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WIND TUNNEL INVESTIGATION OF THE EFFECT OF HIGH RELATIVE VELOCITIES ON THE STRUCTURAL INTEGRITY OF BIRDS

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This information is being published in prelimi-
nary form in order to expedite its early release.

ABSTRACT

An experimental investigation was conducted in the Lewis 8- by 6-Foot Supersonic Wind Tunnel to determine the effect a sudden high velocity headwind had on the physical deformation and structural breakup characteristics of birds. Several sizes of recently killed birds were dropped into the test section at free-stream Mach numbers ranging from 0.2 to 0.8 and photographed with high-speed motion-picture cameras. These conditions simulated flow conditions encountered when birds are ingested into the inlets of high speed aircraft, thereby constituting a safety hazard to the aircraft and its occupants. The investigation shows that, over the range of headwind conditions tested, the birds remained structurally intact and did not suffer any appreciable deformation or structural breakup.

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SUMMARY

An experimental investigation was conducted in the Lewis Research Center's 8- by 6-Foot Supersonic Wind Tunnel to determine the effect a sudden high velocity headwind had on the physical deformation and structural breakup characteristics of birds. Several sizes of recently killed birds were dropped into the test section at free-stream Mach numbers ranging from 0.2 to 0.8. This simulated the airflow conditions they encounter if suddenly ingested by an aircraft inlet.

As the birds accelerated through the test section, they were photographed with color film by four high speed motion picture cameras at 2000 frames per second.

This investigation shows that, over the range of headwind conditions tested, the birds remained structurally intact and did not suffer any appreciable deformation or structural breakup.

INTRODUCTION

The first recorded aircraft accident due to a bird strike occurred at San Diego, California in the spring of 1912 (ref. 1). Since that time, birds have continued to be a hazard to aircraft and the problem has increased in importance in recent years, primarily because of the continuing increase in aircraft flight speeds (ref. 2). This problem is of particular concern to high performance multimission military aircraft. Many of these aircraft have high speed, low level penetration missions where the probability of bird strikes is high. The propulsion system is one of the most important aircraft components that must withstand bird strikes if the aircraft is to safely complete its mission (ref. 3 to 5).

An aircraft inlet may affect birds in several ways that can alter the amount of damage experienced by the engine. One effect is the structural breakup of the birds as they strike the inlet surfaces. A second potential source of damage is the high relative velocity that the bird experiences as it enters the diffused flow in the inlet.

For a typical low altitude penetration mission at a flight velocity of Mach 0.85 the velocity of the aircraft relative to a bird gliding across its path is approximately 290 meters per second (950 ft/sec). However, an inlet with a subsonic diffuser Mach number of 0.45, increases the air velocity, relative to the bird, 128 meters per second (420 ft/sec) and increases air density to 127 percent of the ambient value. A bird ingested by the inlet then would encounter a sudden headwind with a velocity of approximately 128 meters per second (420 ft/sec) at 1.27 times atmospheric density. This would result in a headwind dynamic pressure of approximately 12.7×10^{3} newtons per square meter (266 lb/ft^{2}).

Limited experience with firing birds into engines with bird guns showed that the birds tended to breakup after leaving the gun barrel if fired at speeds from approximately 122 to 153 meters per second (400 to 500 ft/sec) unless they were incased in a protective covering. How much of this damage was due to the effects of the sudden high air velocities on the birds and how much was due to the extremely high acceleration forces of the gun was not known. If the birds flying into the dense headwind encountered in the inlet subsonic diffuser should structurally deform or breakup, it could significantly reduce the amount of damage the bird subsequently does to the engine. This effect has been neglected in analysis to date.

Therefore, the purpose of the test reported herein was to determine if a bird suddenly encountering a dense headwind will structurally deform or breakup. Birds of several sizes were dropped into the NASA Lewis Research Center's 8- by 6-Foot Supersonic Wind Tunnel test section at freestream

Mach numbers from 0.2 to 0.8 with the corresponding freestream velocities of 70.2 to 287.0 meters per second (230 to 941 ft/sec) and dynamic pressures of 2.78×10^3 to 35.0×10^3 newtons per square meter (58 to 731 psf). From four different locations, high speed motion pictures were taken of the bird entry into the wind tunnel and resultant acceleration downstream to determine the effect on the bird's condition. A color film supplement from these cameras is available from NASA Lewis Research Center.

APPARATUS AND PROCEDURE

Before each run, recently killed birds were weighed and then placed in the bird drop chute shown in figure 1, with their heads pointing upstream. The chute, consisting of three trap doors released by solenoids, was located above the tunnel ceiling and extended 0.61 meters (2 ft) into the test section as shown in figure 2. When the desired free-stream condition was reached, the trap doors were triggered at one second intervals dropping the birds into the test section.

As the birds accelerated through the test section, they were photographed with color film by four high speed motion picture cameras at 2000 frames per second. The cameras were located as shown in figure 3, with the upstream, side wall, and floor cameras external to the test section and the downstream camera mounted inside on the tunnel wall downstream of the test section. The arrows indicate the direction the cameras were aimed. The color film supplement to this report does not include any footage from the floor camera.

Three species of birds were used (fig. 4): starlings, averaging 57 to 85 grams (2 to 3 oz); pigeons, averaging 284 to 340 grams (10 to 12 oz); and domestic ducks weighing approximately 1.96 kilograms (4 lb. 5 oz). Domestic ducks were used in this test because of difficulties in obtaining wild ducks. Table I lists the specimens tested at each Mach number. Three birds were dropped at free-stream Mach numbers of 0.2, 0.4, 0.6, and 0.8.

RESULTS AND DISCUSSION

Specimens of three species of birds were dropped into the 8- by 6-Foot Supersonic Wind Tunnel test section at free-stream Mach numbers ranging from 0.2 to 0.8 and dynamic pressures of 2.78×10^3 to 35.0×10^3 newtons/meter^2 (58 to 731 lb/ft^2) to determine the effect a sudden high velocity headwind had on their physical deformation and structural breakup characteristics. As the birds passed through the test section they were filmed by high speed motion picture cameras. Selected frames from the movie supplement to this report for birds tested at Mach 0.6 and 0.8 are shown in figures 5 and 6, respectively, for the upstream camera. Even though the birds were all pointed upstream in the bird drop chute, it can be seen that they first encountered the tunnel airstream at random attitudes.

From figure 5 (Mach 0.6), it can be seen that the birds remained intact and did not suffer any apparent physical damage. The contrail preceding the birds is apparently made up of dust, dirt and small feathers and indicates that they did not accelerate to free-stream velocity by the time they reached the end of the test section.

From the photographs of figure 6 (Mach 0.8) it is apparent that they could also sustain this higher Mach number and dynamic pressure. The birds again remained intact with the exception of the duck (fig. 6(c)) which experienced the separation of the upper portion of its bill because of the whiplike action of its neck.

The results of this investigation show that, over the range of headwind conditions tested, the birds remained structurally intact and did not suffer any appreciable deformation or structural breakup due to high relative air velocities.

SUMMARY OF RESULTS

Specimens of three species of birds were dropped into the 8- by 6-Foot Supersonic Wind Tunnel test section and free-stream Mach numbers ranging from 0.2 to 0.8 and dynamic pressures of 2.78×10^3 to 35.0×10^3 newtons per square meter (58 to 731 lb/ft^2) to determine the effect a sudden high velocity headwind had on their physical deformation and structural breakup characteristics.

The results of this investigation show that, over the range of headwind conditions tested, the birds remained structurally intact and did not suffer any appreciable deformation or structural breakup due to high relative air velocities.

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3. Millar, Donald M.: Investigation of Turbojet Engine Characteristics During Bird Ingestion. Rep. FAA-ADS-58, Federal Aviation Agency, Jan. 1966.

4. Millar, Donald M.: Wind Tunnel Test of Turboprop Engine Characteristics During Bird Ingestion. Rep. FAA-ADS-2, Federal Aviation Agency, Nov. 1963.

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TABLE I. - BIRD SPECIMENS TESTED AT EACH TUNNEL CONDITION

Free-stream Mach number, M_0	Velocity		Dynamic pressure, q		Order of bird release	Weight	
	m/sec	ft/sec	N/m^2	lb/ft^2		g	oz
0.2	70.2	230	2.8×10^3	57.6	Pigeon	299.5	10.54
					Starling	80.4	2.83
					Pigeon	337.1	11.86
0.4	144.0	472	11.7×10^3	245	Starling	83.8	2.95
					Pigeon	271.5	9.56
					Pigeon	278.7	9.81
0.6	217.5	713	24.9×10^3	520	Duck	1.96 kg	4 lb 5 oz
					Pigeon	344.7	12.13
					Starling	75.4	2.66
0.8	287.0	941	35.0×10^3	731	Pigeon	280.1	9.86
					Pigeon	334.4	11.77
					Duck	1.98 kg	4 lb 6 oz

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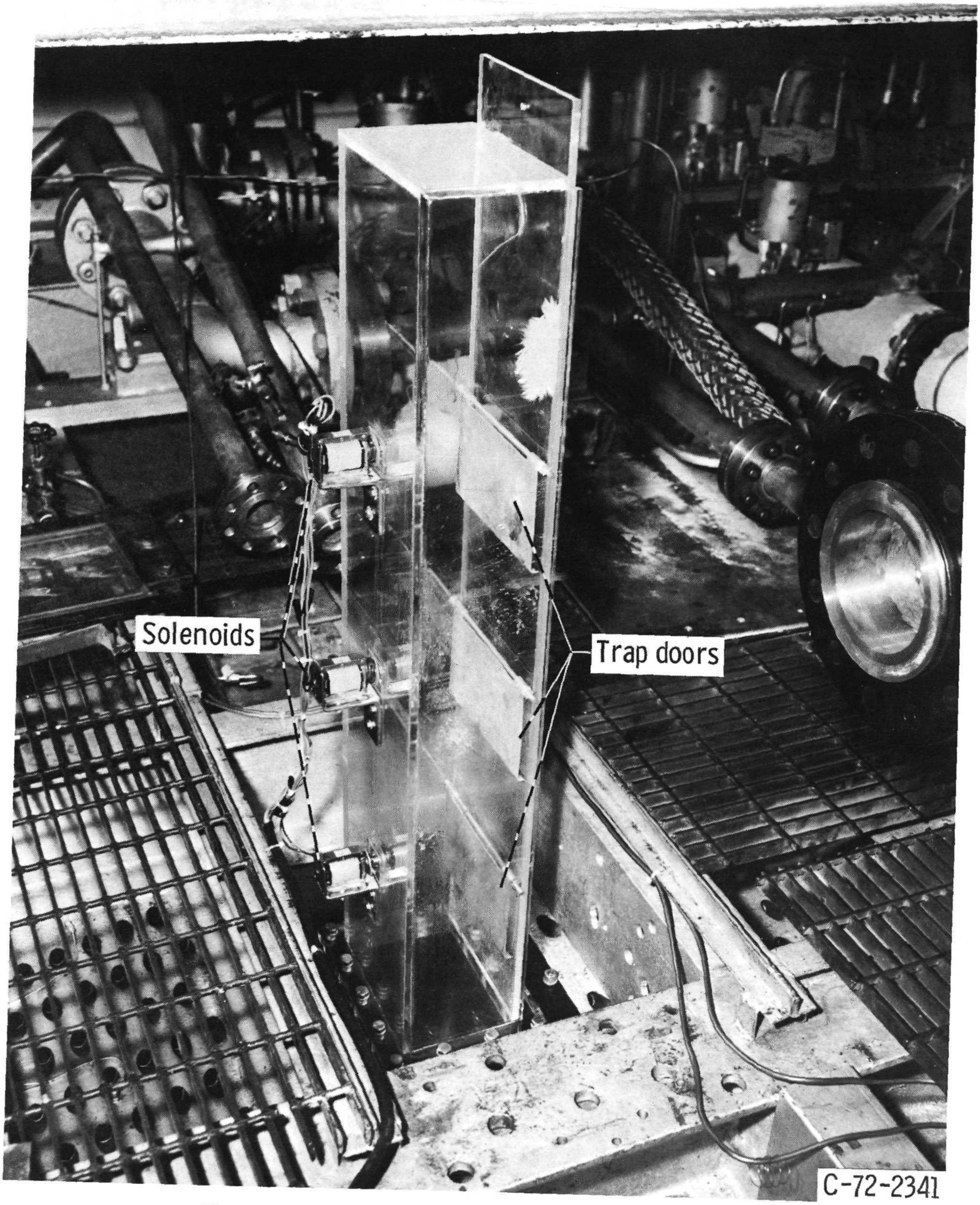


Figure 1. - Bird drop chute above test section.

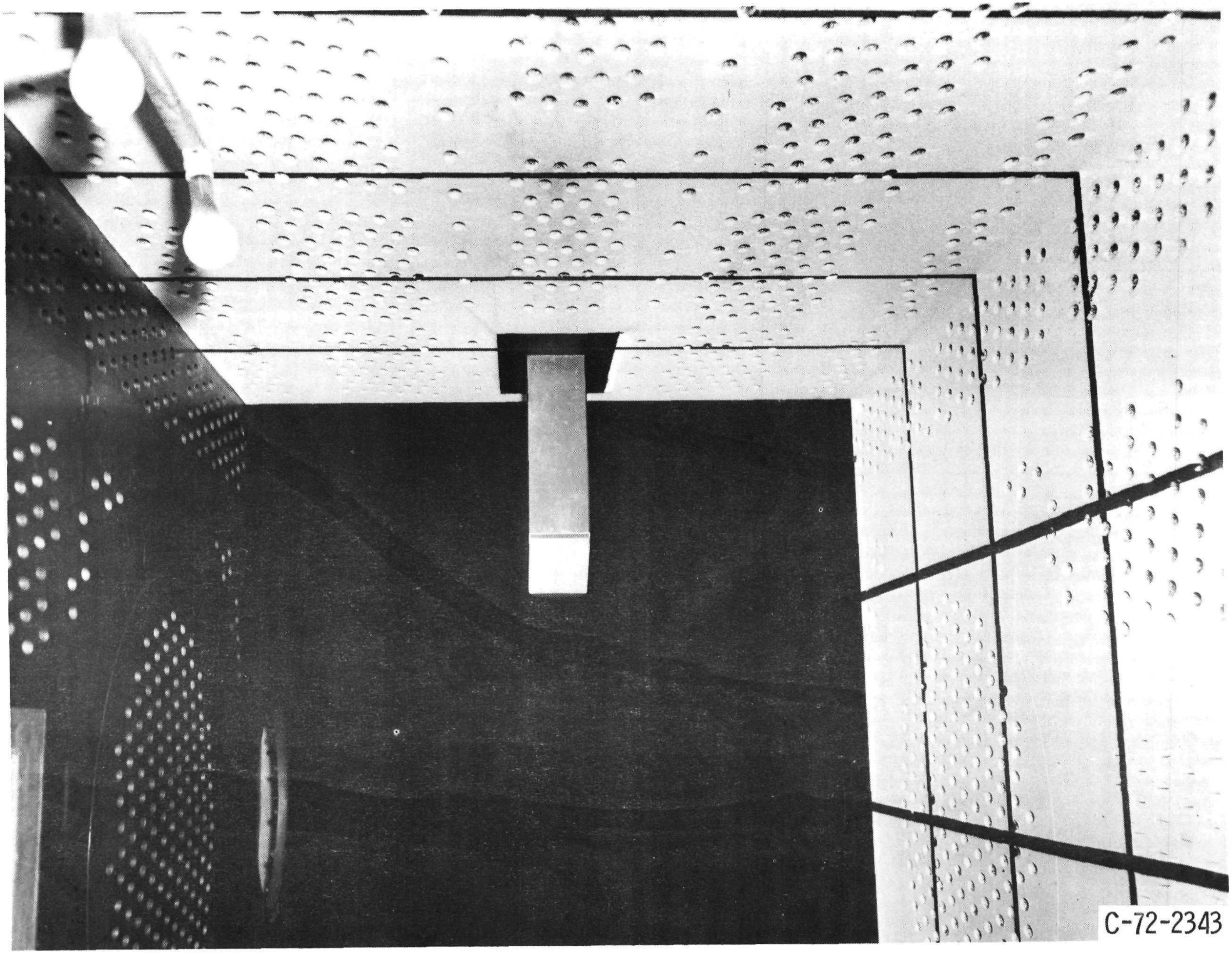


Figure 2. - Bird drop chute inside test section, view looking upstream.

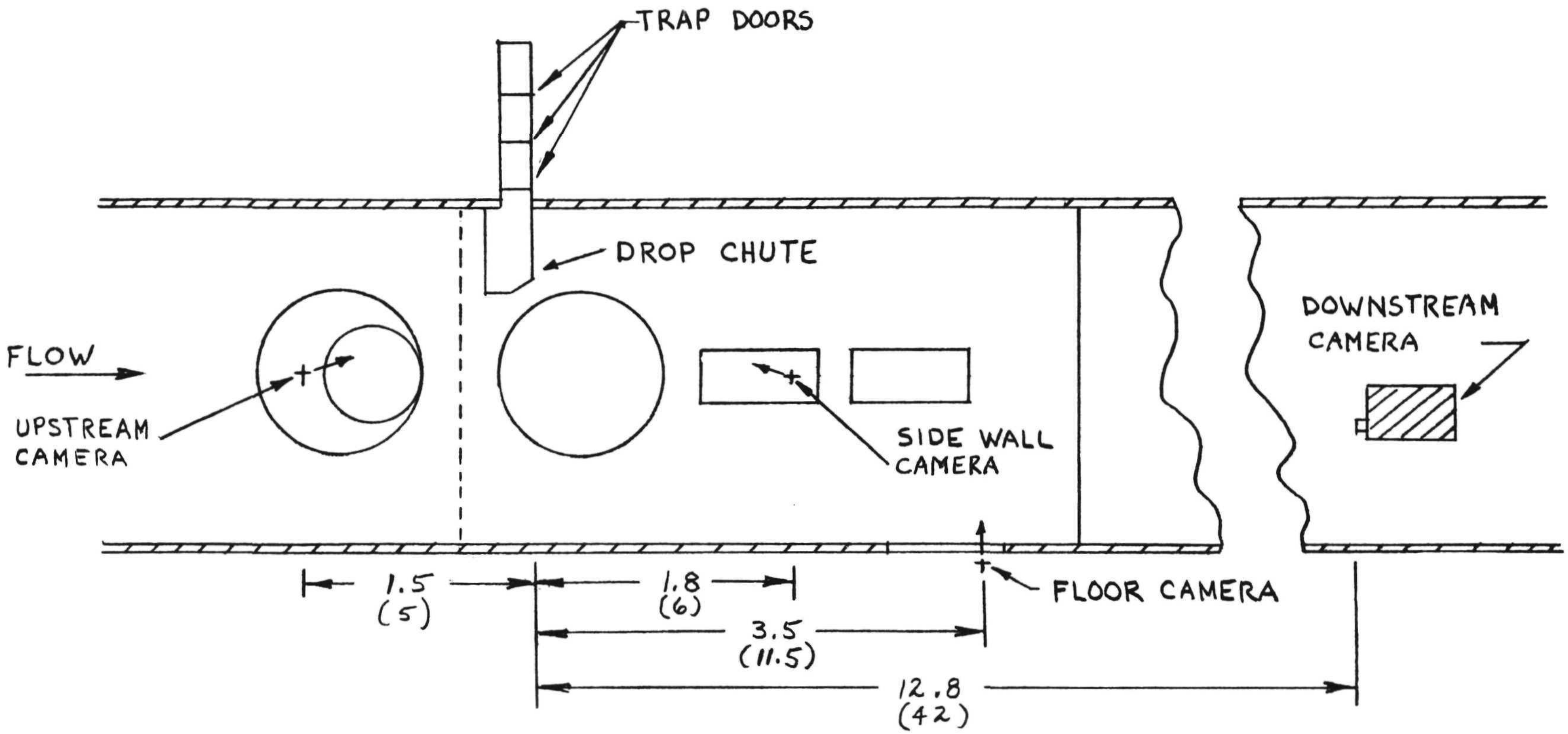
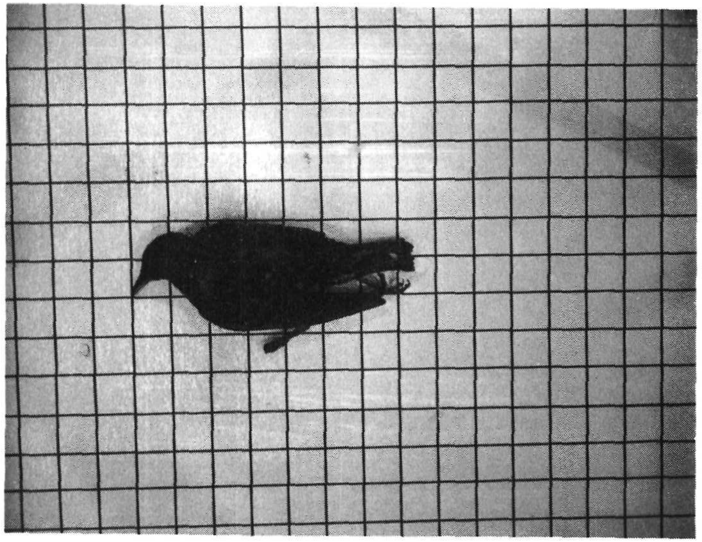
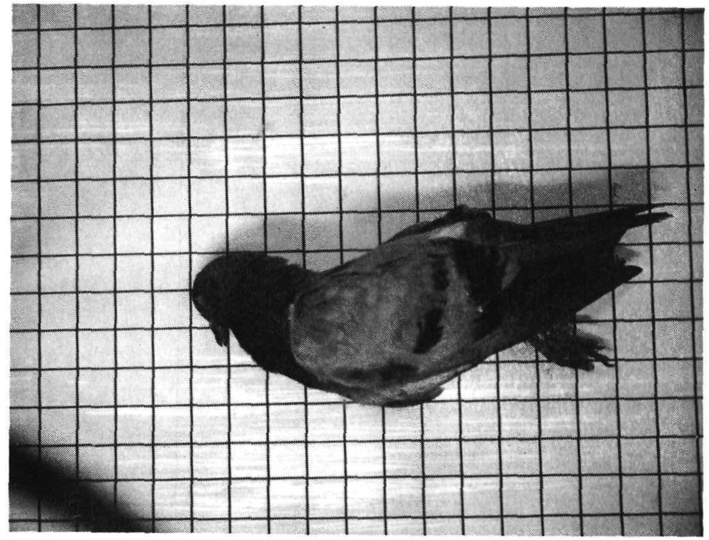


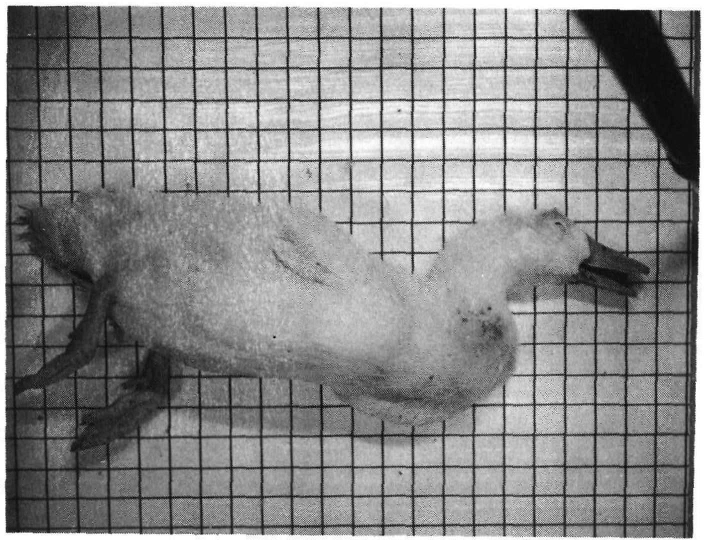
FIGURE 3. CAMERA LOCATION IN 8×6 FT SUPERSONIC WIND TUNNEL TEST SECTION (ALL DIMENSIONS IN METERS (FEET))



(a) Starling.

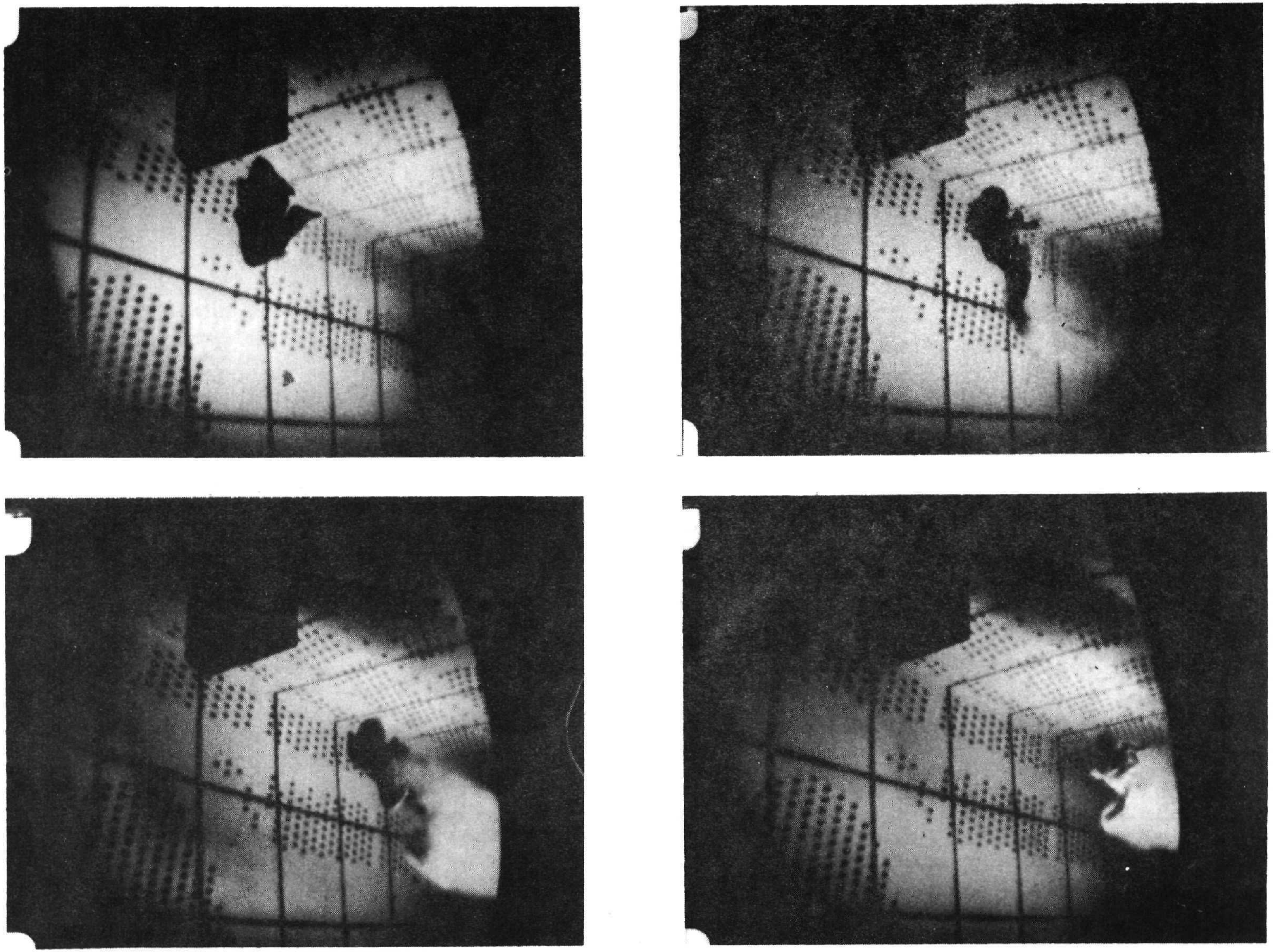


(b) Pigeon.



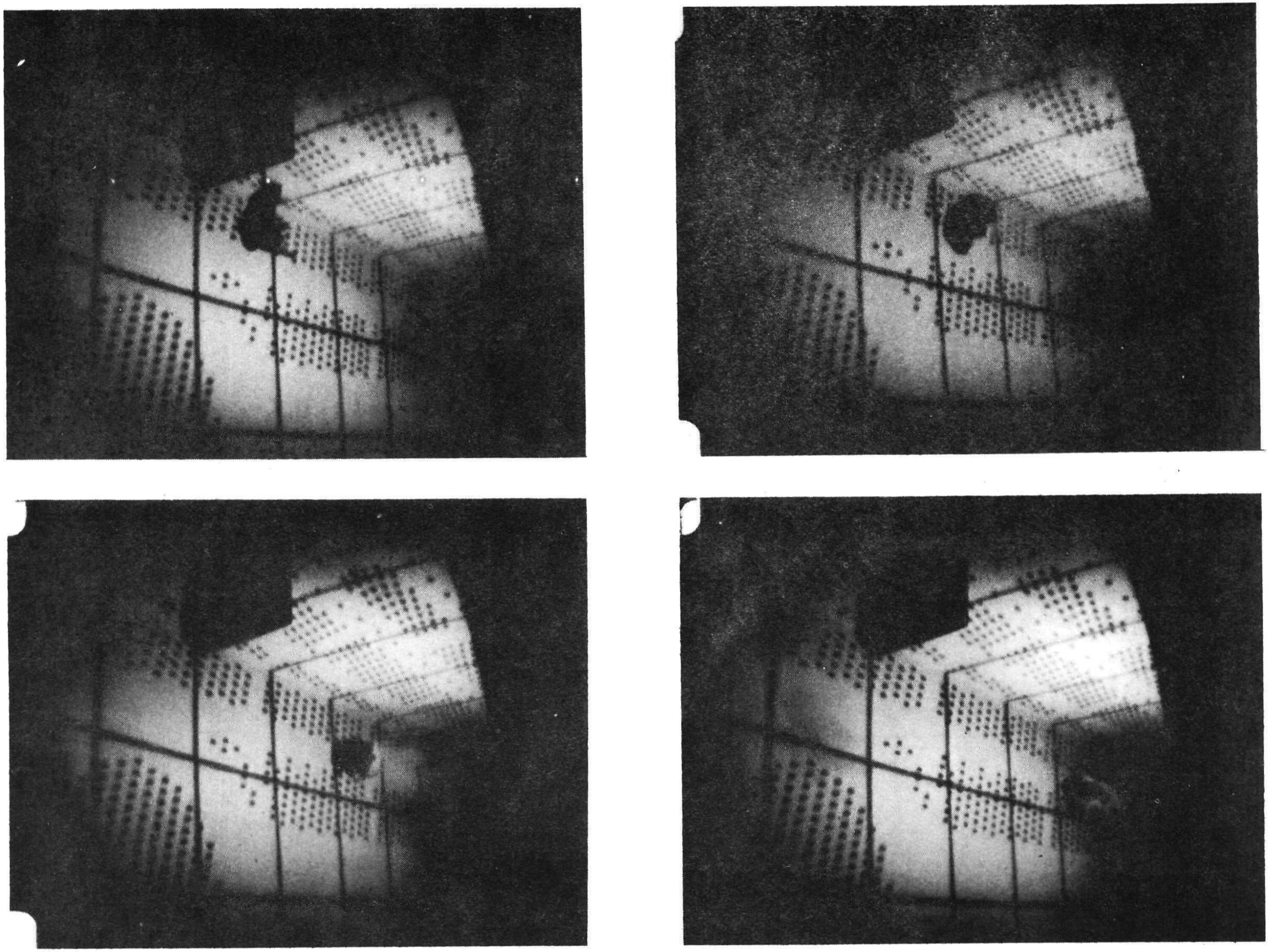
(c) Duck.

Figure 4. - Typical bird specimens, 2.54 cm (1.0-in.) grid.



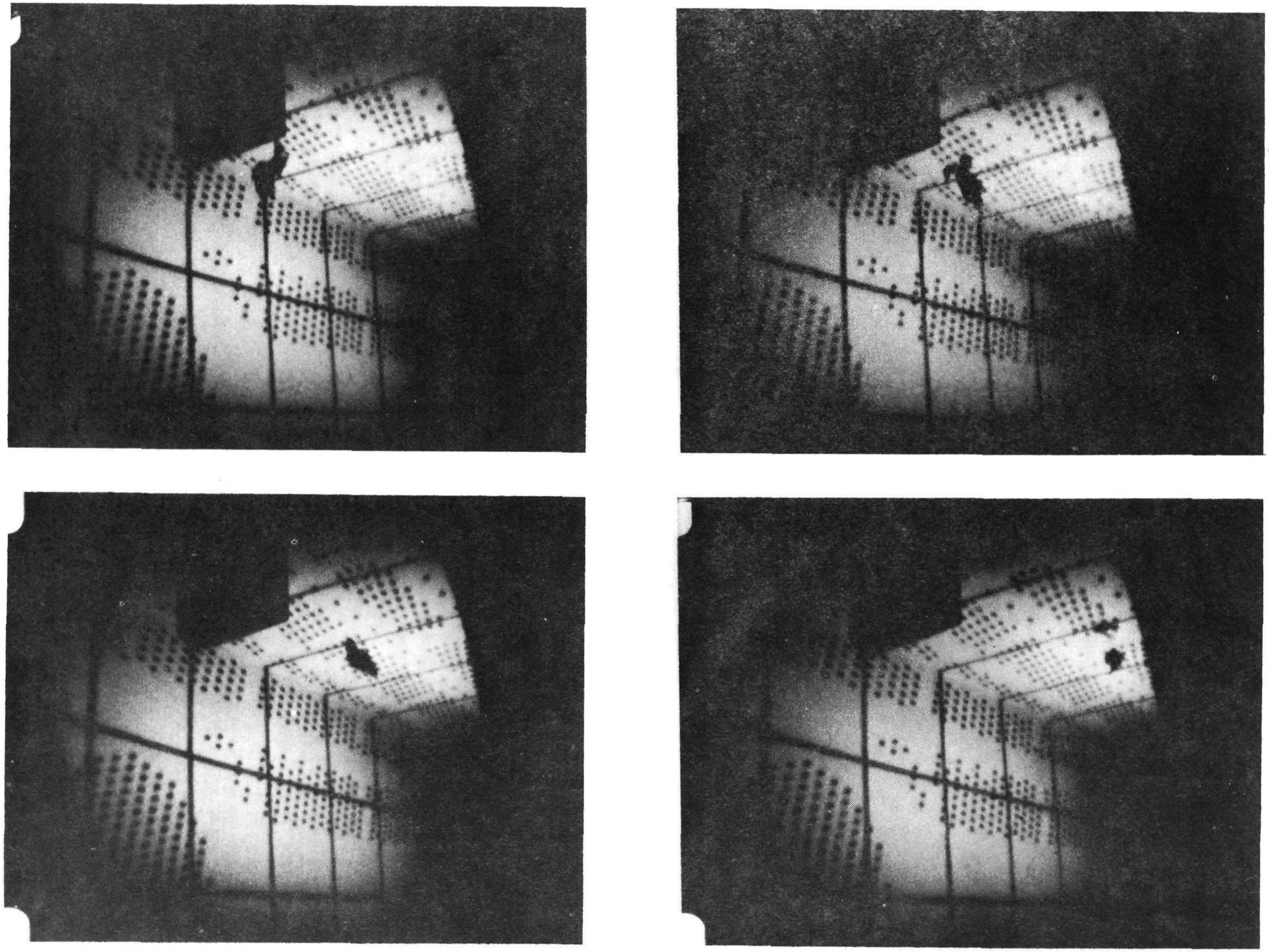
(a) Duck.

Figure 5. - Bird sequence at Mach 0.6.



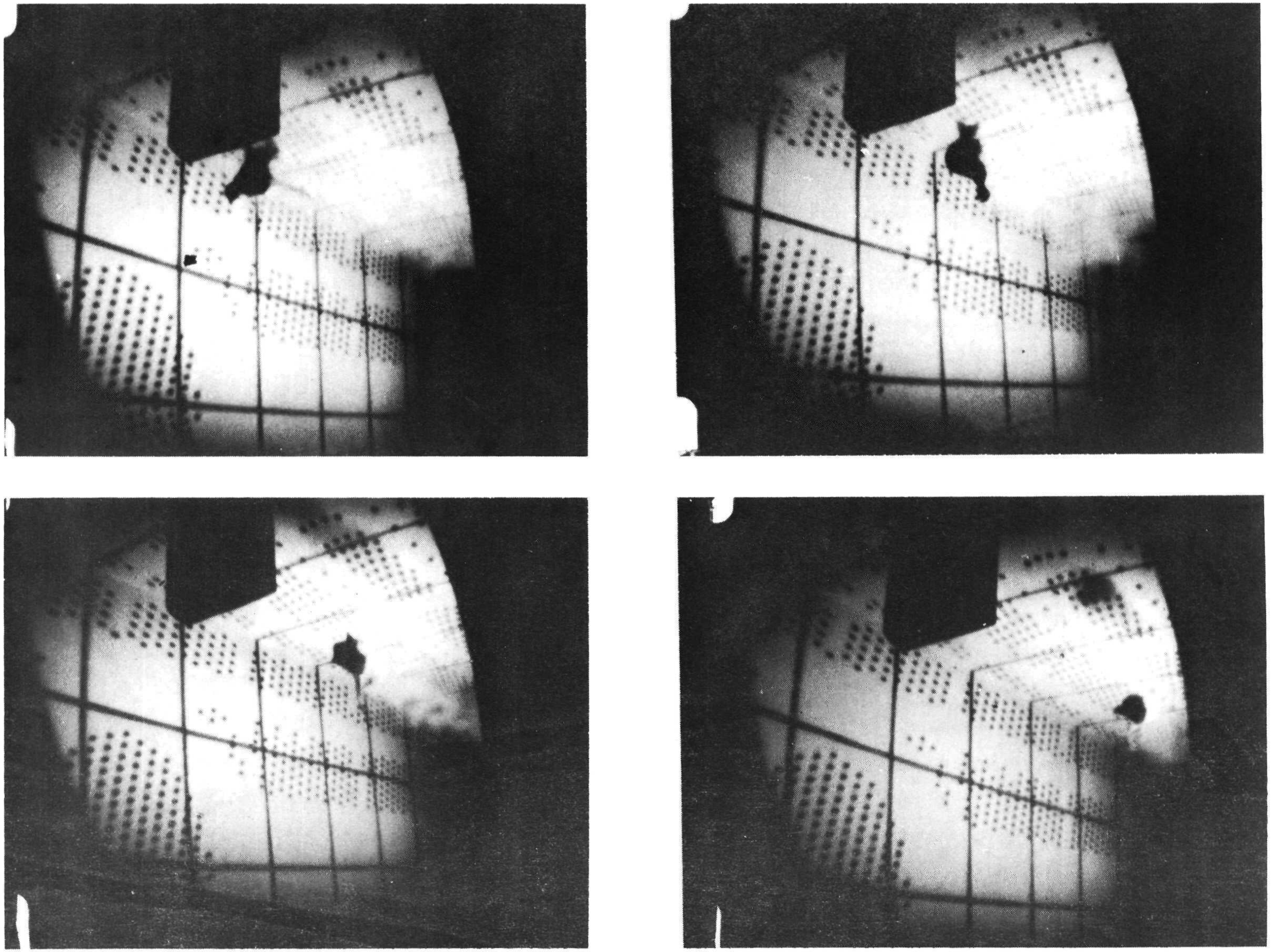
(b) Pigeon.

Figure 5. - Continued.



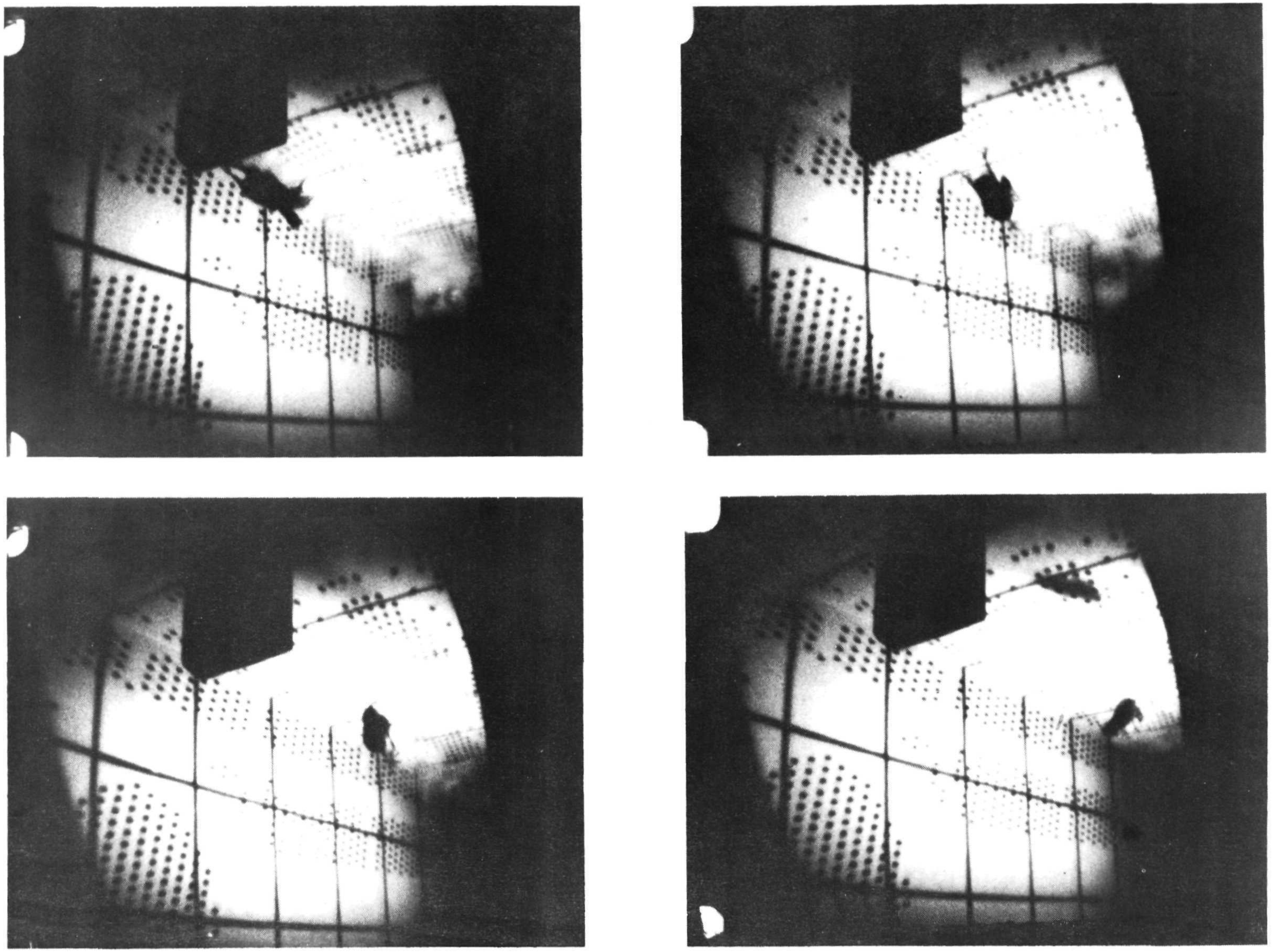
(c) Starling.

Figure 5. - Concluded.



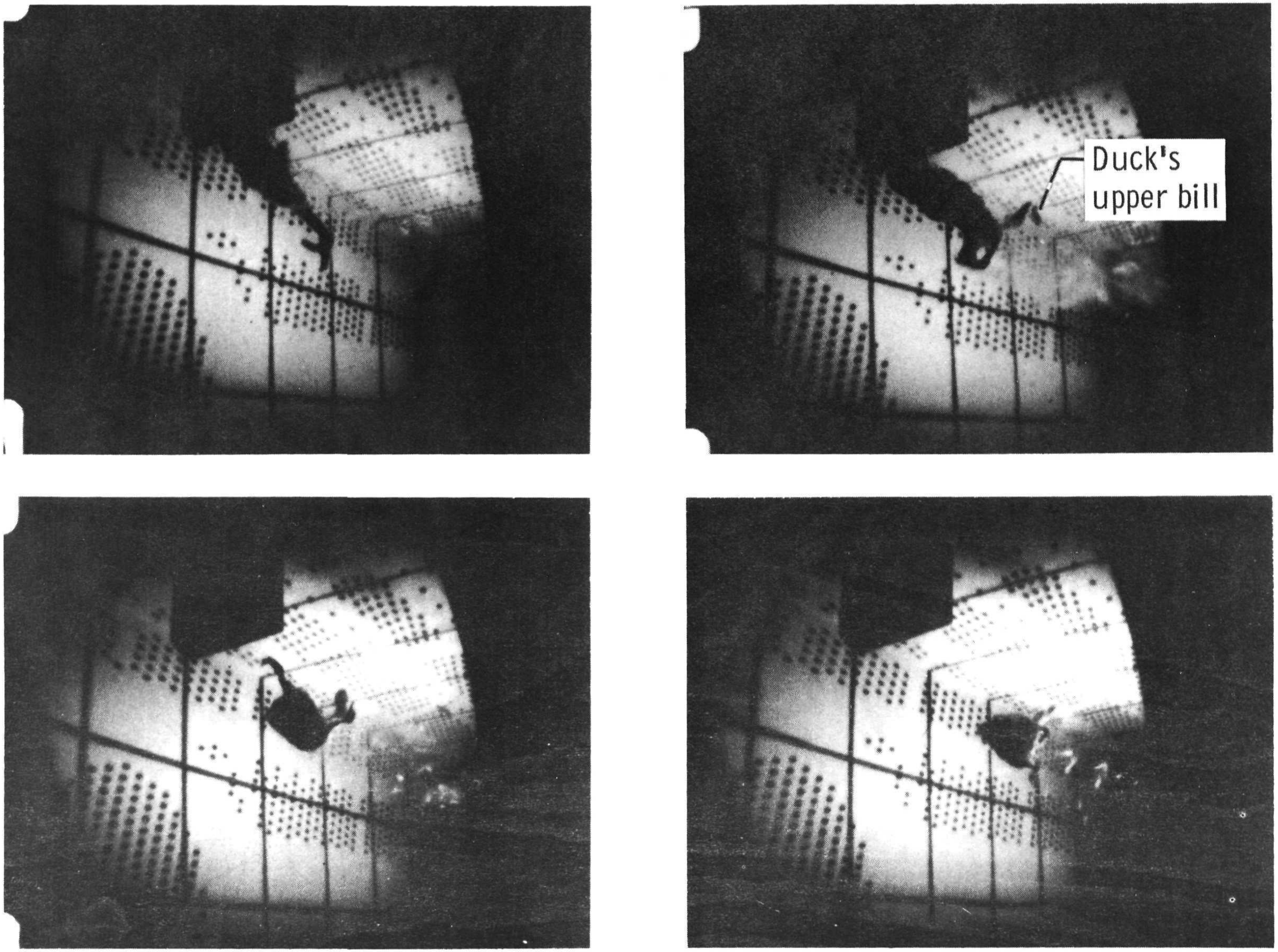
(a) Pigeon.

Figure 6. - Bird sequence at Mach 0.8.



(b) Pigeon.

Figure 6. - Continued.



(c) Duck.

Figure 6. - Concluded.

Motion-picture film supplement MPD-1340 is available on loan. Requests will be filled in the order received. You will be notified of the approximate data scheduled.

The film (16 mm, 11 min, color, silent) shows each bird specimen as it was dropped into the test section at a Mach number ranging from 0.2 to 0.8. Camera views of the bird chute, both upstream and downstream, are shown.

Film supplement MPD-1340 is available on request to:

Chief, Management Services Division (5-5)
National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

CUT

Date ____________

Please send, on loan, copy of film supplement MPD-1340 to TM X-68163

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Name of Organization

____

Street Number

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City and State Zip Code

Attention: Mr. ____________

Title ____________

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