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RESEARCH MEMORANDUM

PRELIMINARY EXPERIMENTAL INVESTIGATION OF THE FLIGHT OF A PERSON SUPPORTED BY A JET THRUST DEVICE ATTACHED TO HIS FEET

By C. H. Zimmerman, Paul R. Hill, and T. L. Kennedy

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An exploratory investigation has been made of the stability and controllability in space of an arrangement comprising a man standing on a small platform which is rigidly connected to a jet nozzle having its thrust axis perpendicular to the platform and its thrust opposed to the pull of gravity. The basic principles investigated may have future military applications.

It has been found that a man can stand on a jet-supported platform with little or no practice. His ability to do so apparently is related to his confidence and to his ability to relax and permit his instinctive reflexes to operate. The translational motion of the flyer and supporting jet can be controlled by the flyer and is accomplished by leaning in the direction toward which motion is desired.

The addition of reasonable amounts of mass and inertia and of a source of a moderate gyroscopic effect had very little effect upon the stability and controllability and did not increase the difficulty of stabilization to an appreciable degree. It was found that it is possible to use a substantially rigid landing gear, at least when operating from a level surface. Flights in a wind varying from 8 to 16 knots were made without conscious additional effort on the part of the flyer.

INTRODUCTION

It has been apparent for some time that there are important military and naval applications for a device which will provide air mobility to individual troops for special operations.

The first author of this paper proposed several years ago that a small aircraft capable of rising vertically and hovering, as well as flying in translational flight, could be stabilized by carrying a man in a standing position. This idea stemmed from the realization that the instinctive reflex responses which stabilize a person when standing will operate in the proper sense, although not necessarily to the right magnitude, when transmitted to the machine. The balance of the aircraft is accomplished because the lift is a force vector on which the man can maintain balance. The manner or type of machine by which the lifting force vector is generated is, therefore, immaterial to the balancing principle. At the present time the lift could be developed by propellers, helicopter rotors, or by the direct use of the thrust of a jet-propulsion device such as a rocket. The original proposal, with the objectives of simplicity, low cost, and economy, was for a small single place machine using counter-rotating propellers.

The test of the principle could be very easily accomplished by attaching to a small platform a jet-propulsion device capable of supporting the weight of a man. The simplest of these devices appeared to be an air nozzle supplied by an air hose. Because of the existence of a compressed-air reservoir of large capacity at the Langley Pilotless Aircraft Research Station at Wallops Island, Va., this site was chosen for the tests. Preliminary tests have been made and qualitative results are available. This paper will present those results along with the flyer's impressions of the flight behavior.

APPARATUS

The principal piece of apparatus used was a jet nozzle of conventional design (fig. 1) having a throat diameter of 1.264 inches and a divergence of 10°. This nozzle was rigidly attached to a 19- by 29- by $\frac{3}{4}$-inch piece of plywood so that the nozzle thrust axis was substantially perpendicular to the plywood platform. This platform was fitted with suitable cleats and tie-down straps to insure that the flyer's feet could not slip off.

The nozzle was supplied with air from the 200 pounds per square inch compressed-air tank through 3-inch piping, a quick cut-off valve and control valve in series, a tee connection, two 1.5-inch flexible fire hoses of equal length, and a tee connector at the nozzle. This arrangement resulted in the hoses tending to form a circle when under pressure with the two tees diametrically opposite each other (fig. 2).

The flyer was provided with a safety harness consisting of a parachute harness attached at its shroud-line attachment points to a shock-cord suspension system carried by an overhead crane. For initial tests, the flyer was suspended in this safety harness and slack ropes were attached to form equally spaced points in azimuth to prevent him from being lifted too high or from being thrown sideways (fig. 3).

In later tests, a rigid landing gear which was fabricated from welded steel tubing was used. (See fig. 4.) It supported the flyer 18 inches from the floor and provided a square base approximately 44 inches on a side. This gear was designed to crush easily in order to provide shock absorption in case of a very severe drop.

A frame carrying lead weights was provided for certain tests. (See fig. 5.) The combination of frame and weights increased the total weight by 48 pounds and the moments of inertia by 12, 2, and 14 slug-feet^2 about the x-, y-, and z-axes, respectively, where the x-axis is horizontal and directed forward, the y-axis horizontal and directed sideways, and the z-axis vertical in hovering flight.

A gyroscope was provided for the tests to determine the effect of gyroscopic couples on the ease of stabilizing and controlling. This gyroscope (figs. 6 and 7) consisted of a solid-steel disk with an inertia of 0.027 slug-feet^2, which was rotated approximately 7000 rpm by a direct-current electric motor. It was mounted with its rotational axis parallel to the z-axis, that is, vertical in hovering flight.

For one series of tests, a seat was provided for the flyer (fig. 8). This seat consisted of a rod having at one end a pivot point to be placed on the jet-supported platform and at the other end a wooden bicycle-seat-shaped supporting member.

A control stick which projected 40 inches was rigidly attached to the platform to make it possible to tilt the platform and jet by hand for certain tests (fig. 9).

The weights of the various items and of the individual flyers are listed in table I.

TESTS

The test program, which has been completed, is outlined in table II. The time of flight in each case is approximate and indicates total time and not necessarily the time of an individual flight. Initial tests were made by supporting the flyer in the safety suspension system and then gradually opening the air-supply control valve until the jet thrust was sufficient to support the weight of the flyer and the jet platform. For these first tests the guy ropes shown in figure 1 were used to insure that the flyer would not be violently thrown about should he lose control. Two valve operators were employed: one to close the quick cut-off valve in case of an emergency and the other to operate the control valve. Four persons tried hovering flight and small translational motions under these conditions. These persons will be designated as A, B, C, and D in the order of their initial trials for future reference.

In order to investigate the controllability of the device under conditions permitting more freedom of action, flights were made by flyer B without the lateral safety ropes, approximately 1 month following the initial flights (fig. 10). Lateral, forward, and rearward translations were made. Ascensions and translations were also made at the maximum altitude allowed by overhead obstructions which permitted ascensions of approximately 12 feet.

On the following day, flights were made in a circle of about 15 feet in diameter at an estimated 5 to 7 miles per hour in both clockwise and counterclockwise directions.

Approximately 9 months after the initial tests, additional tests were made to determine qualitatively the influence of several factors upon the ease of stabilizing and controlling the jet platform in hovering flight and in slow translations. These tests were made of the various devices by the different flyers as indicated in table II. Flyer E was the fifth person to attempt the flight and had not taken part in the initial tests.

Motion pictures were taken of many of the tests.

RESULTS AND DISCUSSION

Initial Flights with Platform

The first and most important result of these investigations was achieved in the first trial made by flyer A. It had been intended to make the first trial by partially supporting the flyer with the jet and allowing him to try control movements under these circumstances. However, after the control valve was opened to the point at which he wished to experiment, he glanced at the overhead suspension and became aware from its slackness that he was totally jet-supported. He made no conscious attempt to control himself and simply stood on the platform. After a minute or two in this condition he signalled for descent. After flyer A was partially supported by the suspension system the second result became apparent. He allowed himself to lean into the suspension system and was immediately thrown into a horizontal position by the untrimmed jet reaction.

These results were fully confirmed by subsequent tests made by flyers B, C, D, and E. In order to stand upon the jet platform without translation, it appears to be desirable to avoid any conscious effort to control. It was the unanimous experience of all the flyers that their steadiest flights were attained when they looked off at a distance and focused their attention on something other than stabilization and control of the jet platform. When they looked down at the platform and concerned themselves with the stability and control of the device, the tendency was to overcontrol and perform rapid oscillations of the feet and platform about the ankles. Very large oscillatory angular deflections of this sort were possible without appreciable movements of the flyer's body in space. The fact that steady hovering was possible without conscious control was strikingly confirmed by flyer B during flight 5 when he was carried toward the ceiling and disentangled himself from the suspension system while standing on the jet platform. His complete attention and the use of both hands were required to disentangle himself. (See fig. 11.)

Several operators demonstrated that it is very difficult if not impossible to retain control if any attempt is made to lean into the suspension system while becoming jet-borne. It appears to be essential that the flyer have sufficient confidence in his ability to stand on the jet-supported platform and to trust himself fully to doing so without attempting to stabilize or brace himself with the suspension system. Flyer D obviously was trying to derive stabilization from the suspension system and did not attain sufficient confidence to stand erect during the approximately 5 minutes he spent in attempting to fly. Flyer C had difficulty the first time he tried it, but after approximately a minute, he stabilized himself without difficulty. Flyers A and B did not have this difficulty. They were probably better prepared psychologically from having given much thought to the problem and having great confidence in their ability to stabilize the platform. In later flights flyer E had experience similar to that of flyer D but after 5 minutes of trial was persuaded to concentrate on watching the camera and observers and just stand up. He then performed very steady flights without difficulty.

In flight 2, flyer B demonstrated that he could perform controlled translational motions by simply leaning slightly toward the direction in which he desired to move and could stop such motion by leaning slightly away from the direction in which he was moving. This result was subsequently confirmed by flyers A, C, and E.

In flight 5, flyer B achieved very rapid lateral translational movements and reversals (fig. 12). Angles of inclination of 20° indicated lateral acceleration and deceleration of about 1/3g. Somewhat gentler movements were executed in the forward and rearward direction.

In flight 6 after some experience, it was found that translational flights in a circular path could be made by no more conscious effort than the mere thought of the path it was desired to follow. Supplying the proper amount of lean and bank soon became automatic.

After the flights reported as flights 1 to 6, questions were raised in regard to the effects of such items as landing gear, inertia of the platform and landing gear assembly, gyroscopic couples, use of a hand control stick, and use of a seat. It was therefore decided to try these items.

Flights with Landing Gear

Rising and descending upon a rigid landing gear was demonstrated without difficulty by flyer B who had spent considerable time in flight on the jet platform and was the most experienced flyer. Flyers A and C found on their initial trials a tendency to become tense and to oscillate the platform rapidly so that it struck the ground on alternate sides when near the ground. They found this tendency could be overcome by deliberately looking toward the horizon and forcing themselves to refrain from conscious attempts to control their motion. Flyer E made his first flight from the landing gear and seemed to have no trouble from the landing gear, although he did have to force himself to trust himself completely to standing on the platform, as reported earlier. Quick or slow landings presented no problem to any of the flyers. It should be noted that the question of arrangements necessary to prevent the flyer from falling or the device and flyer from overturning in the event of a landing with horizontal translational velocity was not investigated. The safety suspension was retained for all these tests and was rigged to prevent such an occurrence. It was generally agreed by all the flyers that it seemed somewhat easier to fly steadily without foot oscillations when well clear of the ground than when the landing gear was only a few inches from the ground. Whether there was a physical justification for this belief or whether it was purely psychological is not known.

Flights with Landing Gear and Inertia

The inertia frame, tried by flyers A, B, and C (fig. 5), was loaded to simulate the inertia of a possible device using a single reciprocating engine to drive two biaxial counterrotating propellers mounted on spanwise booms (along the y-axis). The amount of inertia used (see table I) did not increase the difficulty of making steady flight. The inertia slightly lengthened the period of foot oscillations, and it was the impression of the flyers that more force was required to damp such oscillations with the added inertia.

An interesting point was checked by flyers A and B during the trials with the inertia frame in place. The doors of the preflight-jet facility were opened so that the wind was allowed to blow through. The wind velocity was unsteady, varying from 8 to 16 knots, and came from behind the flyers. This wind direction would probably be the most difficult with which the flyers would have to cope. Neither flyer could detect any difference in flight behavior or any difficulty in remaining over a fixed point. Neither flyer was conscious of a deliberate control effort to remain over a fixed point.

Flights with Landing Gear and Gyroscope

It had been feared that gyroscopic couples attached to the jet platform would seriously interfere with the ease of flying. The gyroscopic device which was tried (figs. 6 and 7) was found to have no discernible effect. Flyers B, A, and C tried it in that order and none of them could detect any difference in behavior or in ease of stabilizing and controlling the platform nor was any difference noticeable to ground observers.

The gyroscopic device weighed a total of 15 pounds and was displaced 15 inches from the center of jet thrust. None of the flyers were conscious of this off-center weight, and it had no discernible effect on stability and control.

Flights with Landing Gear and Control Stick

Flyer A tried using the control stick (fig. 7). He found he could hold the stick and that by doing so did not increase the difficulty of making steady flight so long as he did not attempt to control with the stick but allowed the stick to follow his instinctive foot movements. It was his impression that his hand on the stick tended to damp foot oscillations, but this conclusion is not a positive one. He felt that he could not stabilize the platform if he tried to use the stick alone. This impression should not be taken as an indication that such control is impossible; it is believed, however, that such control will require more training and practice than the foot control.

Flights with Landing Gear and Seat

Flyer B tried using the pivoted seat (fig. 8) and found that he could support part of his weight without much difficulty. He carried the seat in his hands at the beginning of this flight, placed it under him, supported part of his weight on it, then removed and tossed it away all while in flight, and further demonstrated the strong instinctive stabilization effect present when standing on the jet platform.

Flyer B attempted to stabilize and control the jet platform while sitting on it and holding to it with his hands. He found this method of control very difficult and did not achieve a steady flight in the few minutes of attempting to do so. Several times the platform became completely uncontrolled and would have accelerated violently sideways if it had not been restrained by four guy ropes equally spaced in azimuth which had been installed for this test (fig. 13).

Discussion of the Balancing Process

A simple analysis partially explains the balancing process. A person standing on a solid surface is in unstable equilibrium and his reflexes are constantly acting through his muscles to keep him upright. If he starts to fall forward, for example, his muscles attempt to rotate his feet about his ankles so as to shift the center of application of the ground reaction forward and thus create a moment opposing the fall. (See fig. 14(a).) If the person is standing on a platform supported in space by the reaction from a jet issuing from the platform, the instinctive flexing of the ankles will cause the reaction vector to be rotated so as to pass ahead of his center of gravity (fig. 14(b)) and thus create a correcting moment.

It is quite apparent that stabilization of the jet platform is an instinctive process and apparently makes use of the instinctive reflexes which normally serve to keep a person standing upright. In several instances, flyers have been in free flight without being aware of it and such flights were very steady. There is strong indication that conscious attempts to stabilize oneself result in tenseness of the legs and in foot oscillations because of overcontrolling and that the best results are achieved when the flyer is unaware that he is in free flight.

These tests were performed under adverse circumstances from a psychological standpoint. The jet which was used emitted an unpleasant screaming noise which was painful to the ears unless ear plugs were used and upsetting to the nervous system, in general.

It was apparent that the safety suspension system did not influence the flights except in those cases in which the flyer attempted to use it for stabilization purposes. Such attempts were always unsuccessful. In many instances this system was completely slack (fig. 16, for example), and no difference in behavior was discernible between this situation and such cases, as in figure 15, where the slackness is not apparent to the ground observer.

The influence of the hoses is believed to be small; however, if sufficient displacement was effected to pull the hoses taut, it would tend to overturn the flyer. None of the flyers were conscious of hose forces or moments. The hose forces probably tended to impart stability in altitude and thus possibly eased the task of the control operator but did not aid the flyer.

There was considerable surprise that the inertia, gyroscope, off-center weight, and hose forces and moments were not discernible by the flyers. Apparently the feet and legs are so accustomed to the relatively large forces and moments involved in stabilizing and controlling one's own mass, which has an inertia about one's feet of the order of 60 slug-feet^2 for an average man, that the moments introduced during the tests were relatively negligible. The gyroscopic couples were very noticeable when the gyroscopic device was held in the hands, and all the flyers were certain they would cause difficulty until tests showed otherwise.

Description of the Flyers

In view of the fact that stabilization of the jet platform is an instinctive phenomenon and, as was several times demonstrated, was strongly influenced by the degree of confidence and the nervous state of the flyer, it is desirable to discuss the individual flyers.

Flyer A is 44 years old and weighs 180 pounds. He had 25 hours of experience as a student pilot 11 years ago and has been a student of the dynamics of flight over a period of 22 years. He originally conceived the idea that it should be possible to stand on a jet-reaction-supported device several years ago and has studied the problem a great deal. He was very confident of success from the beginning but suffered under the psychological handicap of having his personal reputation at stake in the tests. Flyer A had practiced a little on a device designed to simulate the stabilization behavior of a jet platform several years ago and had also been air-borne on a propeller-jet-supported device for short intervals about 5 years before the present tests.

Flyer B is 42 years old and weighs 175 pounds. He acquired great interest in the possibilities of a jet platform after conversations in which flyer A had expressed his belief that stable and controlled flight is possible with such a device. Prior to the initial tests in February 1951, flyer B spent considerable time practicing how to stand on a platform supported on a sphere resting on level floor and developed the skill necessary to stand on this arrangement. Prior to the initial tests, he was quite confident that, with some training to develop skill, he could stand on the jet-supported platform as he had previously done on the platform-sphere combination. He has found that standing on the jet platform is a different and far easier task. Flyer B has had the most experience in free flight and for that reason has generally been the one to try new arrangements.

Flyer C (fig. 17) is 25 years old and weighs 135 pounds. He holds a private pilot's license with approximately 100 hours of flying time, and also tried unsuccessfully to stand on the sphere-supported platform. He was not convinced that flight would be possible on the jet platform, but had no personal stake in its success or failure.

Flyer D is 32 years old and weighs 168 pounds. He had 200 hours of training and approximately 3000 hours as flight engineer. He was in charge of the installation of the equipment, but had no personal stake in the outcome and no conviction about the possibility of jet-platform flight.

Flyer E (fig. 18) is 39 years old, weighs 155 pounds, and is the chief mechanic and safety engineer for the preflight-jet facility. He had no background of theory or experience relative to the subject device but had seen others use it. He was confident he could stabilize and control the platform and tried it at his own suggestion.

CONCLUSIONS

An investigation of the stability and controllability in space of an arrangement comprising a man standing on a small platform which is rigidly connected to a jet nozzle having its thrust axis perpendicular to the platform and its thrust opposed to the pull of gravity indicated the following conclusions:

1. It has been shown that a person can stand on and control a jet-supported platform in free hovering flight with little or no time required for training.

2. The greatest ease and steadiness in flight occurs when the flyer is not aware he is jet-supported or can focus his attention on something other than his own stabilization and control.

3. A high degree of maneuverability in translational flight within the confines of a limited space was demonstrated.

4. Factors which would be thought to be disturbing, such as gyroscopic couples, off-center weights, inertia of the platform, and unsteady wind velocity, have no objectional effects within the range investigated.

5. The flyer can use both his hands freely for other tasks while standing in free flight on a jet-supported platform.

6. The flyer can rest part of his weight on a seat pivoted near his feet or can hold to a member attached to the platform provided he allows his feet to remain in charge of stabilization and control.

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TABLE I

WEIGHT AND INERTIA CHARACTERISTICS

	Weight (lb)	Inertia (slug-ft^2)		
		(I_x)	(I_y)	(I_z)
Nozzle	18	--	--	--
Platform	9	--	--	--
Landing gear	3	--	--	--
Inertia frame	48	12	2	14
Gyroscope	15	--	--	--
Flyer A	180	--	--	--
Flyer B	175	--	--	--
Flyer C	135	--	--	--
Flyer D	168	--	--	--
Flyer E	155	--	--	--

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TABLE II

RECORD OF FLIGHT TEST

Flight	Date	Flyer	Configuration	Approximate total time in minutes
1	2-2-51	A	Platform	5
2	2-2-51	B	Platform	10
3	2-2-51	C	Platform	10
4	2-2-51	D	Platform	0
5	2-26-51	B	Platform	10
6	2-27-51	B	Platform	10
7	11-8-51	B	Landing gear	5
8	11-8-51	A	Landing gear	5
9	11-8-51	C	Landing gear	5
10	11-8-51	B	Landing gear + inertia	5
11	11-8-51	A	Landing gear + inertia	5
12	11-8-51	C	Landing gear + inertia	5
13	11-8-51	A	Landing gear, inertia, wind	3
14	11-8-51	B	Landing gear, inertia, wind	3
15	11-8-51	B	Landing gear + gyroscope	5
16	11-8-51	A	Landing gear + gyroscope	5
17	11-8-51	C	Landing gear + gyroscope	5
18	11-9-51	A	Landing gear + control stick	5
19	11-9-51	B	Landing gear + seat	5
20	11-9-51	B	Seated on platform, landing gear	0
21	11-9-51	E	Landing gear	10

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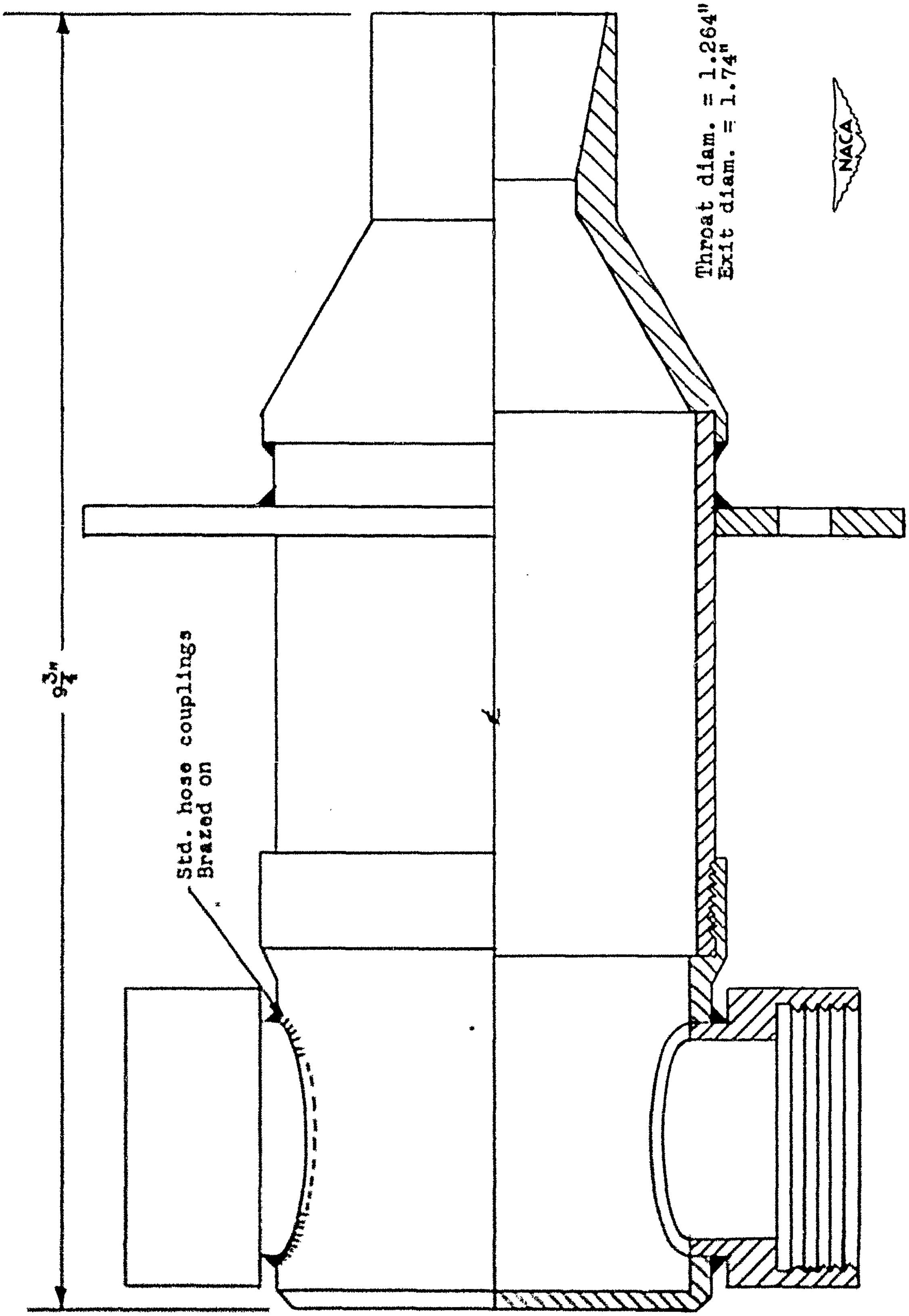


Figure 1.- Sketch of nozzle.

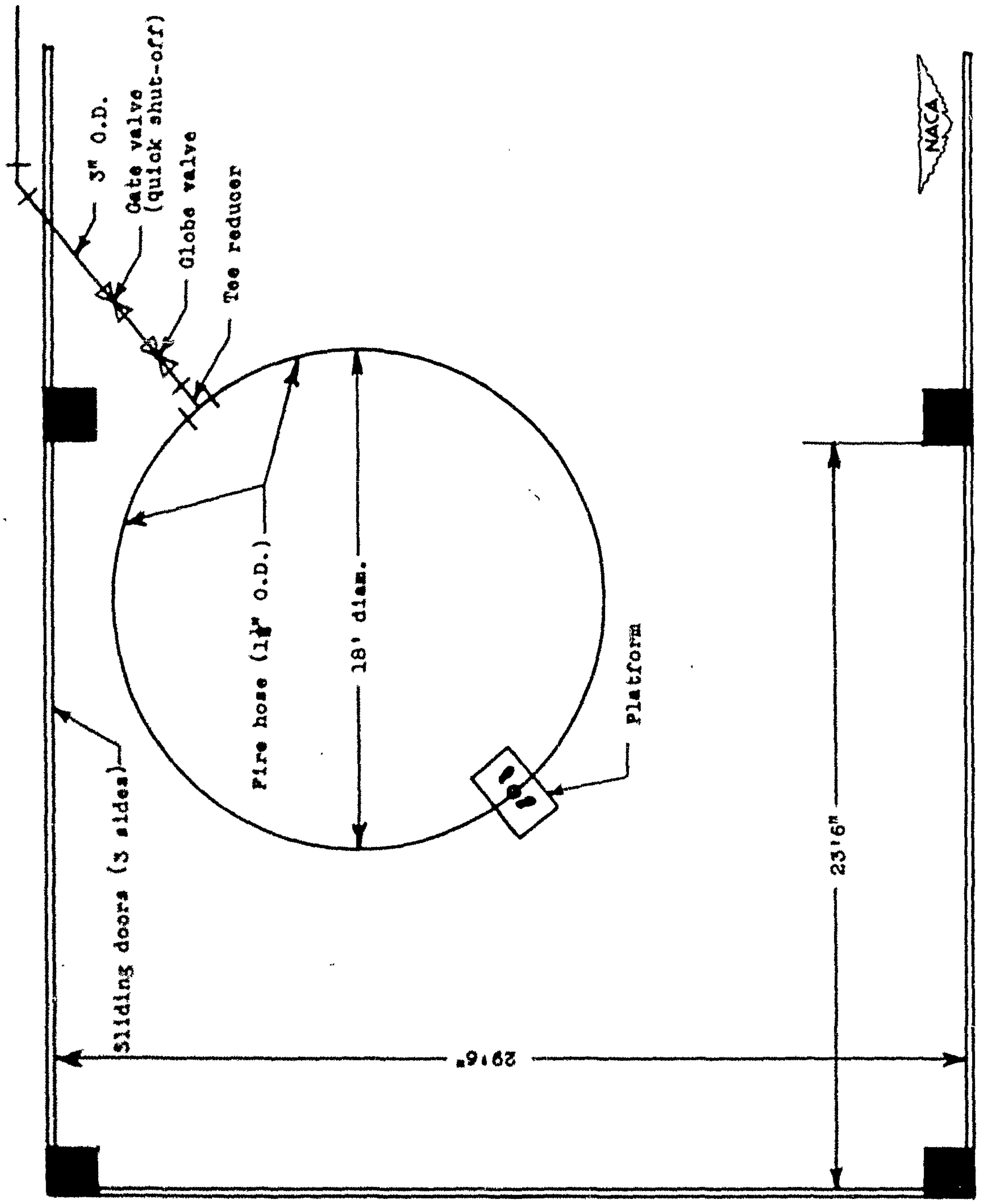


Figure 2.- Test layout.

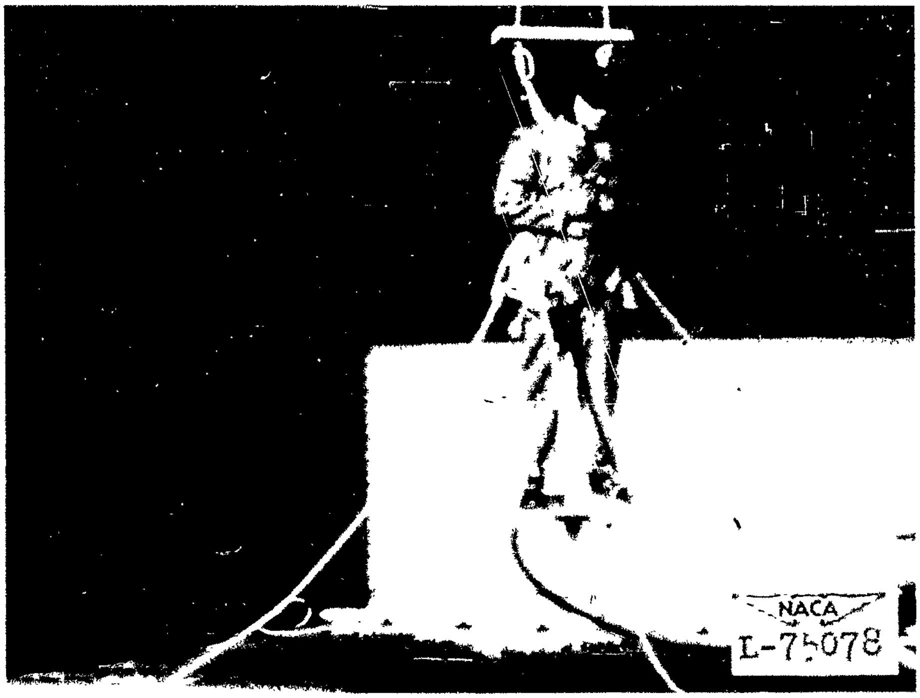


Figure 3.- Flyer with guy ropes.

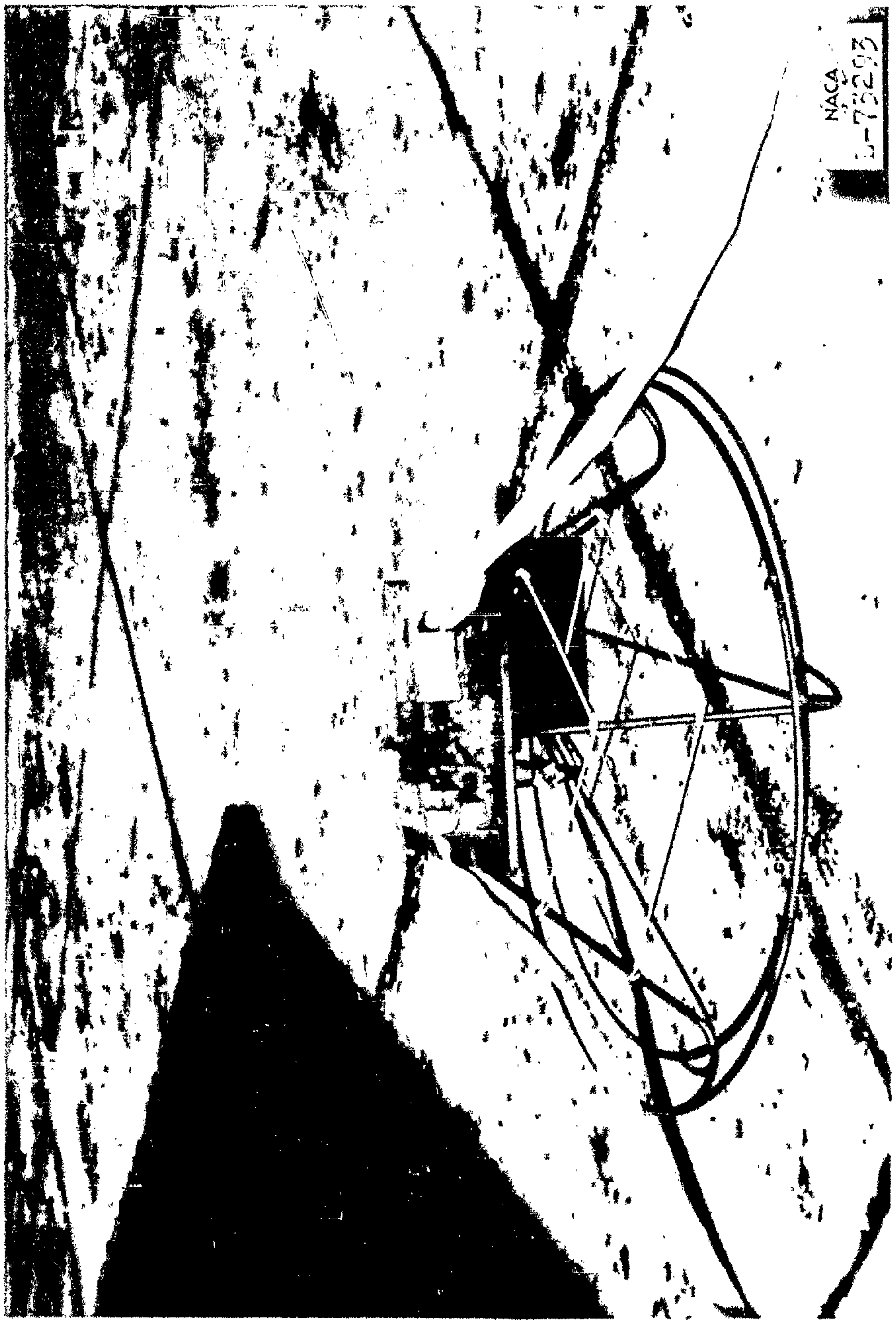


Figure 4.- Landing gear installed.

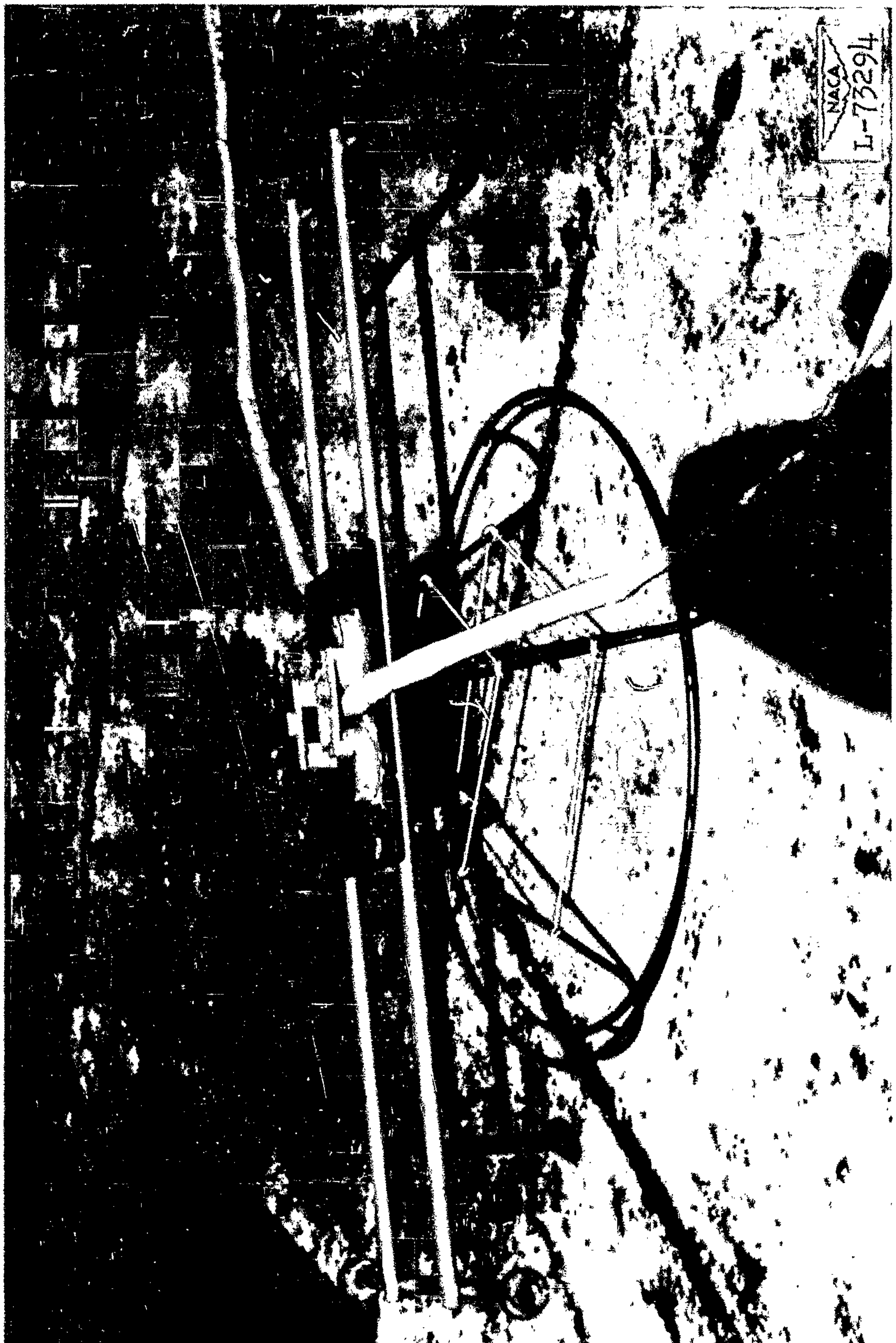


Figure 5.- Inertia frame installed.

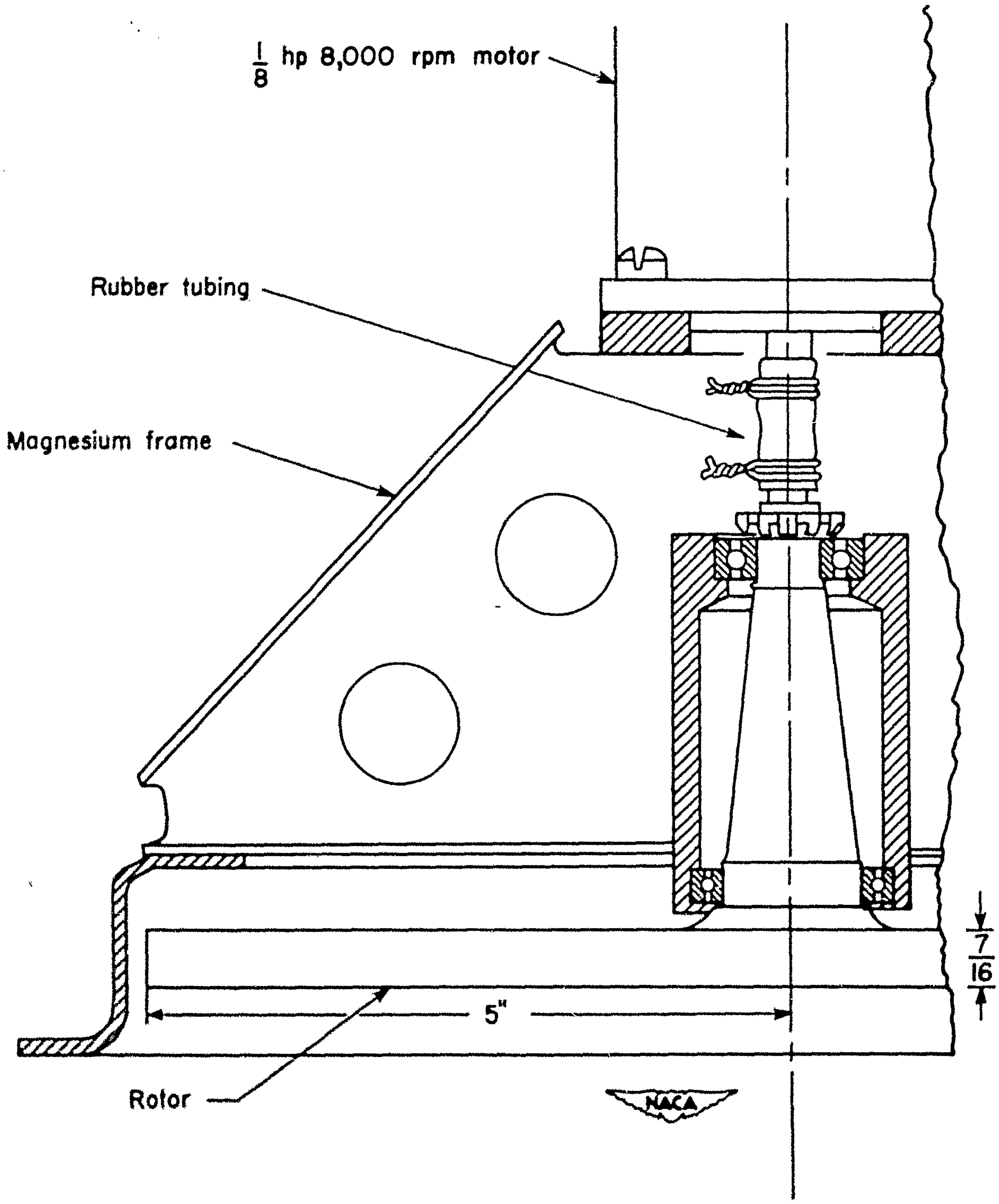


Figure 6.- Sketch of gyroscope.

Figure 7.- Gyroscope installed.

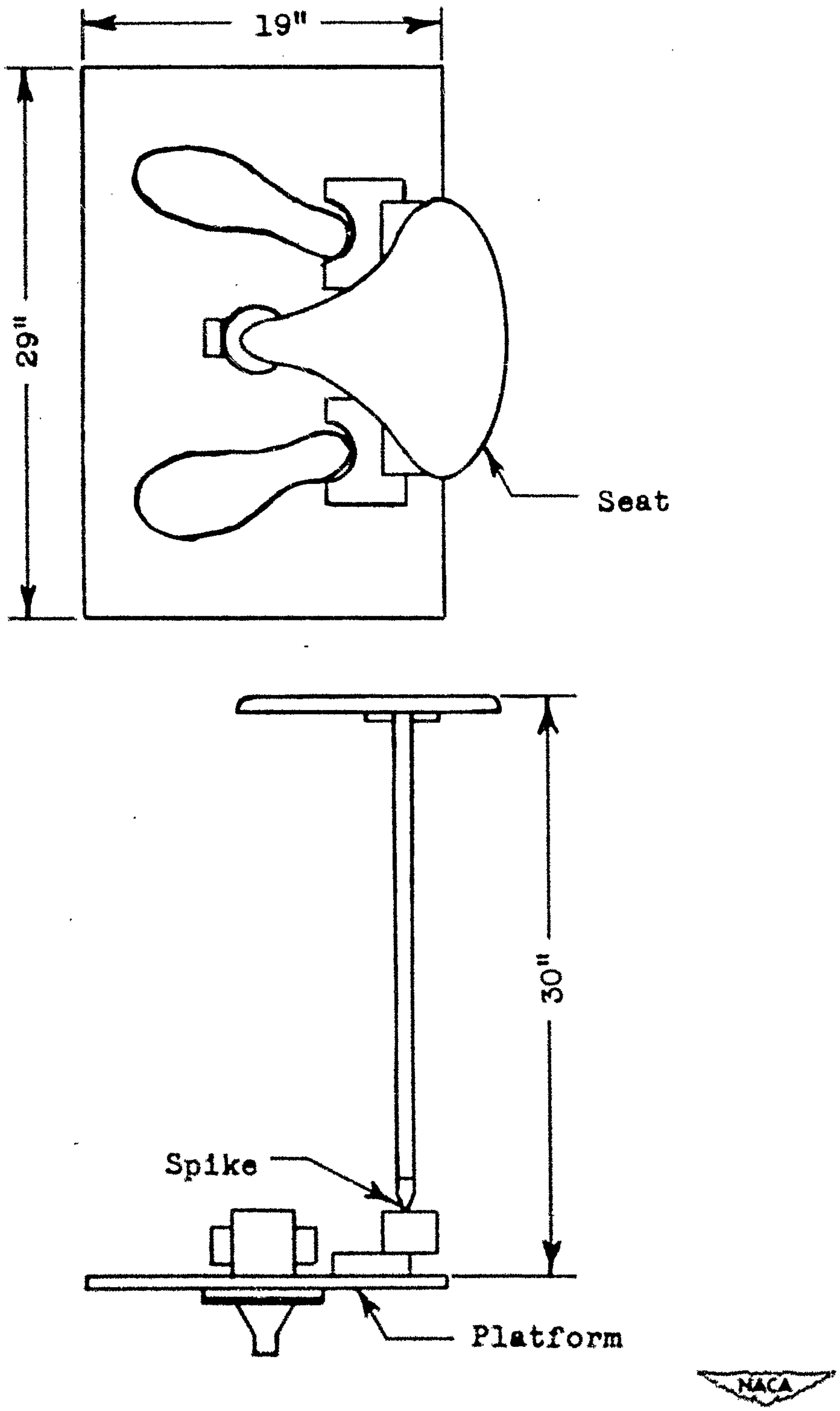
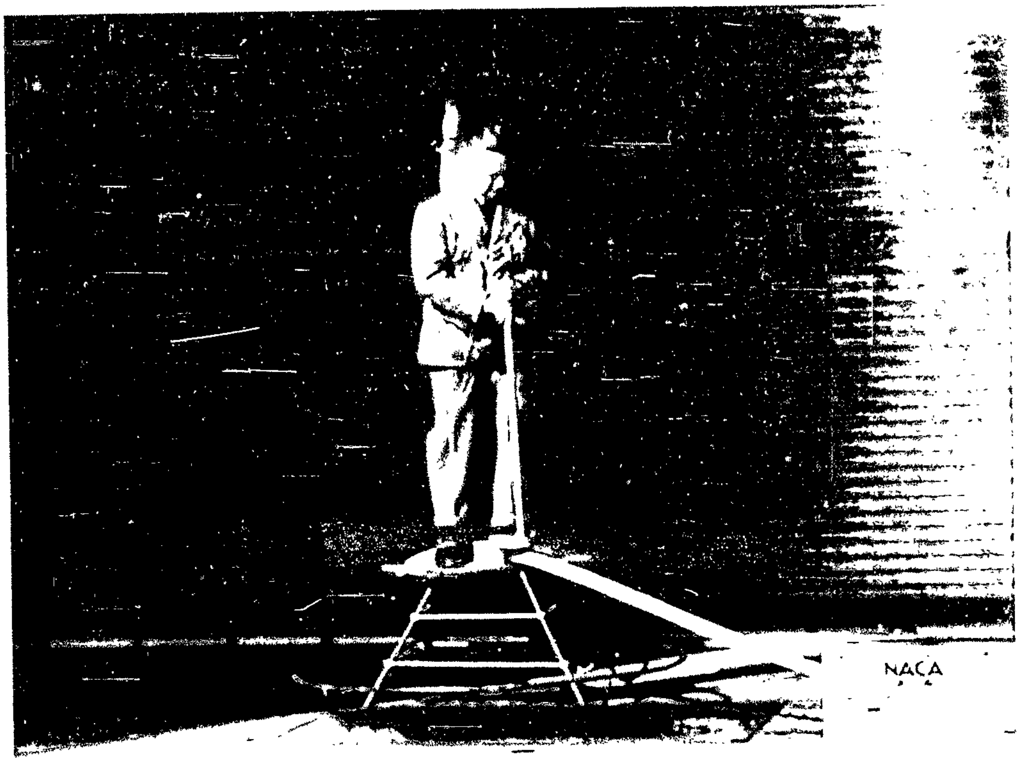
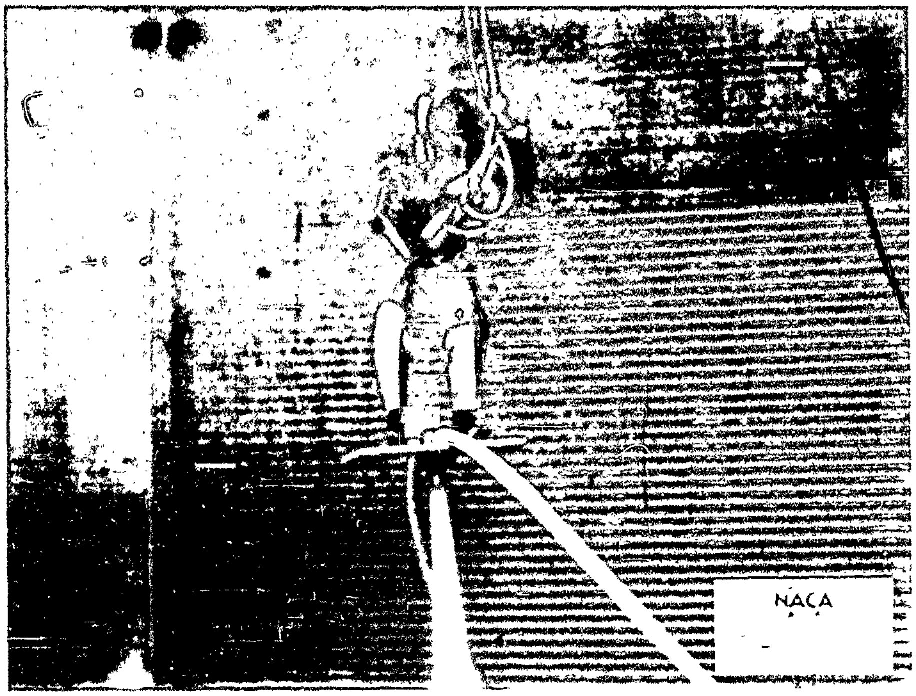


Figure 8.- Sketch of pivoted seat.



[illegible] system.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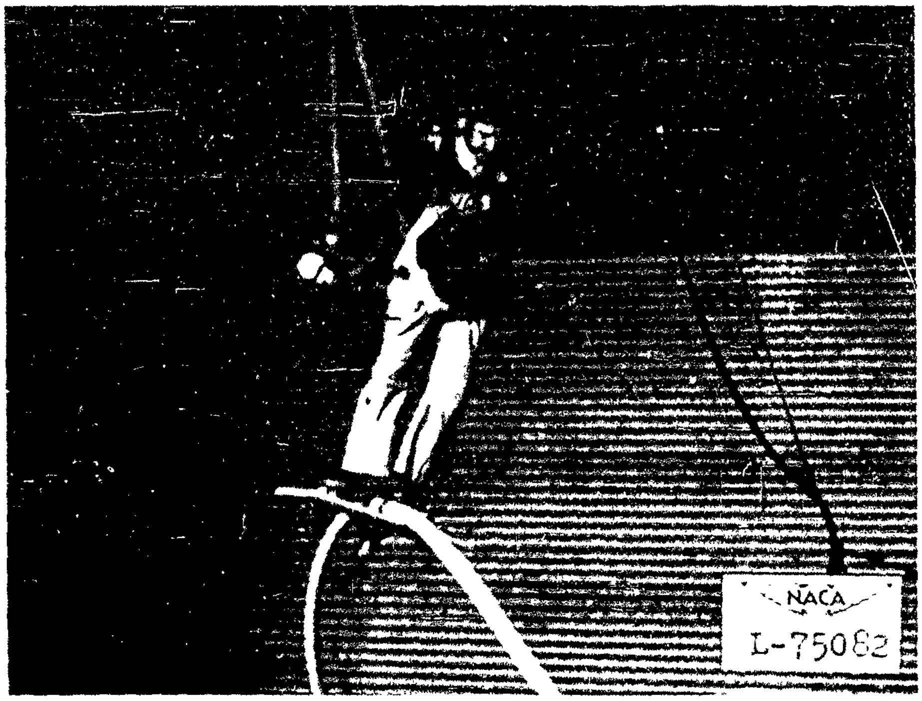
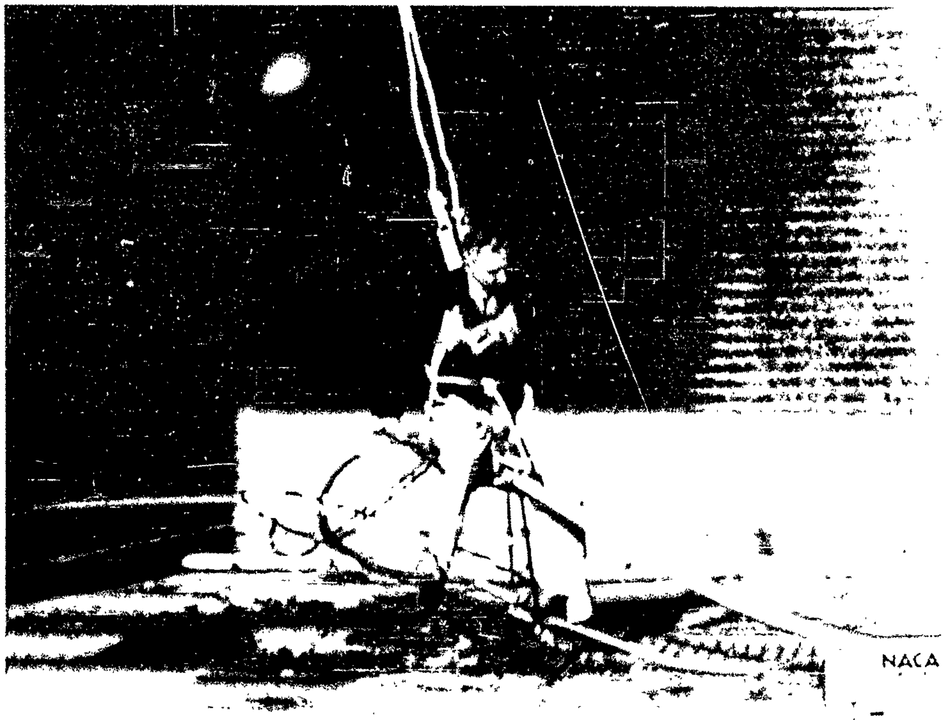


[illegible] movements and reversals.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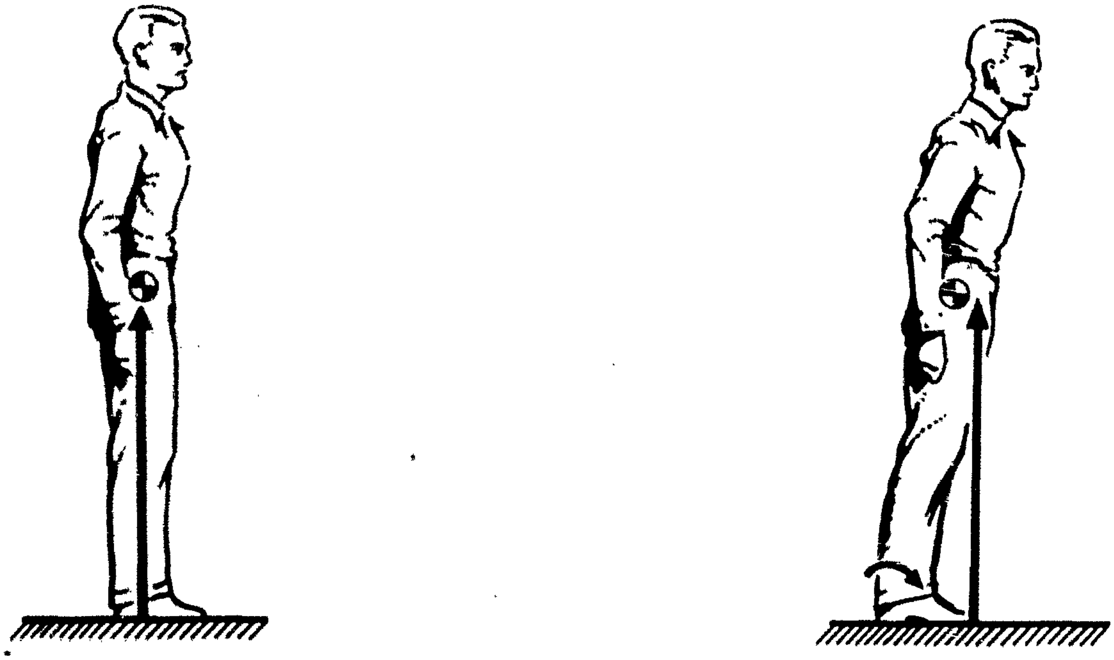
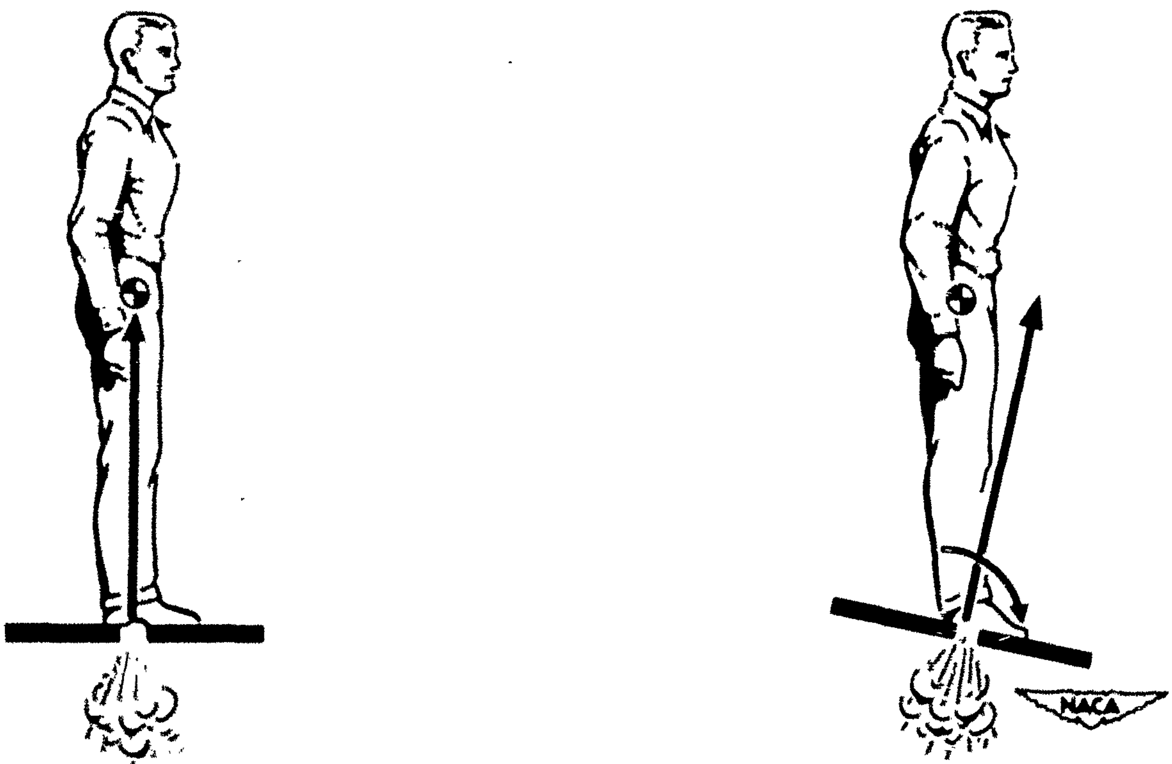


(a) Reflexes applied to a fixed surface.



(b) Reflexes applied to a force vector.

Figure 14.- Application of reflexes to maintaining equilibrium while supported by a force vector.

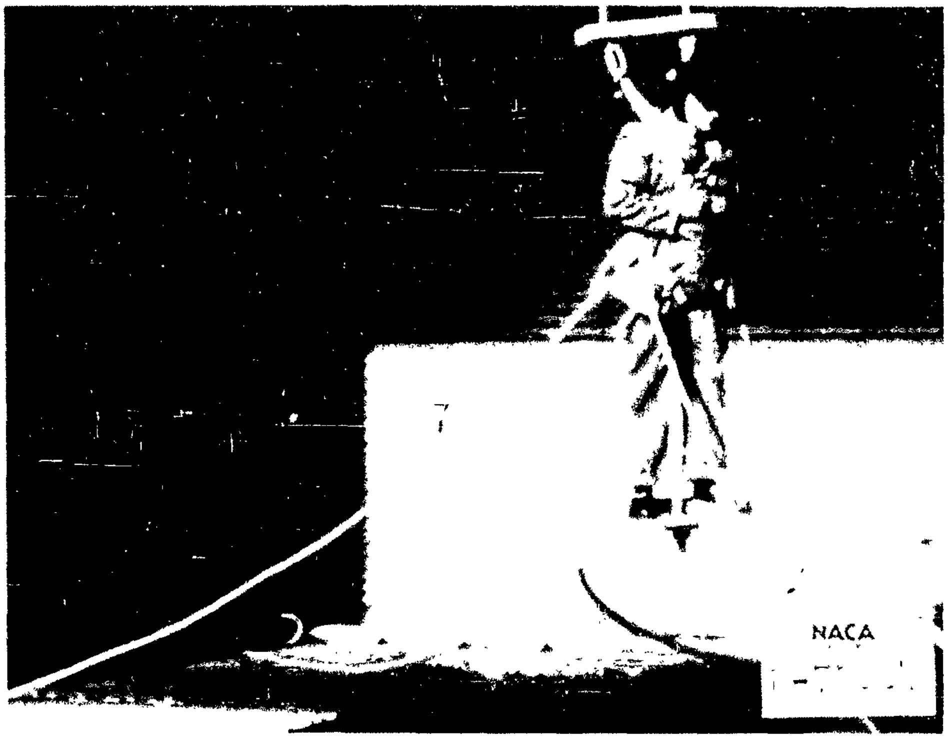


Figure 15.- Flyer A in flight.

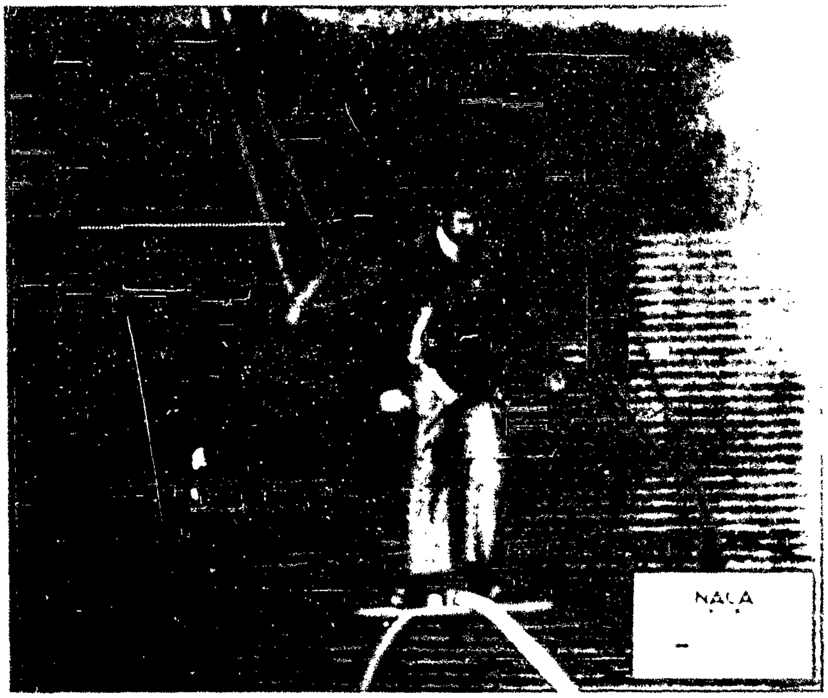
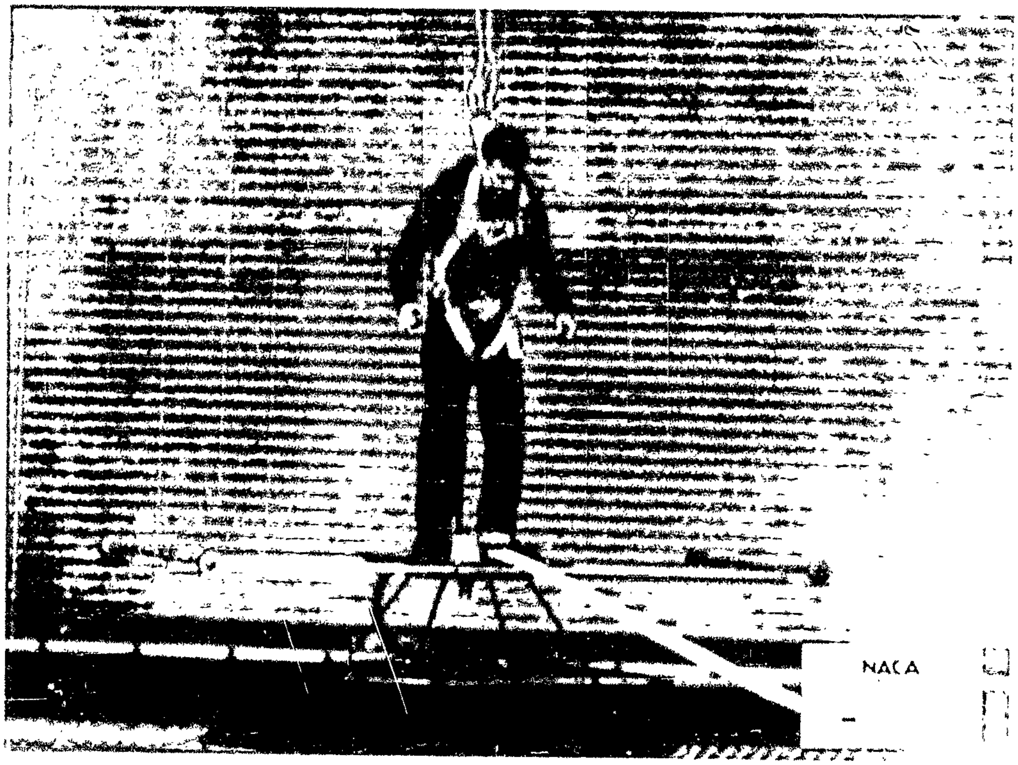


Figure [illegible].- Flyer B in flight.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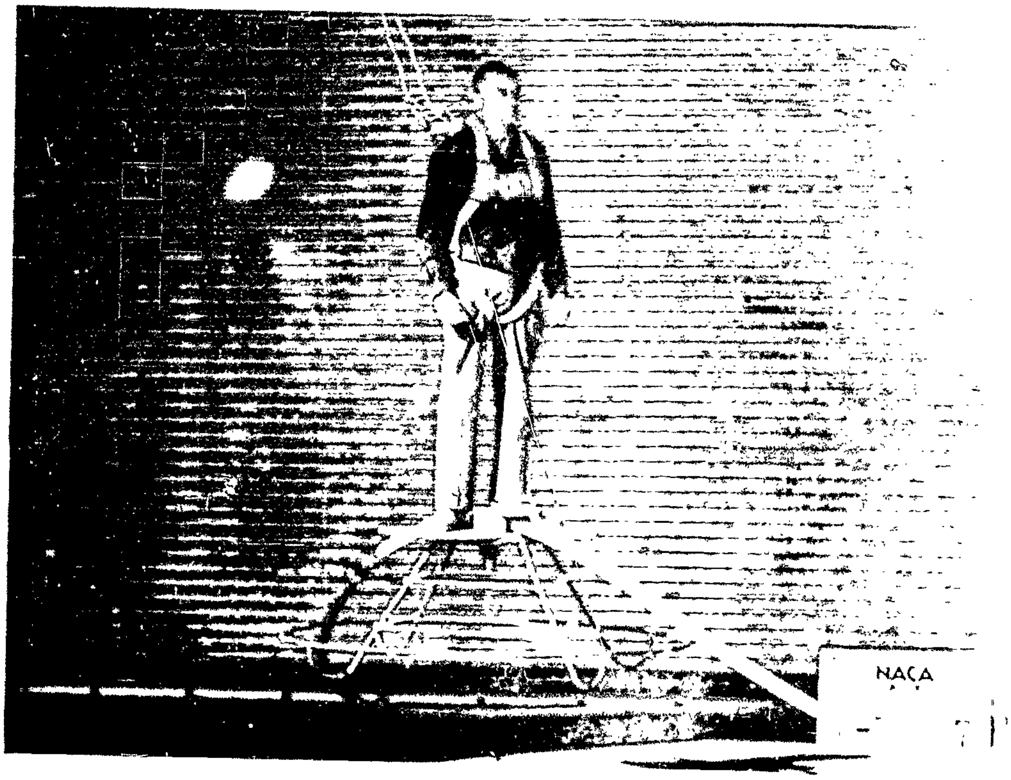

Figure 18.- Flyer [illegible] in flight.

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Copies obtainable from NACA, Washington

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SECURITY INFORMATION

1. Stability, Dynamic (1.8.1.2)
2. Control (1.8.2)
I. Zimmerman, Charles Horton
II. Hill, Paul R.
III. Kennedy, T. L.
IV. NACA RM L52D10

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