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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FLIGHT TESTS OF A 0.13-SCALE MODEL OF THE CONVAIR XFY-1
VERTICALLY RISING AIRPLANE IN A SETUP SIMULATING THAT
PROPOSED FOR CAPTIVE-FLIGHT TESTS IN A HANGAR

REPORT NO. NACA DE 368

By Powell M. Lovell, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

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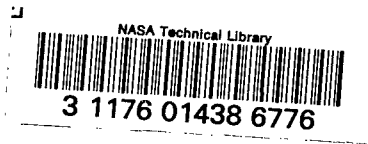
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SUMMARY

An experimental investigation has been conducted to determine the dynamic stability and control characteristics of a 0.13-scale free-flight model of the Convair XFY-1 airplane in test setups representing the setup proposed for use in the first flight tests of the full-scale airplane in the Moffett Field airship hangar. The investigation was conducted in two parts: first, tests with the model flying freely in an enclosure simulating the hangar, and second, tests with the model partially restrained by an overhead line attached to the propeller spinner and ground lines attached to the wing and tail tips.

The results of the tests indicated that the airplane can be flown without difficulty in the Moffett Field airship hangar if it does not approach too close to the hangar walls. If it does approach too close to the walls, the recirculation of the propeller slipstream might cause sudden trim changes which would make smooth flight difficult for the pilot to accomplish. It appeared that the tethering system proposed by Convair could provide generally satisfactory restraint of large-amplitude motions caused by control failure or pilot error without interfering with normal flying or causing any serious instability or violent jerking motions as the tethering lines restrained the model.

INTRODUCTION

An investigation is being made to determine the dynamic stability and control characteristics of a 0.13-scale model of the Convair XFY-1


vertically rising airplane. As a part of this investigation, tests have been made to determine the feasibility of making the first hovering flight tests of the airplane in the Moffett Field airship hangar. Flights in a simulated hangar were made at different heights above the ground and at different positions within the hangar to determine the effects of recirculation of the propeller slipstream.

Tests were also made to evaluate the tethering system to be used to restrain the airplane during the first hovering flights. The system proposed by Convair (see fig. 1) consisted of an overhead safety cable which was attached to the propeller spinner and of four ground lines. The ground lines were actually one continuous cable which ran through pulleys on the wing-tip landing gears, through pulleys on a slack-adjustment device, and then back to the vertical-tail tips where the ends were fastened. The reason for using the continuous cable for the ground lines was that it reduced the stress in the airframe by distributing the load equally to all four tips when the ground lines snubbed the airplane. Two modifications also covered in the tests consisted of systems that were the same as that proposed by Convair except that in one case all of the tethering lines were fastened rigidly at the model and in the other case all of the lines were free to run through pulleys at the model.

APPARATUS AND MODEL

All the tests were made in a large building which provided protection from outside turbulence. A sketch of the simulated hangar and the test setup used in the hangar tests is shown in figure 2. The simulated hangar was made of canvas draped over steel cables stretched across the building. It was arranged so that the walls at one corner of the building served as one side wall and one end of the hangar and the canvas served as the other side wall and the roof. Only one end of the hangar was represented since the proposed setup will be made in one end of the Moffett Field hangar and it was felt that the long distance to the other end of the hangar would be satisfactorily represented by leaving one end of the enclosure open. The full-scale hangar simulated would be 195 feet high, 230 feet wide, and 200 feet long. These values of height and width represent those of the Moffett Field hangar fairly well.

The tethering system proposed by Convair, and two modified versions of that system were covered in the tethered-flight investigation. A sketch of the tethering test setup is shown in figure 1. For all of the tests the model was equipped with a safety cable attached to the nose of the model and to a fixed support 170 feet (full scale) above the ground. The tips of the wings and vertical tails were restrained by cables which ran through pulleys on the floor and through other pulleys



on the device for adjusting the slack which was operated by a member of the flight-test crew. The four pulleys on the floor were equally spaced on the circumference of a 106-foot-diameter (full scale) circle. The Convair tethering system consisted of one continuous cable which ran through pulleys on the wing-tip landing gears and through pulleys on the slack-adjustment device and then back to the vertical tail tips where the ends were fastened. In one modification the cable was rigged to run through pulleys on the tail tips as well as on the wing tips and in the other modification the cable was fastened at the wing tips as well as at the tail tips.

At present, Convair plans to allow a given amount of slack for a flight and not to vary this slack during the flight. They will use the slack-adjustment device only as a means of setting the slack before the flight and as a shock absorber on the tethering lines. In the system used in the model tests, the slack could be held fixed with the operator acting as the shock absorber or the slack could be varied during a flight to pull the model back to a centered position after it had diverged.

A photograph of the model is shown in figure 3 and a sketch showing some of the more important dimensions is presented in figure 4. The model used in these investigations was approximately a 0.13-scale model of the Convair XFY-1 and was the same model used in previous tests of this airplane. (See refs. 1 and 2.) It had a modified triangular wing and modified triangular vertical tail surfaces mounted symmetrically above and below the fuselage and an eight-blade, dual-rotating, fixed-pitch propeller (two four-blade elements in tandem) powered by a 5-horsepower electric motor. Geometric characteristics are presented in detail in table I. The center of gravity was at the design location, 0.15 mean aerodynamic chord and 5.0 inches (full-scale) above the thrust line. The weight and moments of inertia of the model scaled up to full-scale were within 10 percent of the calculated values for the airplane as shown in the following table:

	Model (scaled up)	Airplane
Weight, lb	16,000	16,250
I_x , slug-ft ²	10,900	12,016
I_y , slug-ft ²	25,100	23,361
I_z , slug-ft ²	29,000	30,647

Maneuvering was accomplished by means of flap-type elevons and rudders operating in the propeller slipstream. The control surfaces were deflected by pneumatic actuators remotely operated by the pilots. For some flights made in the simulated hangar, a rate-gyro roll damper with

pilot-operated override was used to control the rolling motions; whereas in the tethered-flight tests, no damping devices were used and all controls were manually operated. Three separate pilots were used to control the model in pitch, roll, and yaw so that they might give careful attention to studying the motions of the model about each of the axes.

TESTS

The investigation covered in the present paper consisted entirely of flight tests of the model. The stability, controllability and general flight behavior of the model were determined qualitatively from the pilots' observations. General flight behavior is a term used to describe the overall flight characteristics of a model and indicates the ease with which it can be flown. In effect, the general flight behavior is much the same as the pilots' opinion of the flying qualities of an airplane and indicates whether stability and controllability are adequate and properly proportioned.

Flight tests in the simulated hangar were made without tethering lines to determine the effects of proximity of the ground and side walls on the stability and controllability of the model. A few tests utilizing colored smoke were also made to try to determine the pattern of the slip-stream recirculation when the model was near the ground or side walls.

The tethered-flight tests were started with the landing gear of the model at arbitrarily selected heights representing values of 70 and 35 feet for the full-scale setup. These were the minimum heights that the landing gears could reach during the tests. The maximum heights reached were these heights plus the amount of slack allowed in the tethering lines. Tests were made using (a) 90 percent of hovering thrust, so that the propellers were supporting 90 percent of the weight of the model and the nose line 10 percent; (b) hovering thrust, in which all tethering lines and the nose line were completely slack and the model was flying freely as long as it was flying near the center of the test area; and (c) maximum thrust, in which the nose line was slack and the model was pulling upward on the tethering lines. Two different amounts of slack (8 and 16 feet, full-scale) were allowed in the lines for each thrust condition. The slack in the lines was measured as the total distance that the model could move vertically in the center of the test area without being restrained by either the tethering lines or the nose line. In some tests the model was pulled down with the ground lines until the nose line was taut to center the model from an off-center position, but for most of the tests it was flown with a given amount of slack in the lines and was not pulled down but was merely snubbed by the lines when it reached the limits of sideways travel allowed by the slack.

Attempts were made to perform take-offs from the ground by developing maximum thrust with the model tethered to the ground and then slowly paying out the tethering lines. For these tests the only tethering system used was the one in which all lines were fastened to the landing gears.

RESULTS AND DISCUSSION

The results of the present investigation are illustrated more graphically by motion pictures of the flights of the model than is possible in a written presentation. For this reason a motion-picture film supplement to this paper has been prepared and is available on loan from the NACA Headquarters, Washington, D. C.

In discussing the results, the model is considered as a conventional airplane in a vertical attitude. The controls are referred to in conventional terms relative to the body system of axes; that is, the rudders on the vertical tails produce yaw about the normal axis, differential deflection of the elevons on the wings produces roll about the fuselage axis, and simultaneous deflection of the elevons produces pitch about the spanwise axis.

Flights Without Tethering Lines in the Simulated Hangar

The model could be flown for long periods of time without difficulty near the center of the enclosure which simulated one end of the Moffett Field airship hangar. When the model was near a wall, however, some difficulty was encountered because of large random trim changes caused by recirculation of the propeller slipstream. These random trim changes caused the model to be only slightly more difficult to control in yaw and pitch whereas occasionally they caused the model to diverge uncontrollably in roll. Random trim changes such as these have been encountered previously in hovering tests of vertically rising airplane models and are discussed in reference 3. Subsequent tests have shown that recirculation of the slipstream causes a variation in the inflow to the propellers resulting in random trim changes in pitch, roll, and yaw. Later flight tests made specifically to study the effects of slipstream recirculation have indicated that under certain conditions these effects are great enough to make sustained flights impossible.

Smoke-flow tests showed that the recirculation was very pronounced when the model was flying near one of the walls of the building. Some horizontal beams in the structure of the building prevented the slipstream from dissipating smoothly and forced it to rebound horizontally toward the model when the model neared the wall. This recirculation apparently

caused large, rapid changes in trim and made the model difficult to control. As long as the model was flown approximately in the center of the hangar, however, no difficulties were encountered. It is possible that large structural members and catwalks in the hangar may at times cause some similar recirculation of the slipstream and make the full-scale airplane somewhat difficult to control when it nears the walls.

Tethered-Flight Tests

Almost all of the tethered-flight tests were made with the landing gear approximately 70 feet (full-scale) above the ground. All of the results will therefore be for this condition except where some other height is specifically given.

Convair tethering system.- The condition in which the model was operated at 90 percent of hovering thrust was chosen to illustrate the behavior when the model was hanging on the safety cable because previous experience with take-off with the model hanging on the safety cable had shown that the model was more difficult to control just before hovering thrust was attained than at any other time during the take-off. Actually, of course, the complete range of partial-thrust conditions was covered for the take-off each time the model was flown in hovering flight. No difficulty was experienced in making take-offs with the model hanging on the safety cable and with the ground lines slack. When the model was being operated continuously at 90 percent of hovering thrust with 8 feet of slack (full-scale) in the tethering lines, it wandered around continually but not violently when uncontrolled in pitch and yaw. It could, however, be held steady in the center of the landing area by use of the controls.

In hovering flight with either 8 or 16 feet of slack (full-scale) in the lines the model was easy to keep in the center of the test area in controlled flight. Since the safety cable was longer than the ground lines, the model was generally restrained first by the ground lines as it moved sideways. This restraint of the rear of the model made it tend to tilt outward (away from the center of the test area) and hang in this position pulling outward on all the lines. It could, however, be brought back to the center with the controls even after it had been allowed to move sideways until it was restrained by the lines. Recoveries could also be made readily by taking up the slack with the slack adjustment until the model was pulled back into the center of the test area with all the lines (safety and ground lines) taut.

In hovering flights started at 35 feet (full-scale) above the floor and with either 8 or 16 feet of slack (full-scale) in the tethering lines, the model could still be flown steadily in the center. Recoveries at 35 feet were difficult or impossible to make, however, when the model


was moved sideways far enough to hang on the lines. Even in cases in which the model was rocked violently by alternate control movements to take advantage of the slight springiness of the lines, recoveries could seldom be made. Thus it appears that reductions in test height will lead to reductions in controllability after the airplane has been snubbed by the tethering lines.

When maximum thrust was applied so that the model pulled upward on the ground lines, the model could be kept in the center for only a short period of time. An unstable oscillation built up, and when the model moved far enough to one side it diverged (usually in yaw) despite the efforts of the pilots to control it. Recoveries from the oscillation or the subsequent divergence could be made, of course, by either reducing the thrust or by taking up the slack with the slack adjustment until all of the lines (safety and ground lines) were taut.

Modified tethering systems.- For the tethering system in which all four lines were fixed at the model, the motions of the model seemed stable when maximum thrust was applied, if the lines had equal lengths and tensions. For most cases, however, this perfect adjustment could not be attained and unstable oscillations developed in either pitch or yaw. Close study of the film records of the tests indicated that for these cases there was some slight amount of slack in either the wing or tail lines and that the model oscillated in the plane in which the lines were slack. For a few flights in which the slack in the lines was equalized by adjustments made during the early part of the flight, the model remained stabilized for an indefinite period of time. Apparently it was practically impossible to obtain the same tension in all of the lines by adjusting their lengths before the test. The oscillations that resulted from unequal tension might be serious because, although the pilot could control these motions, they would become violent if no effort were made to control them.

When maximum thrust was applied and all of the lines were free to run through pulleys at both the wing and tail tips, the model had an unstable oscillation but could be controlled satisfactorily as long as it was kept near the center of the test area. If the model was allowed to move too far to one side, however, it would diverge and could not be brought back to the center of the test area with the controls.

The oscillations experienced in the maximum-thrust condition were different for the two modified tethering systems. When all lines were fixed, the oscillation involved mainly angular motion with very little translation, whereas, when all the lines were free, the oscillation involved considerably more translation in proportion to the angular motion.



In hovering flight the model could, of course, be flown easily in the center of the test area where the tethering lines were slack with either of the modified tethering systems. When the model moved far enough to one side to be snubbed by the tethering lines, the behavior was generally satisfactory with the lines-free system; whereas, the model was often jolted sharply with the lines-fixed system as a result of one line suddenly becoming taut. With either system, however, the model could be returned to steady hovering flight in the center of the test area by use of the controls. It was also possible to restore the model to a steady condition in the center of the test area with either of the modified tethering systems by pulling in the ground lines until the model was pulled back to the center and the nose line was taut.

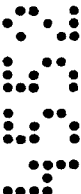
The modified systems appeared to be better than the Convair system for the maximum-thrust condition since the model motions could be controlled with the modified systems and could not be controlled with the Convair system. This is probably not an important consideration however, since a reduction in thrust or sufficient tightening of the lines will produce a stable condition. All of the tethering systems tested provided adequate restraint for the hovering thrust and less-than-hovering-thrust conditions, but in the case where all four lines were fixed at the model the model was jerked violently when restrained by one or more of the lines during hovering flight.

A few take-offs were tried from the ground with all of the ground lines held taut and fixed at the model. All of these attempts were unsuccessful because the model tipped over before all four landing gear legs were off the ground. The model controls were completely ineffective in preventing this motion because the lines restrained the tail and prevented the control moments from acting to right the model.

CONCLUSIONS

The following conclusions were drawn from model tests of the Convair XFY-1 airplane in setups representing those proposed for use in the captive first flight tests of the full-scale airplane in the Moffett Field airship hangar:

1. The Convair XFY-1 airplane can be flown in the Moffett Field airship hangar if it does not approach too close to the hangar walls. If it approaches too close to the walls, the recirculation of the propeller slipstream might cause sudden changes in trim which would make the airplane quite difficult to fly.
2. When the airplane is operated at less than hovering thrust or is actually hovering, the tethering system proposed by Convair should provide



satisfactory restraint of the motions without causing any violent jerking motions when the lines restrain the airplane. Under maximum-thrust conditions, however, an unstable oscillation may build up and the airplane may diverge uncontrollably. A recovery from this divergence can be effected by reducing power or by tightening the tethering lines enough to pull the model back to the center of the test area and make the nose line taut.

3. Both modified tethering systems should produce about the same characteristics as the one proposed by Convair except that in the case where all four lines are fixed at the airplane the airplane may be jerked violently when restrained by one or more of the lines during hovering flight.

4. Tests made at 70 feet above the floor of the hangar will probably be much smoother and provide more controllability after the airplane is snubbed by the tethering lines than those made at lower heights.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., February 4, 1954.

Powell M. Lovell, Jr.

Powell M. Lovell, Jr.
Aeronautical Research Scientist

Approved: *Thomas A. Harris*

Thomas A. Harris
Chief of Stability Research Division

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3. Smith, Charles C., Jr., Lovell, Powell M., Jr., and Bates, William R.: Effect of the Proximity of the Ground on the Stability and Control Characteristics of a Vertically Rising Airplane Model in the Hovering Condition. NACA RM L51G05, 1951.

TABLE I

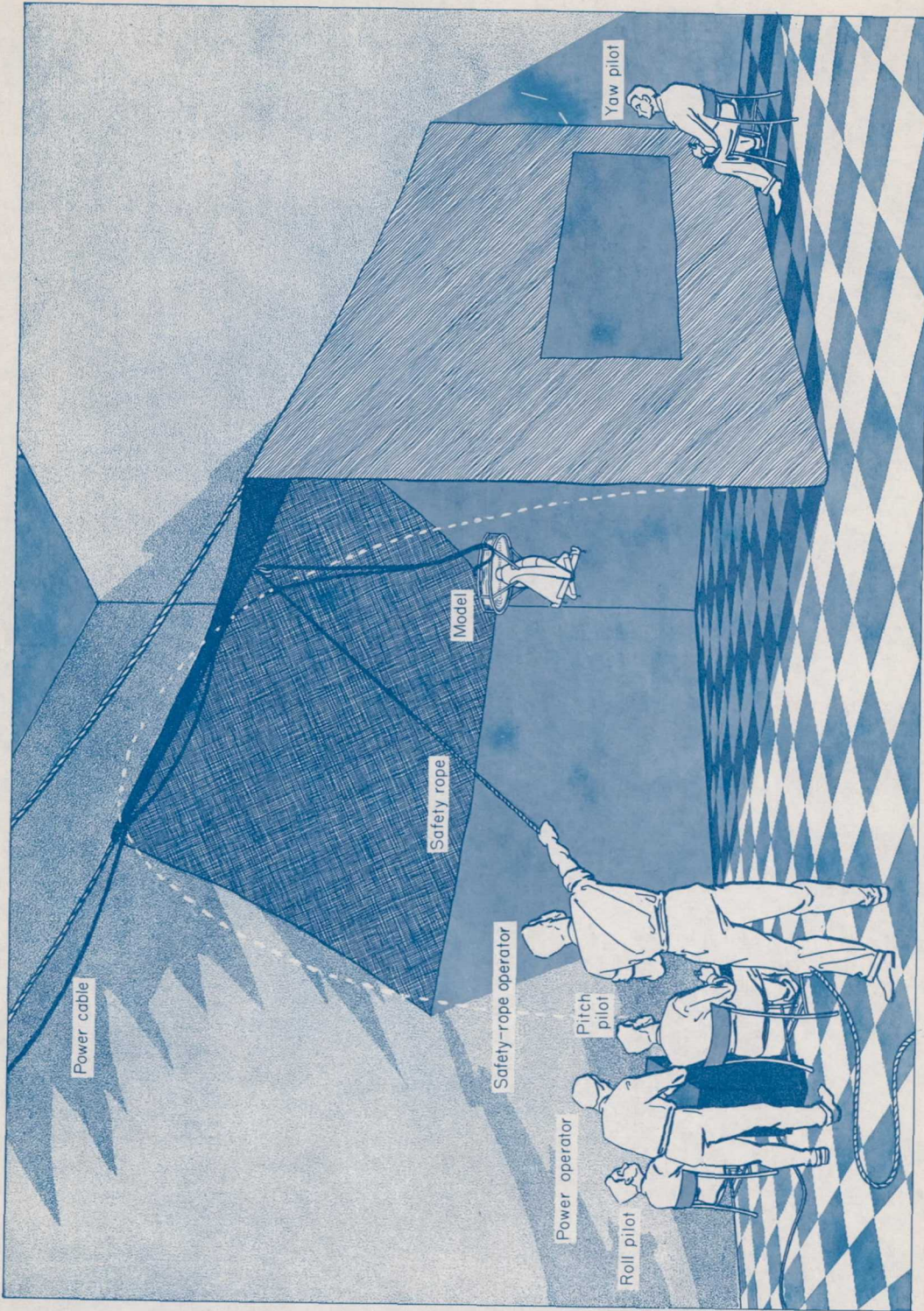
GEOMETRIC CHARACTERISTICS OF THE MODEL

Weight, lb	34.00
Wing (modified triangular plan form):	
Sweepback, deg	55
Airfoil section	NACA 63-009 modified
Aspect ratio	1.90
Taper ratio (root to theoretical tip)	5.23
Area (total to center line), sq in.	818.95
Span (theoretical), in.	39.49
Mean aerodynamic chord, in.	23.94
Span of elevon (each), in.	15.37
Chord of elevon, in.	2.92
Dihedral angle, deg	0
Overall length of model, in.	49.40
Fuselage length, in.	45.40
Vertical tails (modified triangular plan form):	
Sweepback, deg	40
Airfoil section	NACA 63-009 modified
Aspect ratio	3.18
Taper ratio (root to theoretical tip)	3.15
Area (total to center line), sq in.	379.88
Span, in.	34.73
Mean aerodynamic chord, in.	13.07
Span of top rudder, in.	14.13
Span of bottom rudder, in.	11.13
Chord of rudders, in.	2.85
Propellers (eight-blade dual-rotating):	
Diameter, in.	23.85
Hamilton Standard design, drawing number	3155-6-1.5
Solidity, one blade	0.0475
Gap, in.	3.00



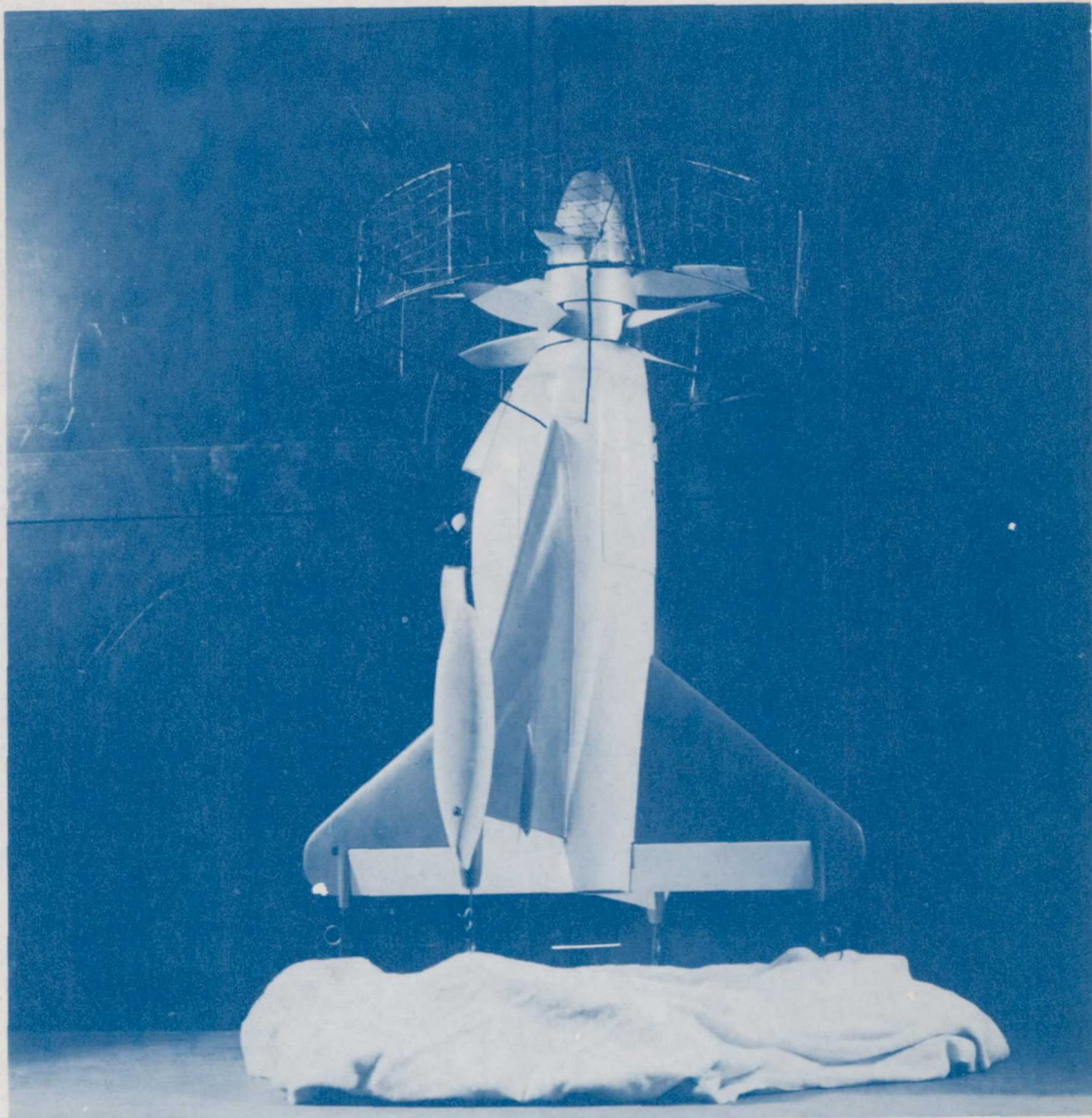
Figure 1.- Tethering system proposed by Convair.

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Figure 2.- Simulated hangar and test setup. Dotted line represents full-scale hangar.



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Figure 3.- Photograph of Convair XFY-1 model showing propeller guard.

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