2A through 2G, listed in table I, with the added feature of adjustable blade angles in each case. For configurations 2A and 2G the wide-long blades having a diameter of 84.5 inches were used. All other configurations had the same 76-inch-diameter blades as the standard airplane.

One other propeller was used on the modified Voyager 150, namely, a fixed-pitch, four-bladed, one-piece wooden propeller, having a diameter of 76 inches with a nominal pitch angle of 25°. Blade-form curves for this propeller are given in figure 13. The modified Stinson with this propeller is shown in figure 5(h) and is called the "solid" four-bladed propeller, configuration 2H.

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Airplane 3, the standard Cub J-3 (fig. 6), was equipped with the conventional two-bladed wooden propeller regularly supplied with this type. This propeller had a diameter of 72 inches with a nominal pitch of 14°; blade-form curves for this propeller are given in figure 14.

The propeller used on airplane 4, the modified Cub J-3, was a four-bladed, two-piece, wooden type, as shown in figure 7. This propeller had a diameter of 80 inches with a nominal pitch of 15°. Figure 15 shows the blade-form curves for this propeller. The modified Cub J-3 with this propeller will be called configuration 4.

Finally, for check runs and take-off tests near the end of the program, a standard, fixed-pitch, wooden propeller was used with the standard Stinson Voyager 165. The combination of this propeller and airplane will be called configuration 5 (see figs. 16 and 17).

Sound-Measuring and Sound-Recording Equipment

The sound-measuring equipment used for these tests consisted of:

(1) Sound Level Meter, General Radio Company, equipped with microphone supplied by the General Radio Company and manufactured by Shure Brothers. For all measurements the microphone was equipped with a standard 25-foot extension cable, General Radio Company.

(2) Sound Analyzer, General Radio Company.

(3) Graphic Level Recorder, Sound Apparatus Company, equipped with potentiometer, 0 to 50 decibels.

The Sound Level Meter and Sound Analyzer are battery-operated instruments. Sixty-cycle, alternating-current power for the Graphic Level Recorder was provided by a synchronous type vibrator converter, operated from a 12-volt battery. This instrument, called an Electronic Converter, is manufactured by Electronic Laboratories, Inc. and has the following specifications: Input, 12 volts direct current; output, 115 volts, 60 cycles, 150 watts.

Flight-Control Apparatus

A Dewey & Almy Chemical Company "Kytoon" captive balloon was used to control flight altitude, plus the usual instruments in each airplane, including particularly the engine tachometer, which was used to observe engine speed during all sound measurements.

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TEST PROCEDURE

All sound measurements were made at the Metropolitan Airport, Canton, Massachusetts, between March 1948 and May 1949. Instrument calibrations were made at the airport, in the Acoustics Laboratory at the Massachusetts Institute of Technology, or at the General Radio Company, Cambridge, Massachusetts.

The sound-level measurements were divided into two parts: First, measurement of the noise produced by actual take-off and flight and second, analysis of the frequency components present in the noise with the airplane on the ground with its engine running at full power. For the flight tests the Sound Level Meter and Graphic Level Recorder were set up on the ground and the airplanes were flown at altitudes of 100 and 500 feet on straight courses passing directly over the microphone. Take-offs were handled in a similar fashion with the airplane leaving the ground as it passed the microphone at a distance of 50 feet. For the ground tests, principal frequency components and over-all levels were measured at a distance of 50 feet at various positions around the airplane.

Detailed description of the test procedure will be divided into the following sections: Flight control, flight and ground operation, use of instruments, and calibration of instruments.

Flight Control

Level flights were made at altitudes of 100 and 500 feet over the microphone. About 100 feet represented the minimum altitude that should be used for test purposes both because of difficulties in flying any lower and because of increasingly larger relative altitude variations possible at lower altitudes. Five hundred feet represented the maximum practicable altitude because of background noise for the quieter flights. When there was any wind, which was generally the case, flights were made first upwind, then downwind; however, no tests were made with winds of over 15 miles an hour since above this velocity fluctuations in the sound level were excessive and because it was difficult to determine the airplane ground speed.

Altitude was controlled by the use of the Kytoon, which is a rather large, hydrogen-filled, kite balloon with tail fins. It has lift due to hydrogen and also wind lift, as does a kite. Thus, instead of riding with its line at a low ground angle, it rides very high in any wind. With 100 or 500 feet of line attached, it served as an excellent altitude marker and the pilot found it a simple matter to aline his height and to pass directly over the microphone.

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To determine the airplane ground speed, the pilot observed and reported his airspeed for each series of flights, and flights were made only upwind and downwind. It was necessary to know the wind velocity at the altitude he was flying. Long cloth streamers tied to the line leading up to the Kytoon afforded indication of that, both by the angle at which they rode the wind and their rate of flutter. By observation and correlation of these indications with wind-velocity readings of the airport anemometer, it was found possible to make estimates of sufficient accuracy.

Flight and Ground Operation

Table II gives data on the power, engine speeds, and propeller tip speeds used in the flight and ground tests. Table III shows the number and character of flights made with each configuration.

Figure 18 is a photograph of the airplane passing over the equipment at 100 feet. Note the Kytoon to the right of the airplane. This is a fairly representative picture of the work as it was done, except that normally the Kytoon was a little farther away from the microphone so that the car to which it was tied would not cause interfering sound reflections.

For the take-off runs, a marker was placed on the ground 50 feet from the microphone, and the pilot was instructed to make his take-off so that he would be just leaving the ground as he passed over the marker. Figure 19 is a photograph of the standard Stinson leaving the ground as it passed the microphone on a take-off test.

Ground measurements were made with the microphone 50 feet from the propeller hub. After the measurement was completed for the position directly in front of the airplane, the airplane was turned 30°, and a new measurement was made. This procedure was repeated for each 30°, on both sides of the airplane, with the exception of the 180° position, which had to be omitted on account of the propeller slipstream.

Use of Instruments

The interconnections of the sound-measuring equipment, both for the take-off and flight measurements and for the ground analysis, are shown in figure 20. For take-off and flight the microphone cable was connected to the Sound Level Meter. The output of the Sound Level Meter was connected directly across the input terminals of the Graphic Level Recorder.

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To get the microphone away from reflections caused by the instrument cases and from internal noises of the Graphic Level Recorder, a 25-foot extension cable was used. The microphone was mounted in a stand which held it 8 inches above the ground and was enclosed by two cloth wind screens, one inside the other; one of these formed a 14-inch cube, the other, a 12-inch cube. This cut down wind noises so that the background noise (with flat weighting) was about 60 decibels in a 15-mile-an-hour wind. The wind screens served the further purpose of keeping the sun off the microphone. With the extension cable used, the readings of the Sound Level Meter had to be corrected for cable losses. The normal correction was about 3 decibels, but when the microphone temperature went above 80° F this correction became greater, and it was therefore necessary to know the microphone temperature for work on sunny, warm days. For example, on a hot June day with the air temperature about 85° F, the microphone temperature rose to 105° F, giving a cable correction of 6 decibels. The microphone temperature was determined by holding a thermometer against its metal case.

Aside from equipment calibration and maintenance, the only problem encountered was how to place some reference mark on the record of the Graphic Level Recorder. A momentary shorting switch was developed which would "short" the input to the recorder for an instant when a hand switch was pressed. In this way the record could be marked just as the airplane passed overhead. It was felt that estimates by eye, of the overhead position, were sufficiently accurate for the purposes of this work. The take-offs were similarly marked as the airplane passed the microphone.

When the Graphic Level Recorder was used, a continuous record was made of the sound level of each flight from the time the airplane was first audible until its noise faded into the background. Concurrently the peak reading of the Sound Level Meter was observed for all flight measurements. For the take-off measurements, the Graphic Level Recorder was started with the take-off and kept running until the airplane noise faded into the background noise. Also concurrently the peak reading of the Sound Level Meter was recorded.

Ground tests included over-all sound-level measurements from a distance of 50 feet at angles of 0°, 30°, 60°, 90°, 120°, and 150° on each side of the airplane measured from the dead-ahead position. The analyzer

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was used to measure the important frequency components, in addition to the over-all measurements, at each of these positions.

Sound-level measurements for all take-offs and flights were made both with an electrically flat weighting and with a 40-decibel weighting network. (See fig. 21.) The 40-decibel weighting gives results comparable to the way the average ear responds at sound levels in the vicinity of 40 decibels. (For a discussion of the relation between instrumental sound measurements and the response of the human ear, see Fletcher and Munson, reference 6.)

Calibration of Instruments

The Graphic Level Recorder required frequent calibration. Sound calibration was made by correlating the peak reading of the Sound Level Meter with the maximum reading of the recorder. This afforded a separate calibration of each record. Calibration of paper speed on the recorder was made occasionally by running it 10 seconds and measuring the length of the strip so obtained. The shorting switch was used to check the "following rate" of the instrument.

The Sound Level Meter was calibrated at the Acoustics Laboratory of the Massachusetts Institute of Technology after each day of use. Its electrical system was checked by means of the built-in electrical calibrating system provided by the manufacturer. This calibration covers everything except the microphone. A check of the system including the microphone was made by using a sound source, built from sketches supplied by the General Radio Company, which was accurately calibrated for several frequencies in their laboratories. With this sound source placed over the microphone, and a signal of known frequency and amplitude applied, any discrepancy between actual and indicated sound level could be corrected by adjustment of the calibration control in the Sound Level Meter.

Throughout this series of measurements the analyzer was set at a fixed sensitivity. Calibration of the analyzer was obtained by applying a constant voltage in series with the Sound Level Meter and reading the analyzer meter tuned to maximum, with flat weighting network. Frequency responses, one for each setting of the range buttons, are shown in the

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upper part of figure 21. From the difference between curves 1 and 3 of figure 21, readings of the analyzer for any frequency could be translated into absolute sound-pressure levels.

PRECISION

Visual observations and measurement of the length of the "Kytoon" nylon cord after the tests indicated that airplane altitudes were held within +15 percent and -10 percent. Variations within this range have a small effect on sound measurements, probably not exceeding ±1.5 decibels.

It will be noted in the results that sound-level measurements of similar flights under supposedly similar conditions sometimes showed a difference of as much as 10 decibels. It is believed that the major part of such differences was real, and was due to variations in atmospheric conditions, terrain, and so forth. This aspect of the results is fully discussed under ANALYSIS AND DISCUSSION of this report.

Laboratory calibration showed that the error in readings of the Sound Level Meter did not exceed ±1 decibel. A reasonable estimate of reading errors under field conditions appears to be about ±1 decibel. The two errors combined would give a maximum error in the sound-level measurements of ±2 decibels, aside from those errors arising at the recorder.

Because the peak readings of the recorder were assumed to be those read simultaneously on the Sound Level Meter, the error in them would still be ±2 decibels. For data depending on recorder values considerably lower than the peak readings it is not possible to determine the error, but, since the machine is generally accepted for work of this kind and was kept in good running order, it is believed that its error was probably not over ±4 decibels.

RESULTS

General Method of Presentation

Table III shows the number and character of tests made on the various configurations. The results are segregated so as to furnish information on four different problems.

Series A.- Series A is a comparative study of the external noise levels of a standard Stinson (configuration 1) and a modified Stinson using two-, three-, four-, six-, and eight-bladed, geared propellers in

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conjunction with exhaust mufflers. The testing of configurations 1, 2A, 2B, 2C, 2D, and 2F was devoted chiefly to this problem. On this group the most complete series of measurements were made, including measurements with the Graphic Level Recorder.

Series B.— Series B is a study of the effect of blade shape on the external noise level of the quieted Stinson with four-bladed propellers, configurations 2E, 2F, 2G, and 2H.

Series C.— Series C is a study of the effect of blade angle (with consequent change in horsepower drawn from the engine) on the external noise level of the quieted Stinson with the four-bladed propeller, configuration 2F, set at various angles, at constant tip speed.

Series D.— Series D includes a study of the external noise level of a standard Cub and a similar airplane modified by the use of a belt-driven, four-bladed propeller and exhaust muffler, and a comparison of the noise level of the two Cub configurations, configurations 3 and 4, with the noise level of the standard and four-bladed Stinsons, configurations 1 and 2F.

Series E.— Series E is a comparison of sound levels at the same power output.

Method of Presenting Results of Recorder Measurements

Records from the Graphic Level Recorder are plotted in terms of sound level against horizontal distance from airplane to microphone (figs. 22 through 25). For any flight, given the ground speed of the airplane and the paper speed in the Graphic Level Recorder, the record could be marked off in 100-foot horizontal intervals and interpreted and plotted. For each flight condition and for many airplane-propeller combinations, there were four records available made with flat weighting and four made with 40-decibel weighting. In this report, it was decided to present plots of only one weighting at each altitude. For the flights at 100 feet the records taken with flat weighting were used. This seemed a reasonable choice since the sound levels for these flights reached 100 decibels. For the flights at 500 feet the records taken with 40-decibel weighting were used. This choice was made because there were several peak levels below 70 decibels, and furthermore the information from these records could be more meaningfully extrapolated to higher altitudes by using the 40-decibel weighting.

For the take-offs it was not possible to plot the sound level against distance, since the airplane was constantly changing its velocity; therefore, the sound level was plotted against time (fig. 26).

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It is worth noting at this point that the graphs of the flights showing sound level against horizontal distance are not corrected for the finite velocity of sound. In other words, the sound level shown when, for example, the airplane was 1000 feet away from the overhead position is actually the sound level at the microphone at that time. Since that sound took some time to reach the microphone, it was actually generated when the airplane was somewhat farther away as it approached, or nearer when it was going away; however, this discrepancy has no effect on comparisons between the different configurations.

Method of Presenting Ground-Analysis Measurements

Information from the ground measurements is presented in the form of polar plots of the over-all level and amplitude of each significant component. (See fig. 27.) In taking the readings, serious fluctuations in sound level were encountered. Furthermore, on the ground the engine overheated quickly and readings had to be taken during a very short period. In each case the maximum reading observed was recorded. The propeller noise was particularly subject to fluctuation, especially in the higher harmonics, where peak readings varied as much as 10 decibels over a short period. Because of this fluctuation the comparative polar plots show only engine and propeller fundamentals, the higher harmonics being omitted.

When comparing these plots it must be kept in mind that the quieted configurations are powered by engines giving considerably more horse-power than the standards. (See table II.)

The frequencies shown on such curves are those actually measured by the analyzer. The "propeller fundamental" in each case is the lowest frequency component observed which could be attributed to the propeller. This frequency represented in all cases the tip-passage frequency. For all except the standard Stinson, configuration 1, the lowest frequency component which could be attributed to the engine occurred at three times the crankshaft rotation frequency. This component is referred to as the "engine fundamental." On the standard Stinson, components attributable to the engine occurred at one and one-half and four and one-half times crankshaft frequency.

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ANALYSIS AND DISCUSSION

Series A. Comparative Study of External Noise Levels of Standard and Modified Stinson Airplanes, with Several Propellers

Flight tests.— Basic data for the flight tests are plotted in figures 22 to 25. These curves show rather wide variations between records taken under supposedly nearly identical conditions. For example, in figure 23, giving the data from the flights at 100-foot cruising power, there is as much as a 10-decibel difference between two consecutive flights at the same distance. Some of the difference is obviously due to fluctuations in the sound of a single flight which were not repeated in the same way on succeeding flights. In the case of the four-bladed propeller (configuration 2F, fig. 23) there is apparently a significant difference between the records of the airplane approaching for the upwind and downwind flights. This is probably partly due to wind effects, but it may also be related to some difference in the terrain over which the airplane approached from the two directions. In as many cases as possible the flights were made over the grass-covered airport, but often some part of the recorded flight was over the swamp around the field. Occasionally (particularly for the six-bladed propeller, configuration 2C) the airplane was over woods with trees of 15- or 20-foot height when it was 1000 feet away.

Variation between records for the same conditions was generally much greater for the flights approaching than for those going away. This would seem to be largely caused by much greater fluctuations in the airplane forward noise. The records of the six-bladed propeller, configuration 2C, and the eight-bladed propeller, configuration 2D, in particular showed that this fluctuation became more apparent with the quieter propellers. The ground analyses indicate that the predominant components in this forward noise are attributable to the engine.

For purposes of comparison the four curves in each of figures 22 to 25 were averaged, and the average curves for each flight condition have been plotted in a single graph. The average curves for the flights at 100-foot altitude, maximum power; 100-foot altitude, cruising power; 500-foot altitude, maximum power; and 500-foot altitude, cruising power are shown in figures 28 through 31 in that order.

Considering these curves as a whole, there is a general tendency for the sound level to decrease as the number of blades increases. The 40-decibel weighting records for the 500-foot runs (figs. 30 and 31) show a considerable separation between the standard and the experimental

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configurations and a smaller apparent difference between the experimental configurations. The explanation is to be found in the effect of the 40-decibel weighting. The effect of such weighting is to reduce response at the lower frequencies. The special two-bladed equipment with reduced propeller speed (configuration 2A) has lower frequency components than the standard configuration (configuration 1) and therefore its relative noise level is reduced by the 40-decibel weighting. The other experimental configurations lack such low-frequency components and therefore are less modified by the 40-decibel weighting. Thus, the four-, six-, and eight-bladed propellers appear relatively louder at 500 feet than they do for the 100-foot runs with flat weighting.

One peculiarity of these records is the relatively high noise level during approach of the two-bladed configuration (configuration 2A) in figures 28 and 29 and of both this configuration and the six-bladed one (configuration 2C) early in the approach at 500 feet (fig. 30). This effect might be due to peculiar radiation characteristics of the noise from the engine intake. An accurate determination of these radiation characteristics would involve serious technical difficulties. Nevertheless, further investigation of this forward noise would be useful, both to try to determine its origin and, if possible, to learn how it might be reduced. In certain flights with the six- and eight-bladed propellers the noise during approach reached levels nearly as high as the peak overhead level when the airplane was as much as 2,000 feet away (see lower graphs of fig. 24). Obviously, it would be desirable to reduce this type of noise if possible.

Take-offs.- The basic data for take-offs (fig. 26) show rather satisfactory consistency between the two runs made in each case.

The averaged curves for each configuration are plotted together in figure 32. There is considerable crossing of these curves which may be accounted for, at least in part, by differences in power and engine speed during the take-off (see table II) and in part by differences in position of the airplane relative to the measuring apparatus at a given time. For example, figure 32 indicates that on the take-off approach and departure the experimental two-bladed configuration (configuration 2A) is not always quieter than the standard configuration (configuration 1). Also, on approach, the six-bladed experimental airplane (configuration 2C) is noisier than expected. One reason why the data for the standard and six-bladed configurations indicate less difference than might be expected is that, at the start of take-off, the standard propeller absorbed 97 horsepower while the two-bladed and six-bladed propellers absorbed 153 and 162 horsepower, respectively. Also, at the start of take-off, the engine speed was 1940 rpm for the standard and 2600 and 2720 rpm for the experimental two-bladed and six-bladed combinations, respectively. The differences in sound-level measurements during approach and departure are also affected by the

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fact that the ground speeds during take-off were not the same with the various combinations and, therefore, at a given point on the time scale, except at zero, distances from the microphone were not equal.

Peak noise levels during take-off and flight.- The average of the peak readings obtained in all take-off and flight measurements, including some rechecks made after the measurements for figures 22 through 26 were completed, are shown in figure 33. A figure similar to figure 33 was originally plotted using only the data shown in figures 22 through 26. For this figure (not shown in this report) the averages of the peak readings shown in these figures were used to establish an average maximum sound level for each flight condition. In this original plotting the take-off readings for the standard Stinson (configuration 1) and the readings for the two- and three-bladed configurations (configurations 2A and 2B) did not show the consistent trend of the other data. In order to determine whether these unexpected results showed up consistently, some rechecks were made of the peak readings for these configurations. Table IV presents the results of these check runs and the results of the original measurements for comparison. The procedure used for the rechecks was similar to that used for obtaining the original data, except that in the interest of saving time only peak readings were taken. In general, however, several successive measurements were made of each peak in question so that the recheck data have a statistical weight similar to that of the original data. To assist the reader in judging the reliability of any value listed in table IV, the number of readings averaged to yield that value is given in a parenthesis beneath it.

In the case of the take-off rechecks for the standard Stinson it may be seen from table IV that the check runs were made with a different configuration of the standard airplane than was used in the original measurements. This unfortunate difference was necessary because the standard Stinson originally used was no longer available when the rechecks were made. The difference between the original Stinson (configuration 1) and the Stinson used for the rechecks (configuration 5) was in the propeller. Configuration 1 had a two-position propeller which was always used in the steeper or cruising pitch. Configuration 5 had a fixed-pitch propeller. Since the two airplanes were not available at the same time, it was not possible to determine what differences there were between the two.

It may be seen from table IV that the take-off rechecks using configuration 5 gave different peak levels from those obtained with configuration 1. It may also be seen that the results of a second recheck, using configuration 5, gave still different results. The take-off rechecks for the two- and three-bladed configurations (configurations 2A and 2B) also gave a somewhat wider spread of data than was

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observed in the rechecks of the flight measurements. Statistically this means, of course, that more take-off than flight readings are necessary to establish a suitable average.

In all cases the final readings adopted for figure 33 are the averages of all the readings taken that were not evidently in error. This final plotting still shows the three-bladed configuration to be a little noisier than the two-bladed one for several of the flight conditions. This effect was not expected and cannot be adequately explained. Perhaps the differences were caused by the several other variables introduced. For example, the two-bladed propeller had to be wider and longer in order to absorb the power effectively and in addition the pitch angle on the two-bladed propeller was lower. Rechecks of the levels for the two-bladed configuration were made on two different occasions, and one set of recheck data was taken for the three-bladed configuration. Since, for the flight measurements, the averages of the readings taken on different days vary only about as much as the small variation between individual readings on the same day, it appears reasonably certain that the three-bladed configuration was slightly noisier than the two-bladed configuration, as the averaged data show.

In the case of the rechecks of the take-off data the final averages for the two- and three-bladed configurations make the take-off data for flat weighting in figure 33 more nearly parallel to the flight data. However, the take-off figure for the standard airplane is very close to the reading for 100-foot, maximum-power flight. This level, which is a little lower than might be expected at first, is perhaps the result of a relatively lower ratio of take-off speed to flight speed for the standard airplane than for the experimental airplanes. For 40-decibel weighting the take-off data cross and recross the 100-foot, maximum-power data and it appears that there was not a very significant difference between the noise generated by any of the configurations for these two conditions.

Ground analysis.- Basic data taken on the ground for series A are given in figure 27. Comparative polar plots for the over-all levels, engine fundamentals, and propeller fundamentals for the six Stinson configurations, standard and modified, are shown in figures 34, 35, and 36. The over-all levels, like the take-offs, show little difference between the standard configuration and the noisier configurations of the modified equipment. Differences are greatest for the 90°, 120°, and 150° positions, a result probably attributable to differences in propeller noise, since it is in these directions that the propellers radiate the most noise (see reference 4). The plot of the engine fundamentals (fig. 35) shows considerable differences both in magnitude and pattern of radiation between the standard airplane and experimental airplanes. This plot would seem to give convincing proof of the

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effectiveness of the muffler installation, especially when considering the fact that the experimental engine has a higher power.

The patterns of engine fundamental are somewhat different for the experimental configurations, even though the same engine installation was used and the engine was run at nearly the same speed in each case. It is interesting to note that, with the exception of the eight-bladed combination, the forward engine noise is reduced with increasing number of blades. Because of the effectiveness of the exhaust muffler, the forward noise appears to come principally from the intake grill. As the propeller rotates, it modulates the noise from the intake grill at a frequency equal to that of blade passage. In addition, the added pressure at the grill produced by the rotating propeller and the resulting air turbulence effects the angular distribution of the noise radiated from the intake grills. This modulation of the engine noise by the propeller noise produces frequencies equal to the sum and difference of the propeller and engine frequencies. Such new frequencies were observed on many occasions, although their significance was not realized at the time the data were taken. These observations lead to the possible conclusions that the reduced levels of the engine fundamentals in the forward direction with increasing numbers of blades result both because energy is transferred from them to the sum and difference frequencies and because the propellers with more blades cause more engine noise to be radiated to the sides than forward because of more air turbulence. Qualitatively this reduction should be greater as the blade-passage frequency becomes higher. Unfortunately, insufficient data were taken to establish thoroughly that the levels of the sum and difference frequencies increased as the fundamental level decreased.

A comparison of propeller fundamentals (fig. 36) does not show a great reduction between the standard and the two-bladed-experimental equipment. Furthermore, the radiation pattern of the propeller fundamental from the standard airplane is quite different from the pattern for any of the slower turning, experimental propellers. Adequate explanation is not possible on the basis of existing data.

Series B. Effect of Blade Shape with Four-Bladed Propellers

Series B is based on peak readings only, since the recorder was not used with four-bladed configurations other than configuration 2F. The averaged peak readings for the four different four-bladed configurations of the quieted Stinson (configurations 2E, 2F, 2G, and 2H) are presented in figure 37.

With the exception of take-off, the differences between the noise levels of the various four-bladed propellers are not very great;

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however, the difference in power of these configurations must be noted — that is, configurations 2E, 2F, and 2G all absorbed approximately 180 horsepower, whereas configuration 2H absorbed only 157 horsepower at maximum power in level flight. The wide-bladed configuration, configuration 2G, was generally slightly noisier than the others, a difference probably attributable to the higher tip speed. The pitch of each of the adjustable propellers was set so that maximum power gave about 3000 crankshaft rpm, and 2600 rpm was used, as previously, for cruising. Hence, the large-diameter propeller of configuration 2G had a higher tip speed. This pitch-setting procedure meant that the engine speed during take-off varied widely for the different configurations. For the thin blades (configuration 2E) the take-off speed was the highest; hence the peak take-off noise level was highest. It is presumably the variation in speed (i.e., tip speed) that explains the great variation in noise level of the take-offs.

Series C. Effect of Blade Angle at Constant Tip Speed

Figure 38 shows the peak noise level in flight overhead at 100 and 500 feet for the quieted Stinson with a four-bladed propeller, configuration 2F, as a function of the propeller pitch setting, with engine speed and hence propeller tip speed held constant. Table V presents the data from which this figure was plotted and shows the power corresponding to each flight condition for each pitch setting of the four-bladed propeller. It is apparent that for a constant speed a reduction of the propeller pitch means a reduction of the power absorbed by the propeller. It is this reduction of engine and propeller power that is chiefly responsible for the decrease of noise level with decreasing propeller pitch, as indicated by figure 39.

Series D. External Noise Level of Standard and Modified Cub Airplanes

The average peak readings from the flight data for the standard and modified Cub airplanes (configurations 3 and 4) are shown in figure 40. For comparison, similar data for the standard and four-bladed Stinsons (configurations 1 and 2F) are also shown. It is interesting to note that, while the experimental Cub is in all cases quieter than the more powerful experimental Stinson, the difference between the standard and experimental Cubs is not so great as the difference between the standard and experimental Stinsons. This is particularly true for the 40-decibel weighting, where the quieting produced a difference in the 100-foot-flight sound levels of only 4 decibels. The primary reason why there is so little difference between the two Cubs is the fact that here also, to utilize the advantage offered

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by gearing, the experimental airplane was purposely set to produce a higher power output than the standard airplane (see table II). Another reason for this smaller apparent reduction with 40-decibel weighting is the somewhat higher propeller frequencies generated by the four-bladed propeller than by the two-bladed propeller. As was explained before, when the 40-decibel network is used, shifting a propeller fundamental of a certain level to a higher frequency causes a higher reading on the Sound Level Meter. The frequency shift for the Cub is not so great as might first appear, however, because the four-bladed propeller turned at lower speed than the two-bladed propeller. An additional reason for the small reduction of noise level for both flat and 40-decibel weighting is the larger diameter of the propeller on the modified Cub. With the belt reduction drive the tip speed of the modified Cub was lower than that of the standard Cub, but the difference was not so great as the difference in tip speeds of the standard and modified Stinsons.

Figure 41 is a polar plot comparing the over-all levels of the standard and modified Cubs, on the ground. As in the flight data, the levels for the comparable standard and modified Stinsons are also given.

Series E. Comparisons at Same Power Output

It has already been noted (see table II) that, in nearly all the tests discussed up to this point, the power output of the experimental airplanes was greater than that of the corresponding standard airplanes.

In order to compare peak sound levels at more nearly the same power, a series of tests was made with throttle stops on the experimental configurations set so that their maximum power in level flight was the same, within estimating limits, as that of the corresponding standard airplanes. This meant that the maximum power in level flight was 153 horsepower for the experimental Stinson configurations and 63 horsepower for the modified Cub.

Take-offs were made with the throttle against the stop in each case; however, the power during take-off was not necessarily the same for the various configurations because of the different way in which different propellers respond to changes in airspeed.

Tests of this type were made on Stinson configurations 2C, 2F, and 2G and on configuration 4, the modified Cub. The results are given in table VI, and in figure 40 for configurations 2F and 4 only. A reduction in sound level due to reduced power is apparent in each case. Whether or not to use the comparisons based on equal power or on the maximum available power will depend on whether or not, in modifying

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a direct-drive airplane by adding a reduction gear, advantage is to be taken of the opportunity to allow the engine to operate at a higher speed.

THEORETICAL CORRELATIONS

Significance of Weighting

The significance of the data made with flat or 40-decibel weighting is dependent on what sound level is being considered. The noise produced by these airplanes at a distance, where the levels will be below 60 decibels, is best interpreted by using the data for 40-decibel weighting. When the relative effects on the average ear of the various configurations operating nearby are considered, the data for flat weighting should be used. To determine the apparent loudness to the ear of the noise level produced by the various configurations in the various flight conditions, it would be necessary to interpolate between the data for 40-decibel and flat weighting.

Correlation with Gutin Formula

Among the experimental configurations, the reduction in sound level with increasing number of blades is due to the decrease in blade loading (see Gutin formula in reference 4). An investigation was made of sound level as a function of power loading per blade for those cases where the tip speeds were about alike. The results indicated that noise levels decrease at a rate slightly in excess of 6 decibels for each halving of the power loading per blade. Gutin's formula yields similar results.

Effect of Tip Speed

The reduced peak sound level of the experimental two-bladed configuration (configuration 2A) as compared with that of the standard (configuration 1) is chiefly attributable to reduced exhaust noise and reduced tip speed. Data by Rudmose and Beranek (reference 7) indicate that, for a constant power per blade, noise levels decrease by about 2.7 decibels for each 100-foot decrease in propeller tip speed. This applies to the normal operating range of the propeller.

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Variation of Sound Level with Height

Theory indicates that for a point source of sound, under conditions where reflection of the sound is not important, the difference in the sound level produced at 100 feet and 500 feet should be close to 14 decibels. The average difference between the levels at 100 and 500 feet for similar flight conditions and sound-level-meter weighting for all the measurements discussed in this report was about 12.3 decibels. The smallest difference obtained was for the flights with flat weighting at maximum power for the standard and modified Stinsons (see fig. 33). In this case the average difference between the levels at 100 and 500 feet was only 10.3 decibels. A maximum averaged difference of 14 decibels was observed for the standard and quieted Cubs, at cruising power, using 40-decibel weighting (see fig. 40). More extensive tests than those reported here would be required to establish whether the difference measured by the methods used here should be the theoretical value of 14 decibels. Other work has indicated that it probably should be. The departure from theory is therefore quite possibly due to consistent errors of some sort, but, of course, the possibility is not ruled out that despite considerable study other factors are entering here that may not have been explored.

SOUND LEVELS COMPARED WITH FAMILIAR SOUNDS

In order to assist in judging the results of the sound levels measured during this research, figure 42 has been included. Reference 8 gives information concerning measured sound levels of ordinary aircraft, highway traffic, and railroad traffic, which should be helpful in evaluating the sound levels discussed in this report.

PERFORMANCE TESTS

In order to determine whether the experimental airplanes had suffered any reduction in flight performance caused by the use of silencers, reduction gears, and special propellers, comparative measurements were made of the take-off runs in still air. To eliminate, as far as possible, differences due to piloting technique, the take-off runs were made with tail wheel on the ground and controls held in the neutral position. Although take-off distances using this technique are probably longer than would be obtained in a normal "tail-up" take-off, the method is believed to be justified when only comparative results are required.

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For the take-off tests the experimental Stinson airplanes were equipped with a throttle stop set to give the same maximum power in level flight (153 hp) as was estimated for the standard Stinson airplane. The throttle stop of the experimental Cub was also reset, for the take-off tests, to give the same maximum power in level flight (63 hp) as the standard Cub.

Results of the measurements for the take-off runs are given in table VII. It is evident that the modifications to the Stinson airplane increased the take-off run slightly, while the opposite was true for the modifications to the Cub. Since the difference in take-off distance between the standard and modified Stinsons was not great, it appears probable that the modified Stinsons would have equal, if not superior, take-off as compared with that of the standard Stinson if the somewhat higher engine power made available by gearing were utilized.

Observations of airspeed in flight showed no noticeable differences between the modified and standard airplanes. In production models, of course, the mufflers used on the modified Stinson would be enclosed within the fuselage.

CONCLUSIONS

From noise measurements on standard light airplanes and on similar airplanes equipped with engine mufflers, propeller reduction gears, and propellers with various numbers of blades and blade shapes, the following conclusions are drawn:

1. Significant reductions in the maximum external noise level of conventional light airplanes can be made without increasing propeller diameter, or making major changes in the basic airframe, and without seriously reducing airplane performance.

2. To effectuate significant reductions in external noise level, exhaust silencers and reduced propeller tip speed appear to be necessary.

3. In general, when using exhaust silencers and reduced propeller speed, the noise level decreases as the number of propeller blades increases.

4. With exhaust silencers and reduced tip speed, increasing the number of blades becomes less effective as the distance to the observer increases.

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5. With exhaust silencers and reduced propeller speed, increasing the blade angle for constant tip speed and number of blades yields increased sound levels. This increase is approximately equal to 6 decibels for each doubling of the power supplied to the propeller.

6. Previous research in this field is confirmed in that both decreasing tip speed and decreasing blade loading tend to reduce propeller noise.

7. No significant conclusion as to the effect on the external noise level of varying propeller blade design can be drawn from the data.

Aeronautical Research Foundation
Boston, Mass., May 4, 1949

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APPENDIX

GROUND AND SERVICE TESTS OF VEE-BELT DRIVE FOR CONFIGURATION 4

Ground Tests

Ground tests were made with the fuselage staked down at the Metropolitan Airport, Canton, Massachusetts, during the months of June through September 1948. The conditions of these tests were as follows:

(1) Fifty hours at 1500 engine rpm, about 20 horsepower. Belt slippage occurred early in these tests but was cured by tightening the belts after 3 or 4 hours of running. Owing to the coarseness of adjustment, they were probably made a little too tight.

(2) Full-throttle tests at 2450 engine rpm, about 103 horsepower. These tests were started without readjustment of the belt tension. After 5 hours, one belt failed by breakage of the cable. This was the shortest belt of the group. After this failure the adjusting mechanism was altered to give a finer adjustment and the belt center distance was reduced by a small amount. Six hours at full throttle on the remaining nine belts were then completed without failure.

Flight Experience

Subsequent to the ground tests, and beginning on September 15, 1948, the modified Cub airplane, configuration 4, was assembled and flown for purposes of the sound-level tests reported herein. For these tests a new set of belts was used. The engine power was limited to about 75 to 80 horsepower at full throttle, level flight (see table II) by means of a throttle stop. Total flying time under these conditions was $42\frac{5}{6}$ hours.

During this time 3 belts (belts 3, 5, and 8) turned over, but were subsequently used after being turned back into their grooves and tightened. The condition of the belts at the end of this time is as follows: Belts 2, 3, and 5 were frayed; and belts 6, 7, 9, and 10 were loose and showed signs of deterioration. On November 26, a third set of belts was installed and had been run for $1\frac{1}{6}$ hours when a telegram from Goodyear Aircraft Corporation advised us to discontinue use of that set because of poor quality. The fourth set was installed on December 17

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and at that time the throttle stop was removed and take-offs were made at full engine power (104 hp estimated at 2475 rpm at start of take-off). The results of this full-throttle testing were as follows:

Date	Time (hr)	Remarks
12/17/48		Started tests
12/22/48		On skis
12/28/48	18	Belt 10 showed deterioration
12/28/48	$19\frac{1}{3}$	Belt 4 turned over
1/2/49	$25\frac{2}{3}$	Belts 6 and 9, deterioration
1/3/49	$26\frac{3}{4}$	Belt 4 loose and removed
1/8/49	$34\frac{2}{3}$	Belt 1 turned over; put back
1/8/49	$35\frac{1}{2}$	Belt 5 rolled over into belt 4 groove Belt 1 came off in flight; belt 5 was left in belt 4 groove
1/9/49	$36\frac{1}{2}$	Belt 6 rolled into belt 5 groove and was left there
1/12/49	$39\frac{55}{60}$	Signs of slipping; tightened adjustment for first time
1/12/49	$40\frac{1}{6}$	Belt 5 turned over and put back
1/14/49	$41\frac{2}{3}$	Belt 4 turned over and put back
	$42\frac{3}{4}$	Belt 4 turned over and removed
	$44\frac{5}{6}$	Belt 5 turned over and put back
	$45\frac{1}{6}$	Belt 8 turned over and put back
1/15/49	$48\frac{1}{6}$	Belt 8 turned over and put back
	$48\frac{1}{4}$	Belt 3 turned over
	Test discontinued	

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During this time $\left(48\frac{1}{4}\text{ hours}\right)$, 620 take-offs (an average of 13 take-offs per hour) were accomplished. From $26\frac{3}{4}$ hours to $35\frac{1}{2}$ hours, nine belts were in use; from $35\frac{1}{2}$ hours to $42\frac{3}{4}$ hours, eight belts were in use; from $42\frac{3}{4}$ hours to the end of the tests, only seven belts were in use. A tendency for the belts to roll forward was shown during this time.

A fifth set was installed on February 25 and has $15\frac{2}{3}$ hours to date, making a total of $167\frac{55}{60}$ hours on the vee-belt drive.

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REFERENCES

1. Theodorsen, Theodore, and Regier, Arthur A.: The Problem of Noise Reduction with Reference to Light Airplanes. NACA TN 1145, 1946.

2. Regier, Arthur A.: Effect of Distance on Airplane Noise. NACA TN 1353, 1947.

3. Hicks, Chester W., and Hubbard, Harvey H.: Comparison of Sound Emission from Two-Blade, Four-Blade, and Seven-Blade Propellers. NACA TN 1354, 1947.

4. Hubbard, Harvey H., and Regier, Arthur A.: Propeller-Loudness Charts for Light Airplanes. NACA TN 1358, 1947.

5. Regier, Arthur A., and Hubbard, Harvey H.: Factors Affecting the Design of Quiet Propellers. NACA RM L7H05, 1947.

6. Fletcher, Harvey, and Munson, W. A.: Loudness, Its Definition, Measurement and Calculation. Jour. Acous. Soc. Am., vol. V, no. 2, Oct. 1933, pp. 82-108.

7. Rudmose, H. Wayne, and Beranek, Leo L.: Noise Reduction in Aircraft. Jour. Aero. Sci., vol. 14, no. 2, Feb. 1947, pp. 79-96.

8. Field, R. L., Edwards, T. M., Kangas, Pell, and Pigman, G. L.: Measurement of Sound Levels Associated with Aircraft, Highway and Railroad Traffic. Tech. Development Rep. 68, CAA, U. S. Dept. Commerce, July 1947.

TABLE I.- PROPELLERS USED IN SOUND-LEVEL MEASUREMENTS

Configuration	Airplane	Illustrated in figure	Number of blades	Type of blade	Diameter (in.)	Hub adapter	Pitch setting at 3/4 station (deg)
1	Standard Stinson 165	1	2	Skyblade	76	None	$18\frac{1}{2}$ (fixed)
2A	Modified Stinson 150	5(a)	2	Wide	84.5	Eight-bladed	21
2B	Modified Stinson 150	5(b)	3	Medium	76	Six-bladed	$23\frac{1}{2}$
2C	Modified Stinson 150	5(c)	6	Thin	76	Six-bladed	21
2D	Modified Stinson 150	5(d)	8	Thin	76	Eight-bladed	$18\frac{1}{2}$
2E	Modified Stinson 150	5(e)	4	Thin	76	Eight-bladed	25
2F	Modified Stinson 150	5(f)	4	Medium	76	Eight-bladed	22
2G	Modified Stinson 150	5(g)	4	Wide	84.5	Eight-bladed	18
2H	Modified Stinson 150	5(h)	4	Solid	76	None	25 (fixed)
3	Standard Cub	6	2	Wooden	72	None	14 (fixed)
4	Modified Cub	7	4	Two-piece, wooden	80	None	15 (fixed)
5	Standard Stinson 165	16	2	Wooden	76	None	14 (fixed)

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TABLE II.- PROPELLER TIP SPEEDS AND ESTIMATED ENGINE POWERS

Airplane	Configuration	Propeller			Ground tests			Flight tests					
								Full throttle			Cruising		
		Number of blades	Diameter (in.)	Ratio of propeller speed to engine speed	Engine speed (rpm)	Engine power (hp)	Propeller tip speed (ft/sec)	Engine speed (rpm)	Engine power (hp)	Propeller tip speed (ft/sec)	Engine speed (rpm)	Engine power (hp)	Propeller tip speed (ft/sec)
Series A through D; tests at unequal powers													
Standard Stinson	1 and 5	2	76	1.00	1940	97	646	2600	153	862	2350	115	779
Modified Stinson	2A	2	84.5	.632	2600	153	603	3100	183	720	2600	108	603
	2B	3	76	.632	2740	164	572	3050	181	638	2600	111	544
	2C	6	76	.632	2720	162	568	3100	183	645	2600	108	544
	2D	8	76	.632	2700	161	564	3000	179	627	2625	119	548
	2E (thin)	4	76	.632	2900	175	607	3050	181	638	2600	111	544
	2F (medium)	4	76	.632	2640	156	552	3100	183	645	2675	113	558
	2G (wide)	4	84.5	.632	2000	101	464	3000	179	697	2600	111	603
	2H (solid)	4	76	.632	1950	98	407	2650	157	554	2250	96	476
Standard Cub	3	2	72	1.00	2110	58	663	2250	63	707	2000	44	628
Modified Cub (throttle stopped)	4	4	80	.632	2150	68	474	2550	80	562	2150	48	474
Series E; tests at comparative powers													
Modified Stinson	2C	6	76	.632	2450	131	514	2860	153	600	----	---	---
	2F	4	76	.632	2225	118	465	2880	153	603	----	---	---
	2G	4	84.5	.632	1950	104	452	2860	153	663	----	---	---
Modified Cub	4	4	80	.632	2040	54	448	2400	63	527	2150	45	474

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TABLE III.- TEST PROGRAM

Flight measurements		
Configurations	Flight conditions	Number of runs; weighting network; and recorder
1, 2A through 2D, and 2F	Take-offs	Two, flat; two, 40-decibel; recorder
	100-foot flight; maximum power	Four, flat; four, 40-decibel; recorder
	100-foot flight; cruising power	Four, flat; four, 40-decibel; recorder
	500-foot flight; maximum power	Four, flat; four, 40-decibel; recorder
	500-foot flight; cruising power	Four, flat; four, 40-decibel; recorder
2E, 2G, 2H, 3, and 4	Same as above	Same as above, except no recorder; Maximum readings only taken
2F, with propeller pitch settings of 23°, 21°, 19°, 17°, 15°, and 13°	100-foot flight; 3000 crank-shaft rpm	Four, flat; two, 40-decibel, no recorder
	500-foot flight; 3000 crank-shaft rpm	Four, flat; two, 40-decibel, no recorder
5	Take-off	Two, flat; two, 40-decibel, no recorder

Ground measurements	
Configurations	Data taken
1, 2A through 2D, and 2F	Frequency component and over-all levels at 50-foot distance; at 0°, 30°, 60°, 90°, 120°, and 150° both sides of airplane; flat weighting
3 and 4	Over-all levels at 50-foot distance; at 0°, 30°, 60°, 90°, 120°, and 150° both sides of airplane; flat weighting

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TABLE IV.- SERIES A. CHECK RUNS COMPARED WITH ORIGINAL DATA

[Each value represents the average of several successive observations. Numbers in parentheses refer to the number of observations in each case.]

Type of configuration		Standard Stinson			Geared two-bladed			Geared three-bladed	
Configuration		1	5	5	2A	2A	2A	2B	2B
Type of run	Weighting	Original run	Check run	Second check run	Original run	Check run	Second check run	Original run	Check run
Take-offs	Flat	99.5 (2)	107 (3)	103 (3)	99 (2)	104 (2)	104 (2)	97 (3)	101 (2)
	40-db	99 (3)	92 (2)	90 (3)	88 (2)	86 (2)	87 (2)	82 (2)	84 (2)
100-foot altitude, maximum power	Flat	102 (4)	---	---	94 (4)	95 (4)	94 (4)	93 (4)	95 (4)
	40-db	97 (4)	---	---	83 (4)	83 (4)	84 (4)	83 (4)	82 (4)
100-foot altitude, cruising power	Flat	99 (4)	---	---	88 (4)	91 (4)	91 (4)	90 (2)	91 (4)
	40-db	92 (4)	---	---	79 (4)	78 (4)	78 (4)	80 (4)	77 (4)
500-foot altitude, maximum power	Flat	90 (4)	---	---	84 (4)	83 (4)	82 (4)	86 (4)	86 (4)
	40-db	82 (4)	---	---	71 (4)	72 (4)	70 (5)	69 (6)	71 (4)
500-foot altitude, cruising power	Flat	86 (4)	---	---	78 (4)	79 (4)	---	81 (4)	---
	40-db	77 (4)	---	---	65 (4)	65 (4)	---	65 (6)	---

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TABLE V.- SOUND LEVEL WITH CHANGING HORSEPOWER AND CONSTANT TIP SPEED

[Air temperature, 65° for first five settings, 75° for sixth test (13°); engine speed, 3000 rpm; propeller speed, 1900 rpm.]

Pitch settings of four-bladed propeller (3/4 station) (deg)	Manifold pressure (in. Hg)	Estimated power (hp)	Altitude (ft)	Over-all level	
				100 ft	500 ft
23	28.5	175	100	91	
	28.5	175	500		81
21	26.3	159	100	92	
	26.0	156	500		81
19	21.2	118	100	89	
	21.1	117	500		75
17	18.9	99	100	88	
	18.7	97	500		74
15	17.0	83	100	85	
	17.0	83	500		73
13	15.5	71	100	85	
	16.0	75	500		73

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TABLE VI.- PEAK NOISE LEVELS AS EFFECTED BY ENGINE POWER

[Each value is an average of four readings.]

Airplane / Type of run	Standard Stinson	Modified Stinsons							Standard Cub	Modified Cub	
	Configurations 1 and 5	Configuration 2C		Configuration 2F		Configuration 2G		Configuration 2H	Configuration 3	Configuration 4	
Engine power, hp	153	183	153	183	153	179	153	157	63	80	63
Flat weighting											
Take-off	107	92	81	98	92	88	85	88	100	91	85
100-foot altitude, maximum power	102	82	81	92	87	92	89	89	91	83	78
100-foot altitude, cruising power	99	79	--	87	--	86	--	86	89	82	77
500-foot altitude, maximum power	90	73	68	82	77	82	79	78	81	70	68
500-foot altitude, cruising power	86	69	--	76	--	75	--	72	79	67	65
40-db weighting											
Take-off	99	82	68	82	74	74	71	76	83	78	71
100-foot altitude, maximum power	97	79	77	82	77	83	77	82	81	75	68
100-foot altitude, cruising power	92	74	--	79	--	75	--	78	79	73	66
500-foot altitude, maximum power	82	68	63	69	65	70	65	68	70	62	61
500-foot altitude, cruising power	78	63	--	65	--	64	--	63	66	58	57

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TABLE VII.- COMPARISON OF PERFORMANCE OF STANDARD AND EXPERIMENTAL AIRPLANES

[Take-off run; no wind; tail down]

Airplane	Configuration	Approximate over-all weight (lb)	Maximum power in level flight (hp)	Take-off run (ft)		
				Average (1)	Maximum	Minimum
Standard Stinson	5	1592	153	412 (4)	425	398
Experimental Stinson; six-bladed propeller	2C	1591	153	471 (4)	486	471
Experimental Stinson; four-bladed; medium propeller	2F	1592	153	445 (4)	451	439
Experimental Stinson; four-bladed, wide propeller	2G	1593	153	449 (4)	455	439
Experimental Stinson; four-bladed, solid propeller	2H	1592	153	500 (4)	508	490
Standard Cub	3	1177	63	343 (4)	349	336
Experimental Cub	4	1177	63	277 (4)	280	273

[1]Numbers in parentheses indicate number of runs made to obtain average figure.

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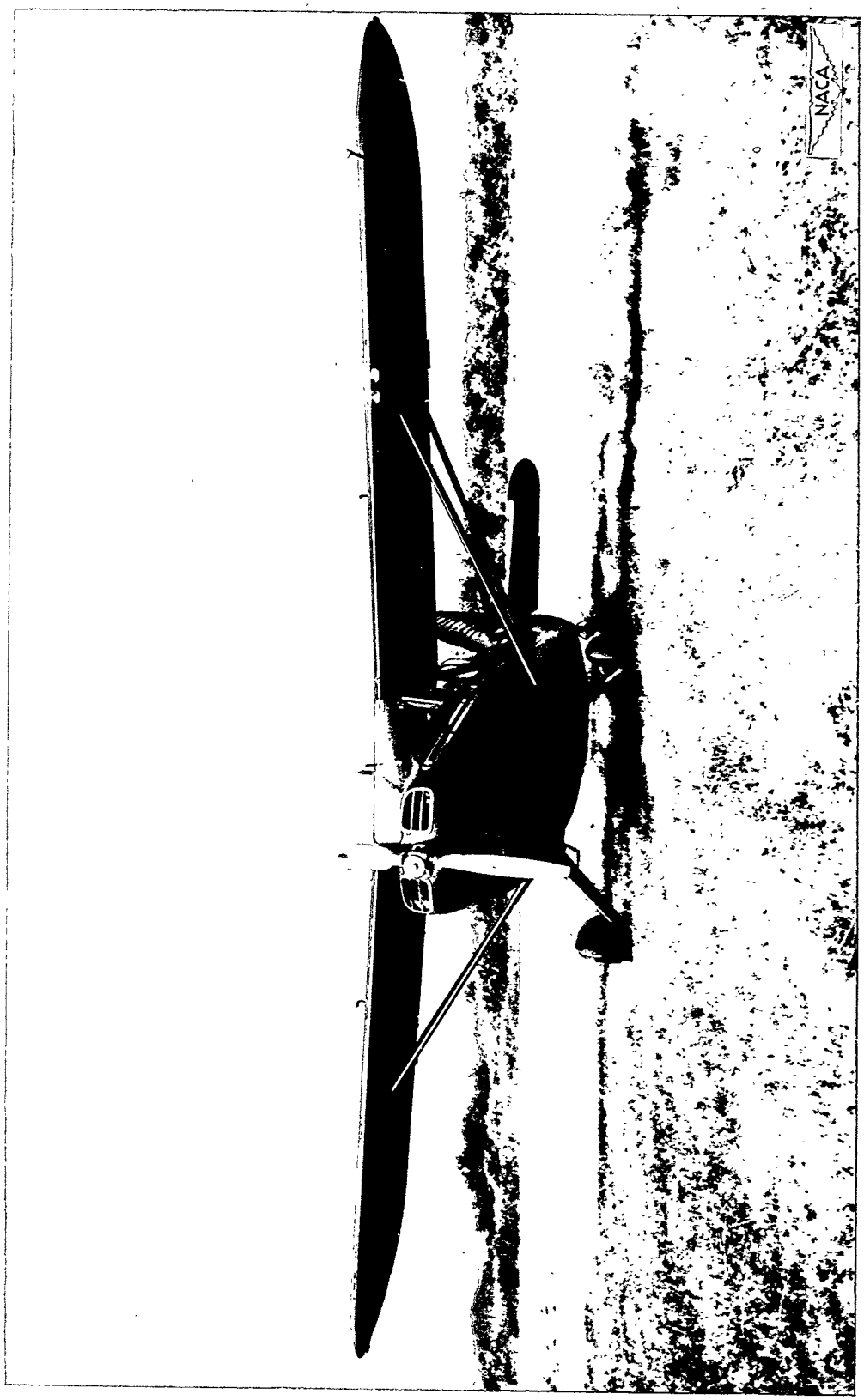

Figure 1.- Standard Stinson, configuration 1.

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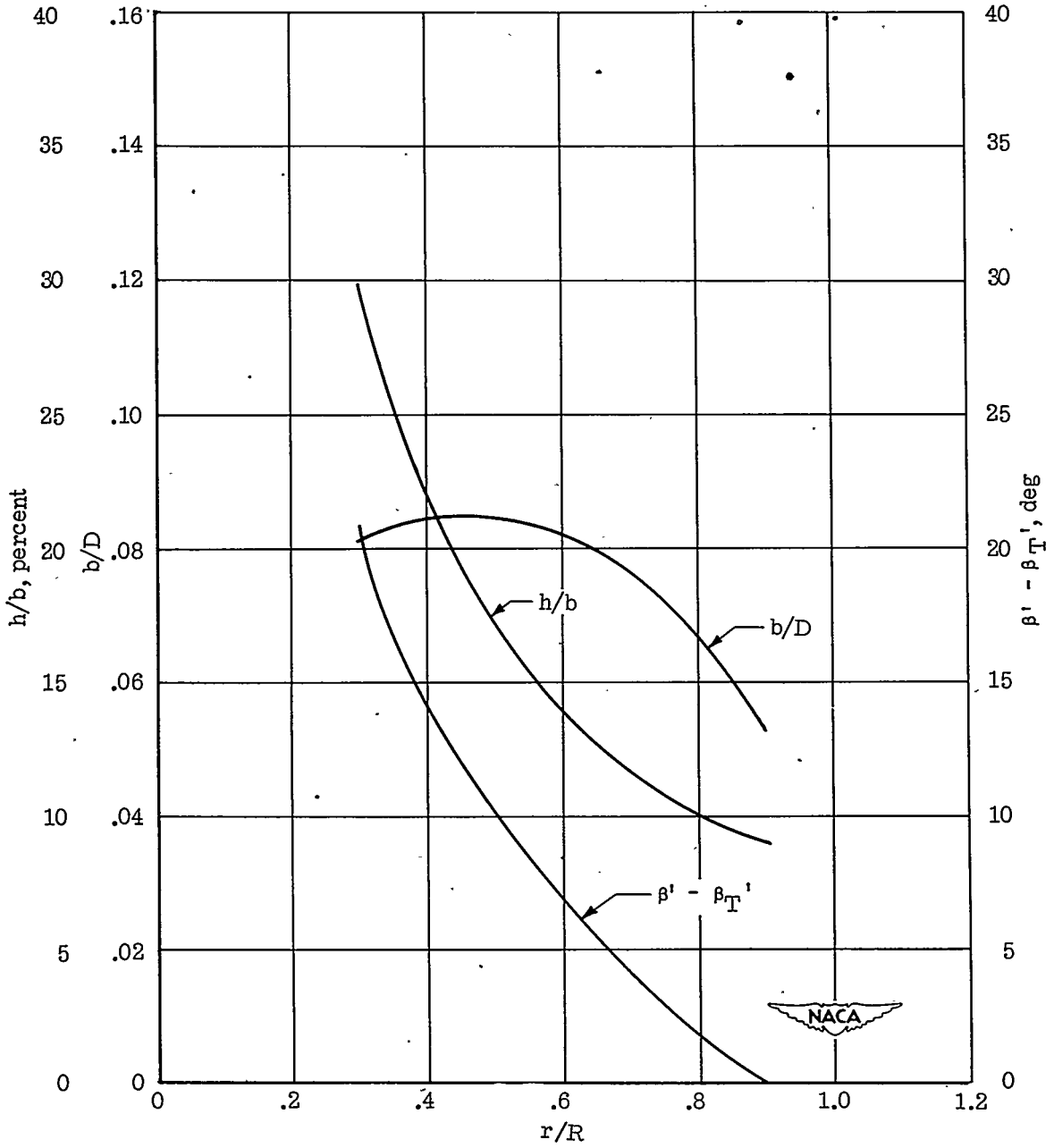

Figure 2.- Blade-form curves for Sensenich Skyblade propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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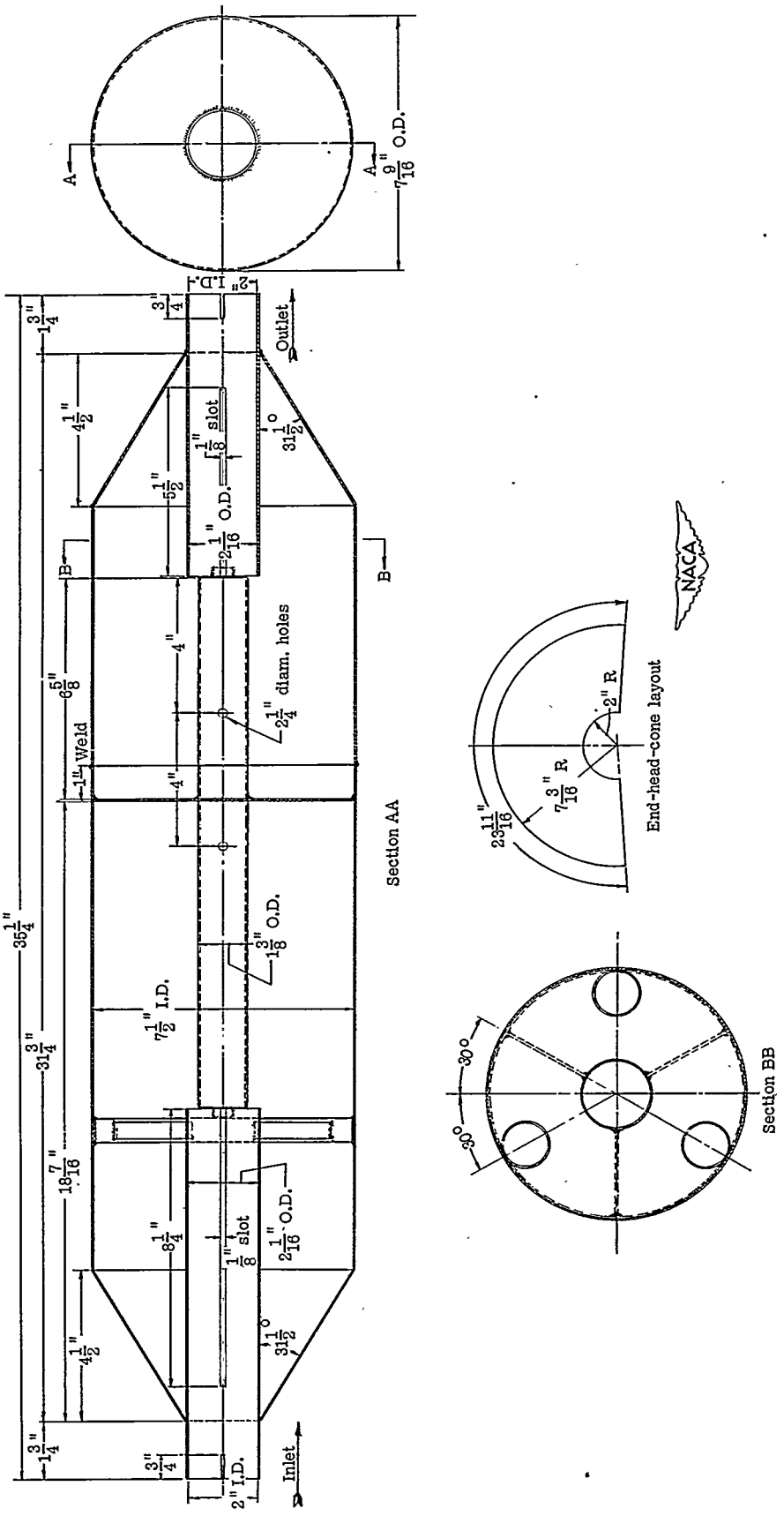

Figure 3.- Cross-sectional drawing of Maxim Silencer.

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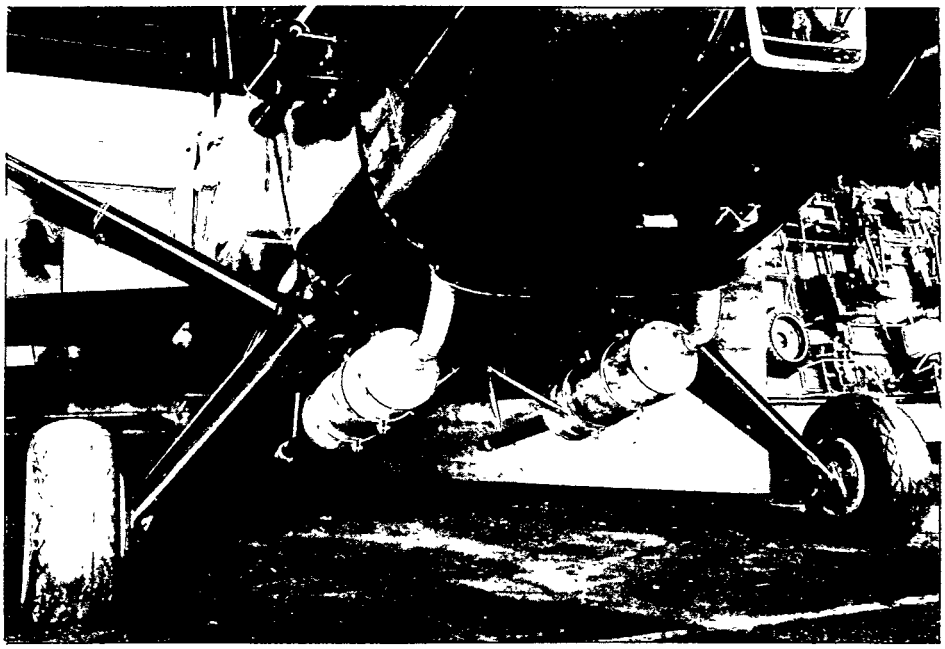
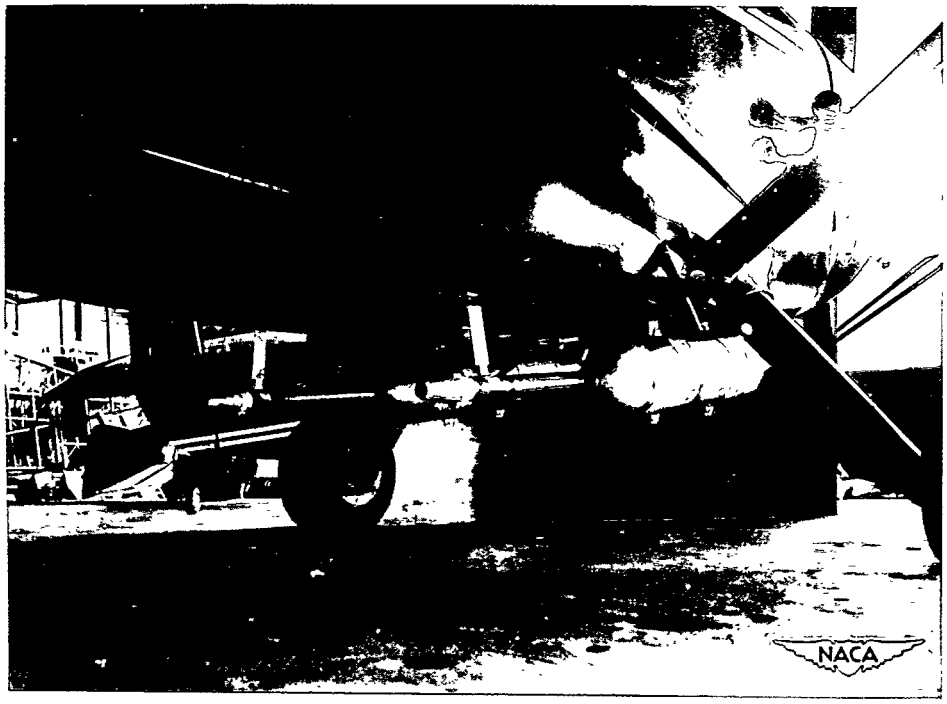


(a) Front view showing mounting.



(b) Rear view showing tailpipes and reducing cones.

Figure 4.- Maxim Silencers mounted on modified Stinson.

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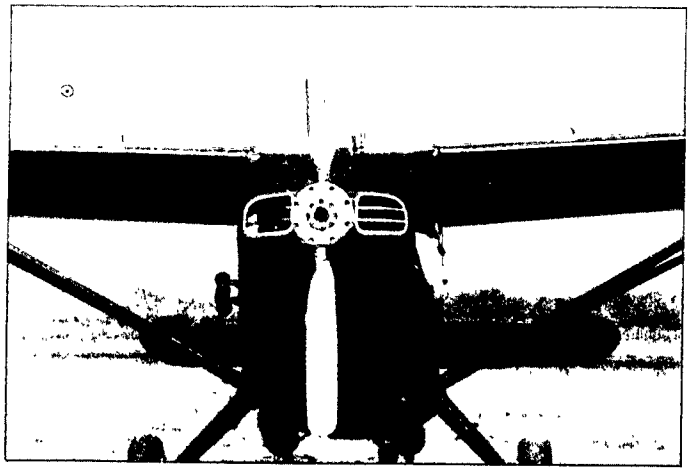
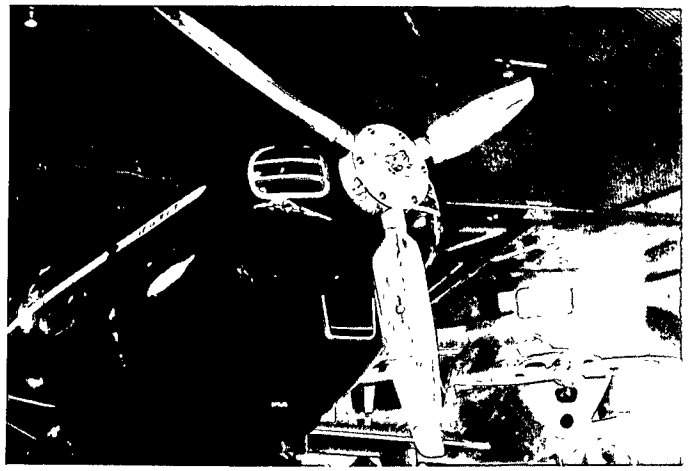
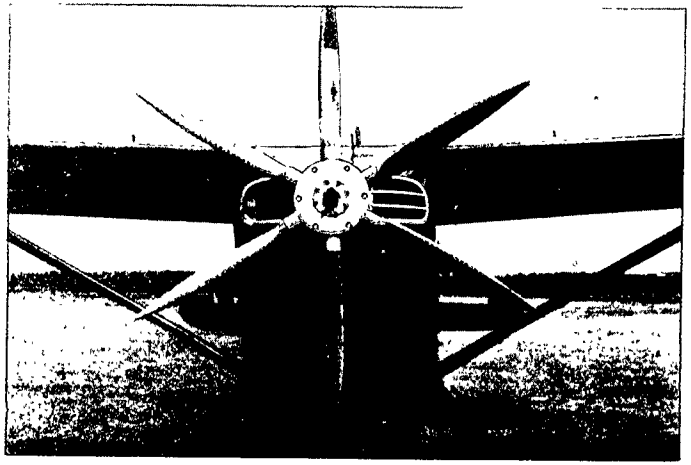


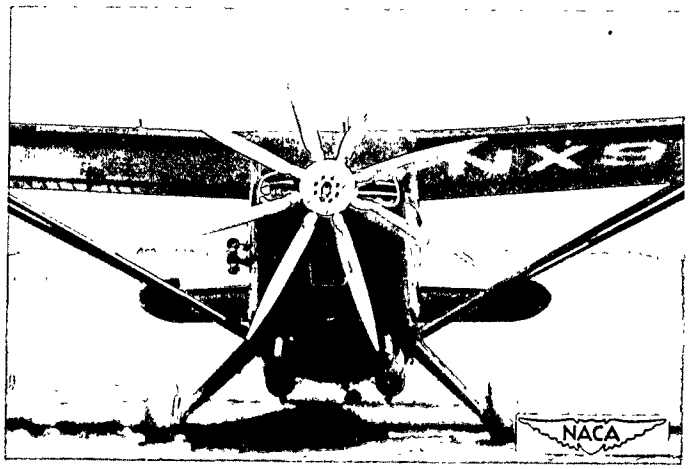
(a) Two-bladed propeller, configuration 2A.



(b) Three-bladed propeller, configuration 2B.



(c) Six-bladed propeller, configuration 2C.



(d) Eight-bladed propeller, configuration 2D.

Figure 5.- Modified Stinson, various propellers.

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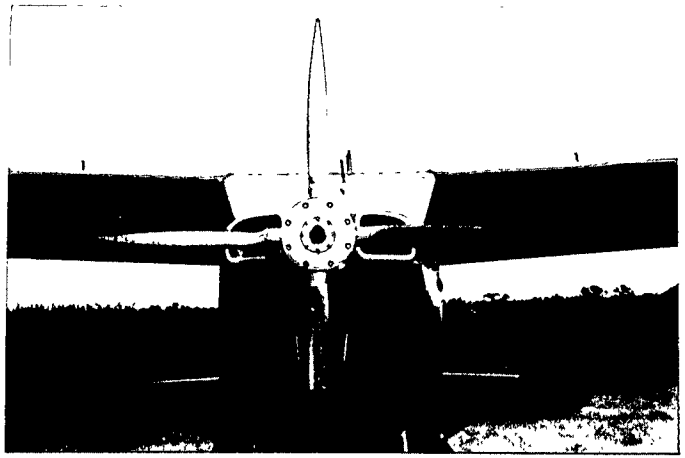
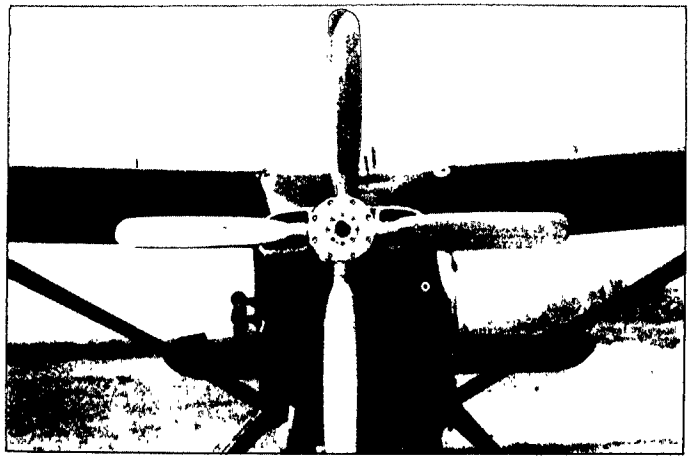


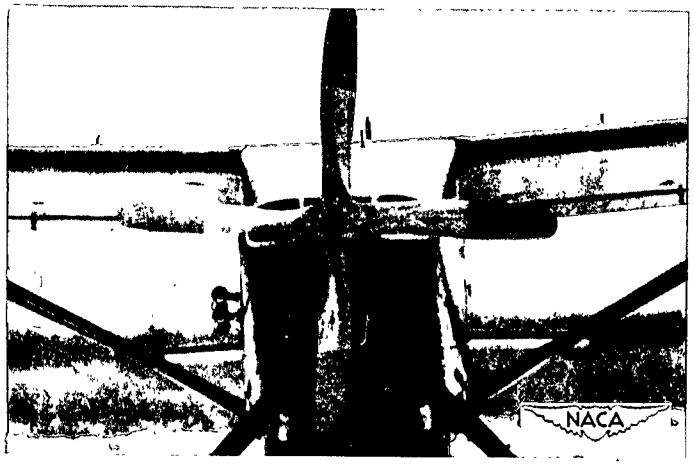
(e) Thin-bladed propeller, configuration 2E.



(f) Medium-bladed propeller, configuration 2F.



(g) Wide-bladed propeller, configuration 2G.



(h) Solid-bladed propeller, configuration 2H.

Figure 5.- Concluded.

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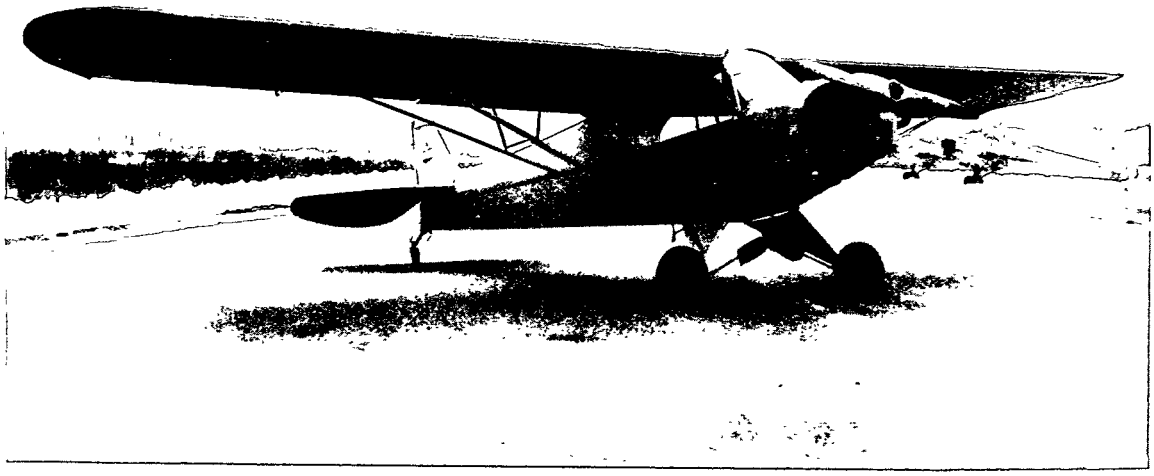
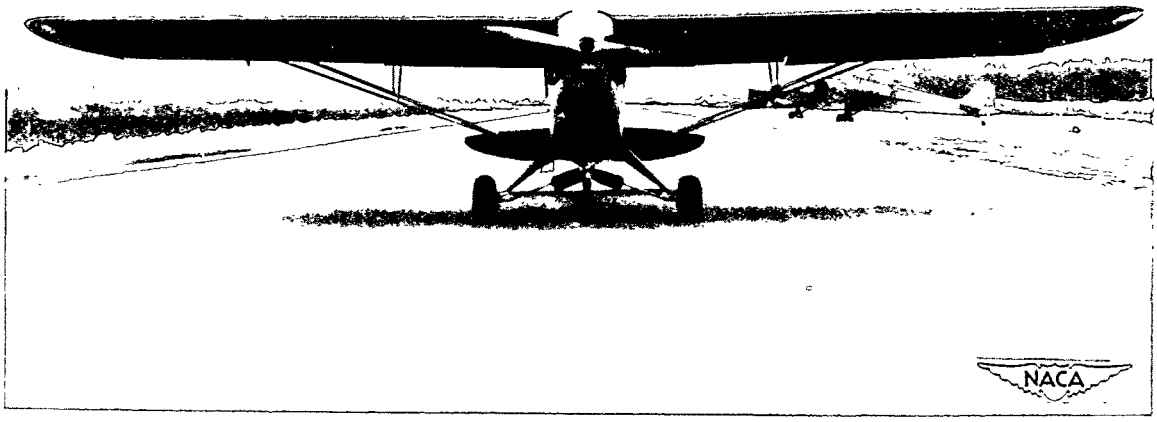


(a) Side view.



(b) Front view.

Figure 6.- Standard Cub, configuration 3.

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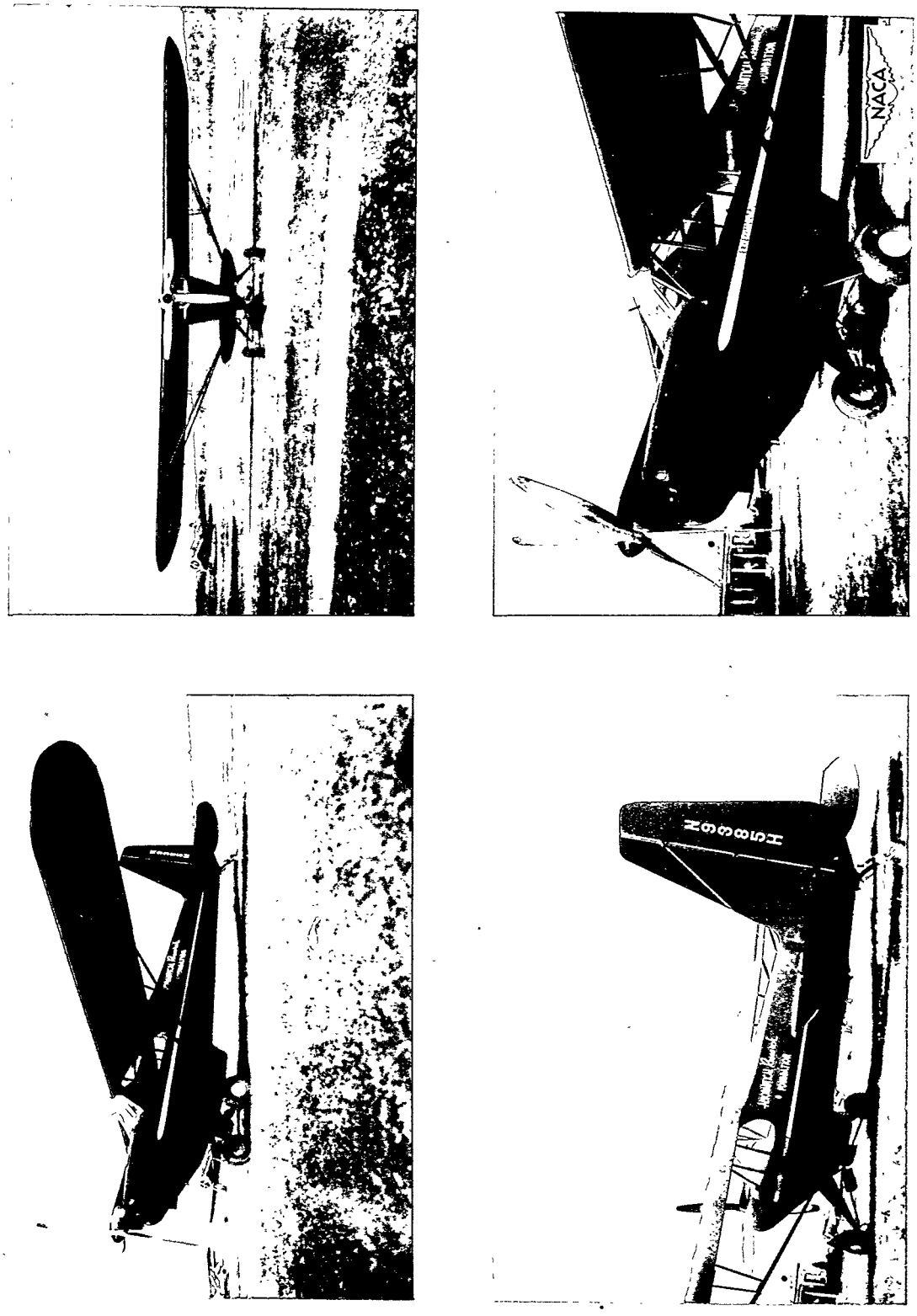

Figure 7.- Various views of modified Cub, configuration 4.

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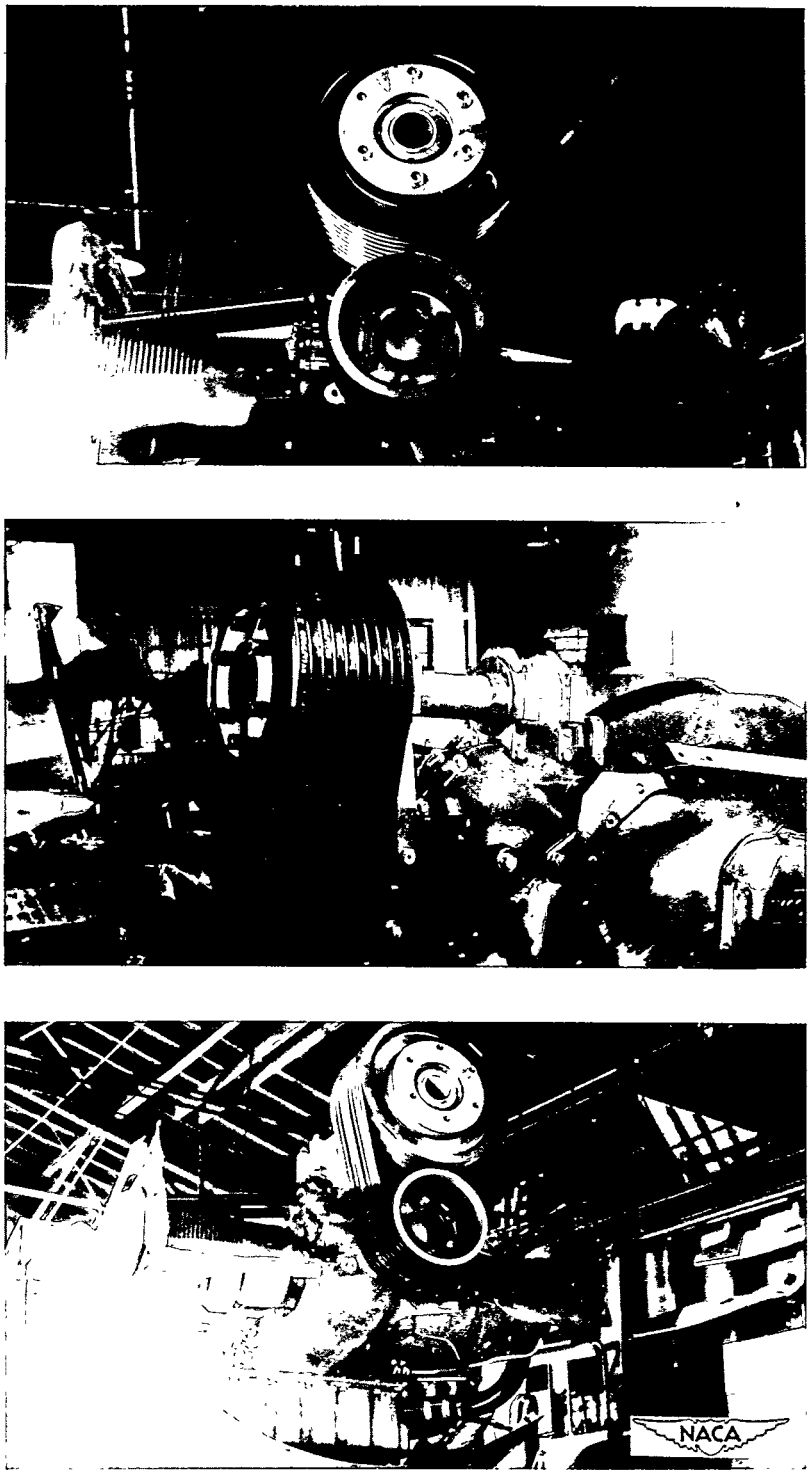

Figure 8.- Three views of vee-belt propeller drive used with engine of modified Cub.

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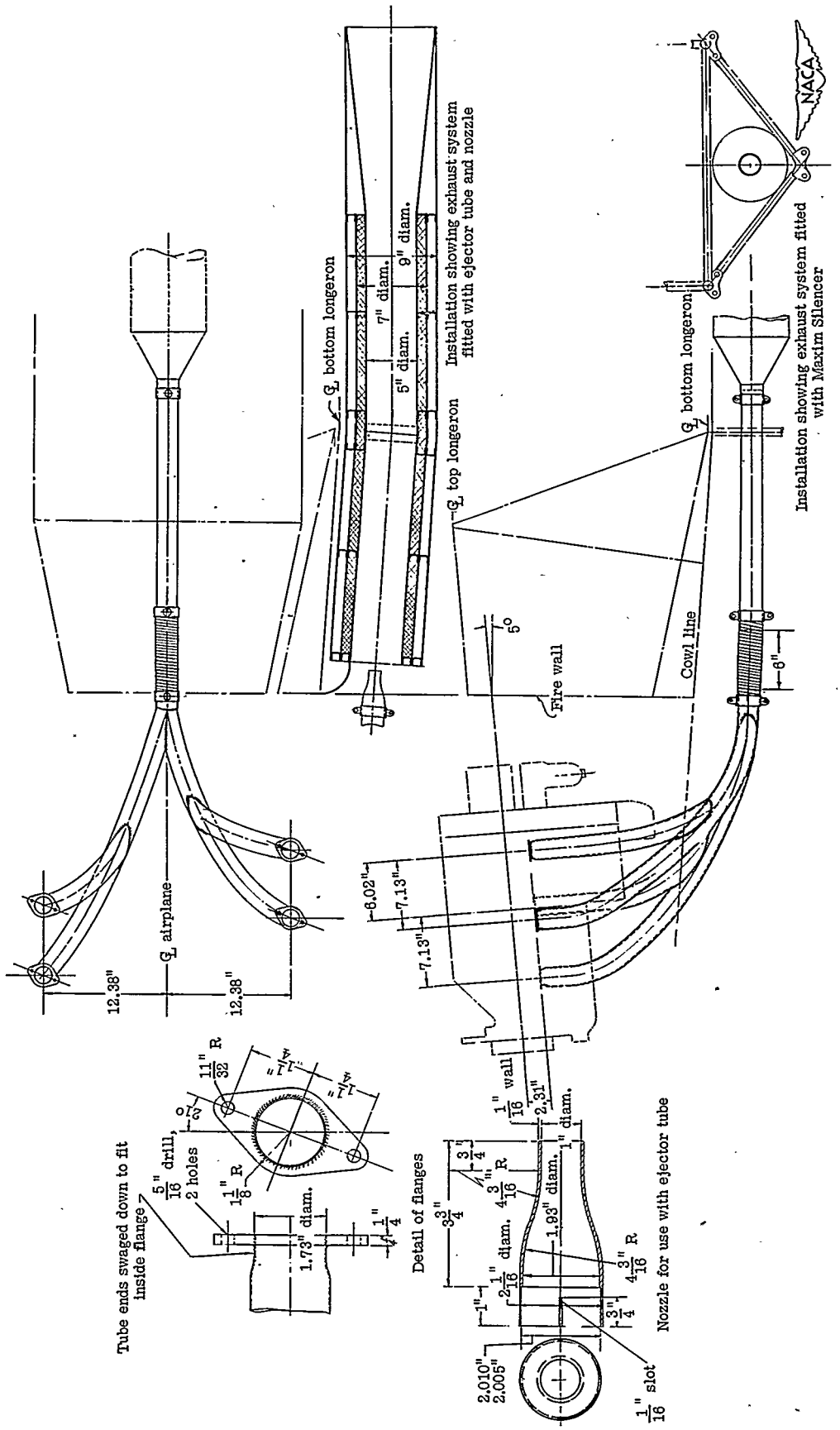

Figure 9.- Assembly drawing of exhaust system used on modified Cub.

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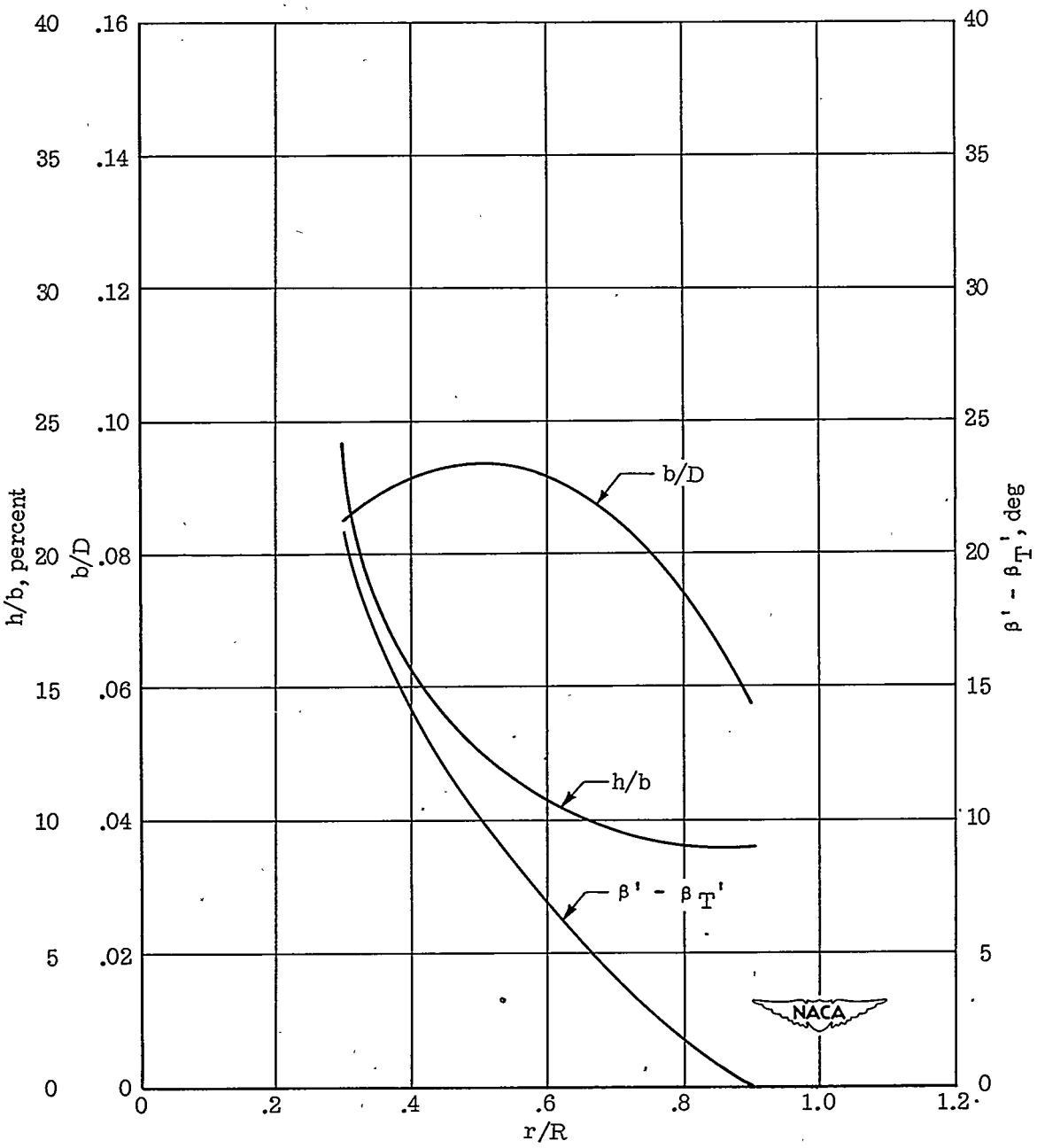

Figure 10.- Blade-form curves for medium-bladed propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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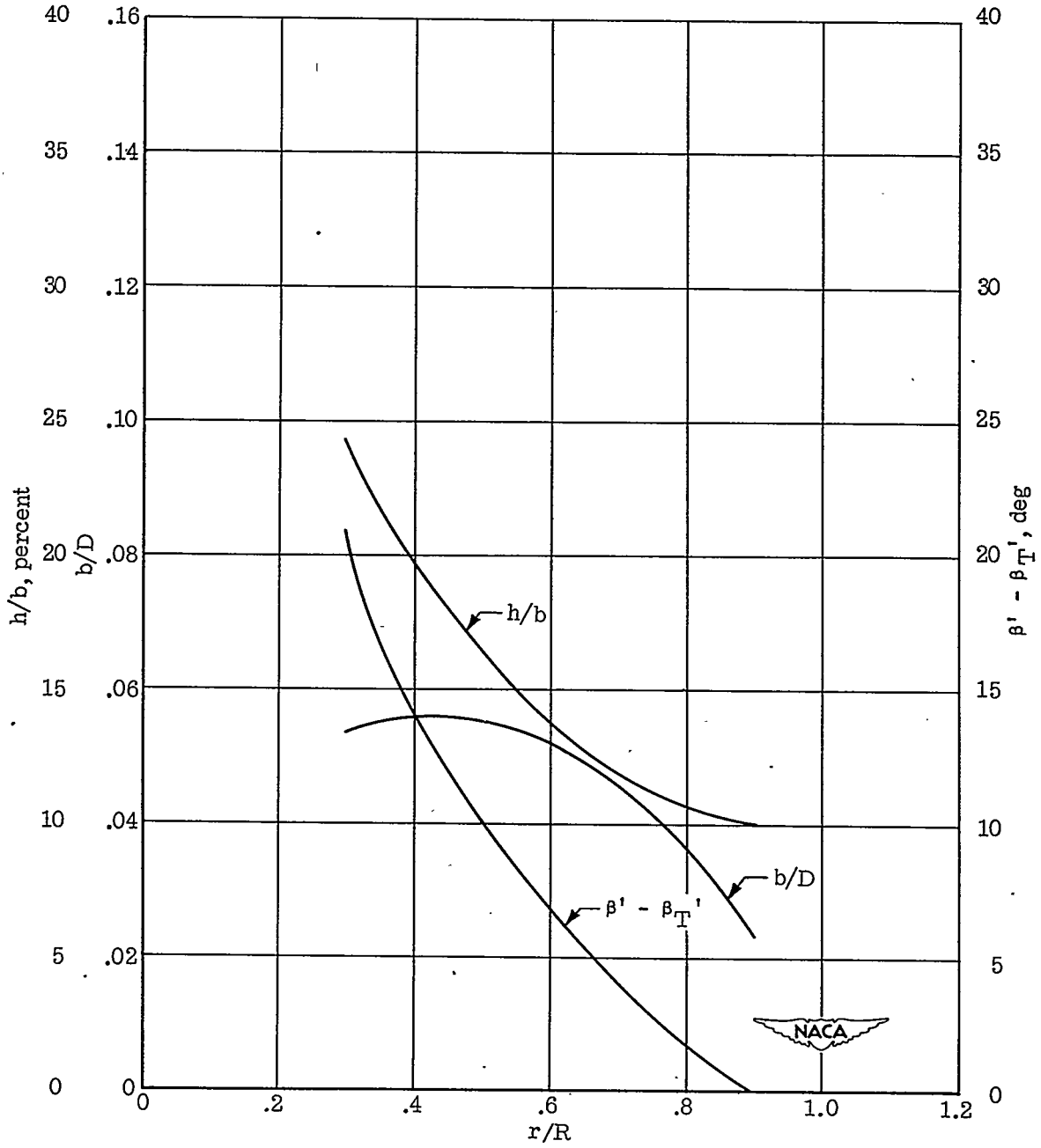

Figure 11.- Blade-form curves for thin-bladed propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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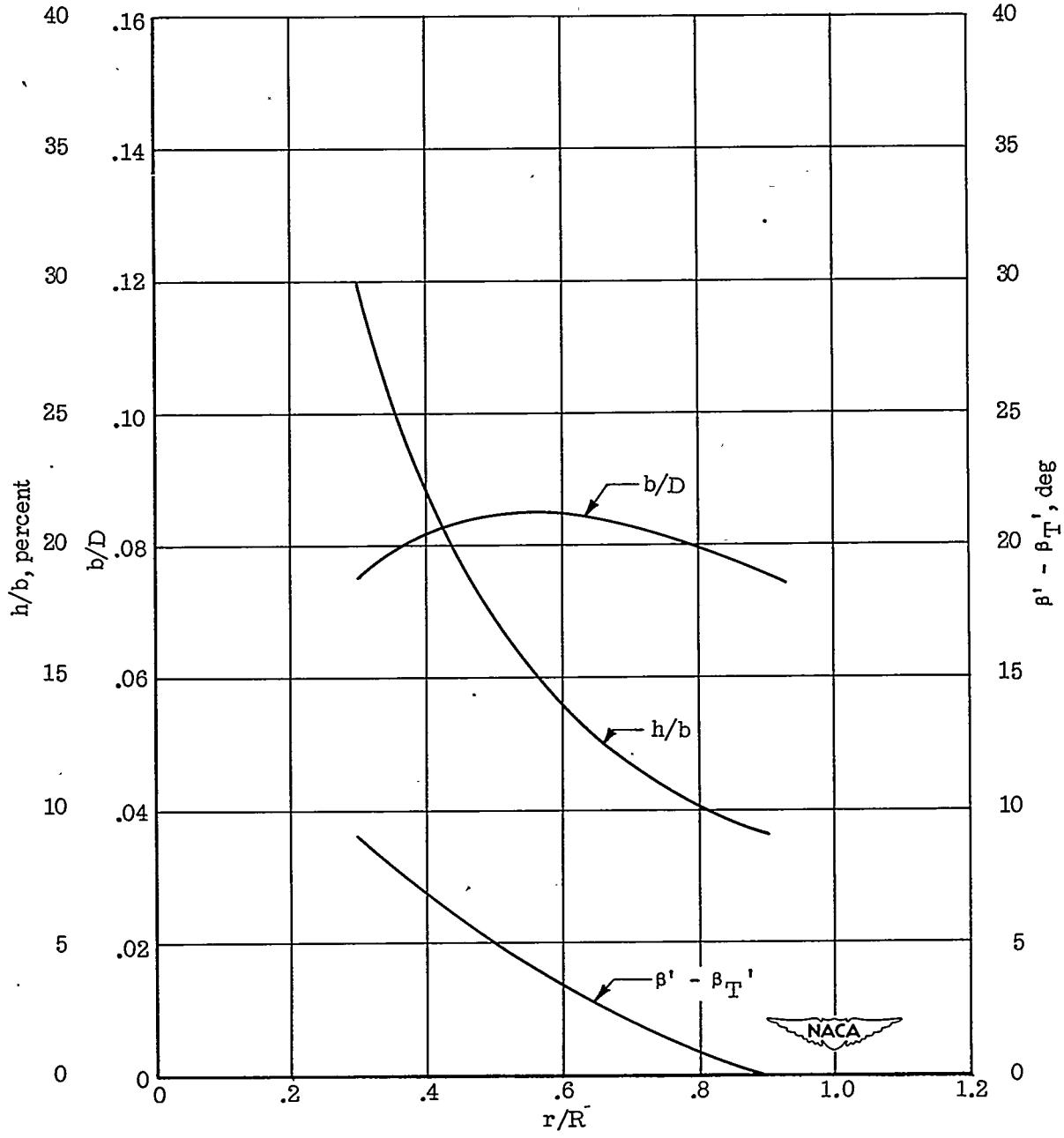

Figure 12.- Blade-form curves for wide-bladed propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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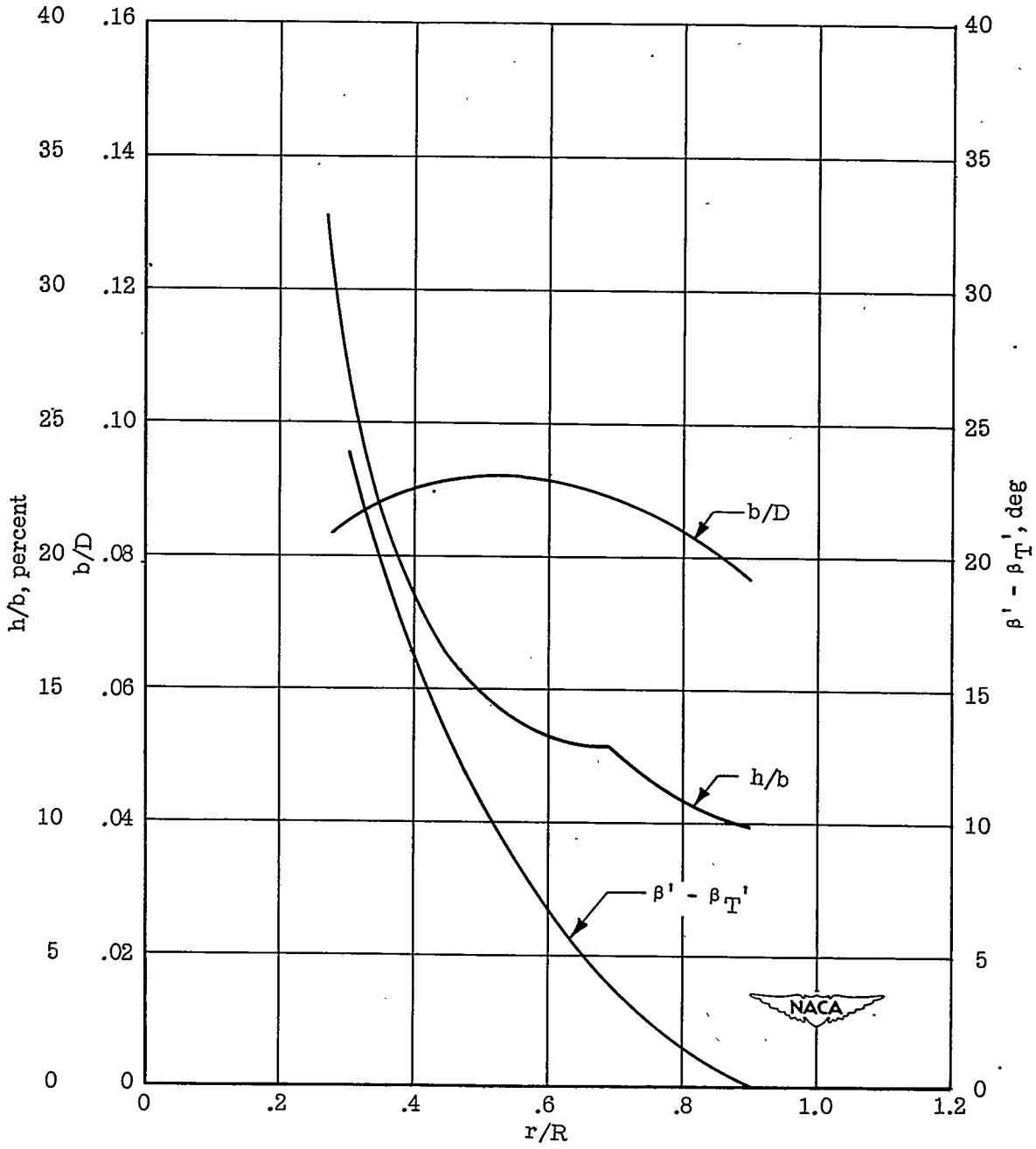

Figure 13.- Blade-form curves for solid-bladed propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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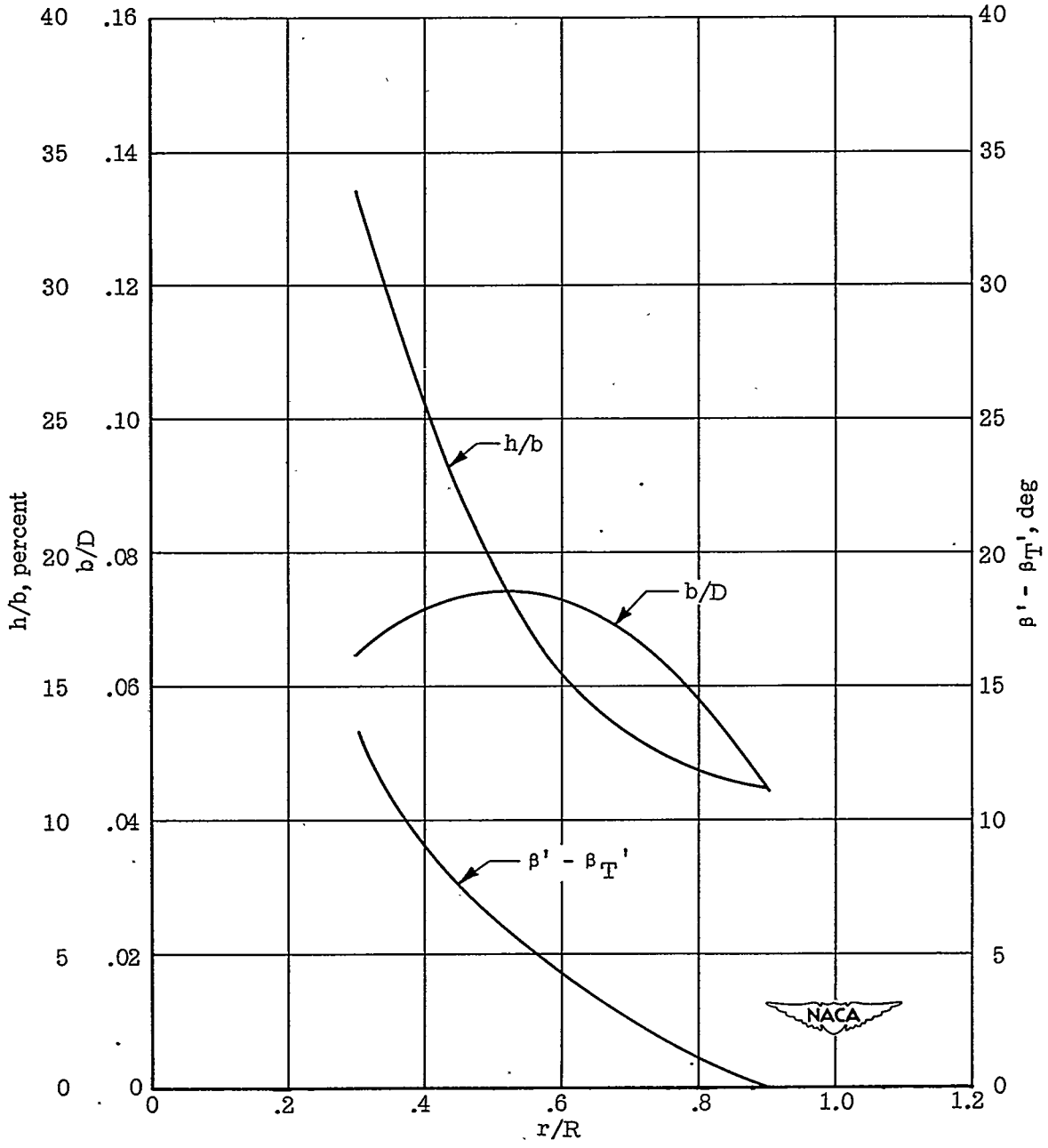

Figure 14.- Blade-form curves for conventional two-bladed wooden propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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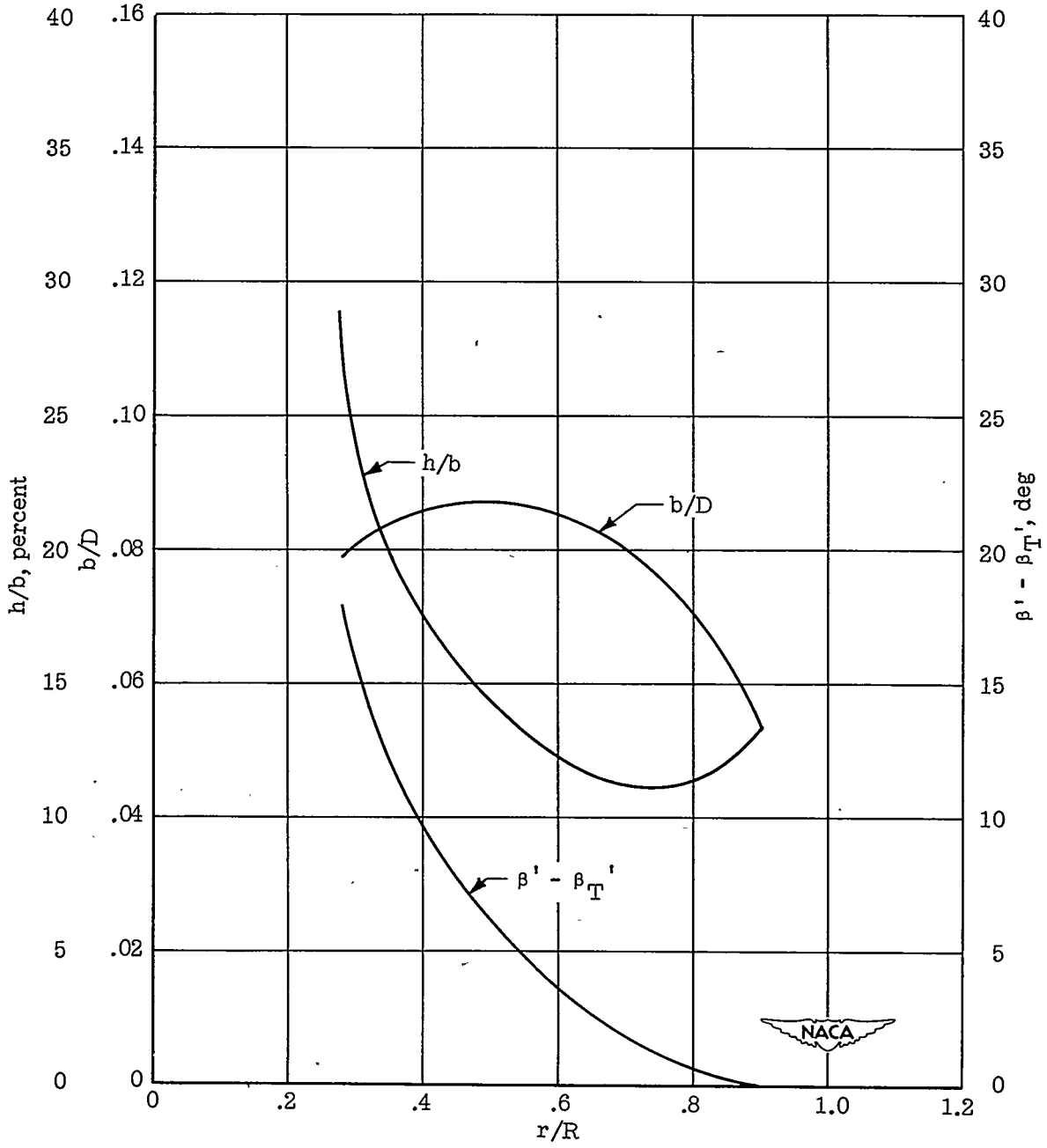

Figure 15.- Blade-form curves for four-bladed, two-piece, wooden propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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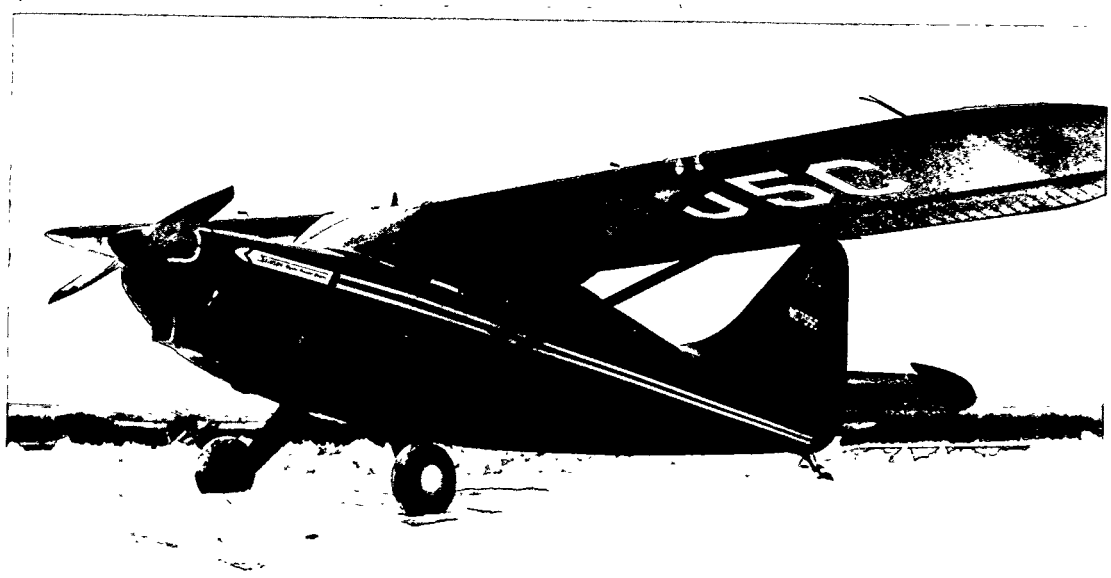
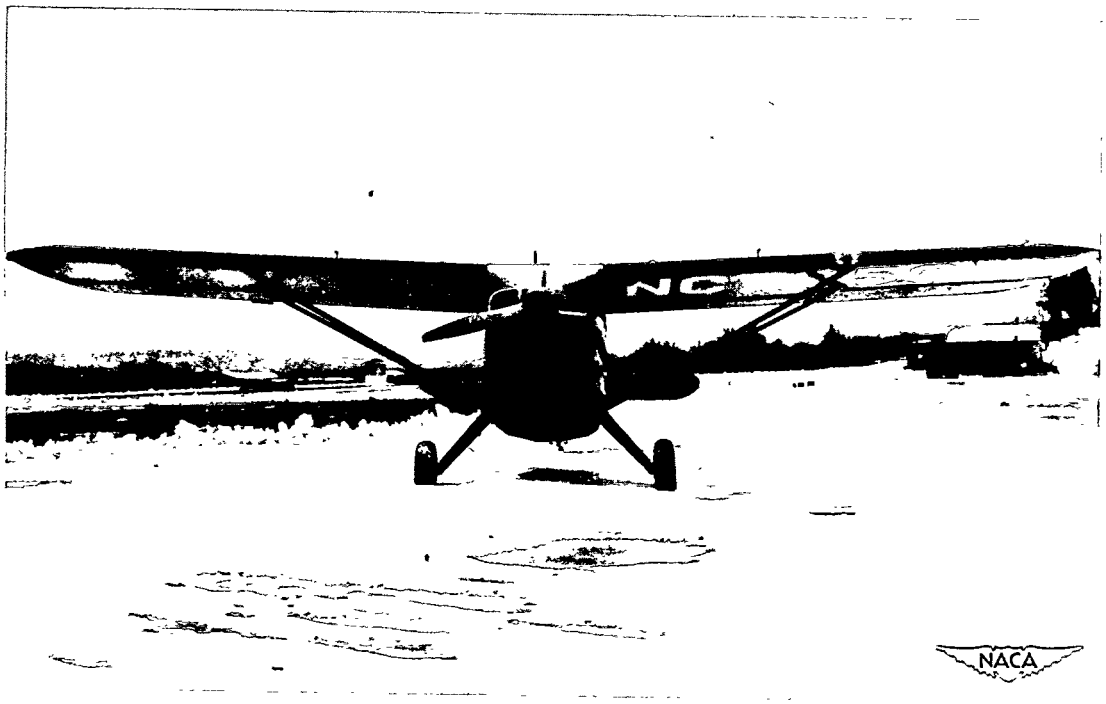


(a) Side view.



(b) Front view.

Figure 16.- Standard Stinson, configuration 5.

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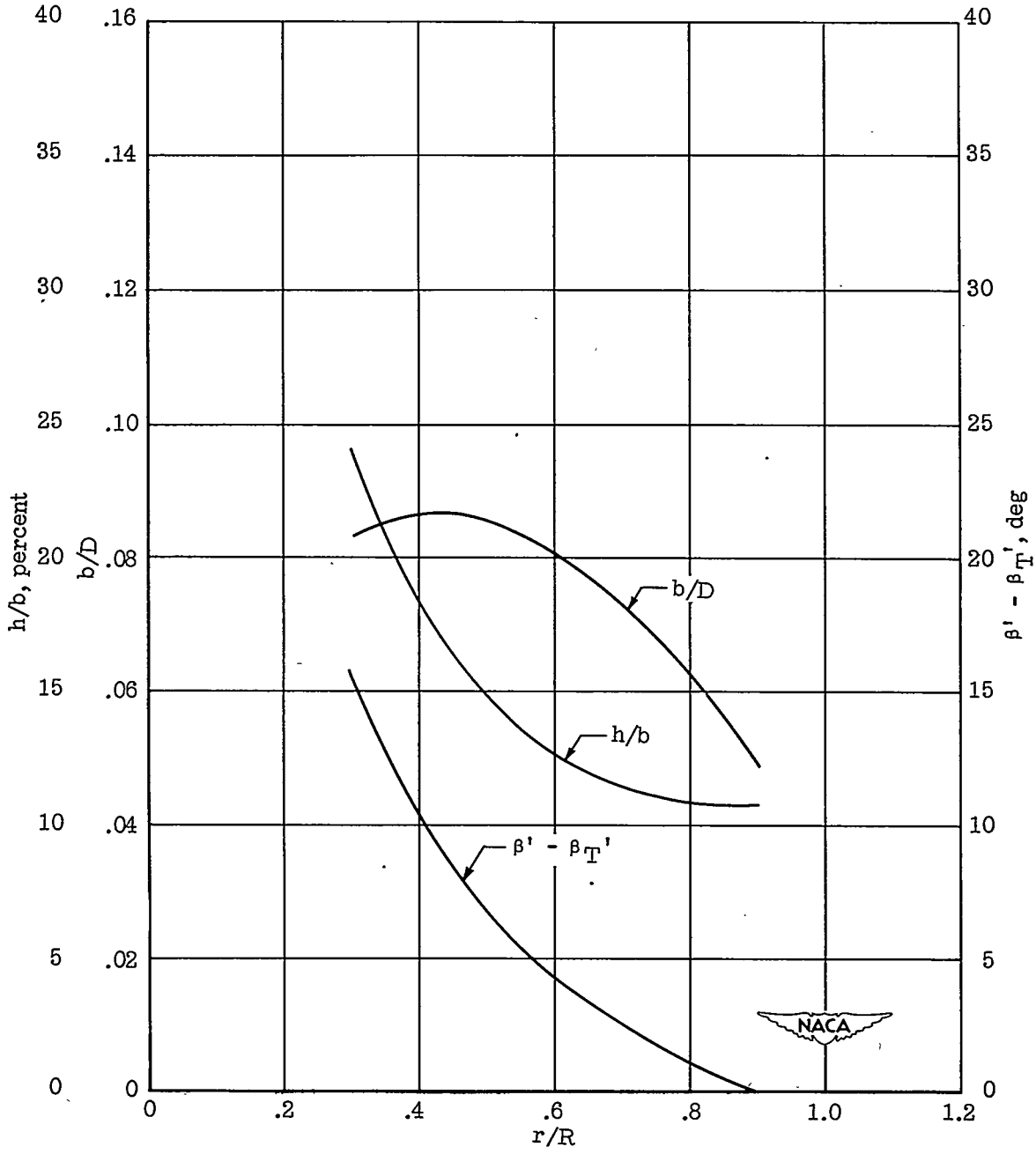

Figure 17.- Blade-form curves for standard, fixed-pitch, wooden propeller (see table I). h, maximum thickness of element; b, width (chord) of element; r, radius of element; R, tip radius; D, diameter of propeller; β', pitch angle of element; β_T', pitch angle of tip element.

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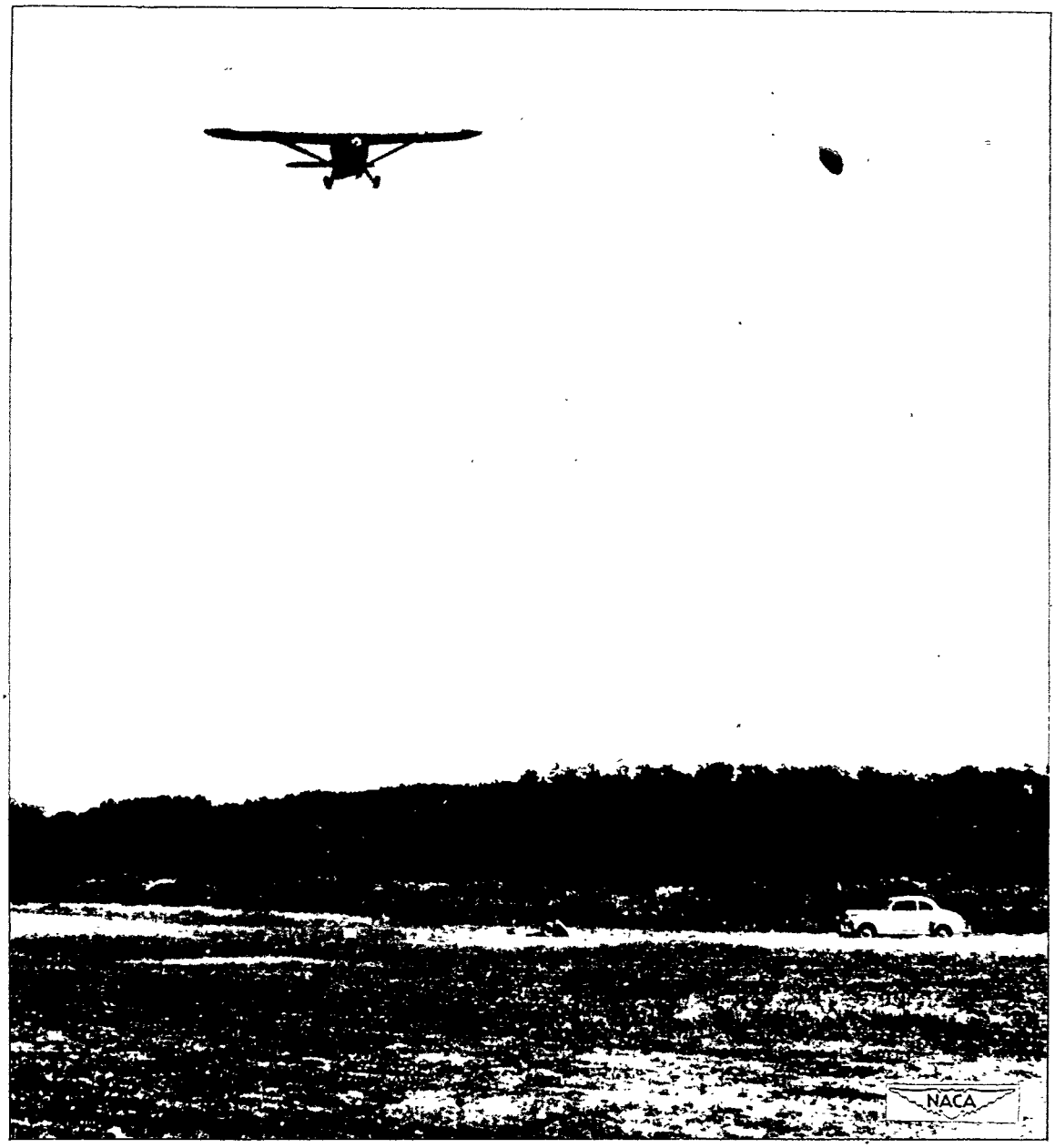

Figure 18.- Airplane passing over equipment at 100 feet. Note Kytoon to right of airplane.

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Figure 19.- Take-off procedure. Standard Stinson leaving ground as it passed marker 50 feet from microphone.

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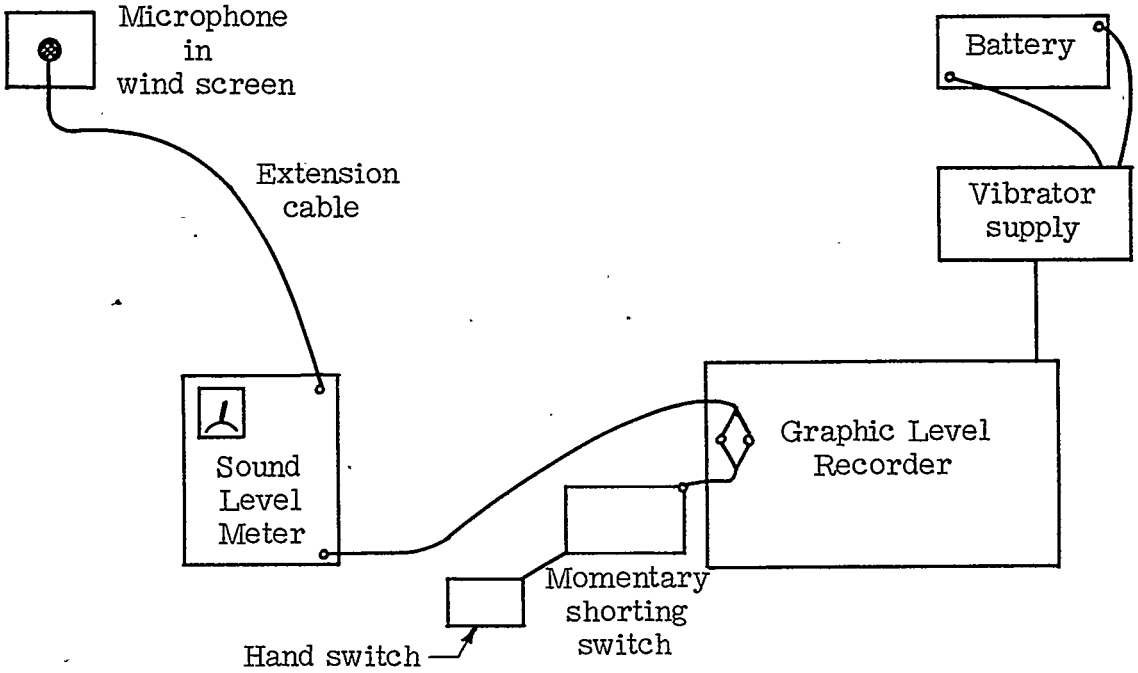
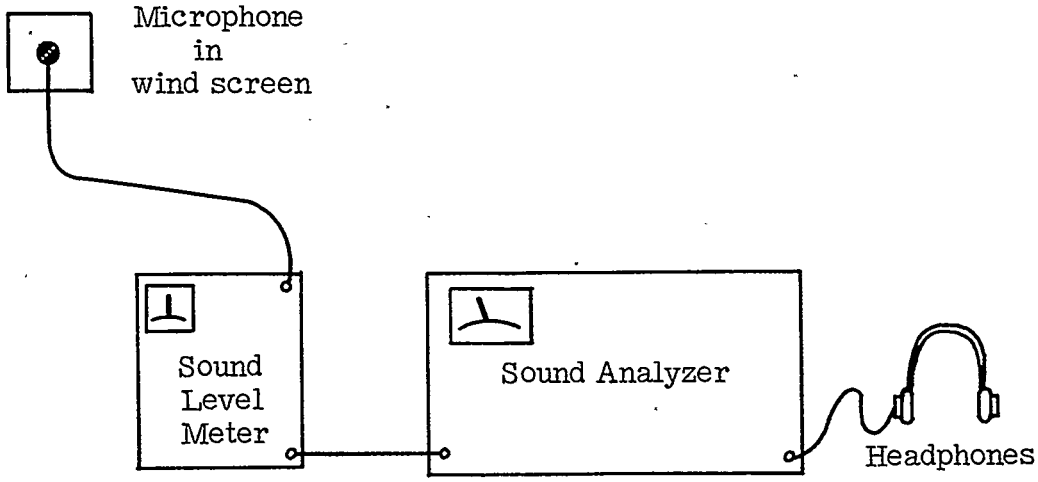


(a) For flight and take-off measurements.



(b) For ground analysis.

Figure 20.- Equipment interconnections.

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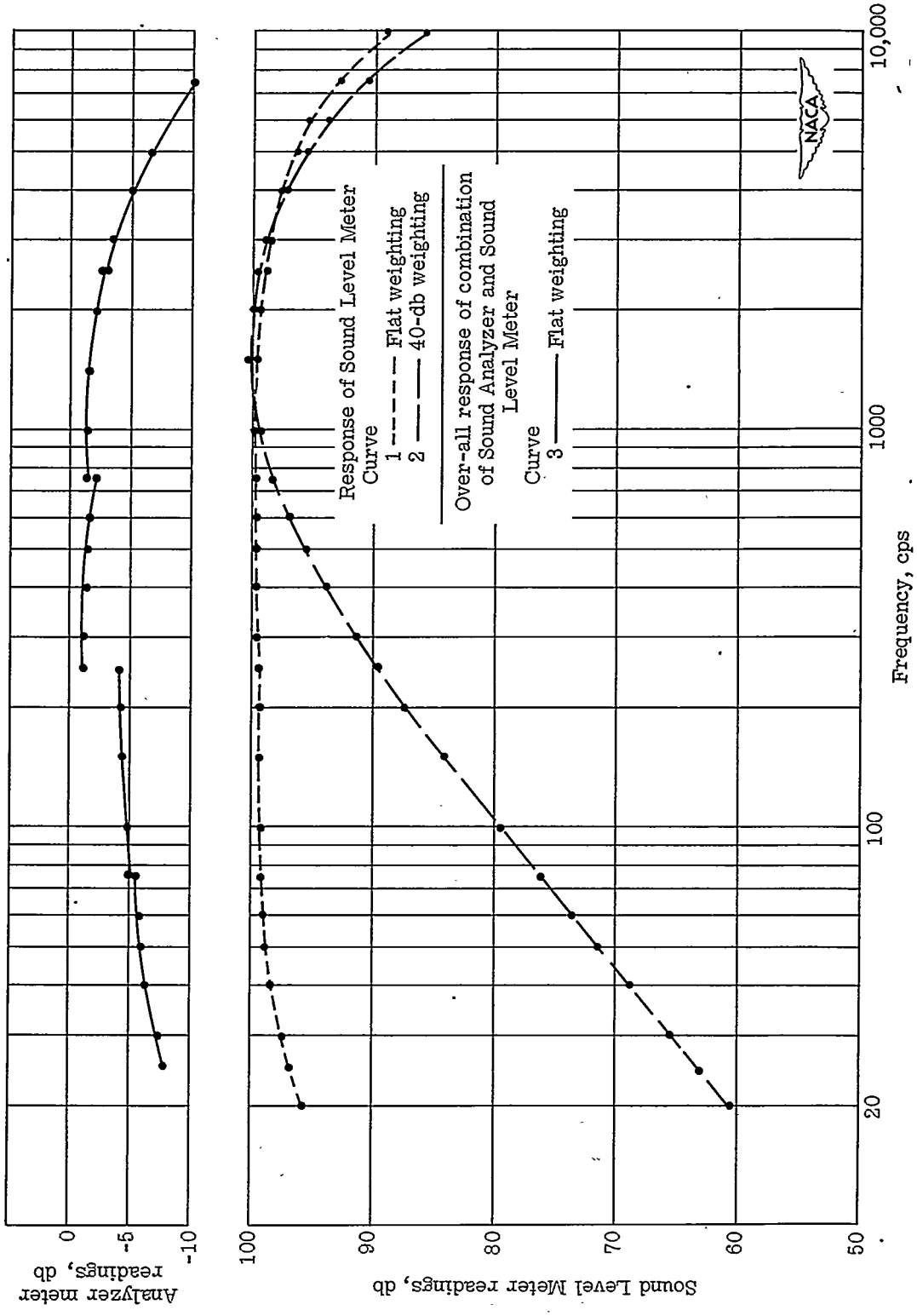

Figure 21.- Frequency response of Sound Level Meter and Sound Analyzer. Measured with constant voltage applied in series with Sound Level Meter microphone.

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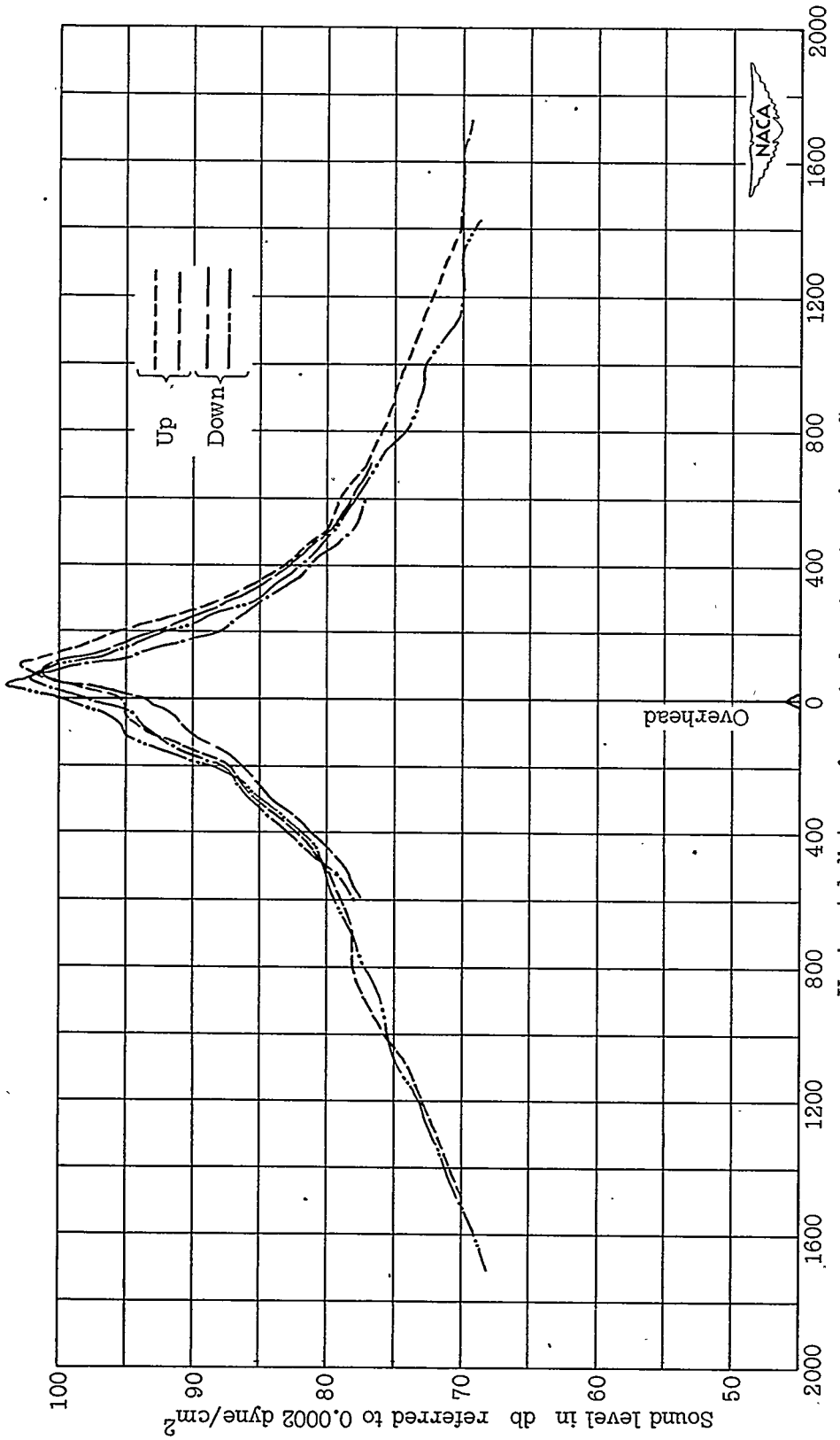

(a) Standard Stinson, configuration 1. Sensenich Skyblade, cruising pitch.

Figure 22.- Sound level against horizontal distance from airplane to microphone from records from Graphic Level Recorder. Altitude, 100 feet; maximum power; flat weighting. Refer to table II for engine power, tip speed, and propeller diameter.

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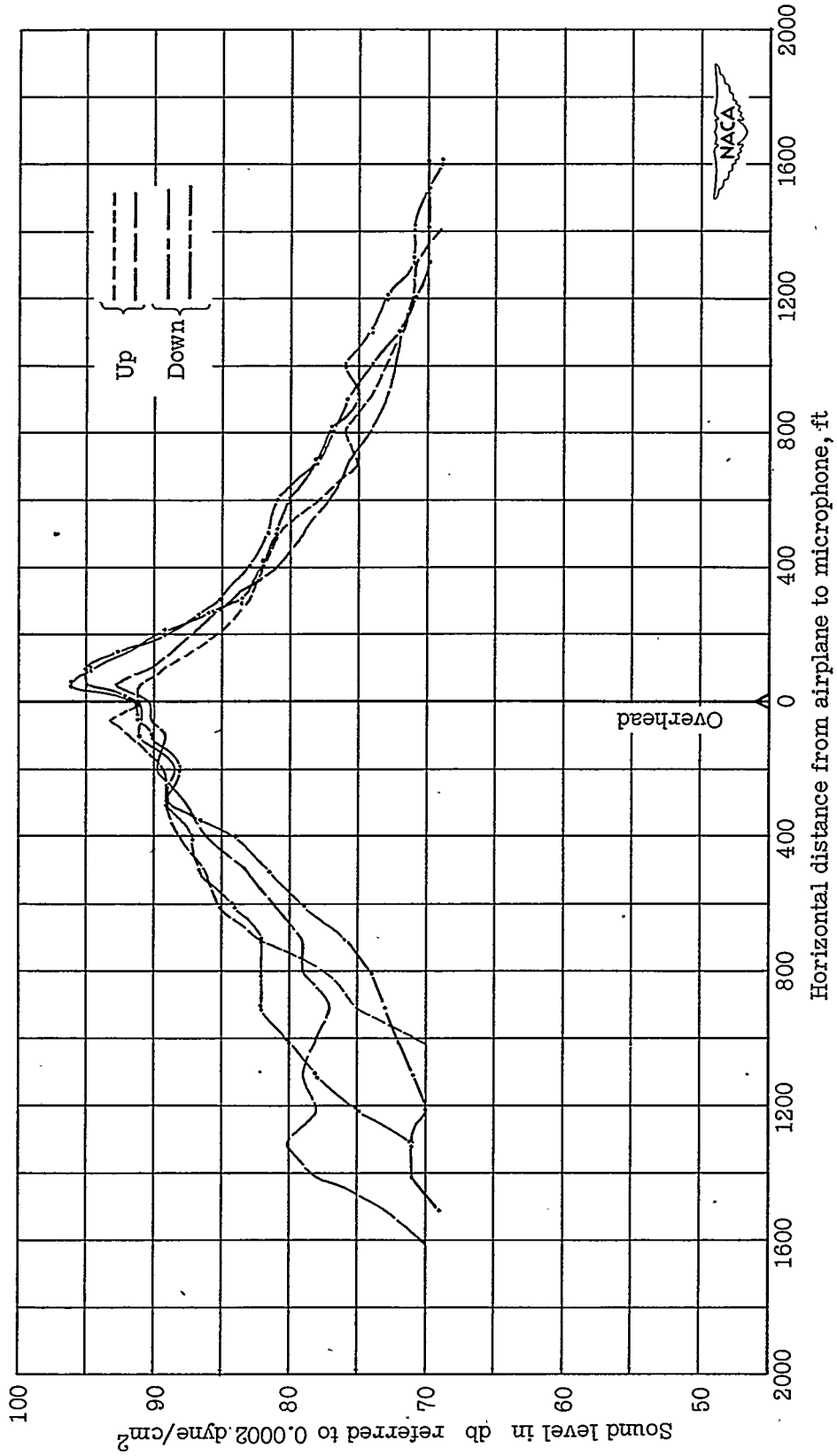

(b) Two-bladed propeller, configuration 2A.

Figure 22.- Continued.

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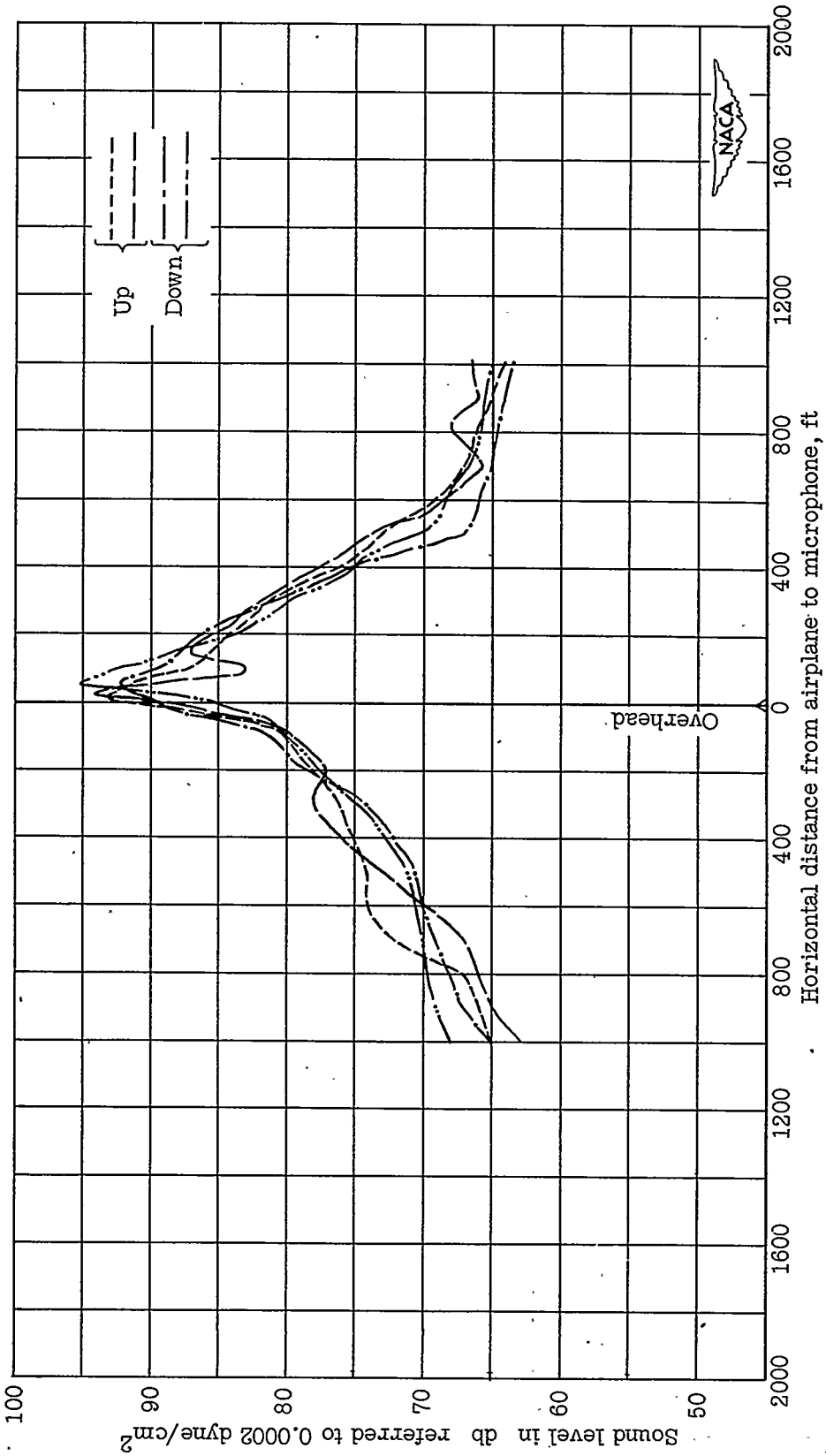

(c) Three-bladed propeller, configuration 2B.

Figure 22.- Continued.

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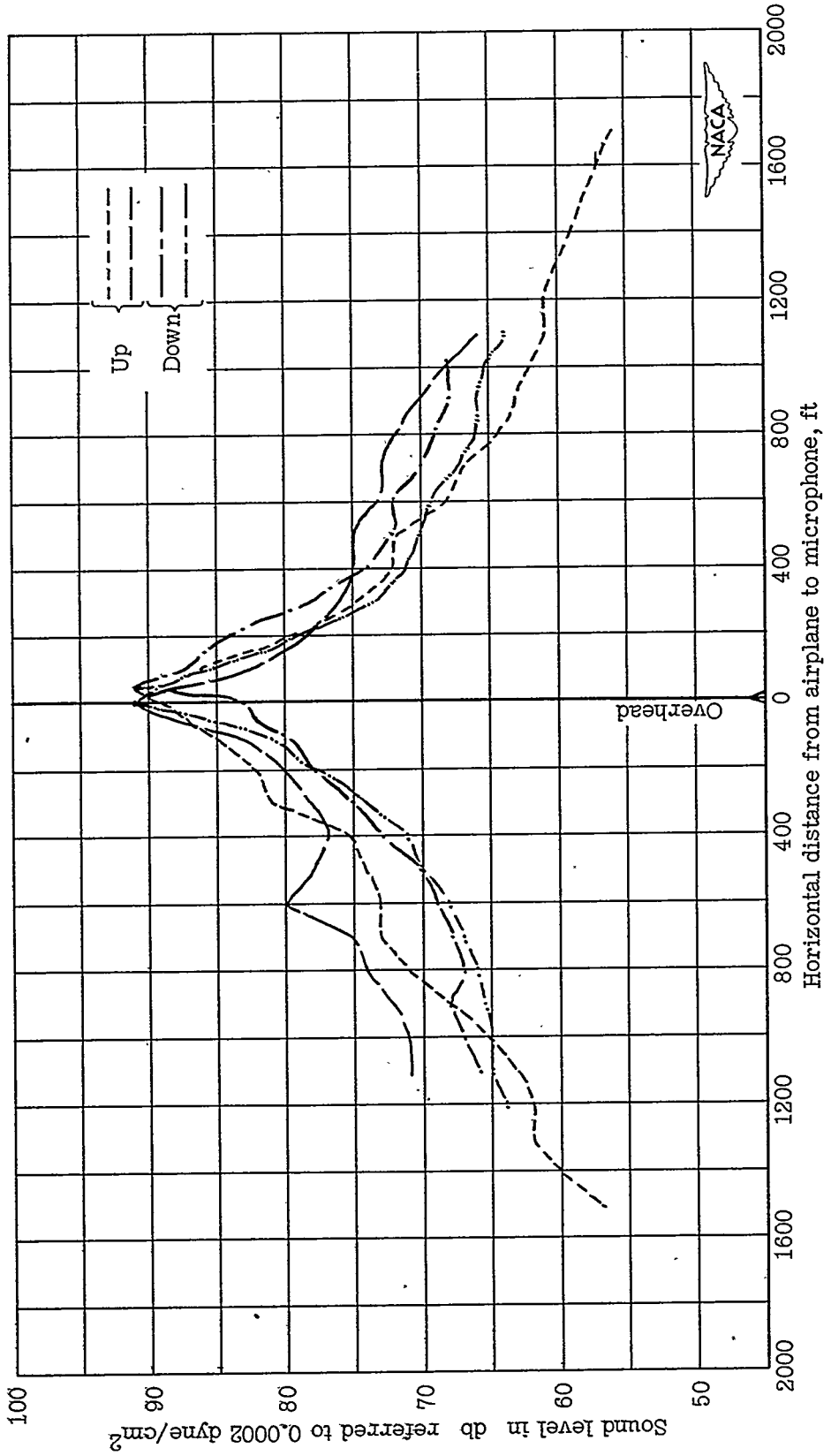

(d) Four-bladed propeller, configuration 2F.

Figure 22.- Continued.

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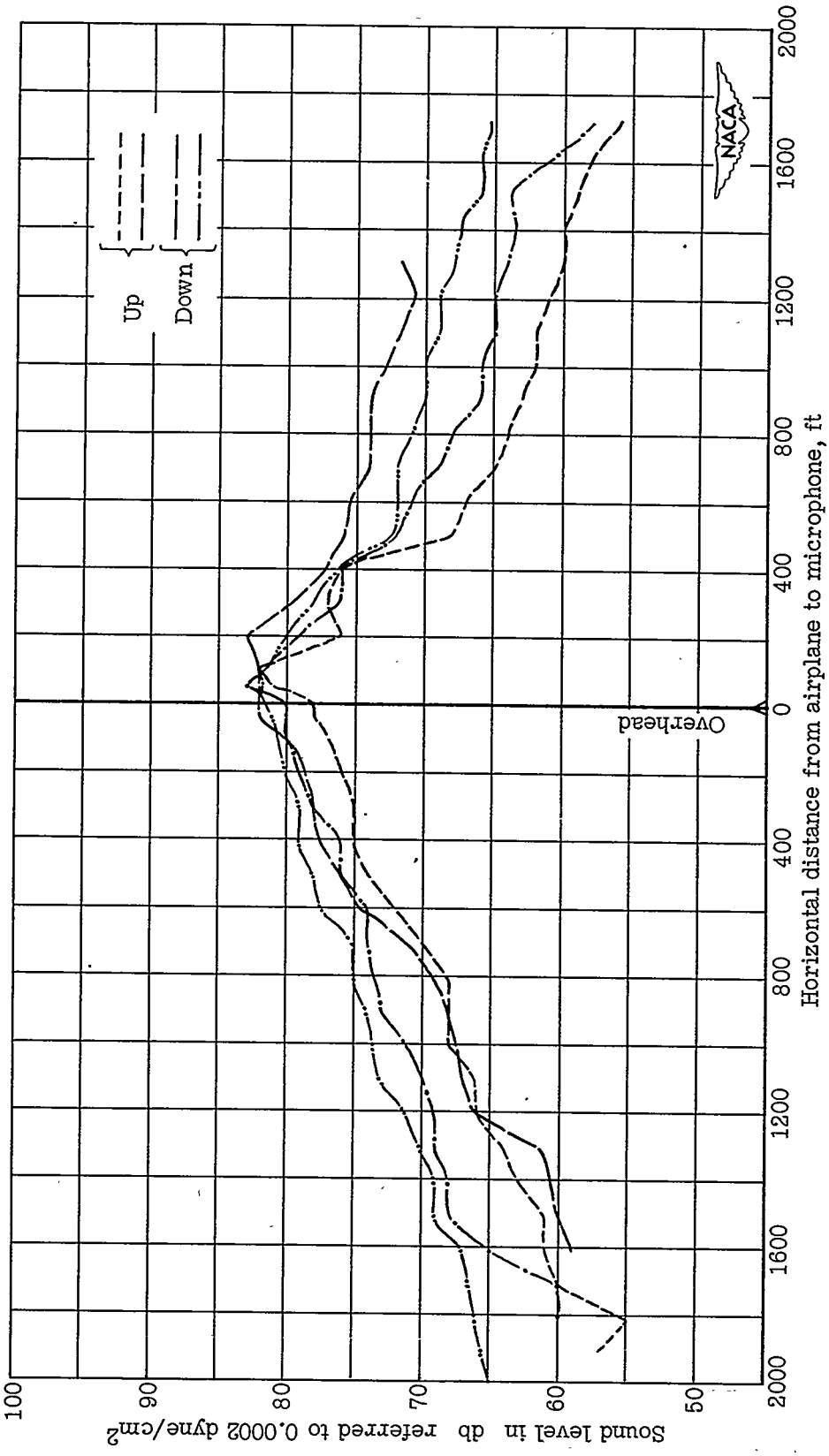

(e) Six-bladed propeller, configuration 2C.

Figure 22.- Continued.

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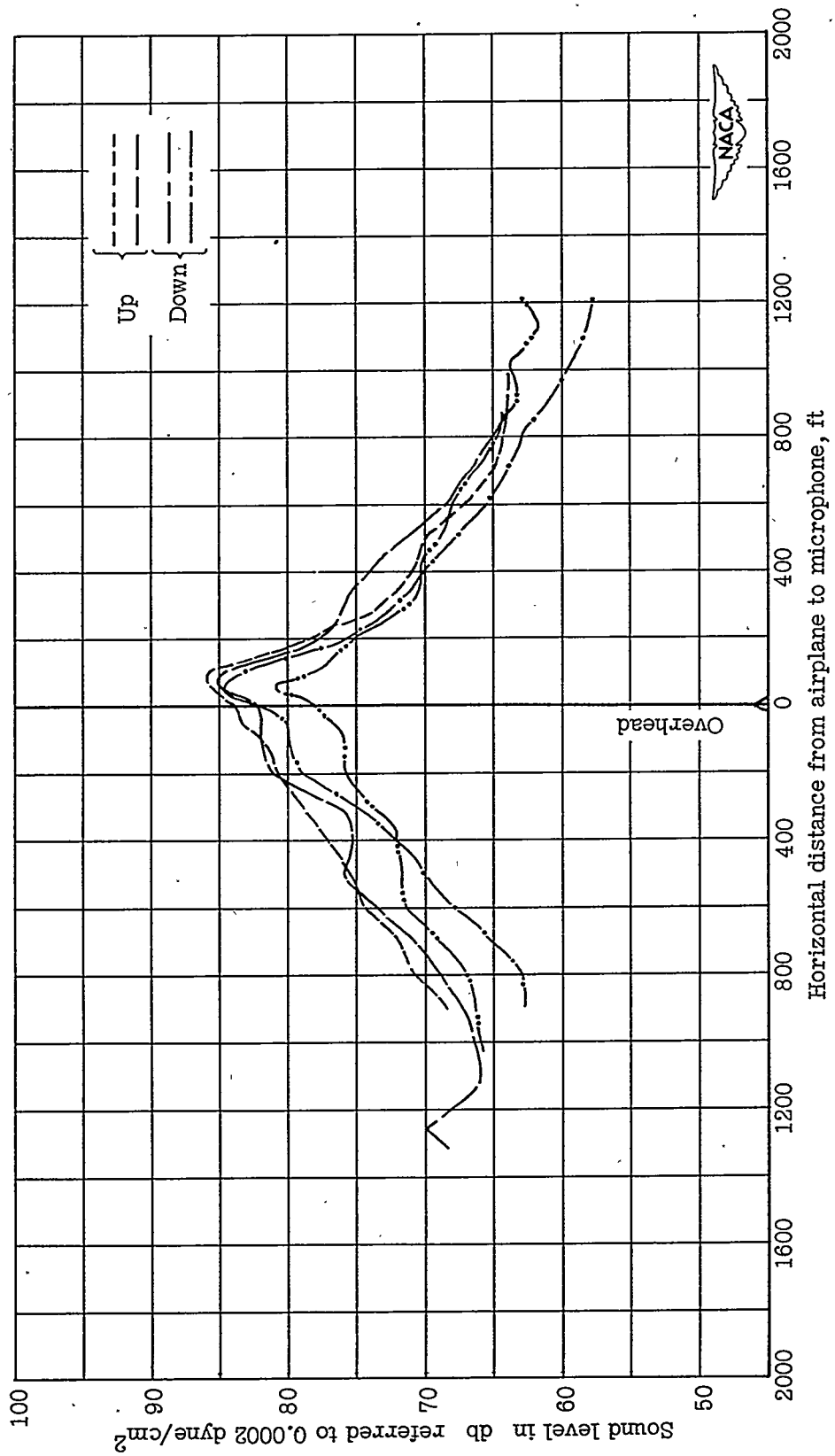

(f) Eight-bladed propeller, configuration 2D.

Figure 22.- Concluded.

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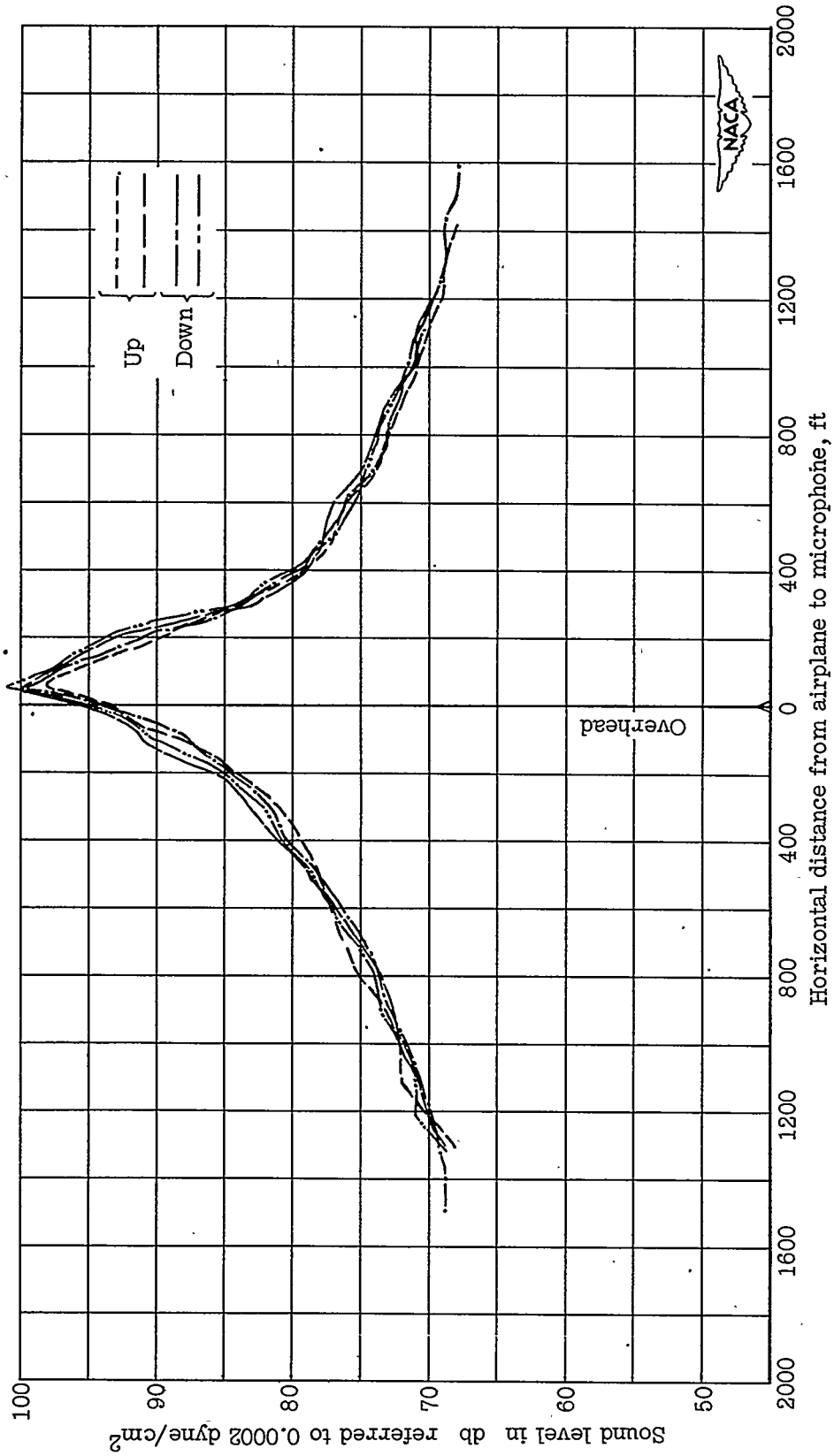

(a) Standard Stinson, configuration 1. Sensenich Skyblade, cruising pitch.

Figure 23.- Sound level against horizontal distance from airplane to microphone from records from Graphic Level Recorder. Altitude, 100 feet; cruising power; flat weighting. Refer to table II for engine power, tip speed, and propeller diameter.

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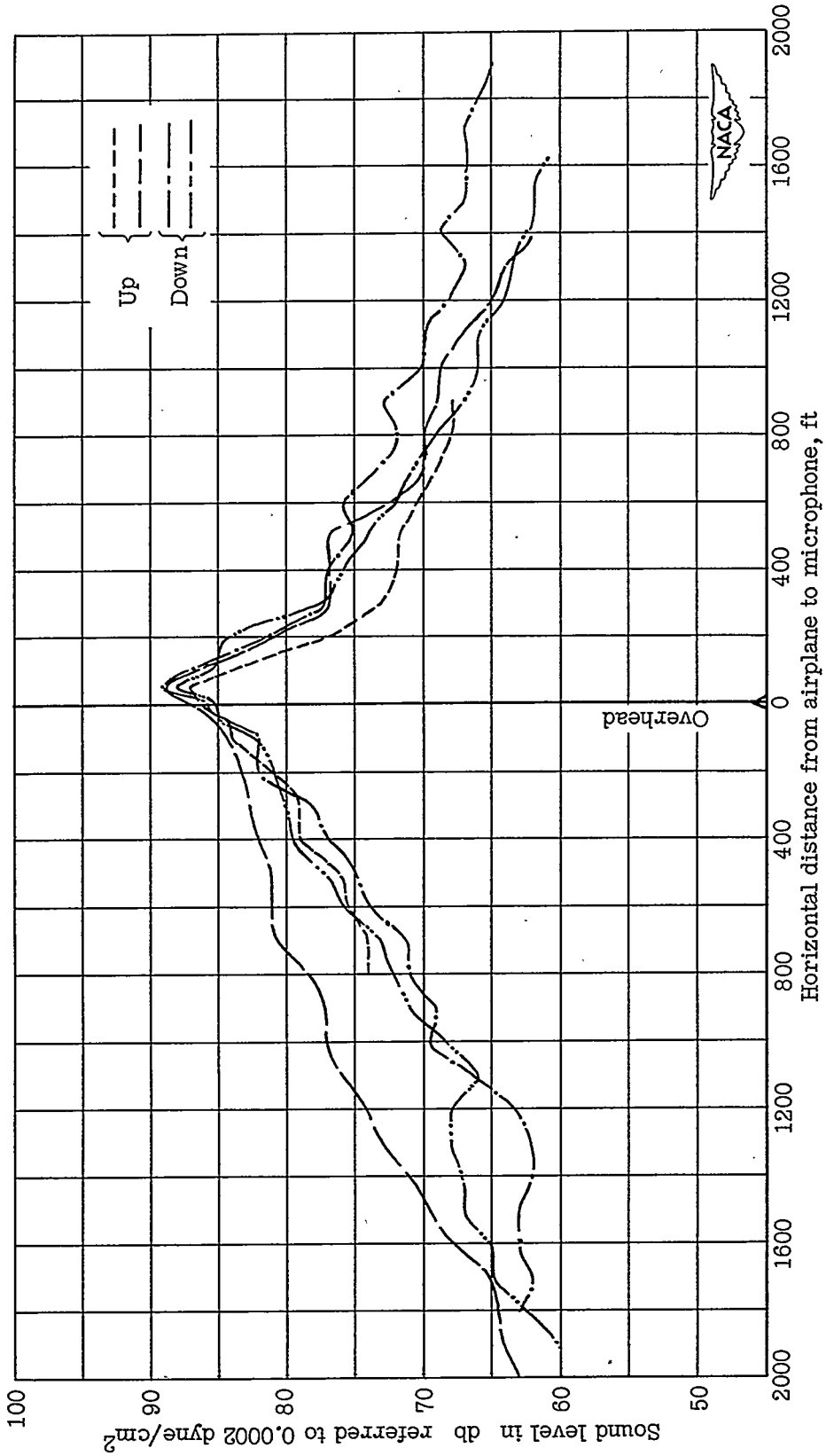

(b) Two-bladed propeller, configuration 2A.

Figure 23.- Continued.

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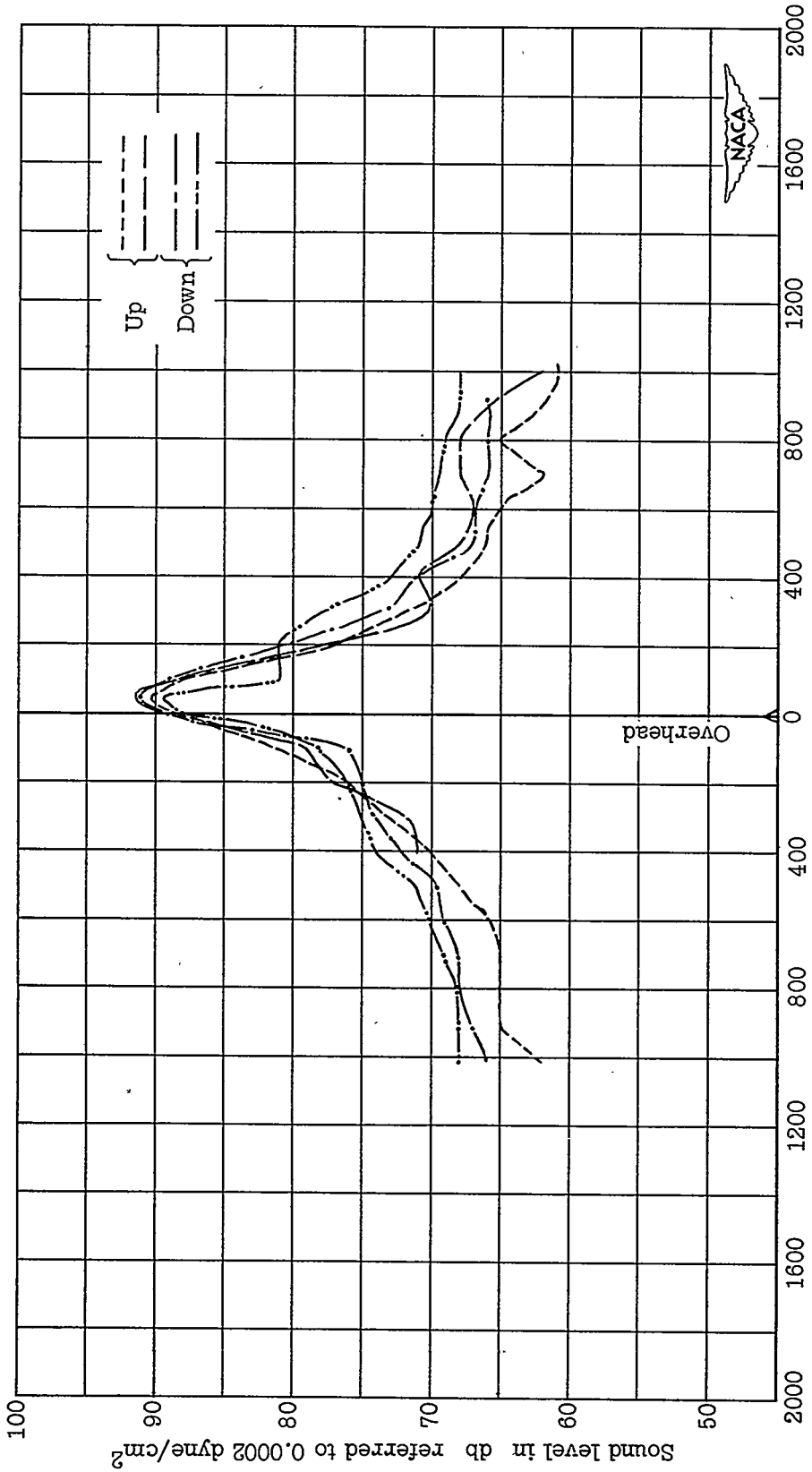

(c) Three-bladed propeller, configuration 2B.

Figure 23.- Continued.

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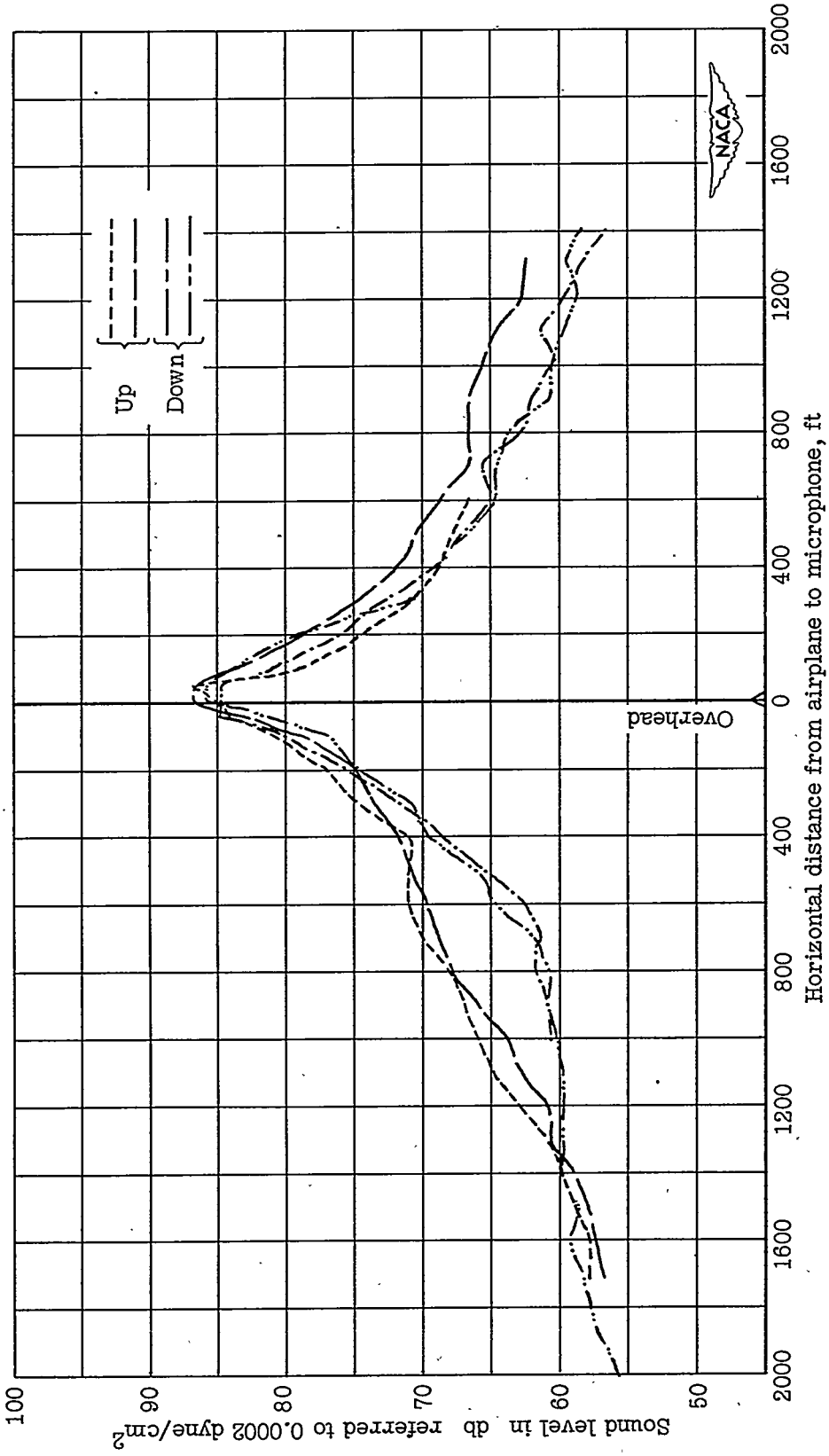

(d) Four-bladed propeller, configuration 2F.

Figure 23.- Continued.

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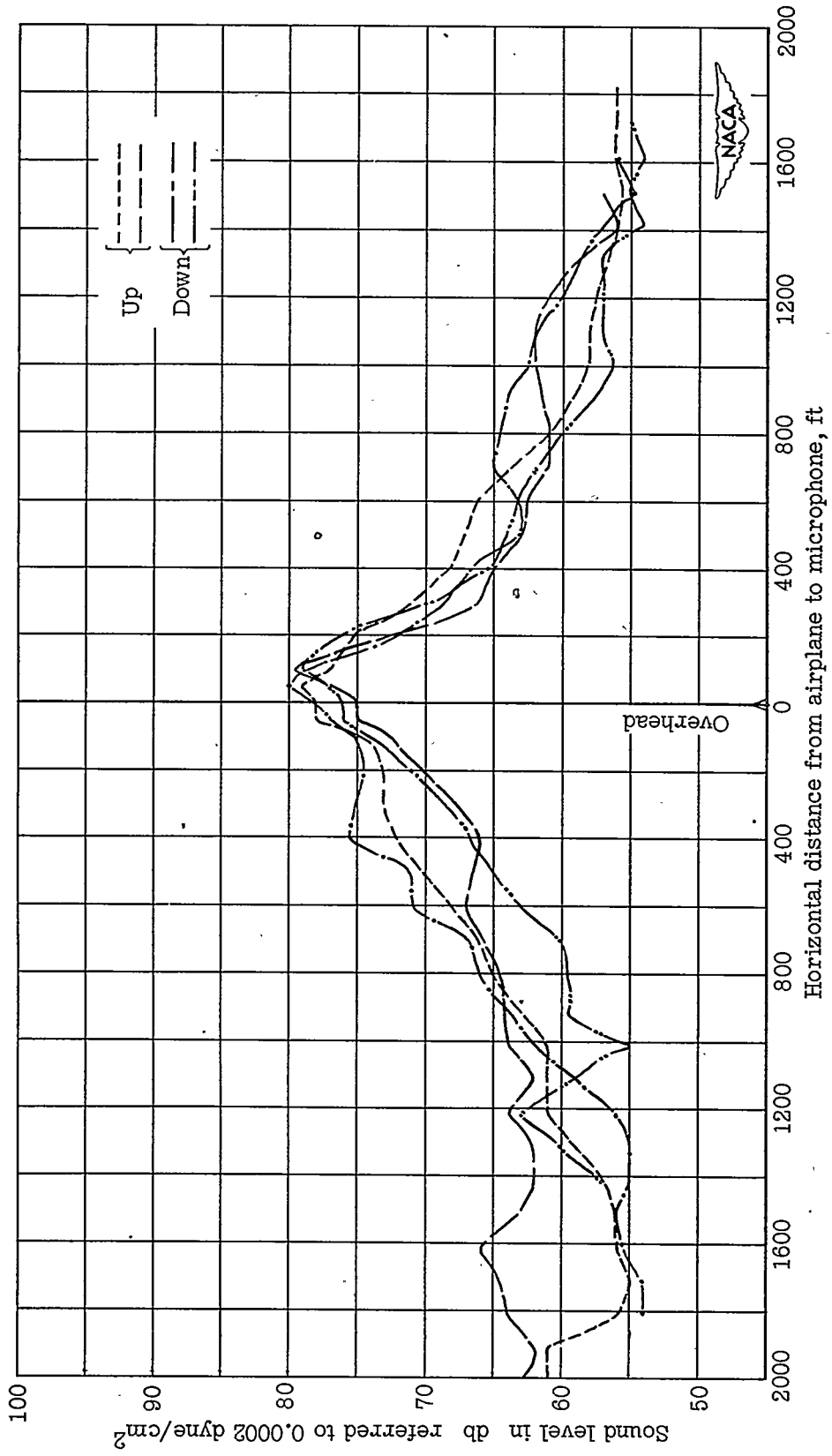

(e) Six-bladed propeller, configuration 2C.

Figure 23.- Continued.

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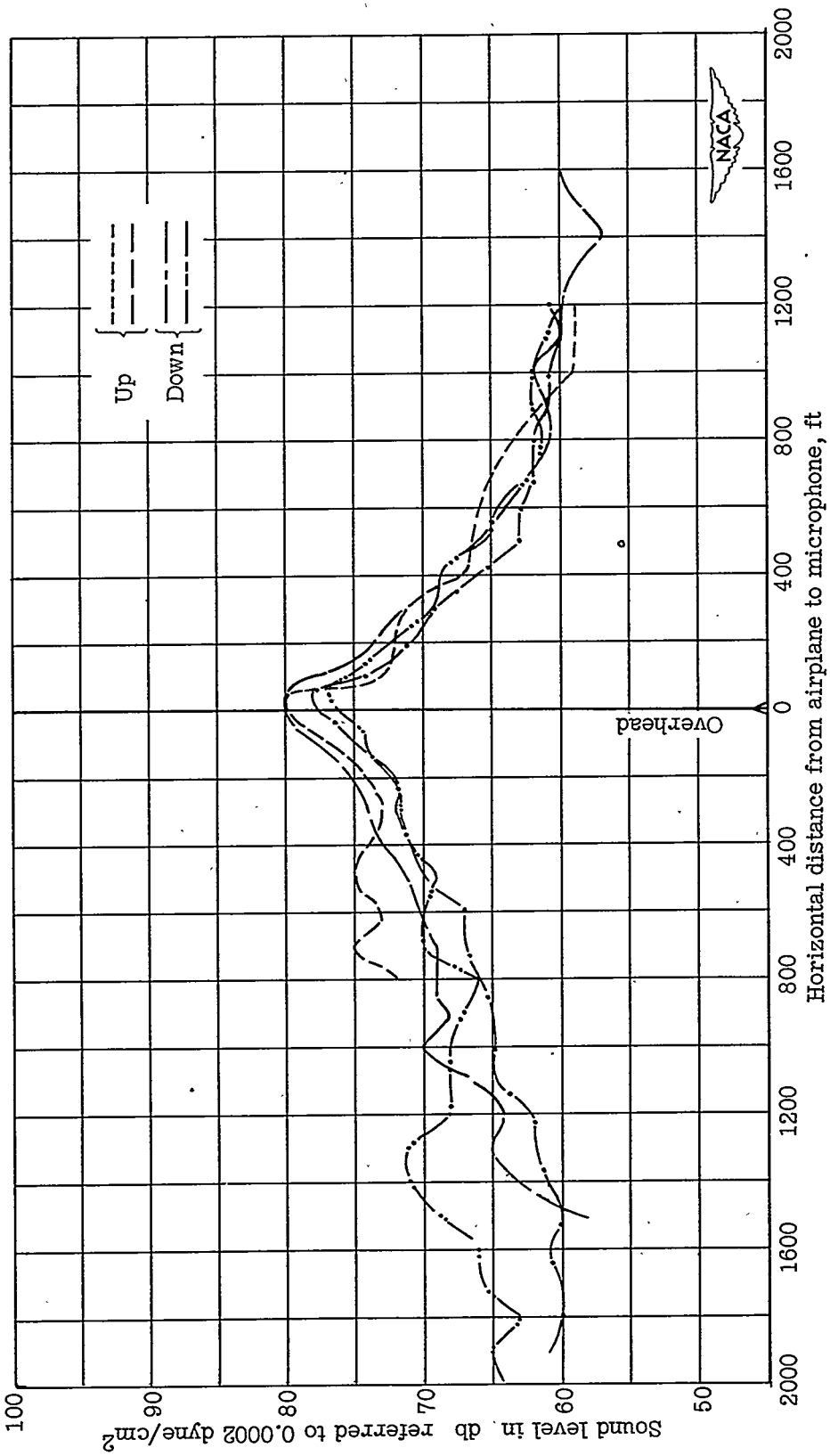

(f) Eight-bladed propeller, configuration 2D.

Figure 23.- Concluded.

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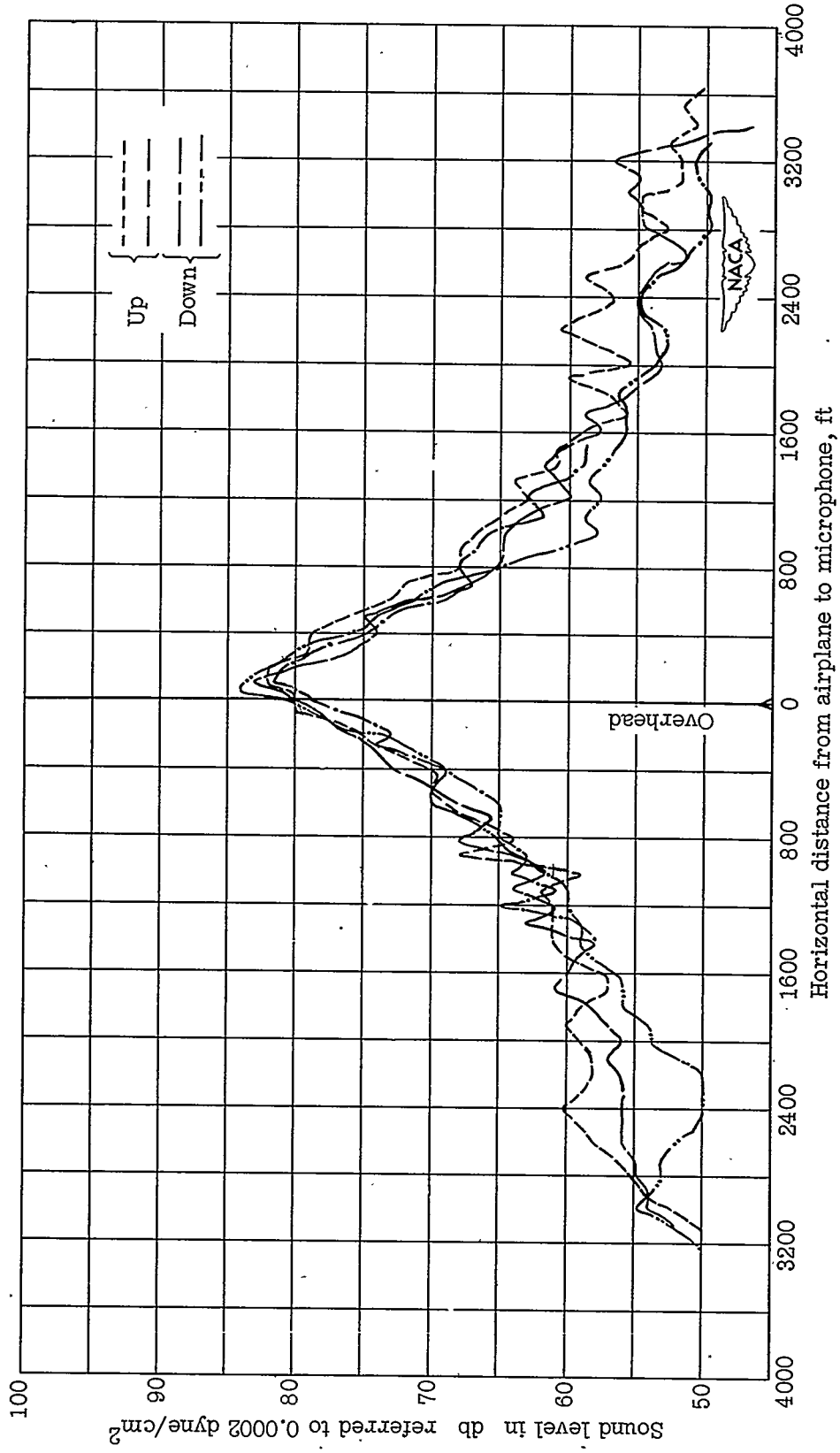

(a) Standard Stinson, configuration 1. Sensenich Skyblade, cruising pitch.

Figure 24.- Sound level against horizontal distance from airplane to microphone from records from Graphic Level Recorder. Altitude, 500 feet; maximum power; 40-decibel weighting. Refer to table II for engine power, tip speed, and propeller diameter.

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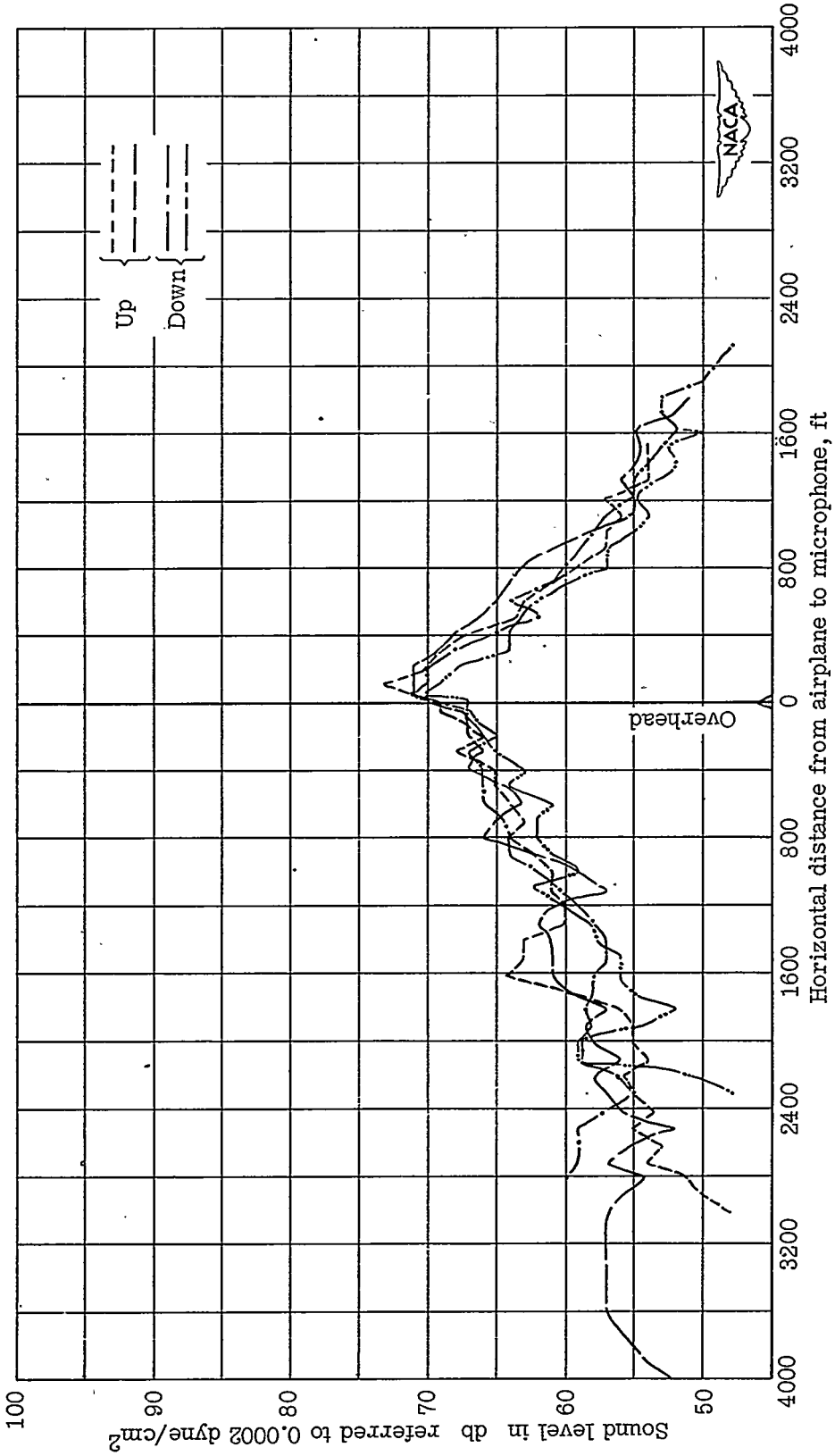

(b) Two-bladed propeller, configuration 2A.

Figure 24.- Continued.

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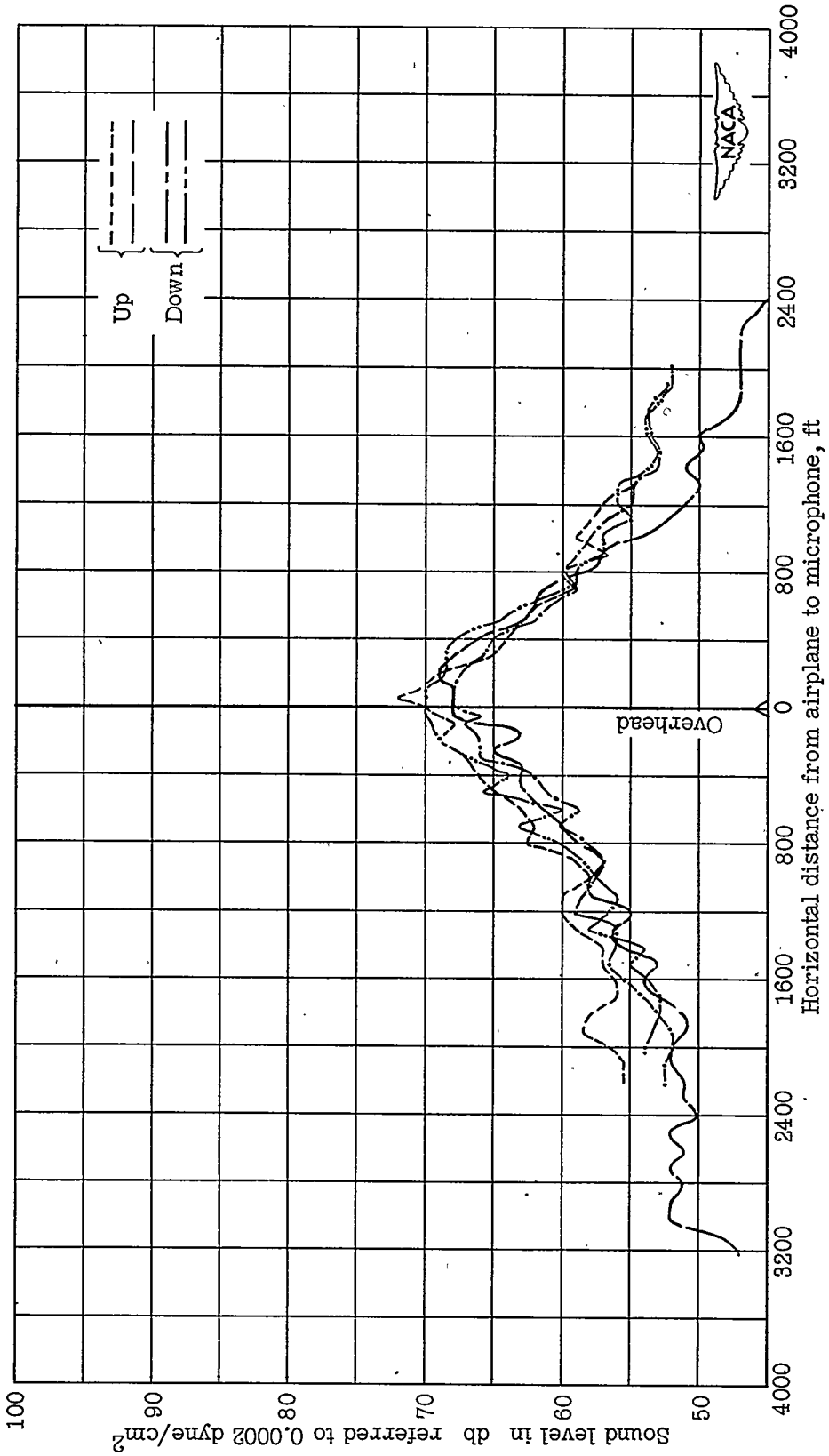

(c) Three-bladed propeller, configuration 2B.

Figure 24.- Continued.

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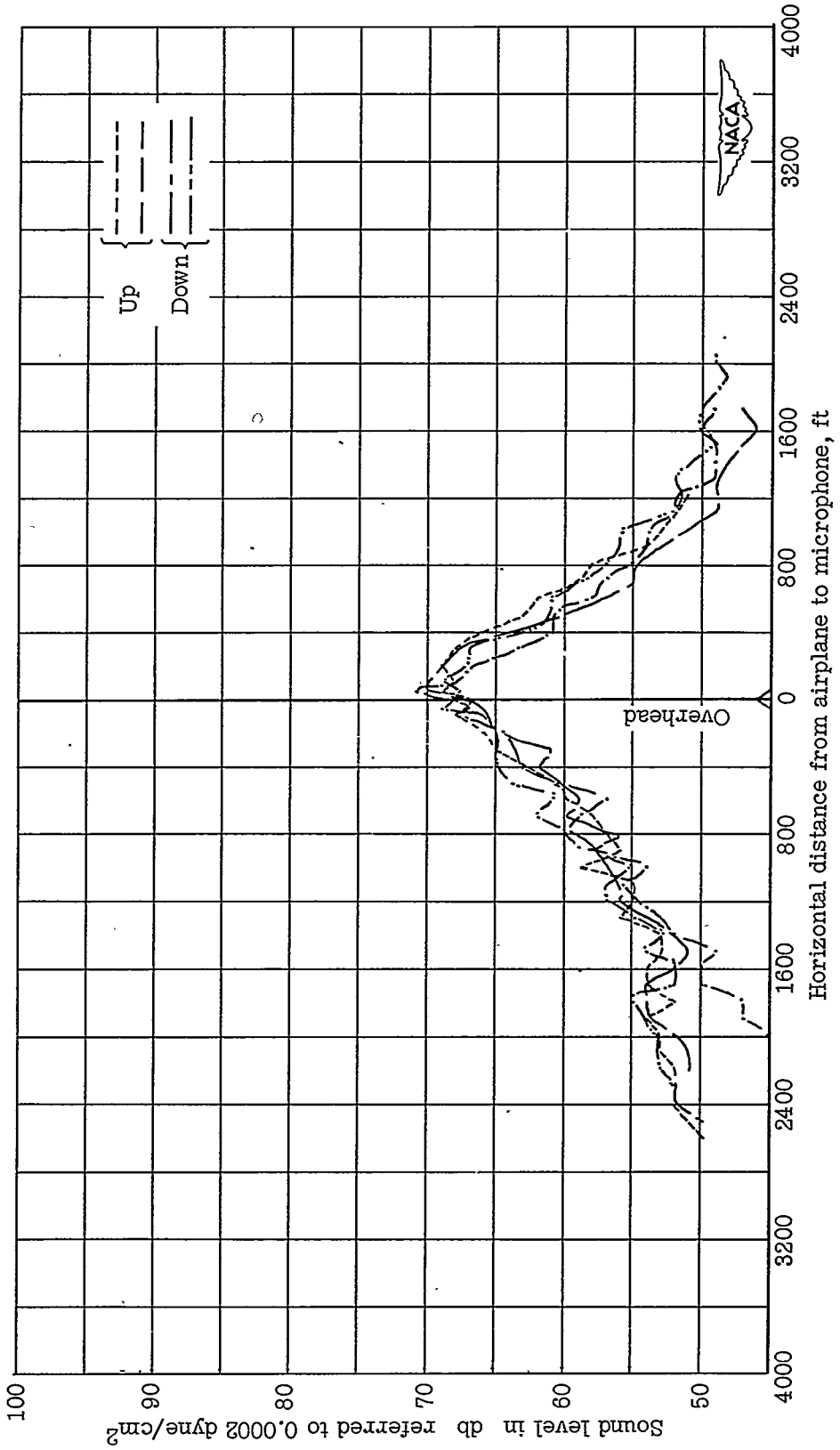

(d) Four-bladed propeller, configuration 2F.

Figure 24.- Continued.

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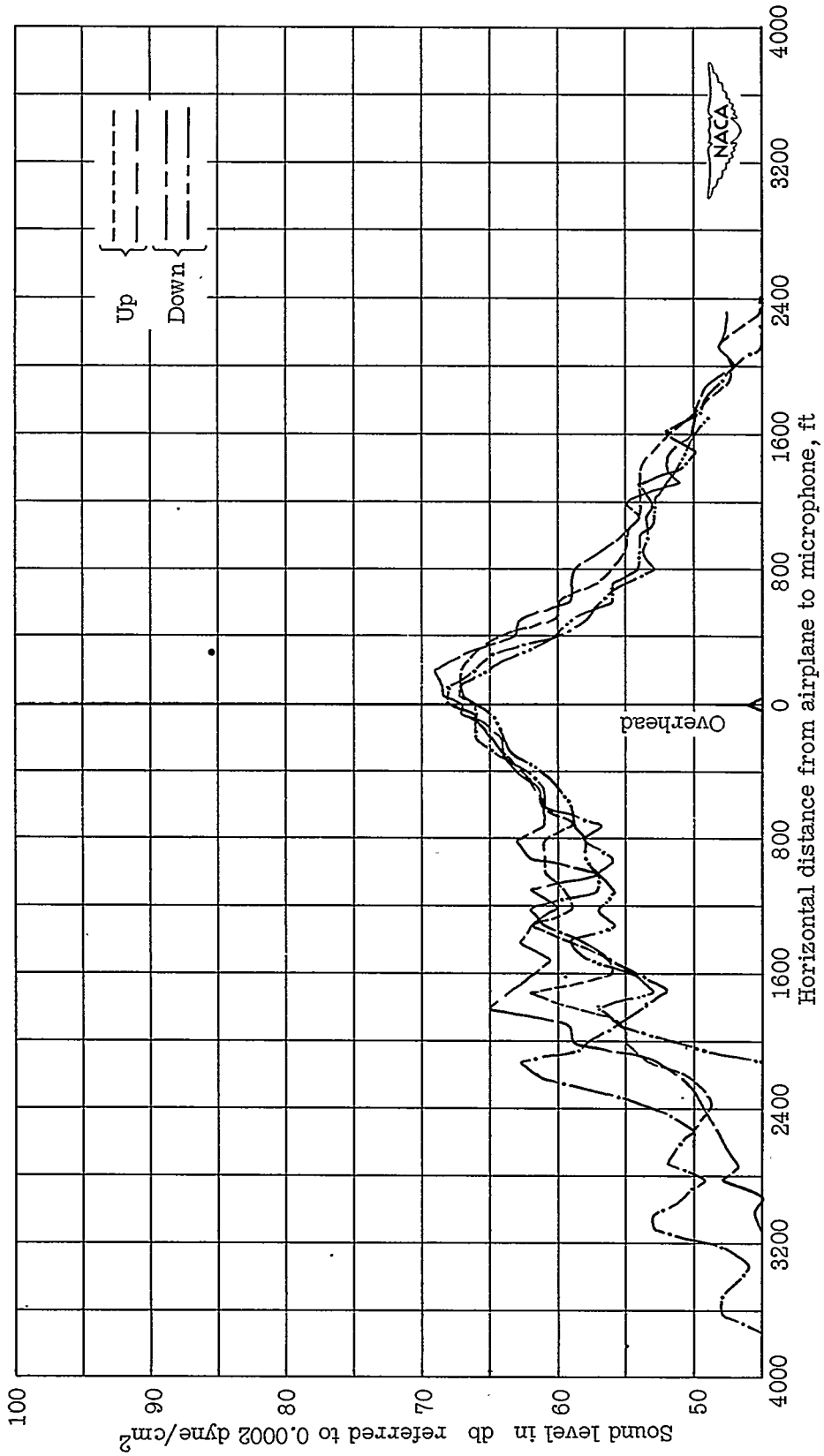

(e) Six-bladed propeller, configuration 2C.

Figure 24.- Continued.

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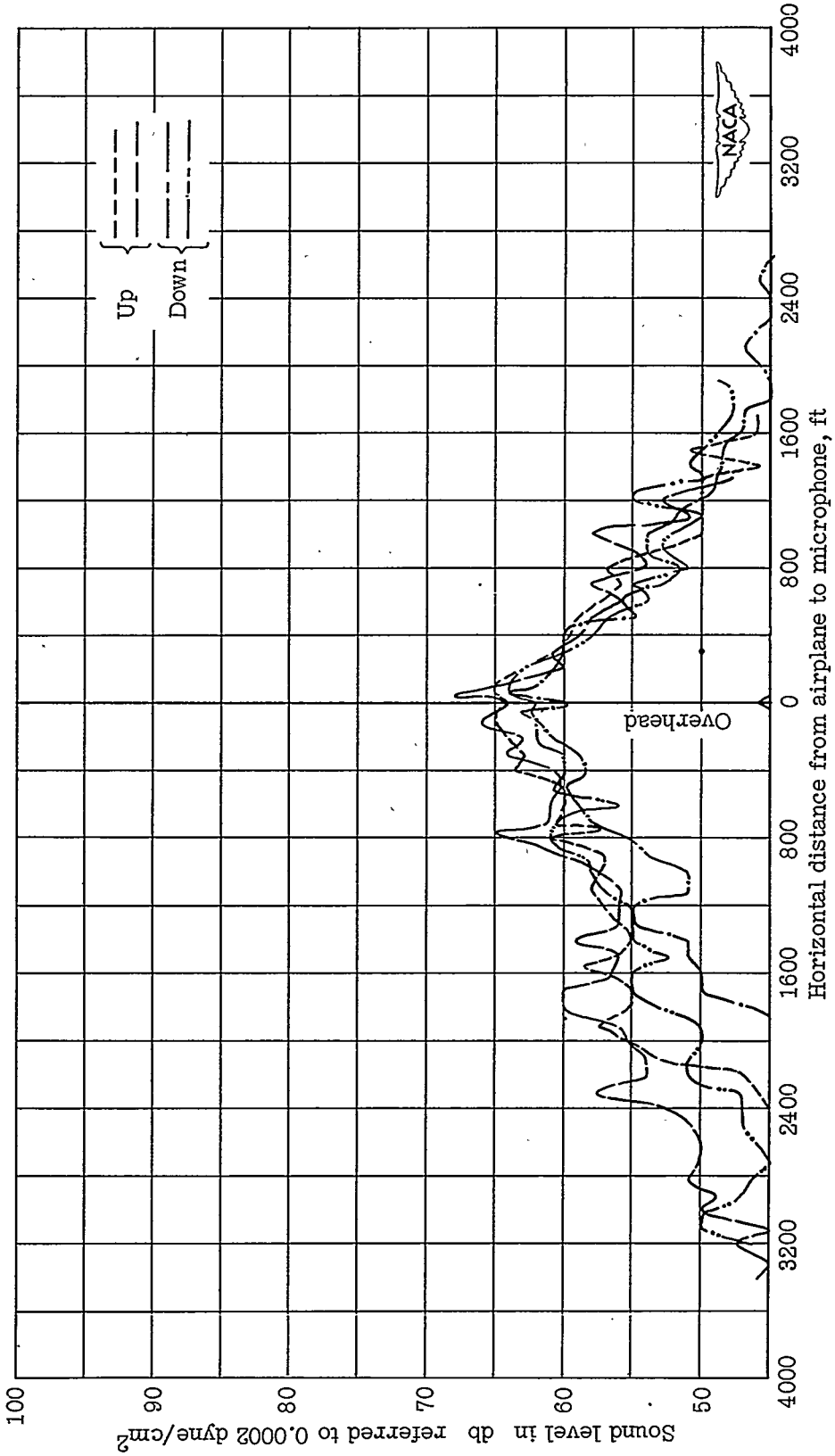

(f) Eight-bladed propeller, configuration 2D.

Figure 24.- Concluded.

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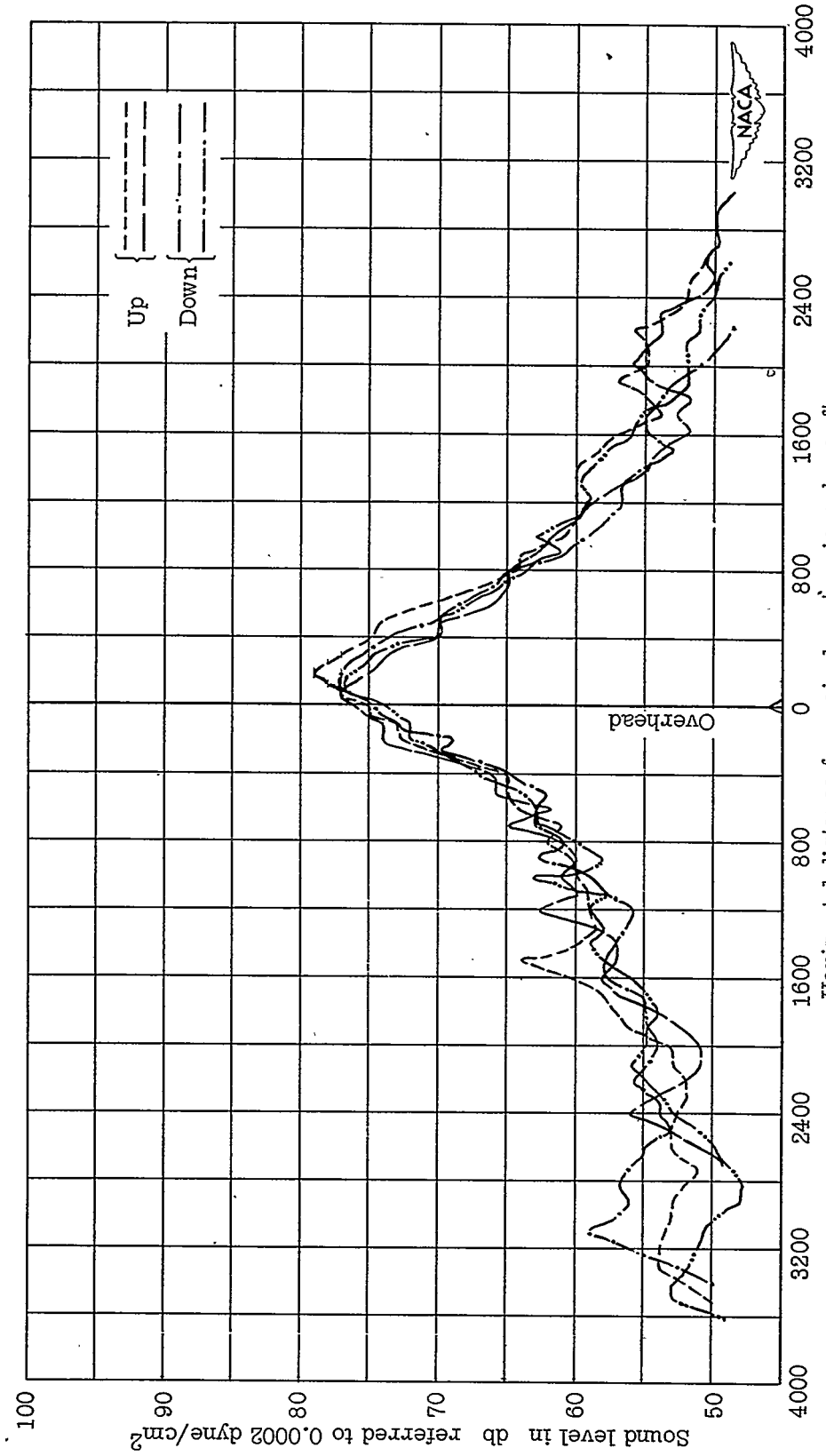

(a) Standard Stinson, configuration 1. Sensenich Skyblade, cruising pitch.

Figure 25.- Sound level against horizontal distance from airplane to microphone from records from Graphic Level Recorder. Altitude, 500 feet; cruising power; 40-decibel weighting. Refer to table II for engine power, tip speed, and propeller diameter.

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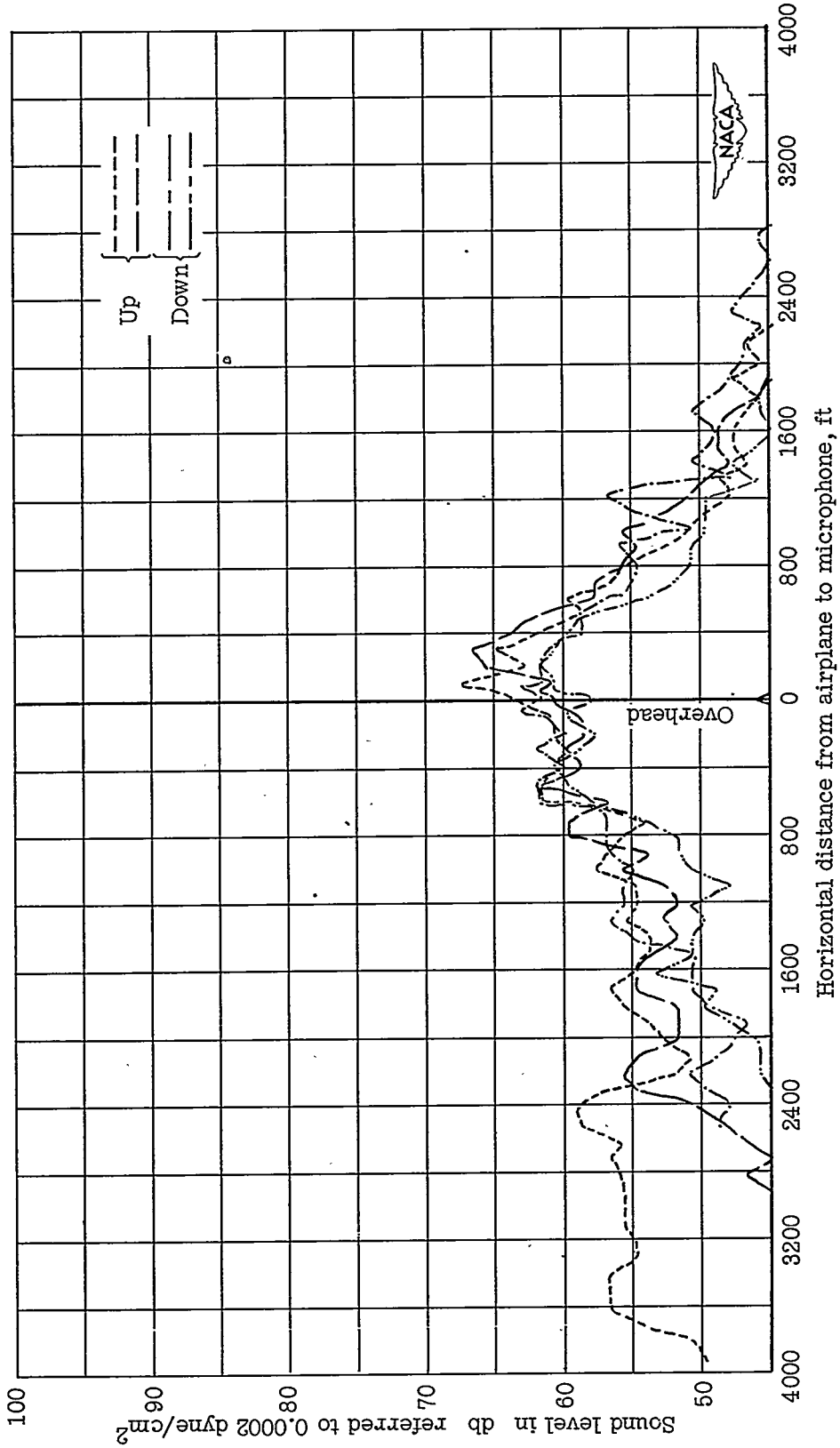

(b) Two-bladed propeller, configuration 2A.

Figure 25.- Continued.

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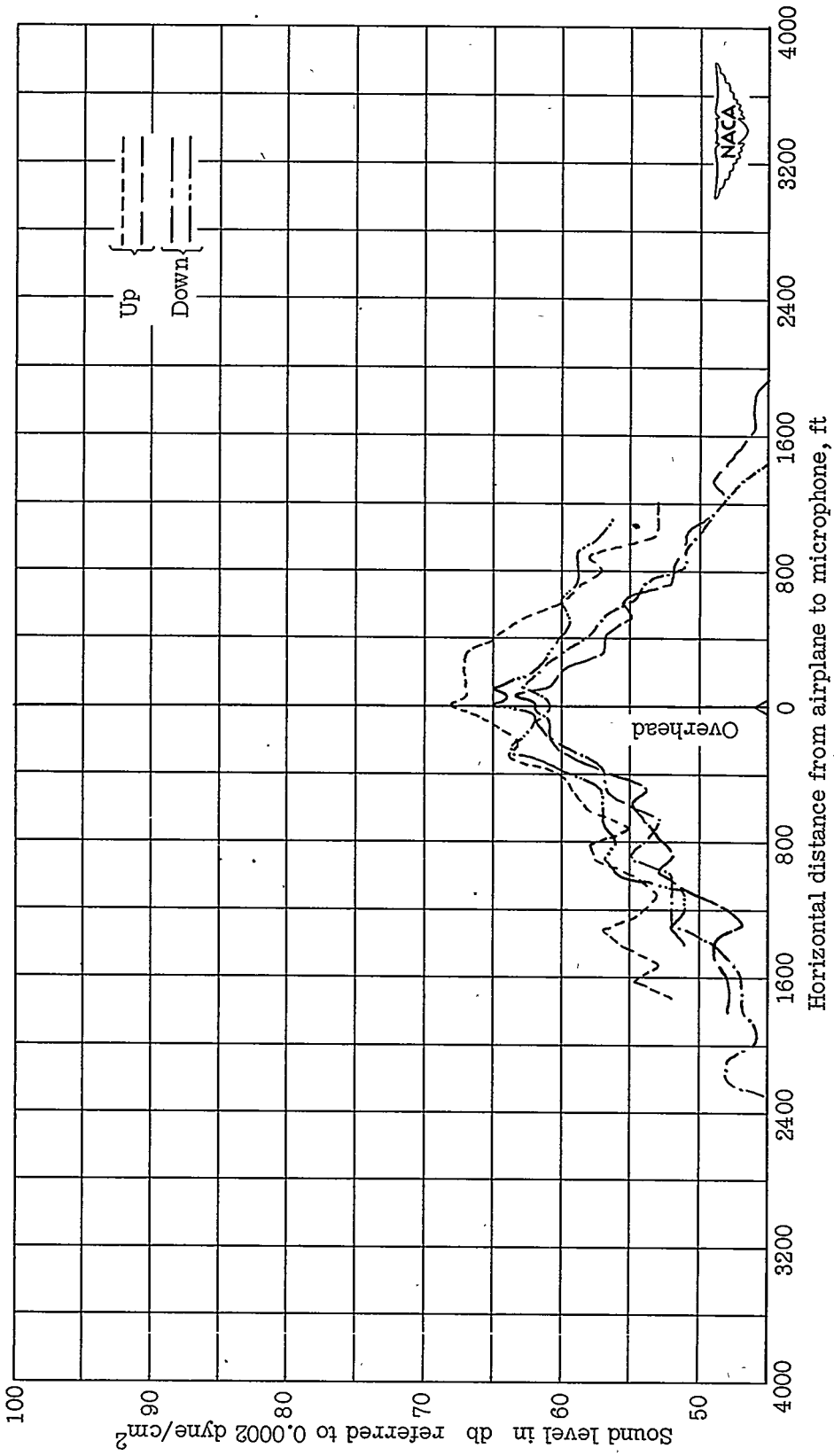

(c) Three-bladed propeller, configuration 2B.

Figure 25.- Continued.

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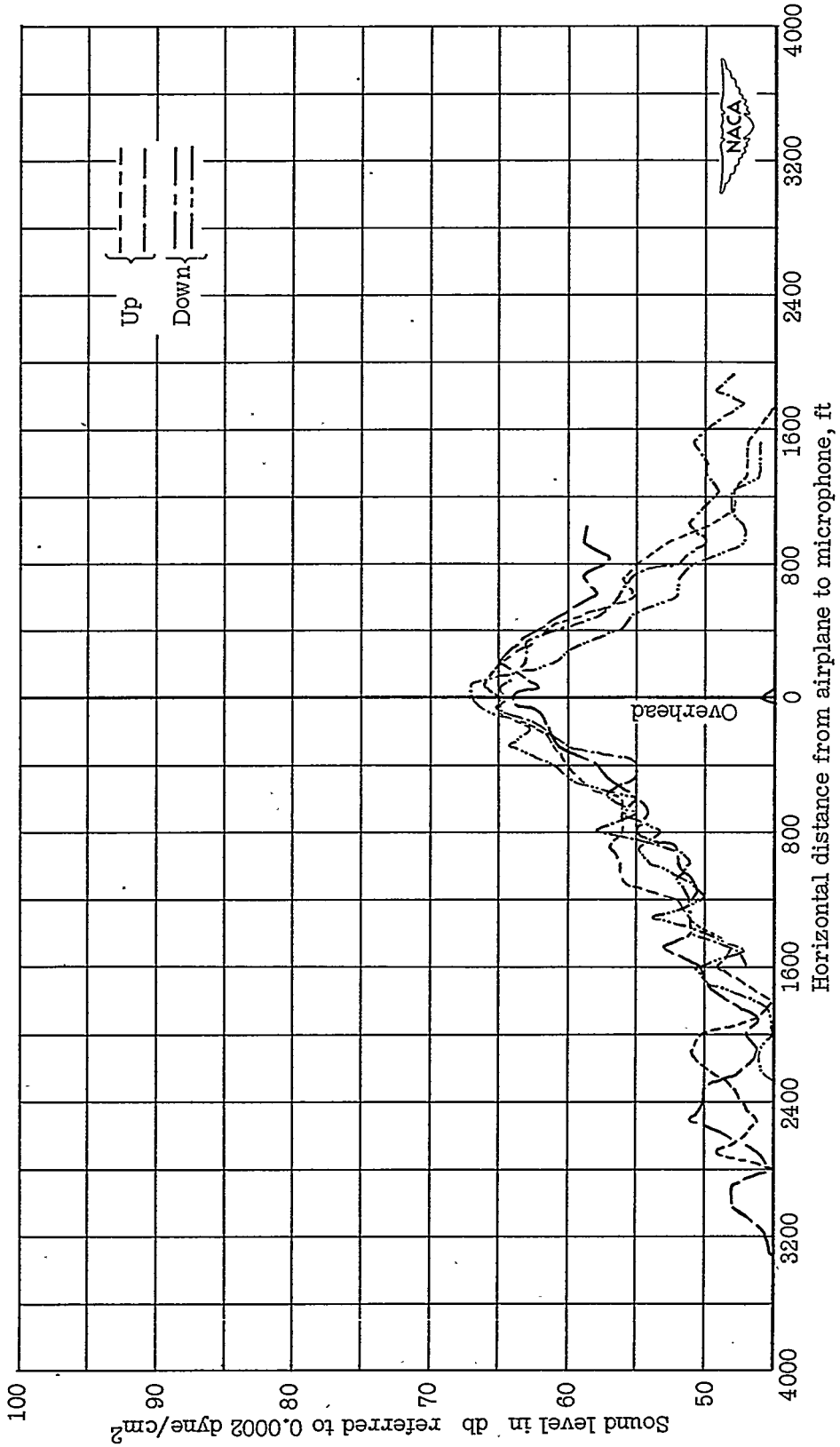

(d) Four-bladed propeller, configuration 2F.

Figure 25.- Continued.

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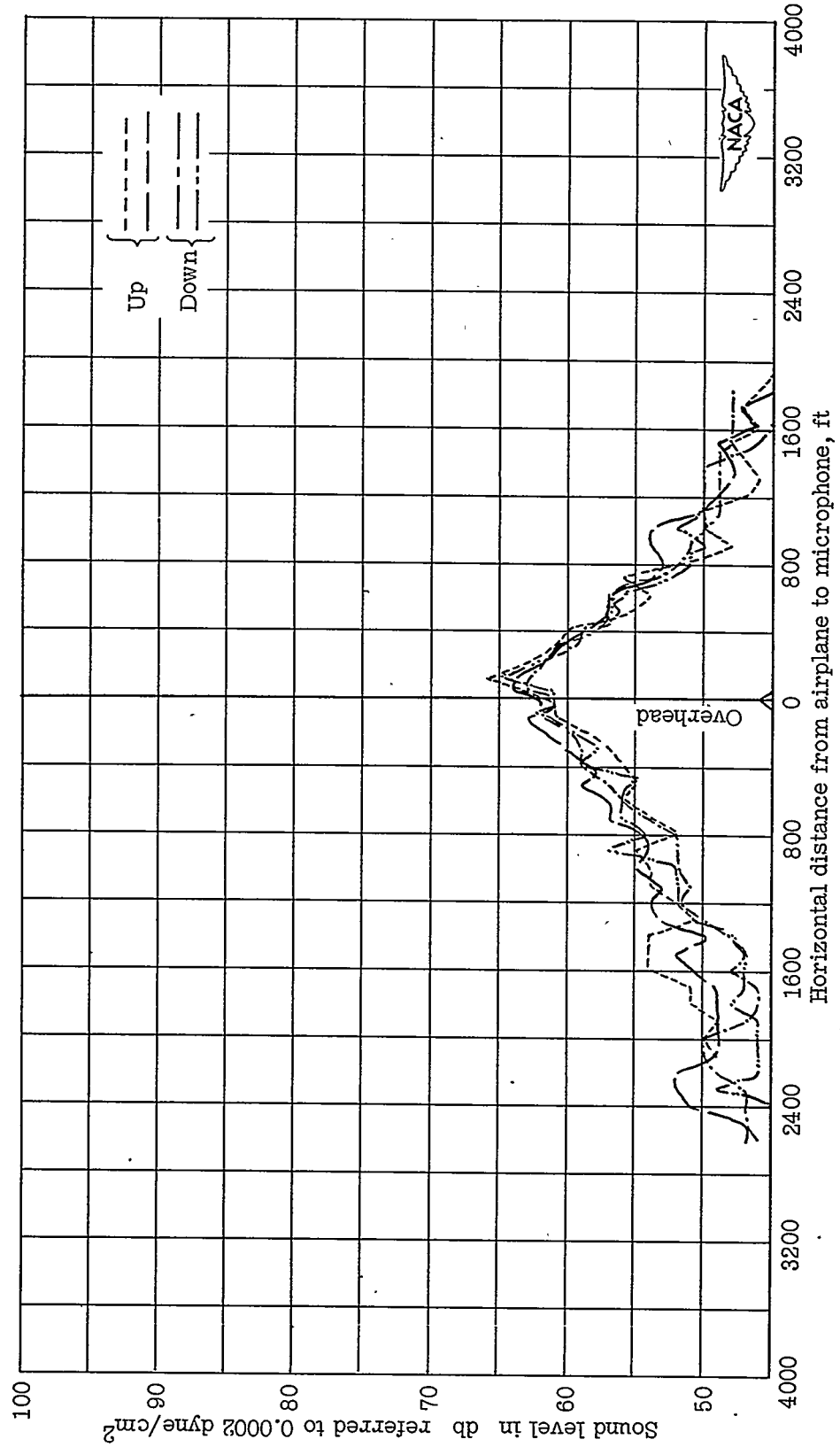

(e) Six-bladed propeller, configuration 2C.

Figure 25.- Continued.

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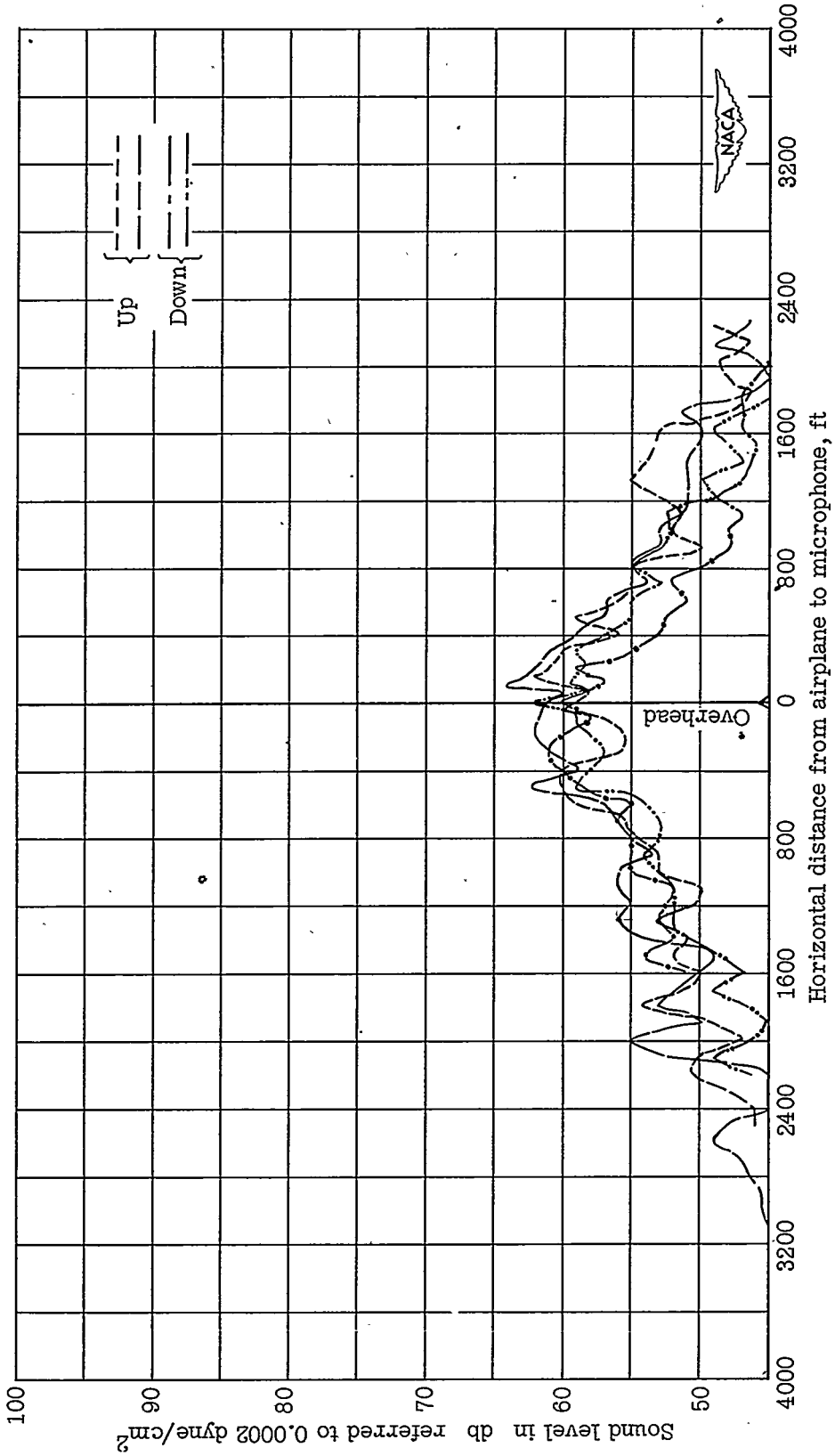

(f) Eight-bladed propeller, configuration 2D.

Figure 25.- Concluded.

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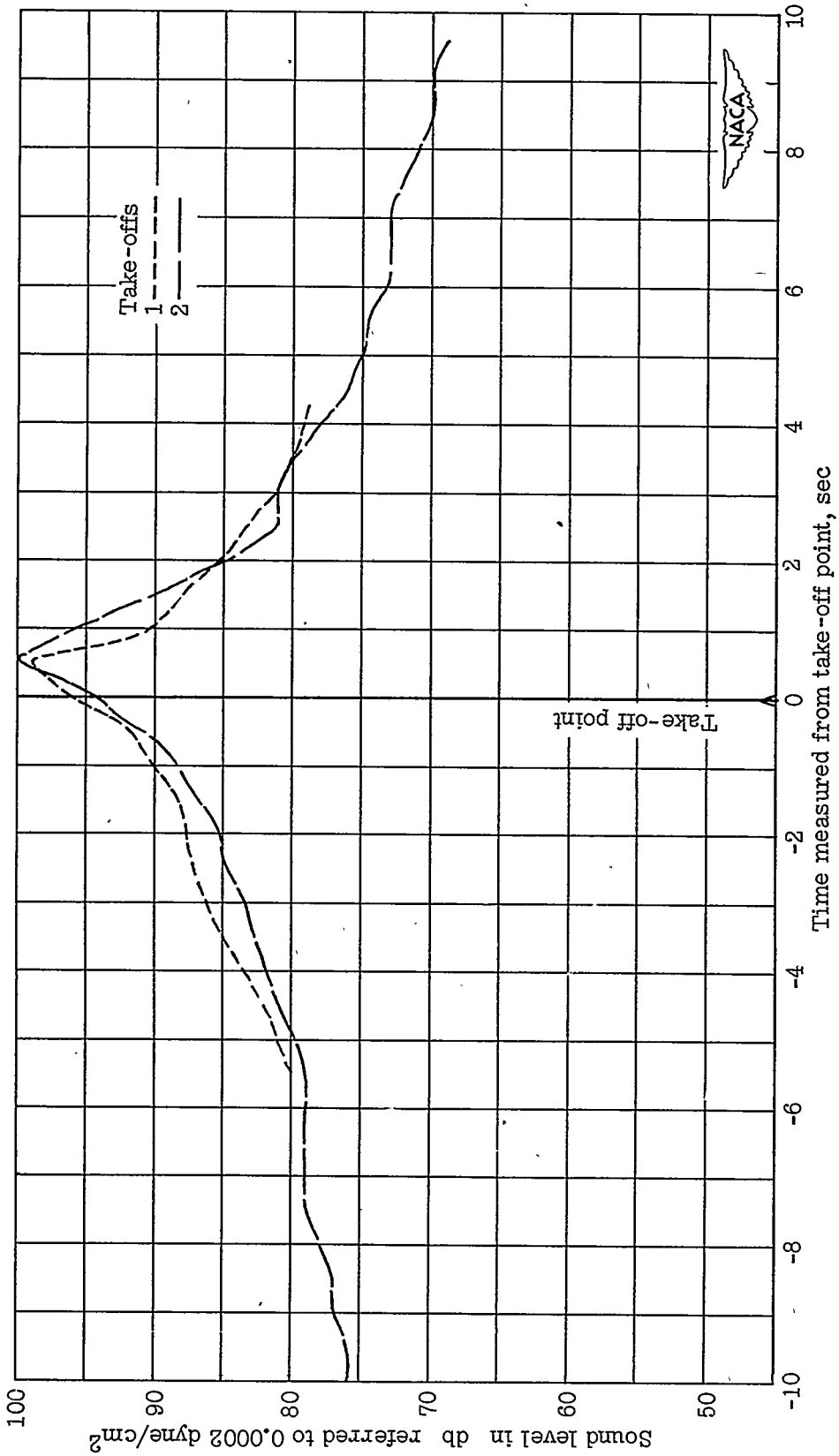

(a) Standard Stinson, configuration 1. Senserich Skyblade, cruising pitch.

Figure 26.- Sound level against time measured from take-off point. Take-offs; airplane leaving ground as it passes 50 feet from microphone; flat weighting. Refer to table II for engine power, tip speed, and propeller diameter.

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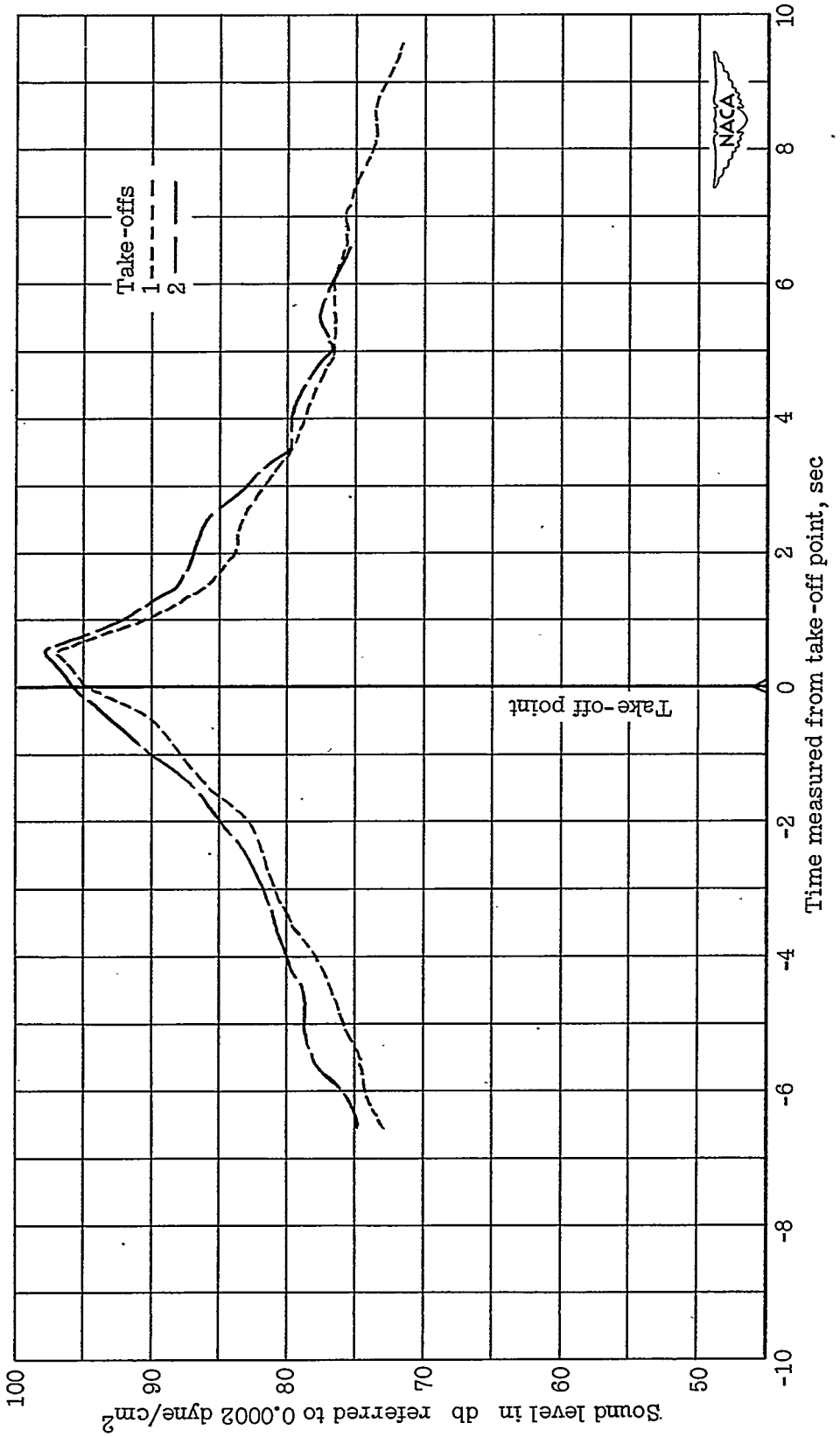

(b) Two-bladed propeller, configuration 2A.

Figure 26.- Continued.

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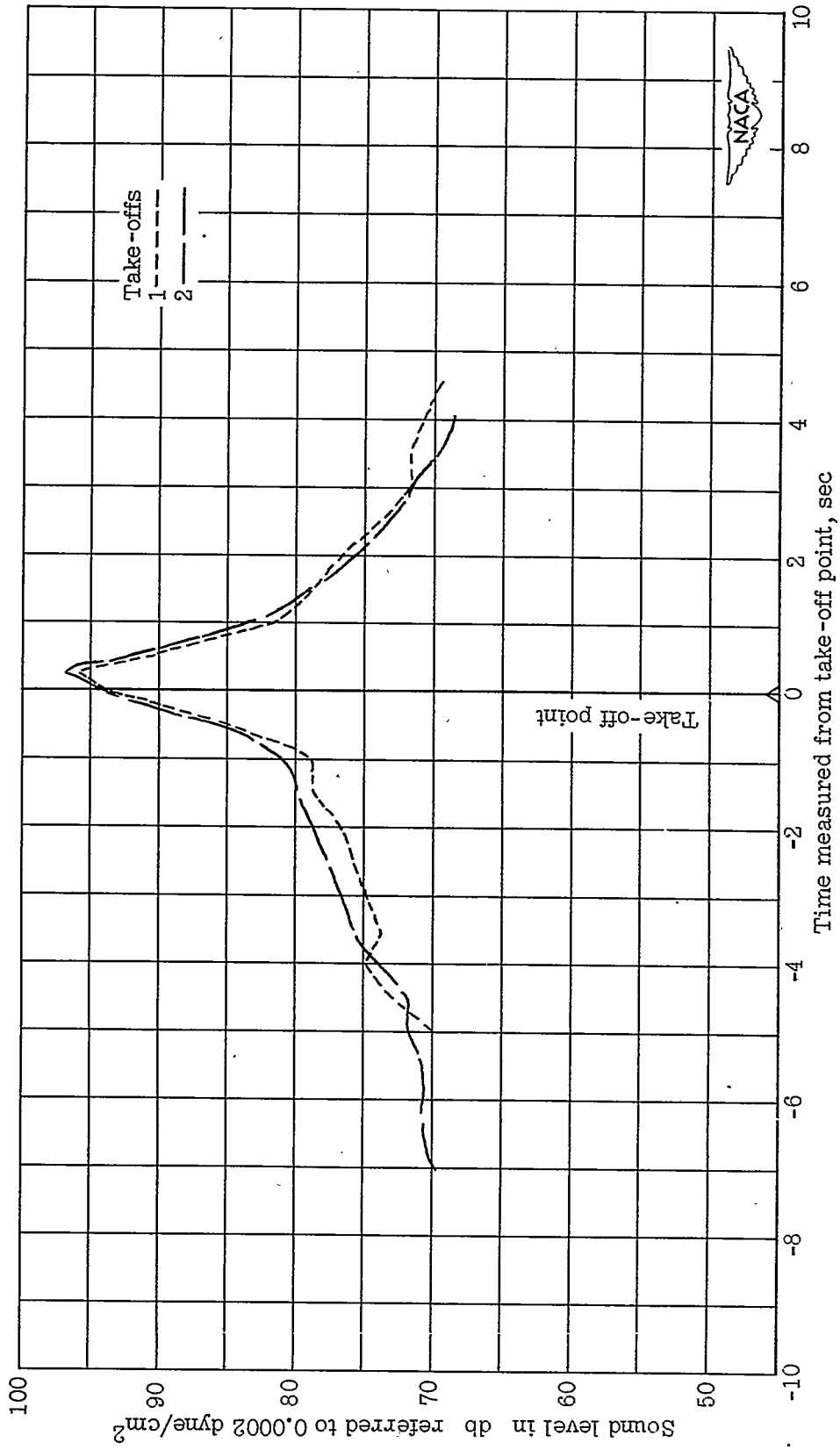

(c) Three-bladed propeller, configuration 2B.

Figure 26.- Continued.

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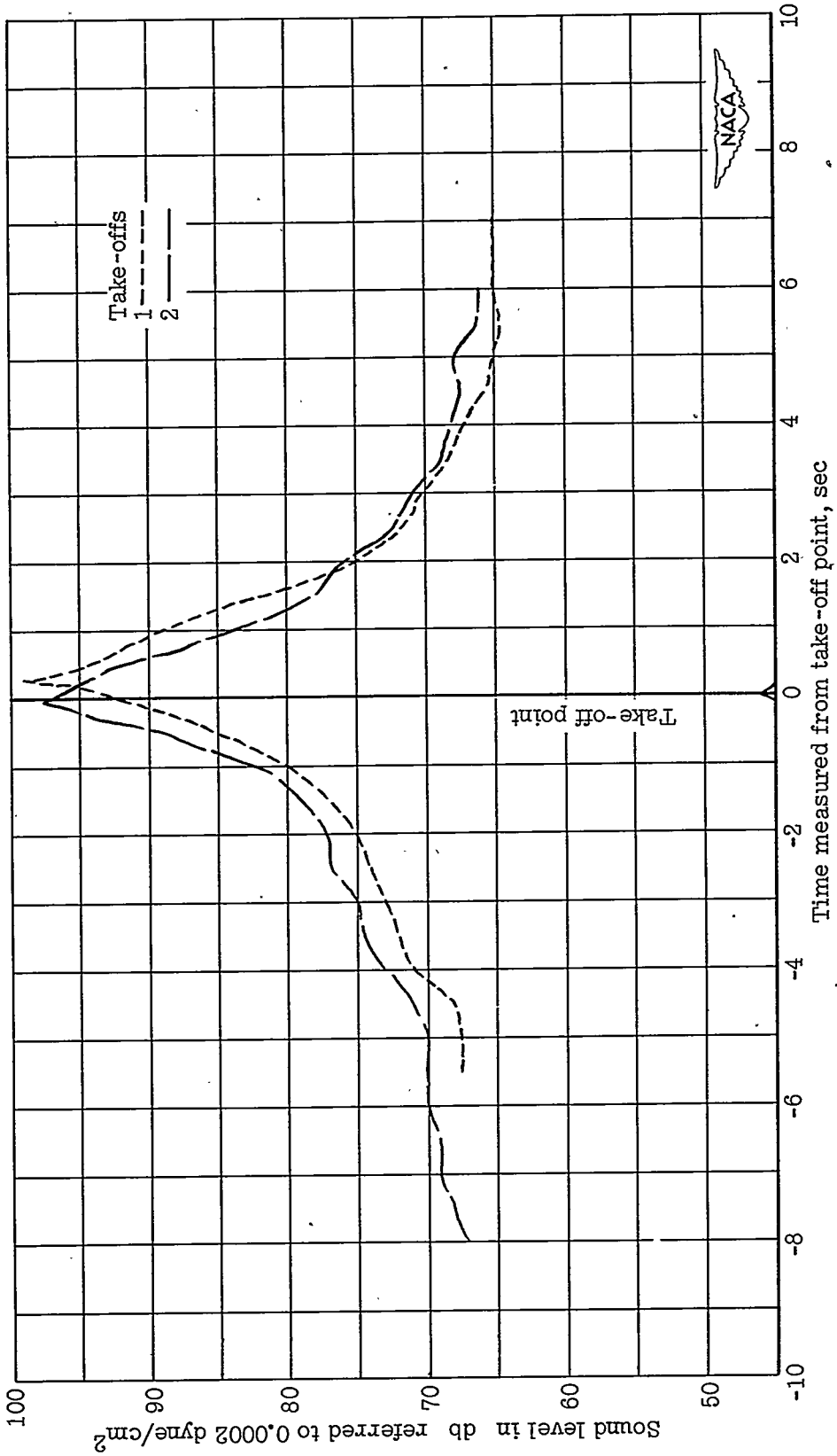

(d) Four-bladed propeller, configuration 2F.

Figure 26.- Continued.

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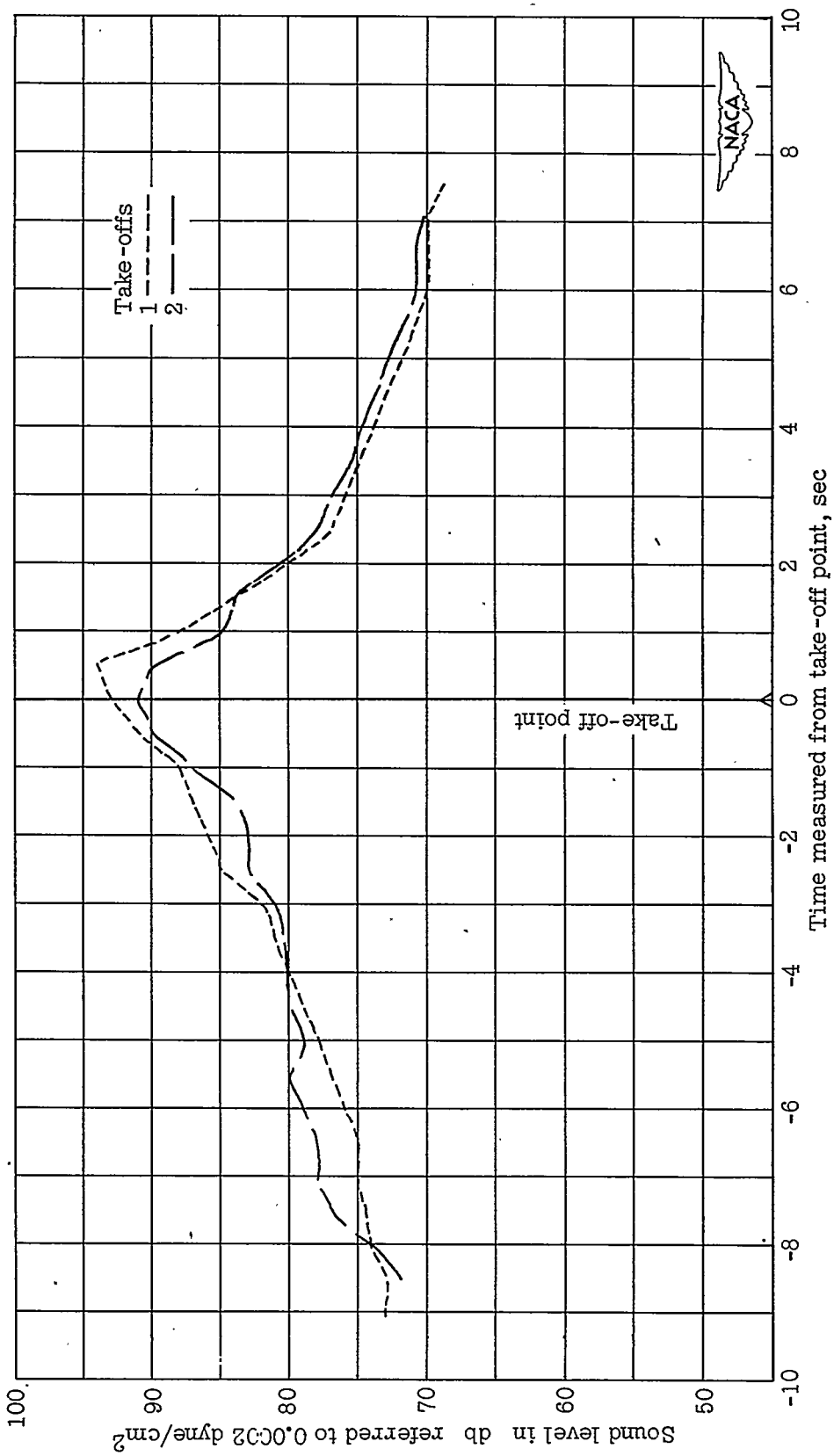

(e) Six-bladed propeller, configuration 2C.

Figure 26.- Continued.

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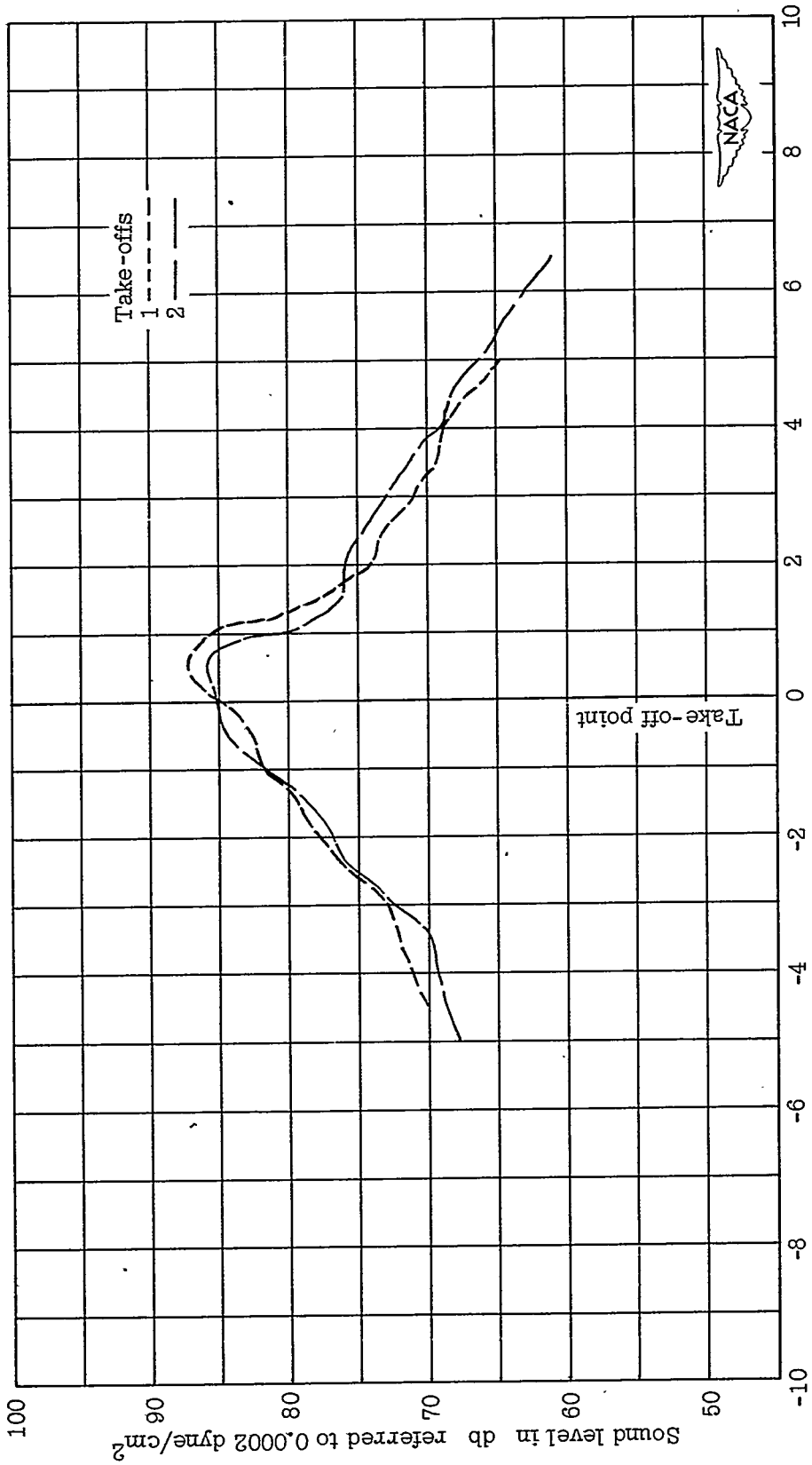

(f) Eight-bladed propeller, configuration 2D.

Figure 26.- Concluded.

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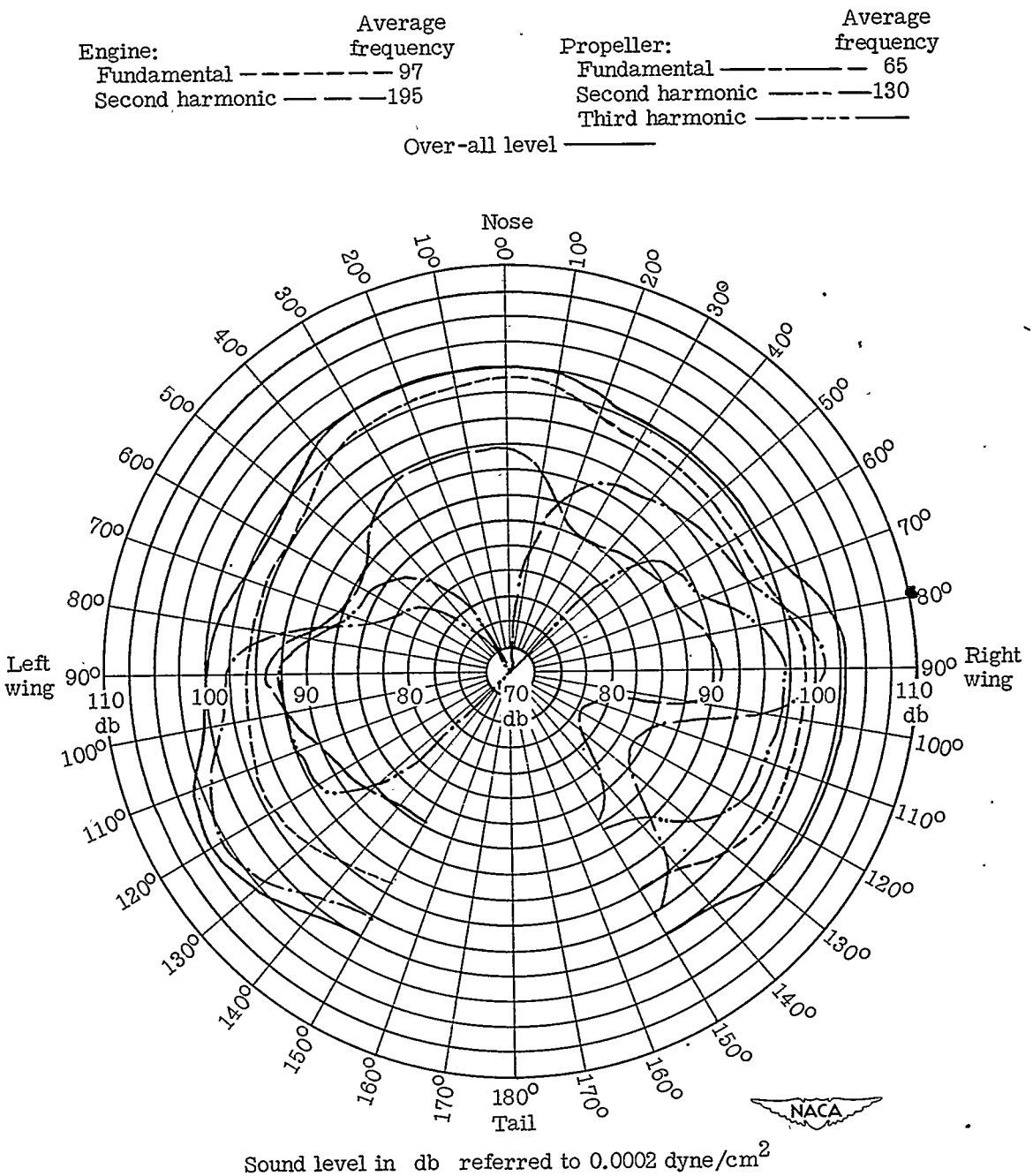

Sound level in db referred to 0.0002 dyne/cm^2

(a) Standard Stinson, configuration 1. Sensenich Skyblade.

Figure 27.- Frequency analysis on ground 50 feet from hub. Six configurations. Refer to table II for engine power, tip speed, and propeller diameter.

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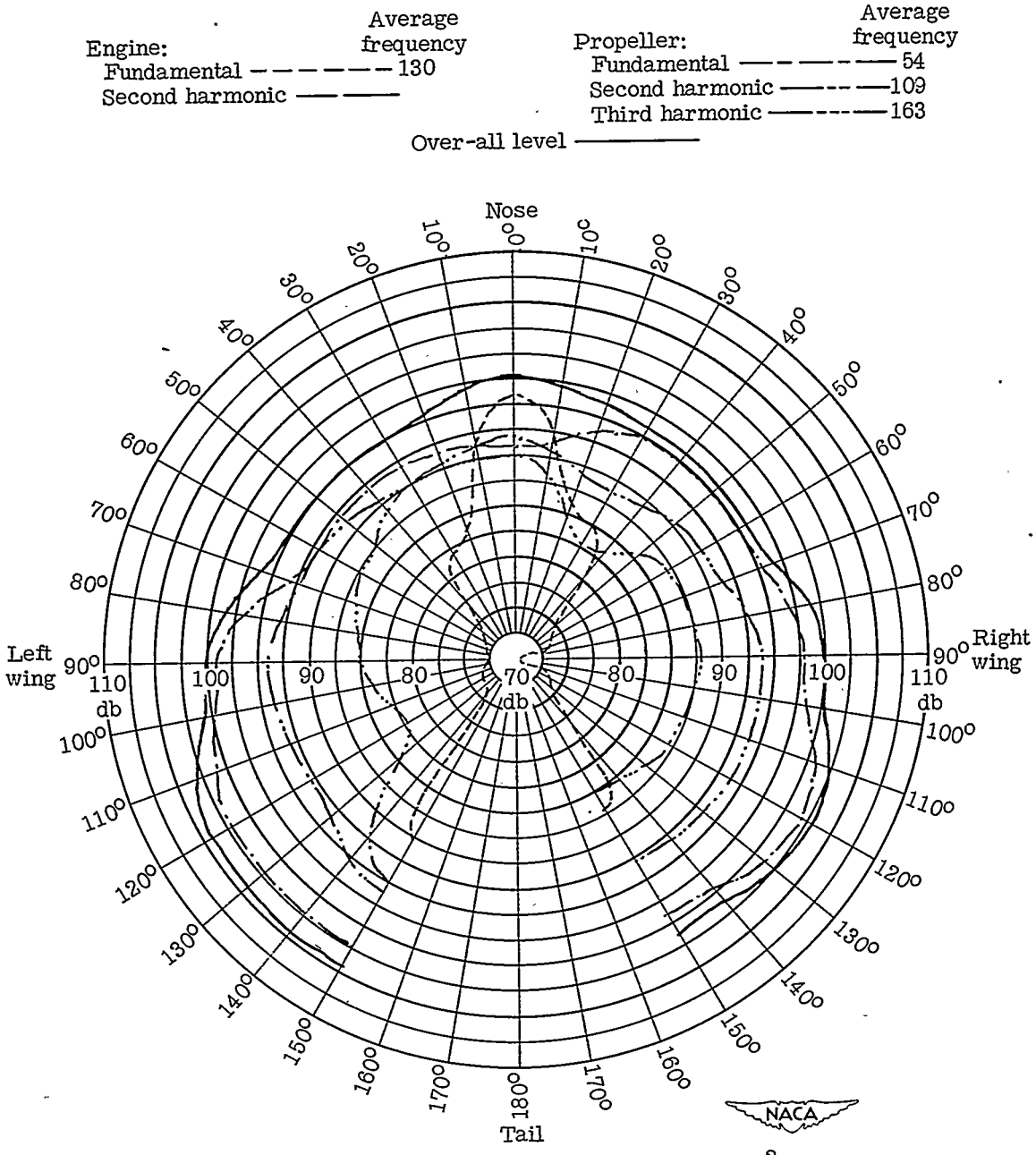

Sound level in db referred to 0.0002 dyne/cm^2

(b) Two-bladed propeller, configuration 2A.

Figure 27.- Continued.

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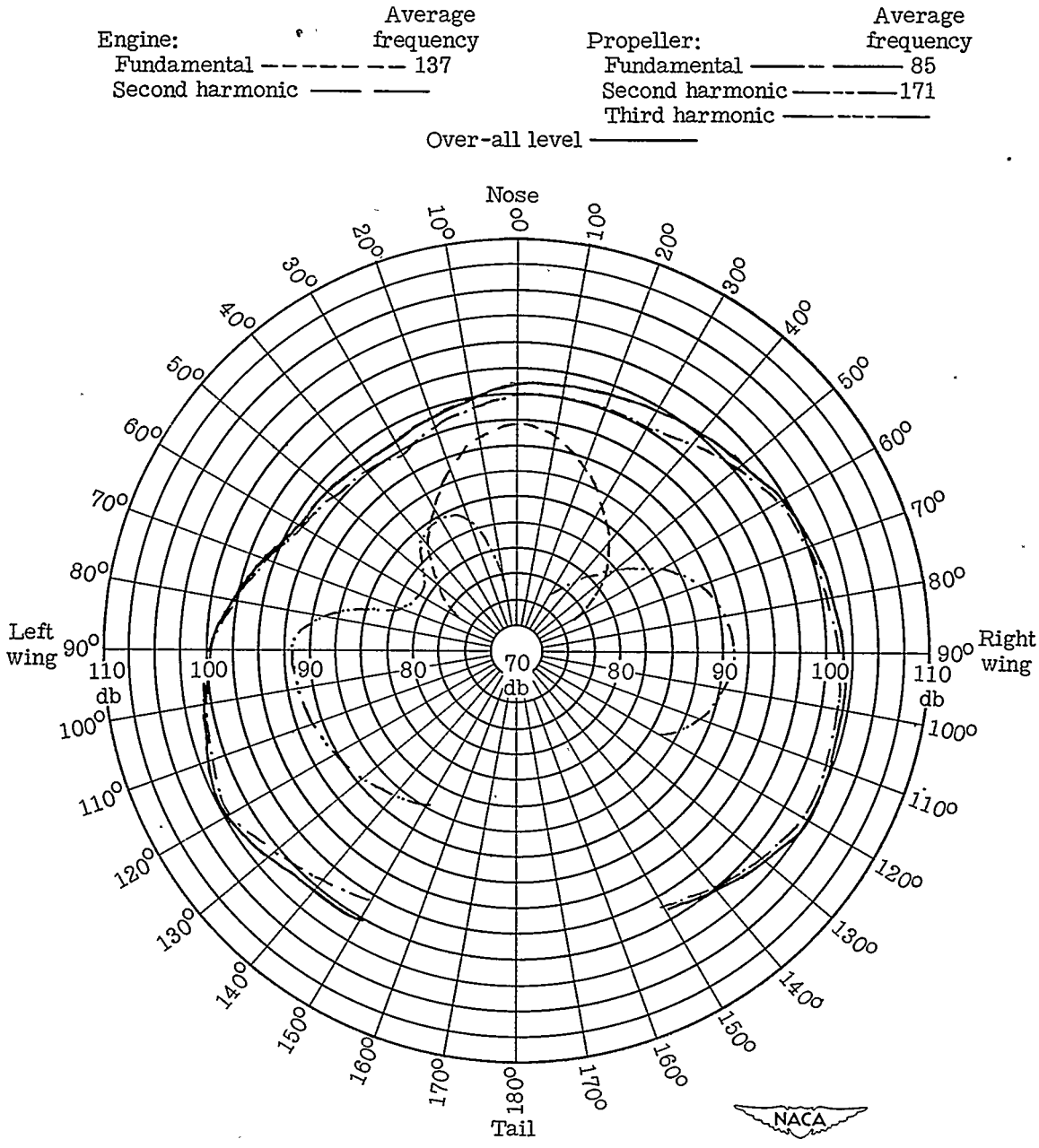

Sound level in db referred to 0.0002 dyne/cm^2

(c) Three-bladed propeller, configuration 2B.

Figure 27.- Continued.

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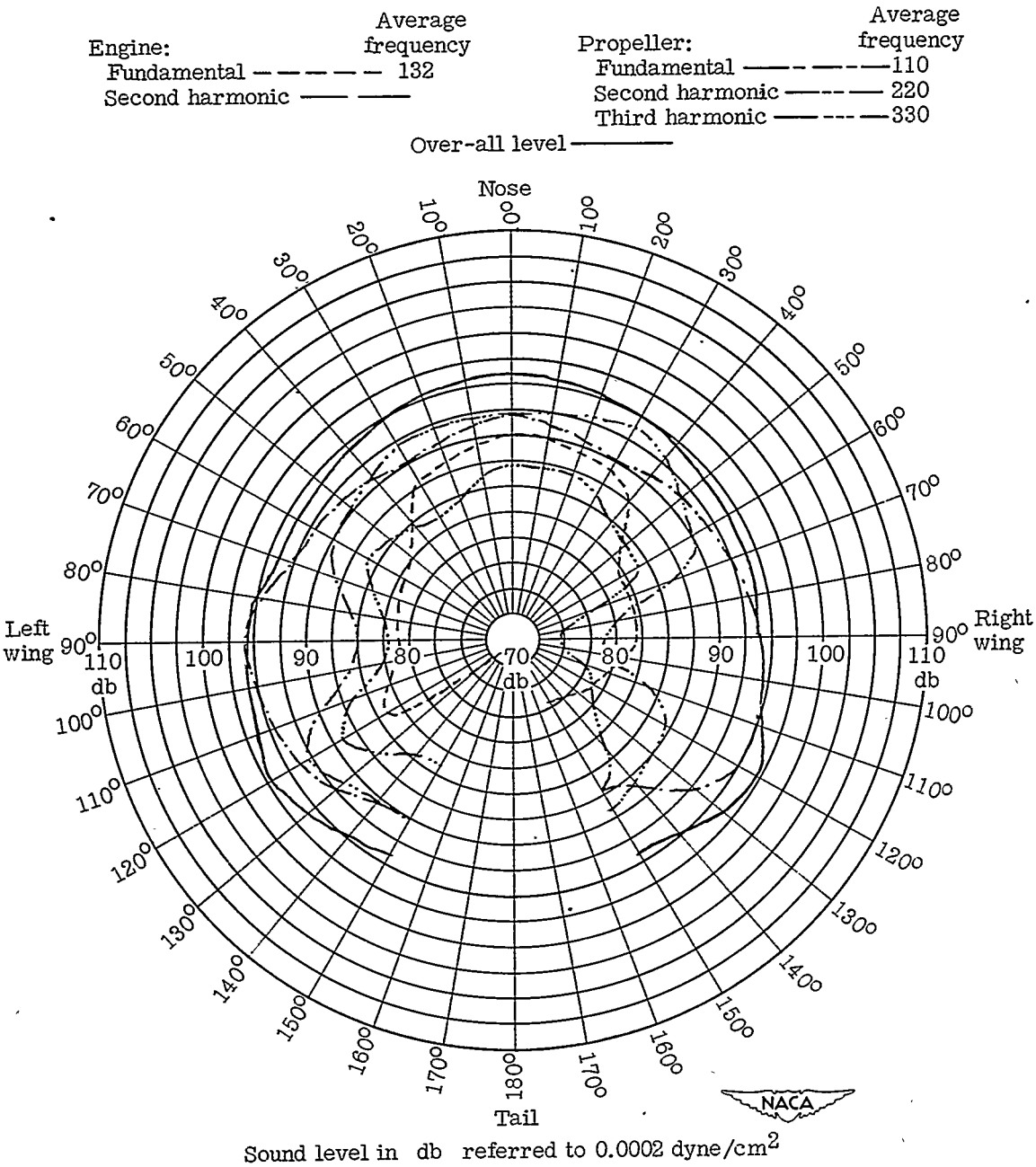

Sound level in db referred to 0.0002 dyne/cm^2

(d) Four-bladed propeller, configuration 2F.

Figure 27.- Continued.

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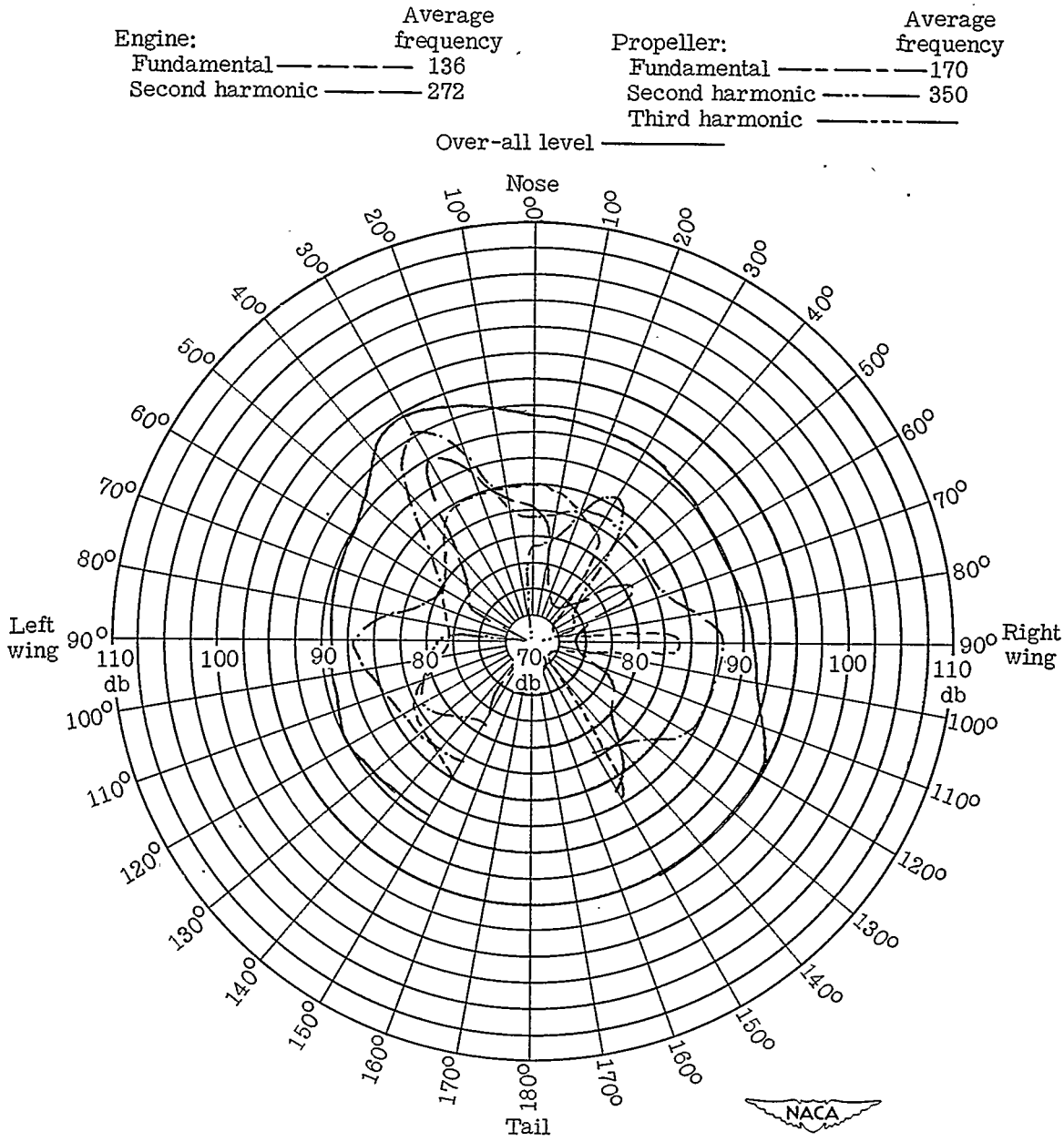

Sound level in db referred to 0.0002 dyne/cm^2

(e) Six-bladed propeller, configuration 2C.

Figure 27.- Continued..

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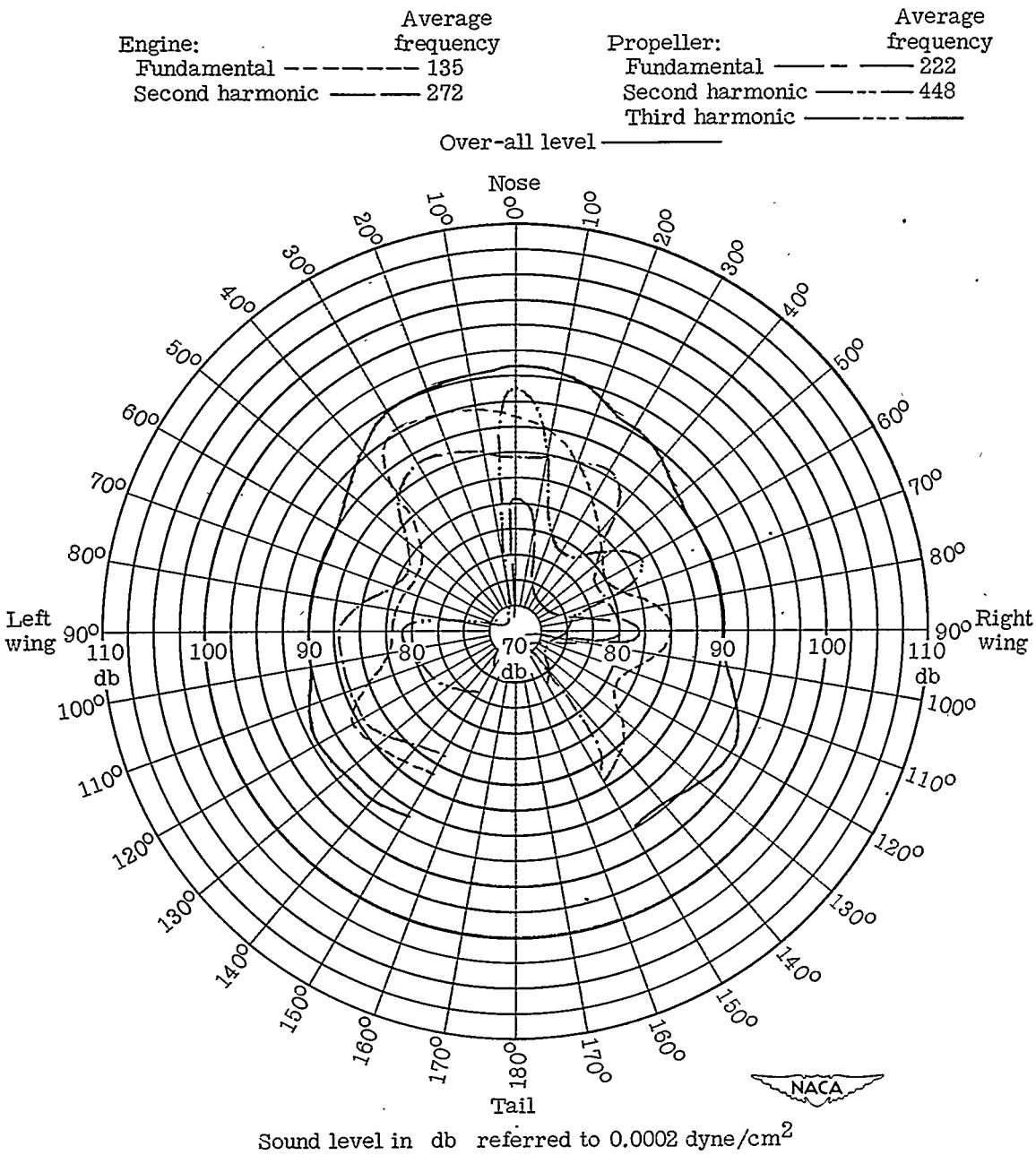

Sound level in db referred to 0.0002 dyne/cm^2

(f) Eight-bladed propeller, configuration 2D.

Figure 27.- Concluded.

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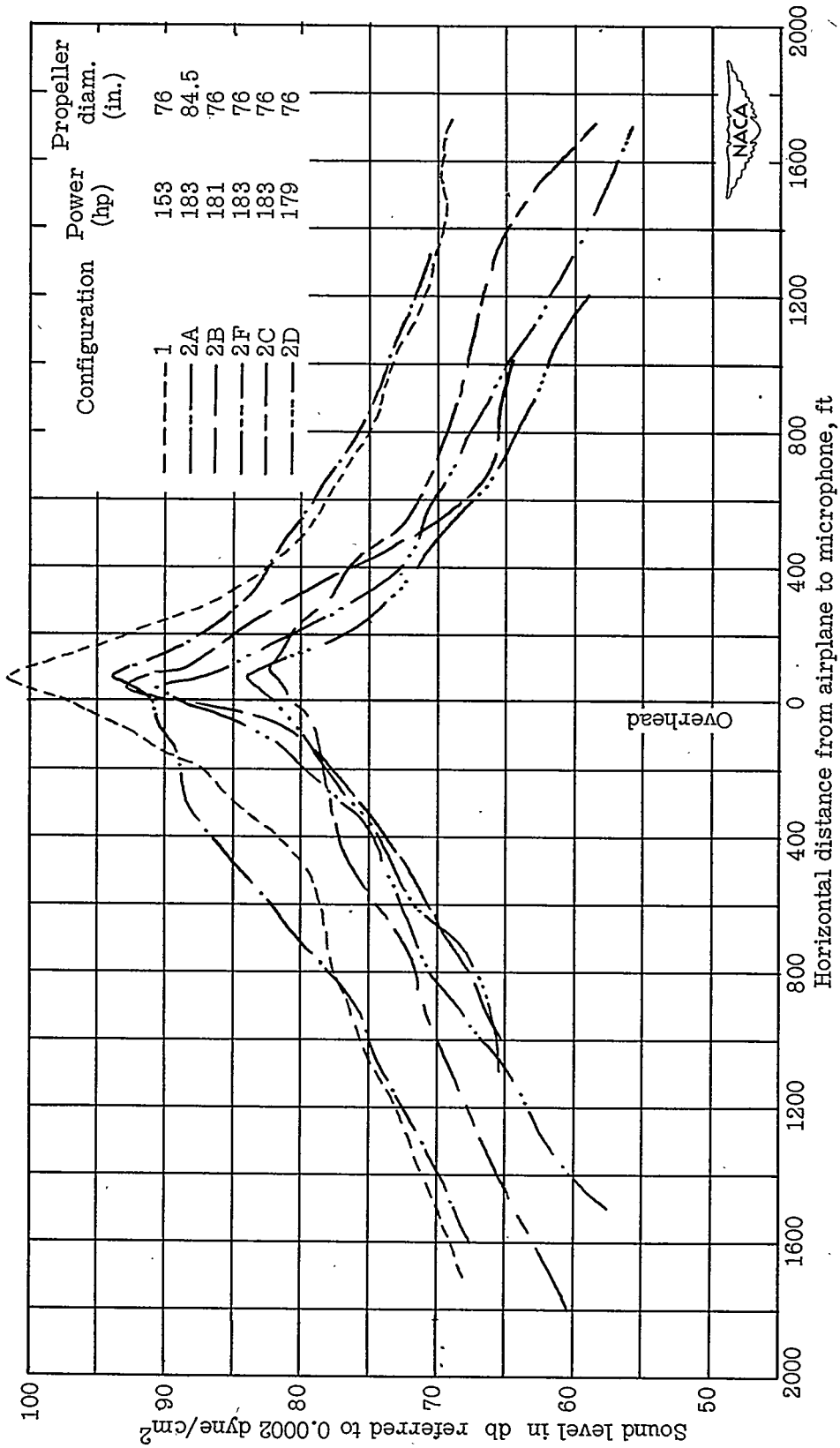

Figure 28.- Average curves of sound level against horizontal distance from airplane to microphone. Six configurations. Altitude, 100 feet; maximum power; flat weighting.

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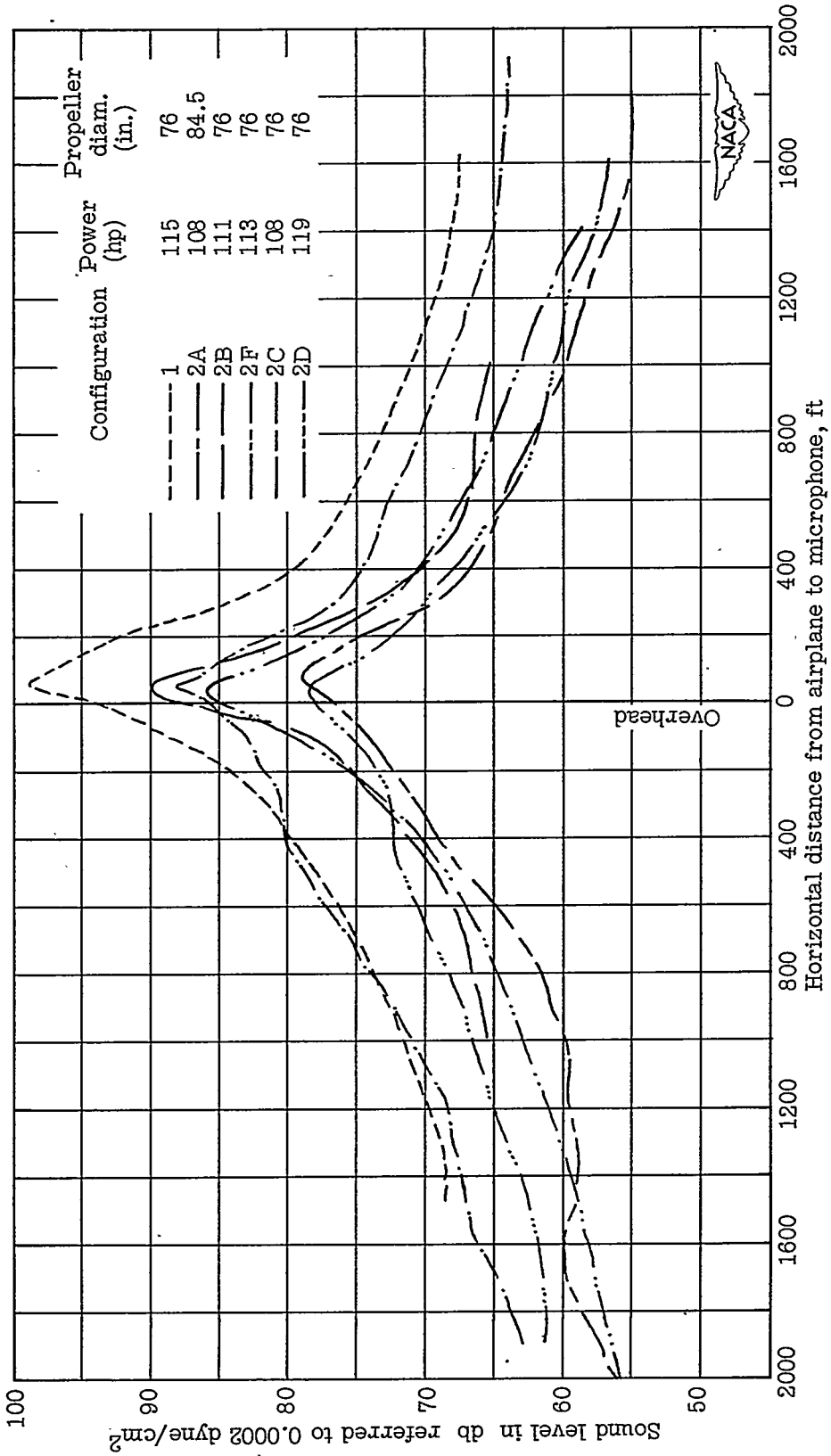

Figure 29.- Average curves of sound level against horizontal distance from airplane to microphone. Six configurations. Altitude, 100 feet; cruising power; flat weighting.

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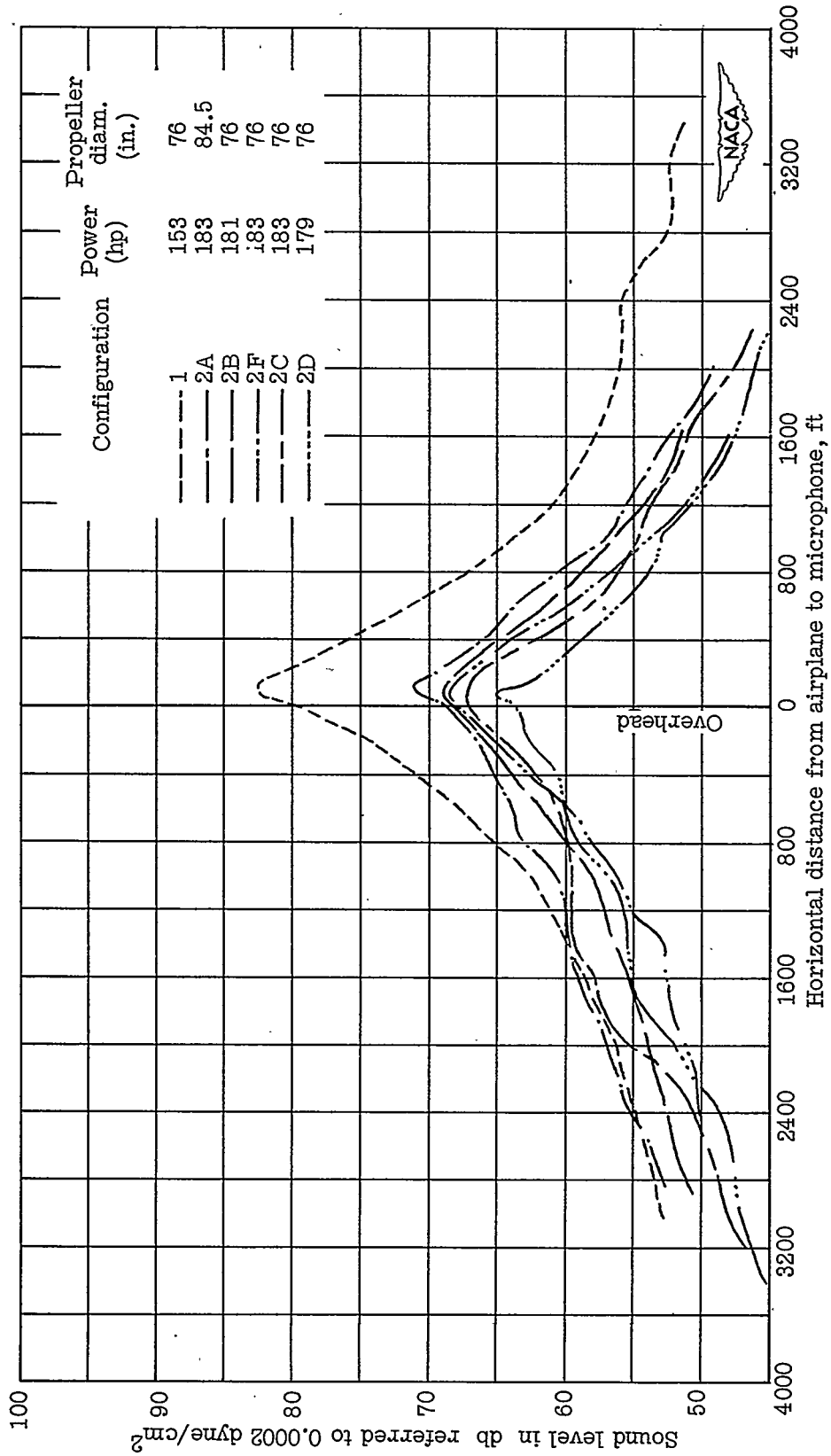

Figure 30.- Average curves of sound level against horizontal distance from airplane to microphone. Six configurations. Altitude, 500 feet; maximum power; 40-decibel weighting.

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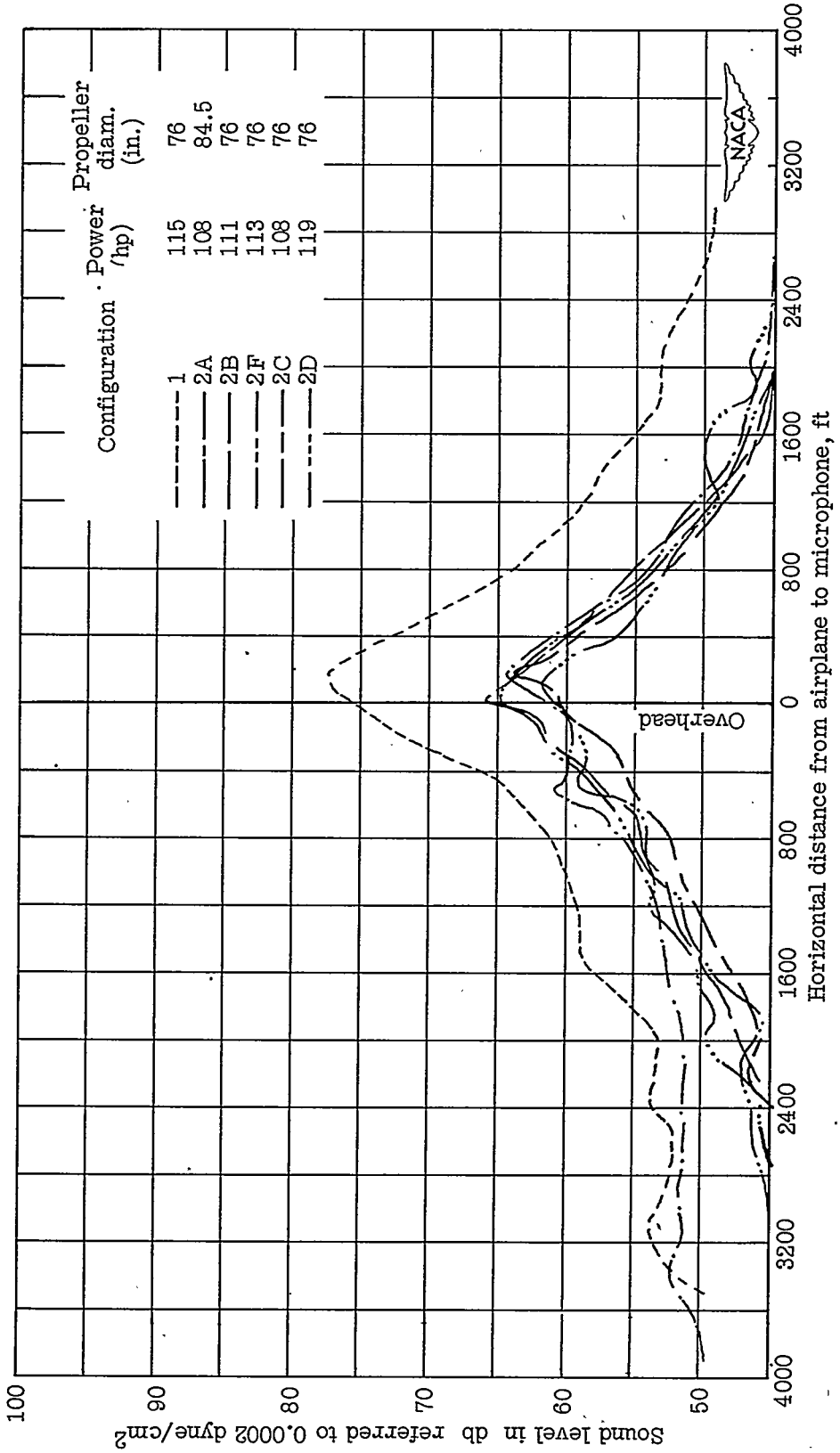

Figure 31.- Average curves of sound level against horizontal distance from airplane to microphone. Six configurations. Altitude, 500 feet; cruising power; 40-decibel weighting.

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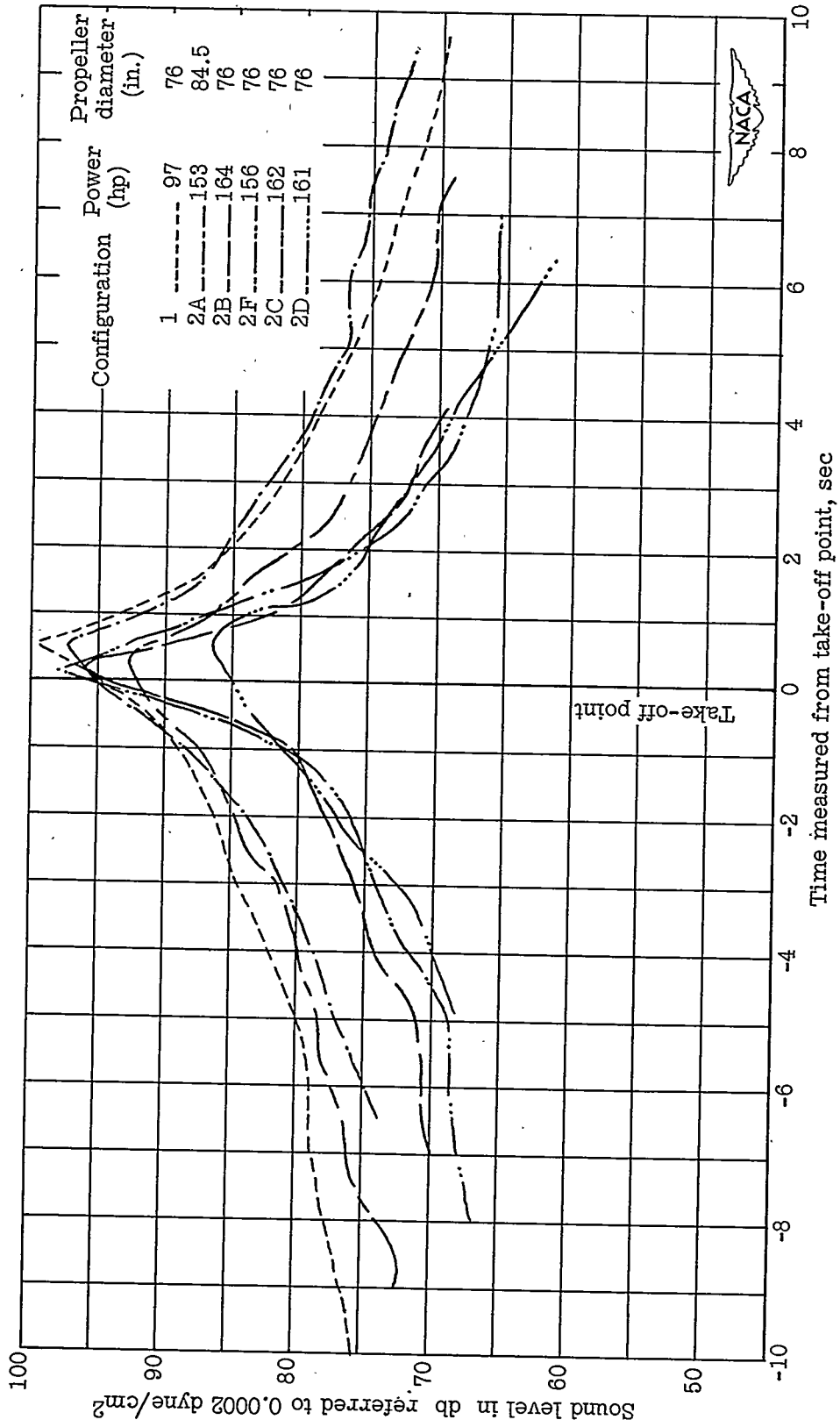

Figure 32.- Average curves of sound level against time measured from take-off point. Six configurations. Take-offs, flat weighting.

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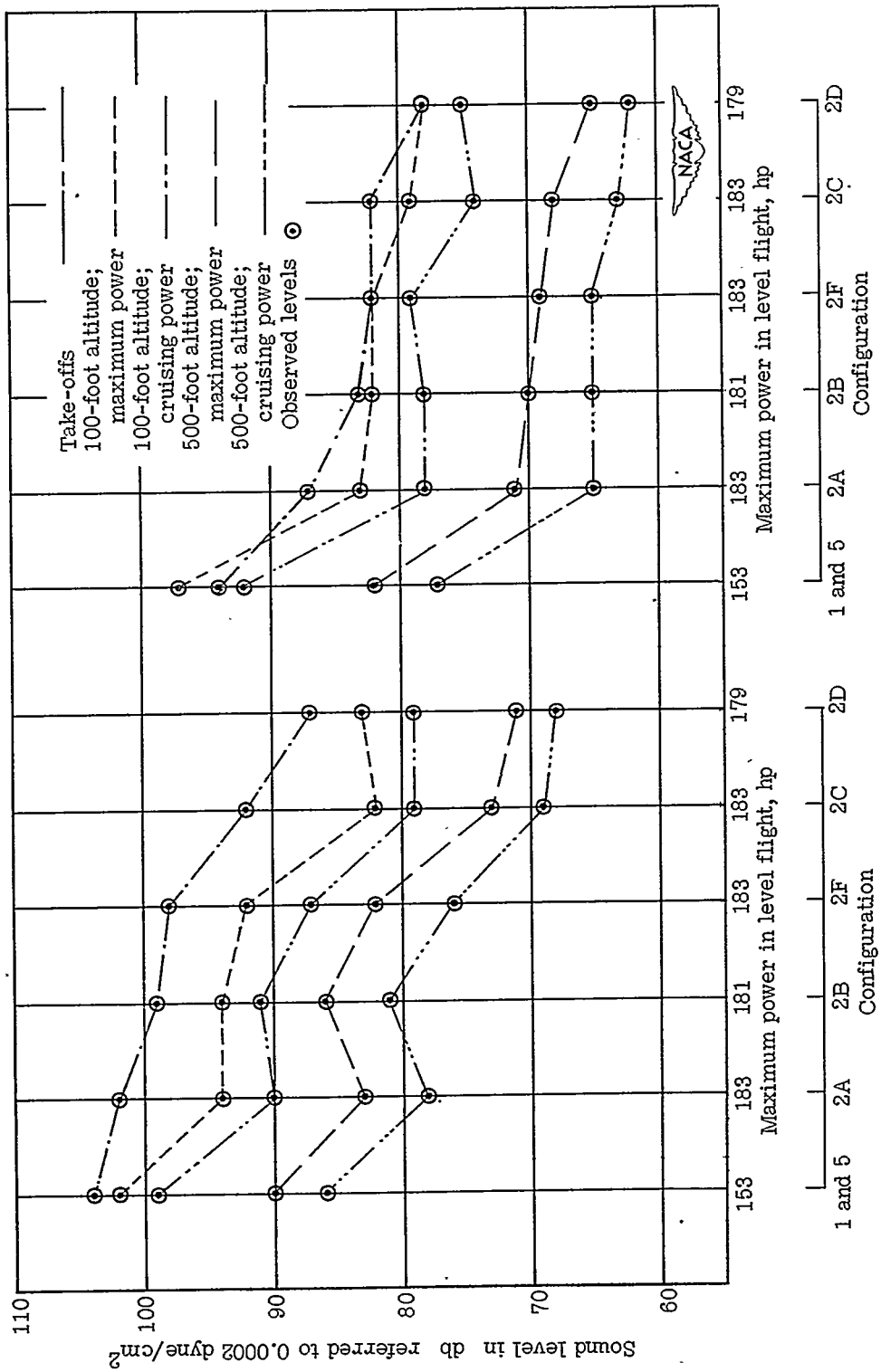

(a) Flat weighting.

(b) 40-decibel weighting.

Figure 33.- Comparative plots of average maximum sound levels for the standard Stinsons and the two-, three-, four-, six-, and eight-bladed configurations of the modified Stinson. Refer to table II for power tip speed, and propeller diameter.

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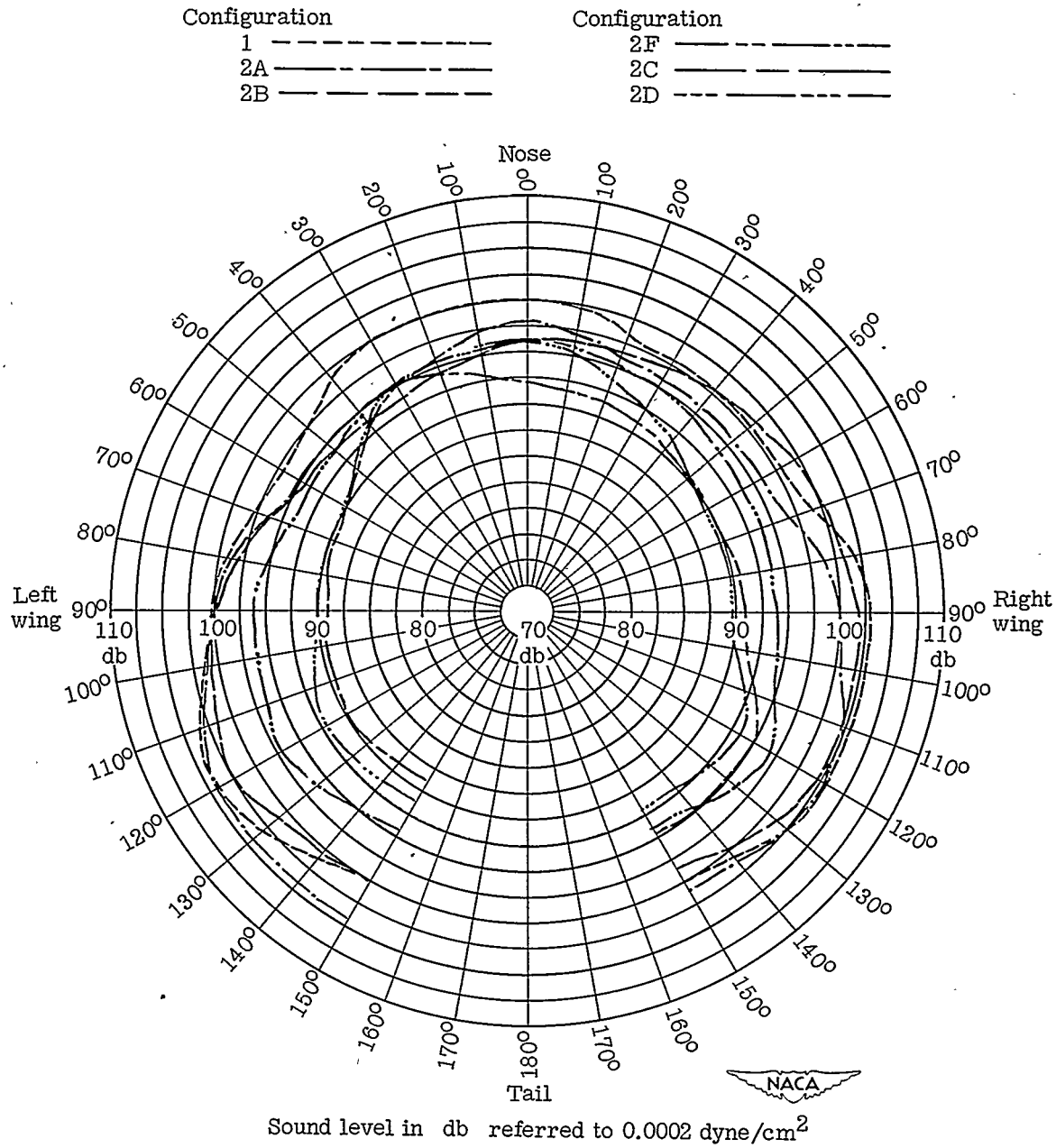

Figure 34.- Comparative polar plot of over-all levels from data taken on ground 50 feet from hub. Six configurations. Refer to table II for engine power, tip speed, and propeller diameter.

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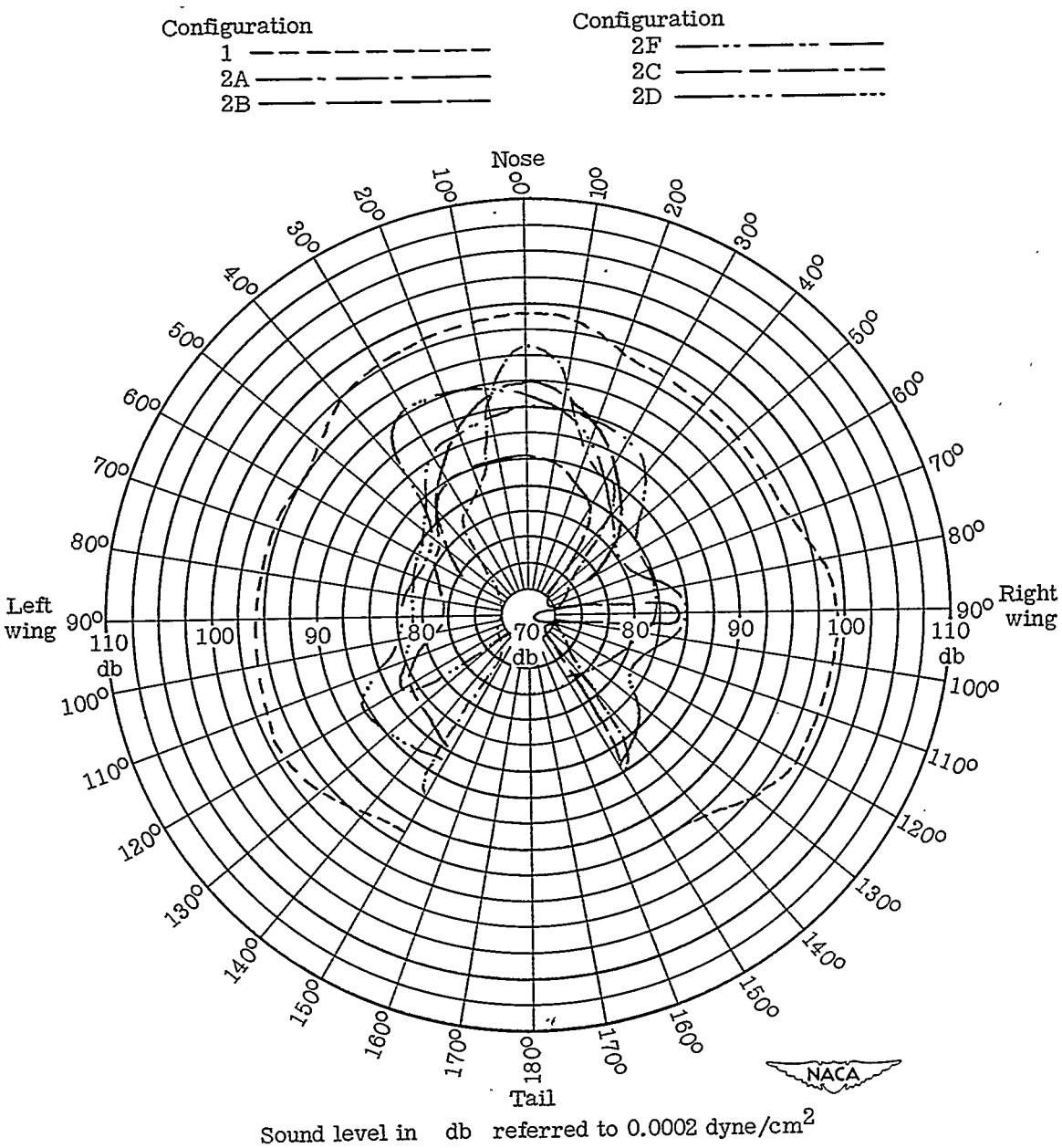

Figure 35.- Comparative polar plot of engine fundamentals from data taken on ground 50 feet from hub. Six configurations. Refer to table II for engine power, tip speed, and propeller diameter.

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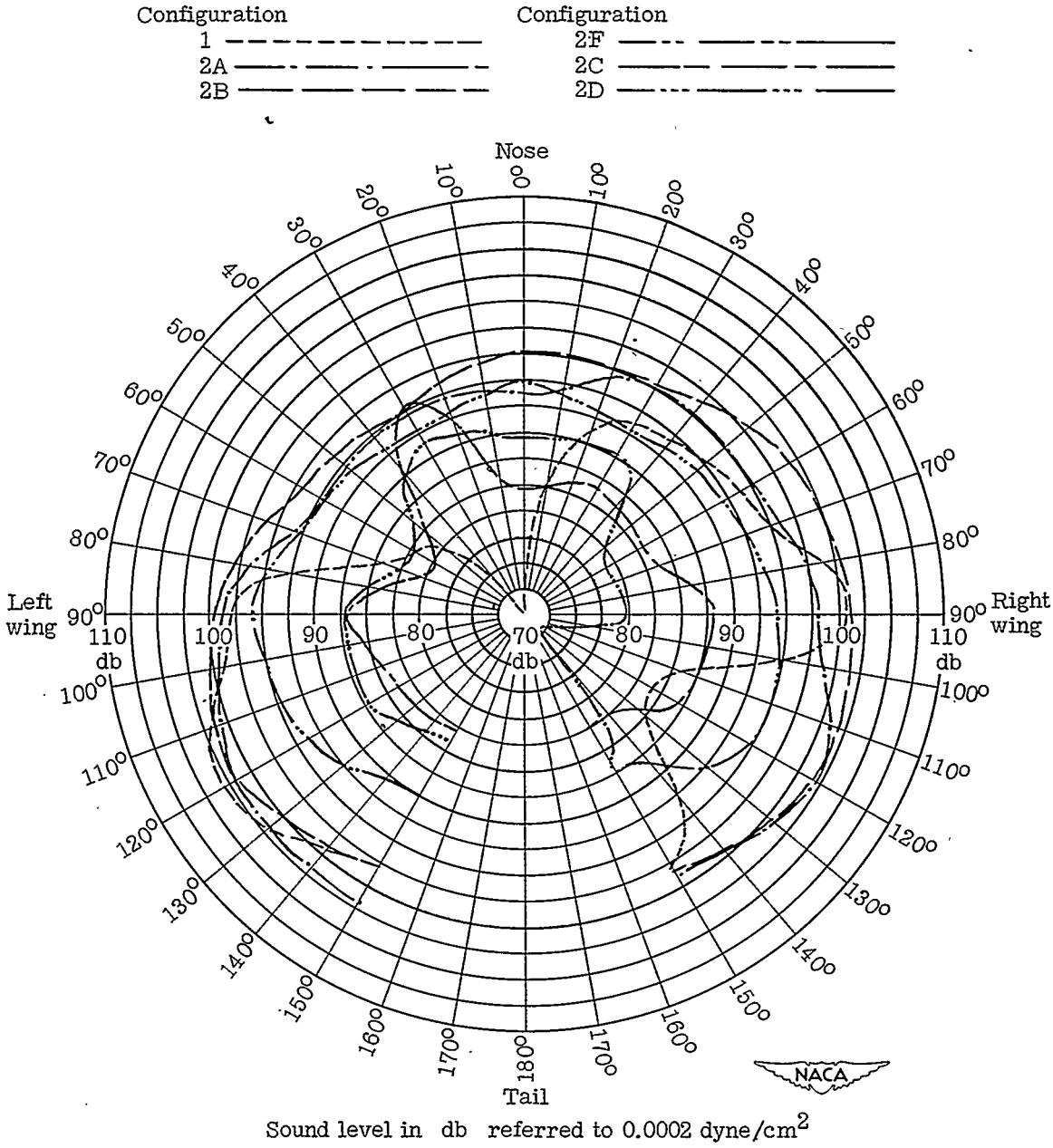

Figure 36.- Comparative polar plot of propeller fundamentals from data taken on ground 50 feet from hub. Six configurations. Refer to table II for engine power, tip speed, and propeller diameter.

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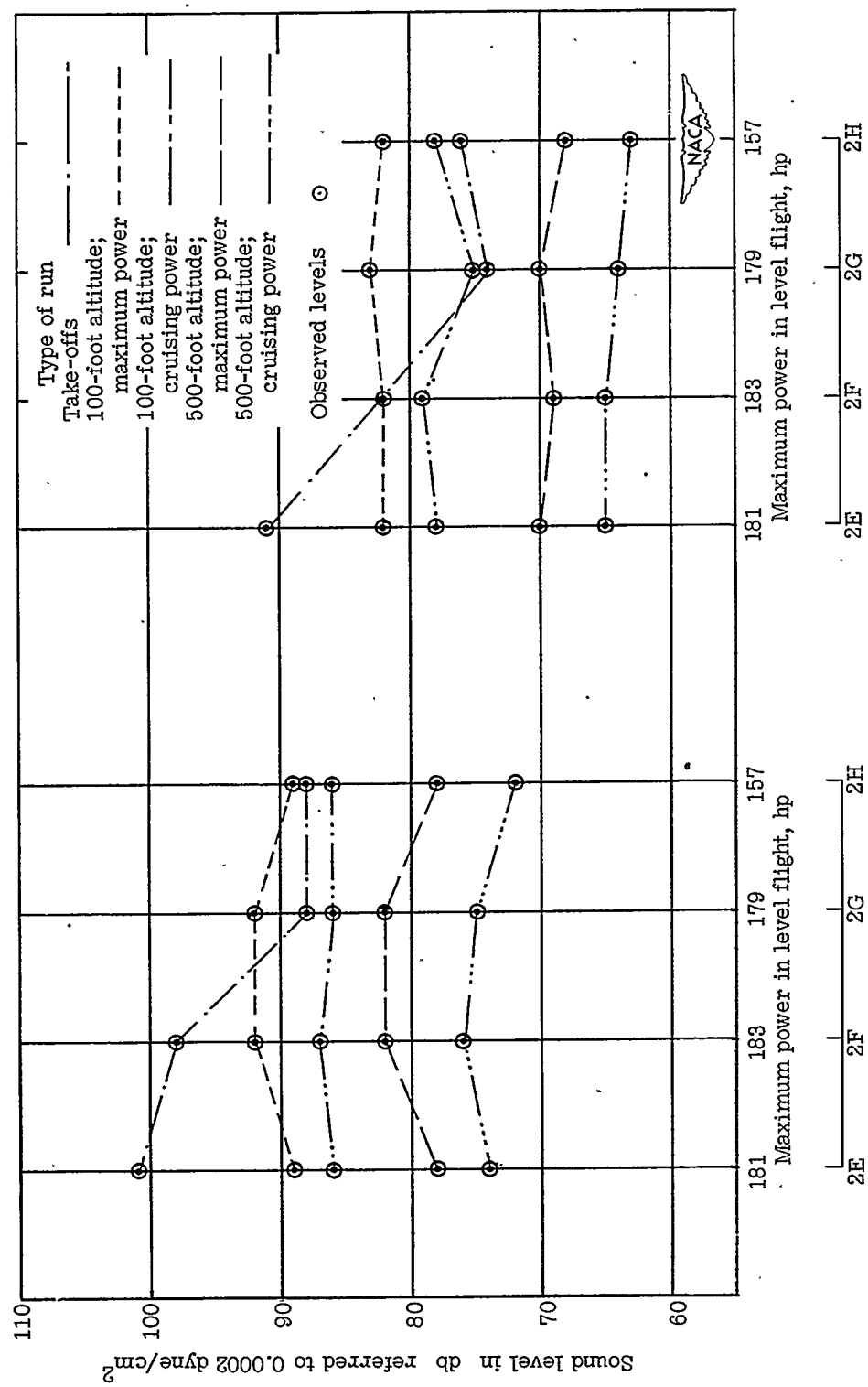

(a) Flat weighting. (b) 40-decibel weighting.

Figure 37.- Comparative plots of average maximum sound levels for the four different four-bladed configurations of the quieted Stinson. Refer to table II for power, tip speed, and propeller diameter.

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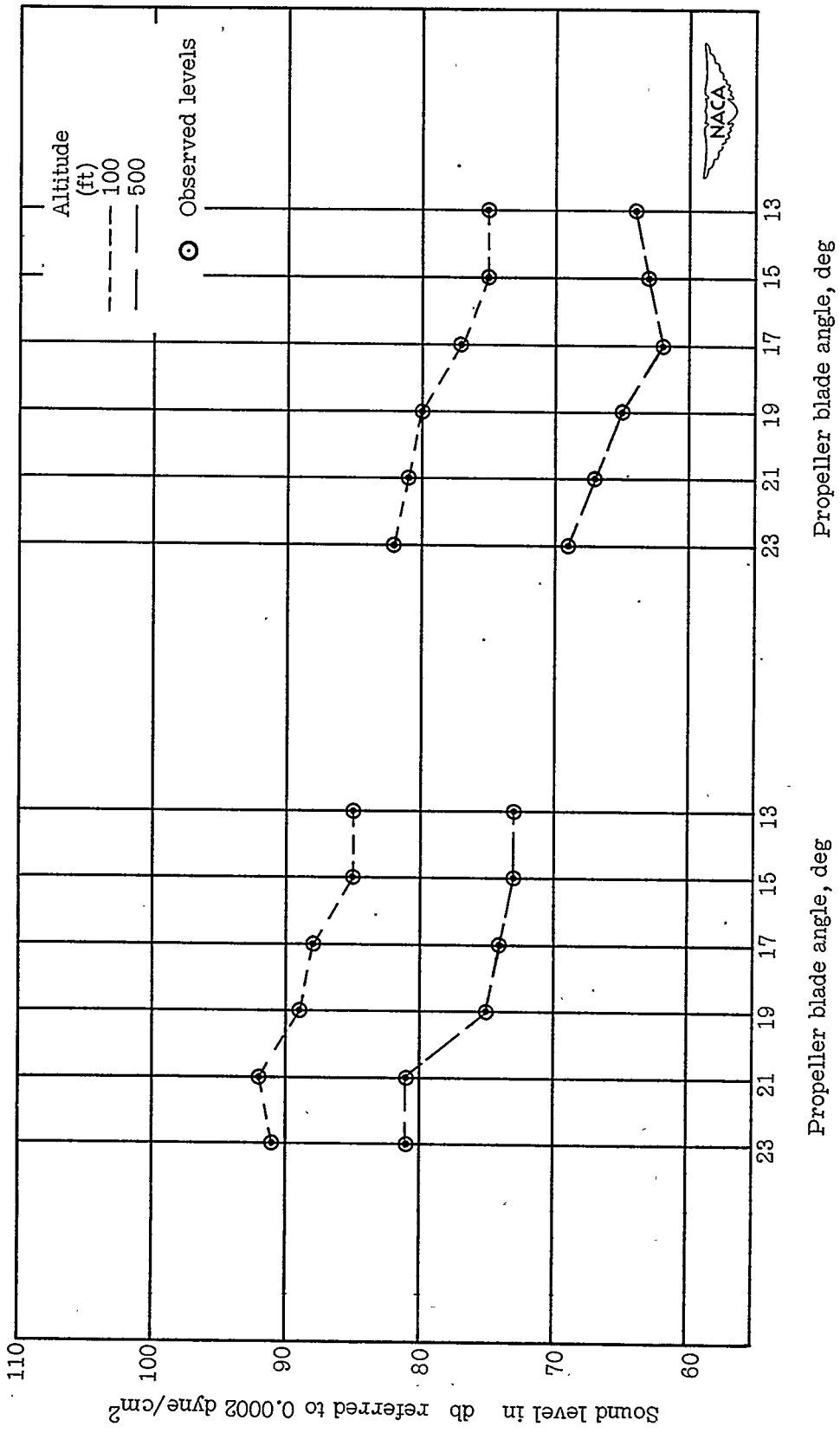

(a) Flat weighting. (b) 40-decibel weighting.

Figure 38.- Comparative plots of average maximum sound level against propeller blade angle at constant tip speed. Configuration 2F.

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Figure 39.- Decrease in noise level caused by reduction of engine and propeller power. Configuration 2F, constant tip speed, flat weighting.

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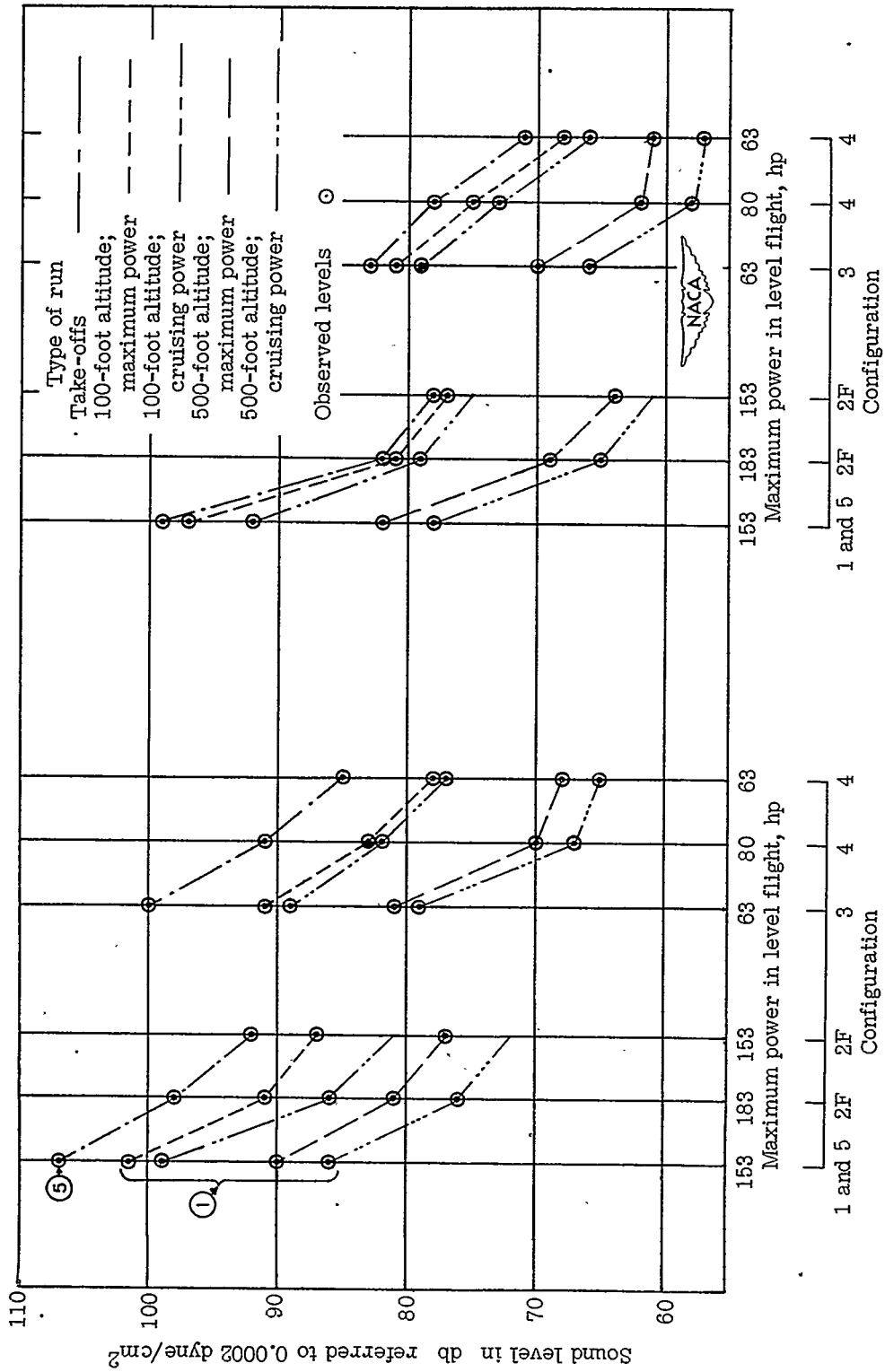

Figure 40.- Comparative plots of average maximum sound levels for standard and modified Cubs and standard and modified Stinsons. Refer to table II for power, tip speed, and propeller diameter.

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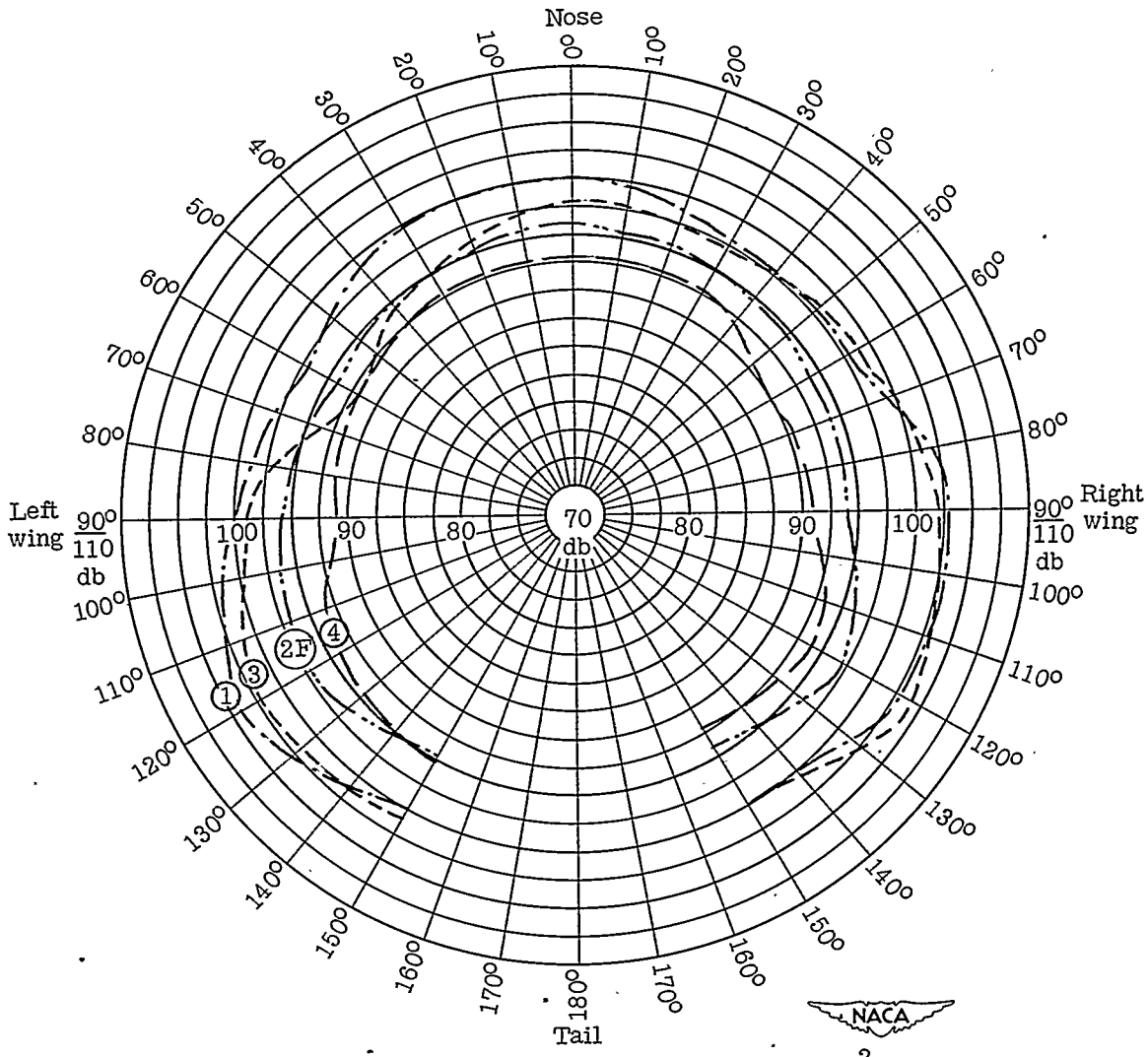
Standard two-bladed Cub, configuration 3 — — — — —
Belt-drive four-bladed Cub, configuration 4 —— —— ——
Standard two-bladed Stinson, configuration 1 —— - —— ——
Geared four-bladed Stinson, configuration 2F —— -- —— --



Sound level in db referred to 0.0002 dyne/cm^2

Figure 41.- Comparison of over-all levels of standard and modified airplanes from data taken on ground 50 feet from hub. Refer to table II for engine power, tip speed, and propeller diameter.

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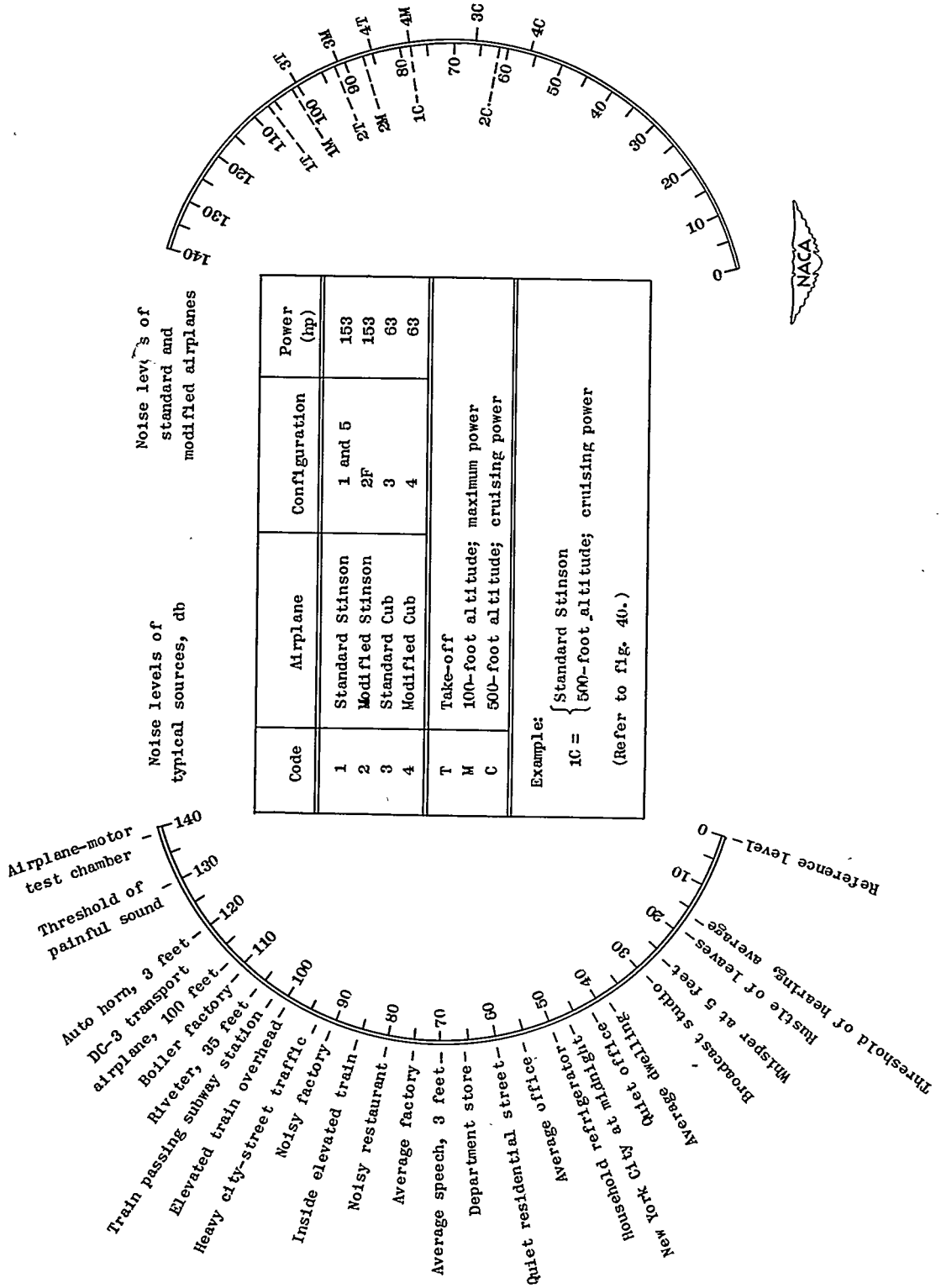

Figure 42.- Noise-level comparisons.