

NRC Publications Archive Archives des publications du CNRC

Capabilities of the NAE/NRC Flight Impact Simulator Facility

Bosik, A. J.; Heath, J. B. R.; Gleeson, M. R.; National Research Council
Canada. National Aeronautical Establishment

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:

<https://doi.org/10.4224/40002713>

Laboratory Technical Report (National Research Council Canada. National Aeronautical Establishment. Structures Laboratory); no. LTR-ST.701, 1978-04-08

NRC Publications Archive Record / Notice des Archives des publications du CNRC :

<https://nrc-publications.canada.ca/eng/view/object/?id=e8845724-b536-487b-a182-ec534367959>.

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=e8845724-b536-487b-a182-ec534367959>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.



National Research
Council Canada

Conseil national
de recherches Canada

NATIONAL AERONAUTICAL
ESTABLISHMENT

ÉTABLISSEMENT AÉRONAUTIQUE
NATIONAL

PAGES 10
PAGES _____

**REPORT
RAPPORT**

REPORT LTR-ST.701
RAPPORT _____

FIG. 13
DIAG. _____

LABORATORY / LABORATOIRE

DATE 8 April 74
DATE _____

TABLES
TABLES _____

LAB. ORDER
COMM. LAB. _____

FILE 4040-5
DOSSIER _____

FOR Internal
POUR

REFERENCE
RÉFÉRENCE

LTR - ST.701

CAPABILITIES OF THE NAE/NRC
FLIGHT IMPACT SIMULATOR FACILITY

SUBMITTED BY A. H. Hall
PRÉSENTÉ PAR _____
LABORATORY HEAD
CHEF DE LABORATOIRE

A. J. Bosik
J. B. R. Heath
M. R. Gleeson

AUTHOR
AUTEUR _____

APPROVED F. R. Thurston
APPROUVÉ _____
DIRECTOR
DIRECTEUR

1.0 INTRODUCTION

Through the years, the extensive use of the NAE/NRC Flight Impact Simulator for both commercial and internal bird impact test programs has fostered the further broadening and development of the facility. Among these, is the extension of the velocity calibrations and the use of the nominal one, two and eight pound bird weights, corresponding with further development in packaging techniques and sabot design.

It is the purpose of this report to provide information on the present capabilities of the facility and on the techniques being used.

2.0 GENERAL CAPABILITIES

The NAE/NRC Flight Impact Simulator Facility, including the gun, packaging, and instrumentation has been fully calibrated for one, two, four and eight pound bird weights over the following velocity ranges:

Nominal Bird Weight (lb.)	Velocity Range (ft. /sec.)
1	100-700
2	115-600
4	105-1210
8	240-760

A large percentage of the impacts have been with the four pound bird over the velocity range of 300 to 1000 ft. /sec. The velocity repeatability for these tests has typically been within 3% of the predicted value with the actual repeatability being within 5% at the lower speeds and within 2% at the higher speeds. The calibration for the other bird weights has not been as extensive but based on the tests to date, the velocity repeatability is expected to be similar to that of the four pound bird.

The impact velocity is determined from the time interval obtained by timer-counters, triggered by the birds' interruption of two consecutive light beams, located a calibrated distance apart and each set normal to the flight path of the bird. The accuracy of the velocity measurement system is considered to be within 0.5%.

The aiming accuracy of the gun is within a two inch diameter circle at a distance of 20 feet from the end of the barrel.

The existing camera and lighting equipment permit high speed filming of up to 7000 pictures per second.

The completely enclosed test area is shown in Figure 1. As part of the facility, an insulated 8 x 8 x 14 feet long environmental chamber can be erected around a test specimen. The temperature within the chamber can be controlled to $\pm 5^\circ$ F over the range of -40° F to 130° F. Alternatively, a small test specimen can be pre-soaked in a 3 x 3 x 3 feet environmental chamber located in an nearby building, mounted, and then allowed to warm up or cool down to the required test temperature before impacting. A deep freeze, situated next to the test area, is also available for cooling down a specimen prior to impacting.

Other features of the test area include the existing tie-down rails with relocatable tie-down plates and pre-drilled structural steel for mounting the test specimens. Portable vertical steel plate baffles are positioned around the test specimen to contain any debris resulting from the impact. The services in the test area include electric power, compressed air, heating, water and steam.

The instrumentation within the facility includes the readout and recording of the outputs of both thermocouples and strain gauges.

3.0 COMPRESSED AIR POWERED BIRD GUN

The design and operation of the air powered bird gun has been previously described in references 1 and 2 and only a brief description is included here. The gun, Figure 2, is of the double diaphragm design, approximately 70 feet long with a 10 inch diameter barrel, 40 feet long. The air reservoir has a 60 foot³ capacity with a rated pressure of 200 psi. The step chamber has a capacity of approximately one foot³. A horizontal pivot in the gun support frame at the reservoir end permits elevation of the barrel to facilitate vertical aiming at a target. A spring mounted sabot arrestor (Fig. 3) at the muzzle end completely arrests the sabot, allowing only the packaged bird to continue to the target.

The reservoir and step chamber pressures are monitored by bourdon-tube pressure gauges for pressures above 40 psi (corresponding to 630 ft. /sec. for the four-pound bird) and by mercury manometers for pressures below 40 psi.

4.0 BIRD

Only actual bird carcasses, selected from domestic fowl, are at present being used at the NRC facility.

In preparation for future use, a live chicken is asphyxiated, placed in a plastic bag and immediately stored in a deep freeze (-5° to 10°F). When readying for use, the carcass is removed from storage, allowed to thaw under room temperature for at least 24 hours and then weighed just prior to packaging and impacting. The rectal temperature may be taken prior to packaging for verification that the complete carcass has attained room temperature.

It has been our policy to use chicken carcasses (without packaging) weighing at least the nominal value required with the following tolerances:

Nominal Bird Weight (lb.)	Allowable Limits (lb.)
1	+ 1/8 0 + 1/8
2	0 + 1/4
4	- 0 + 1/2
8	-0

Our experience has shown that the Leghorn breed of chicken, when approaching full maturity, typically lies within the range of the nominal four pound weight. It is more difficult, however, to obtain chickens meeting the nominal one, two and eight pound weights. For our own calibration and preliminary screening shots, it has been found acceptable to meet the weight tolerances by either removing a portion of the carcass or by adding a small amount of jell (98% water and 2% sodium carboxymethyl cellulose by weight). The weight removed from, or added to, the bird carcass has been limited to about 10% of the carcass weight.

Cleaning up the chicken carcass debris has not been found a problem. A wet and dry vacuum cleaner, combined with the occasional water hosing and steaming has yielded both rapid and satisfactory results.

5.0 PACKAGING

For velocities up to 450 ft. /sec., the chicken carcass is inserted head first into a 0.003 inch thick polyethylene bag and the bag is secured with two turns of one inch wide masking tape.

For velocities in excess of 450 ft. /sec., in addition to the polyethylene bag, either one or two cloth bags are placed over the carcass, the open end is secured with a short length of string and the excess bag material is trimmed off. The cloth bags, before trimming, measure five inches in diameter and twelve inches long and are made from either cotton material (5.6 oz/sq. yd. in griegie state) or nylon canvas (6.2 oz/sq. yd). One cotton bag package is used for velocities to 700 ft. /sec. and one nylon bag is used for velocities to 1000 ft. /sec. Two nylon bags are used for packaging when the velocity is in excess of 1000 ft. /sec. The weights of the various packaging materials are as follows :

- polyethylene bag - 13 gm
- cotton bag (untrimmed) - 27 gm
- nylon bag (untrimmed) - 40 gm

A chicken carcass with the packaging material is shown in Figure 4. A packaged chicken carcass being placed into a sabot is shown in Figure 5.

6.0 SABOT

The sabot comprises a welded aluminum container nominally 10 inches in diameter, an aluminum honeycomb filler, and a Mylar sheet insert, Figure 6. Presently, three different container designs are used, for intended velocity ranges of up to 700 ft./sec., 700 to 900 ft./sec., and above 900 ft. /sec. The design parameters of wall thickness, material alloy, and welding are varied in each case to obtain the optimum weight, strength and cost.

The aluminum honeycomb filler acts both as a support for the packaged bird and as an energy absorbent material during arresting of the sabot. By choosing the proper aluminum honeycomb thickness, either a one, two, four or eight pound packaged bird carcass is accommodated, Figure 7.

The 0.010 inch thick Mylar sheet provides a free sliding surface between the honeycomb filler and the packaged bird carcass.

An assembled sabot weighs approximately 3.5 pounds.

7.0 VELOCITY MEASUREMENT

The velocity is measured with an optical-electronic system (Fig. 8) consisting of a wide, narrow beam of light projected normally through the birds' flight path onto a collector lens which focuses the light on a photodiode unit incorporated in an electronic trigger circuit. Two such units are installed 21 feet apart and the successive pulses generated by the birds' passage are counted and recorded on an electronic counter-timer. Two completely separate systems are used, one in the horizontal and the other in a vertical plane, providing redundancy in case of a system malfunction.

One outstanding feature of this system is that at least 50% of the light beam must be obscured before a signal is generated, thus minimizing the chance of a false count being triggered by small stray objects. At the 50% obscuration level a signal is generated within a band of 0.005 inches in width (Fig. 9).

To date this system has proven to be extremely reliable and convenient to use as no adjustment or replacement of parts is required between measurements.

The accuracy of the velocity measuring system is considered to be within 0.5%.

8.0 HIGH SPEED PHOTOGRAPHY

The extent of high-speed film coverage of the bird impact has varied according to the specific requirements of the particular test setup. Typically, two 16mm revolving prism type cameras with either black and white or colour film are used. One camera is used to obtain a general view of the impact and for the verification of the package remaining intact and striking the intended target point (the position is marked with tape for ease of identification when viewing the film). The second camera, used in conjunction with a suitable gridwork background, is strategically located to view more specifically a particular event such as the deflection of the test specimen or spall. Occasionally, a mirror is used as an aid for this purpose.

The present cameras may be operated up to 7000 pictures per second (p.p.s.) but typically they are operated in the range of 4000 to 6000 p.p.s. thereby permitting the use of lower illumination levels and reducing the wear on the camera mechanisms. Timing marks are automatically placed on the film at a rate of either 100 or 1000 per second, to an accuracy of +1%. The synchronization control of the firing sequence is adjusted so that approximately 1/3 of the 100 foot film is used for bringing the camera to the desired speed with the event being recorded on the remainder of the film.

Lighting for the high speed filming is provided by high intensity aircraft lamps and/or long duration (1-3/4 sec.) flood lamps. The aircraft type lamps are switched on manually approximately five seconds prior to firing and have the advantage of reusability as well as for predetermining the illumination levels prior to high-speed photography. The long duration flood lamps are triggered as part of the firing sequence and have the advantage of radiating less heat to the test sample than the aircraft lights.

9.0 FIRING SEQUENCE

The loaded sabot is first inserted into the gun breech (Fig. 10), the Mylar diaphragms are installed on each side of the step chamber, Figure 11, and the step chamber flanges are secured. Both the reservoir and the step chamber are

then charged, maintaining a reservoir to step chamber pressure ratio of 2:1, until the calibrated reservoir pressure is reached. A switch on the control panel (Fig. 12) is then closed, activating an electronic synchronization control for sequencing the operation of the step chamber solenoid valve, the flood lamps, and the high speed cameras. This sequence is predetermined according to the intended impact velocity and the required film speed. With the opening of the solenoid dump valve, the step chamber air immediately bleeds off, subjecting the full reservoir pressure to be felt by the adjacent diaphragm of the step chamber. Since the diaphragms are chosen to burst at about 75% of the reservoir pressure, the reservoir charge bursts each diaphragm in rapid succession and accelerates the loaded sabot down the barrel, the sabot is arrested, and only the packaged bird continues past the timing rack to the target.

The electronic synchronization control initiates the flashing of the flood lamps and the motion of the high speed camera approximately 0.5 seconds prior to the impact. This sequencing ensures that the camera is up to speed when the event occurs.

The operation of the gun is somewhat modified for very low and very high velocity impacts. For very low velocity impacts (below 200 ft./sec.), the loaded sabot is placed 30 feet down the barrel prior to firing thereby reducing the sensitivity of the low reservoir pressure operation. For high velocity impacts (above 1100 ft./sec.), the performance of the gun is extended by installing a third diaphragm at the gun muzzle and evacuating the barrel to approximately 29.3 inches of mercury below atmospheric pressure.

10.0 TEMPERATURE CONTROL

Because the test area (Fig. 1) is maintained at normal room temperature, other methods are used to lower or raise the specimen temperature before impacting.

One method is to cool the mounted specimen with dry ice bags, below the required test temperature. The bags are then removed and the specimen is allowed to warm up to the desired temperature.

Another method is to erect around the mounted test specimen the insulated 8 x 8 x 14 feet long environmental chamber (Fig. 13) and controlling the temperature within the chamber to obtain the desired specimen temperature. By using liquid nitrogen for cooling and electric heaters for heating, the chamber has been used to achieve specimen temperatures of -40°F to 105°F.

When a specimen is of relatively small size and is readily mountable, the specimen can be pre-soaked, prior to mounting and impacting, either in a deep freeze adjacent to the test area or in a 3 x 3 x 3 feet environmental chamber located in an nearby building.

The specimen temperature is monitored by one or more surface and/or internally mounted thermocouples.

11.0 INSTRUMENTATION

The instrumentation, in addition to that related to the gun and camera operation, includes the readout and recording of the outputs of thermocouples and electric strain gauges.

The scale used for measuring the weight of the bird and packaging is a balance type with a resolution of one gram.

The primary method of determining the deflections of a specimen has been through the use of high speed photography with a suitable gridwork background.

12.0 ASSESSMENT OF IMPACT DAMAGE

The assessment of the damage to impacted specimens has in general consisted of spall and penetration determination.

The intensity and distribution of the spall is estimated by suitably positioning a backboard faced with plasticine or aluminum foil backed by styrofoam. The total spall is determined by either the loss in weight of the test panel or by collecting and weighing the spalled fragments.

A specimen is considered penetrated by the bird if a hole or tear, completely through the specimen, is detected by careful inspection with the unaided eye.

13.0 FUTURE DEVELOPMENTS TO THE FACILITY

Although the present capabilities of the NRC Flight Impact Simulator makes it a completely acceptable instrumented impact loading tool, future refinements are being considered which will further improve its operation.

A statistical analysis of the velocity repeatability is planned in the near future, providing useful information for potential users as well as possibly leading to improvements in the velocity predictability.

Other, more economical, sabot designs are being investigated with particular emphasis being placed on their application to very high velocity impacts.

It is also conceivable that future impact programs, with diversified applications, may require the development for using other projectiles and at velocities outside the presently calibrated ranges.

14.0 REFERENCES

1. Noonan, J.W. Aerospace Materials Selection and Verification of Structural Designs, Developed by Means of High Velocity Testing. 16th National Symposium and Exhibit, Vol. 16, Materials '71, Anaheim, California, Paper, Society of Aerospace Material and Process Engineers, April 1971.
2. Noonan, J. W. NAE Flight Impact Simulator.
Heath, J. B. R. National Research Council, Quarterly Bulletin of the Division of Mechanical Engineering and the National Aeronautical Establishment, Report No. DME/NAE 1969(4).

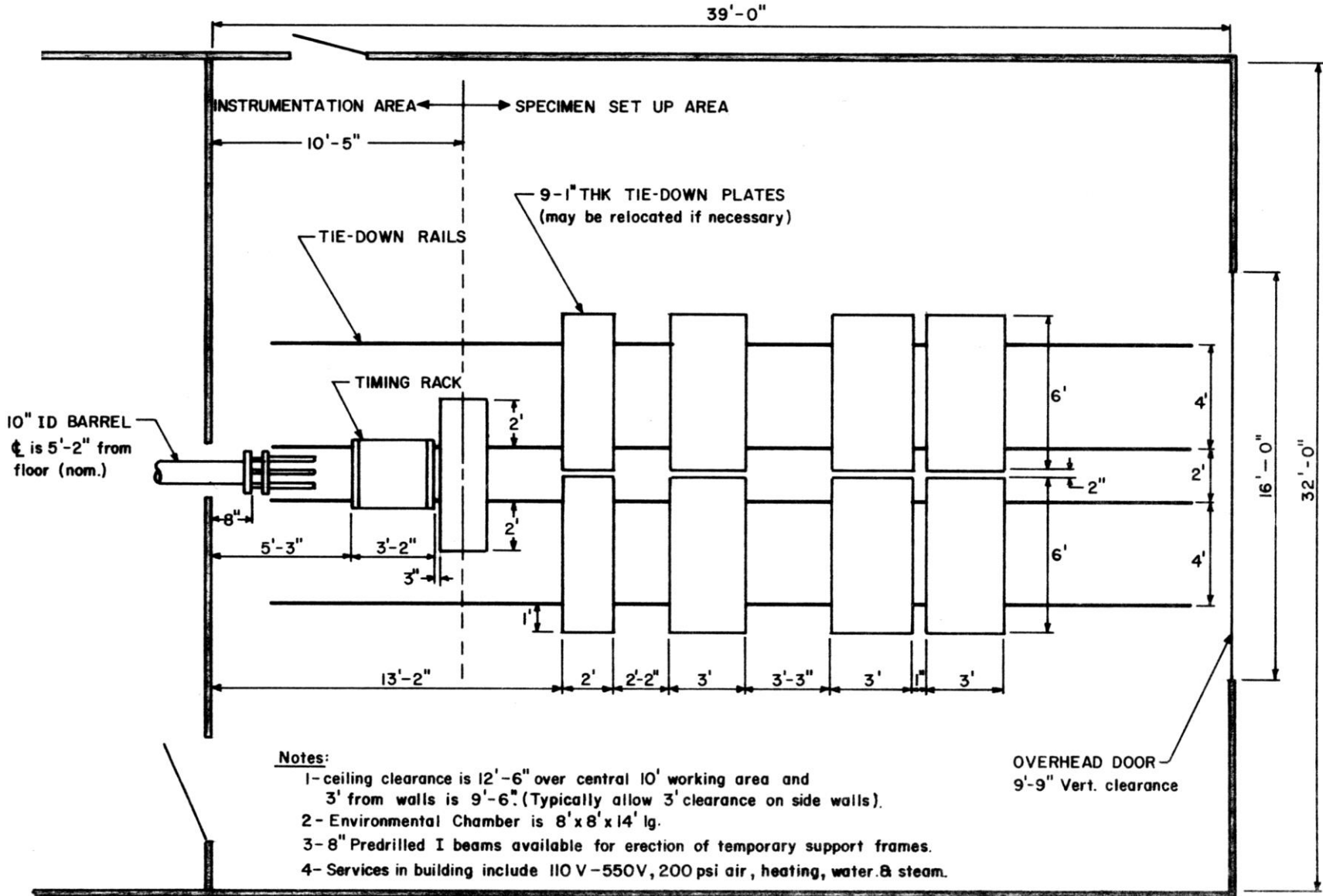


Fig 1. Plan view of the NAE Flight Impact Simulator Test Area (March 1974)

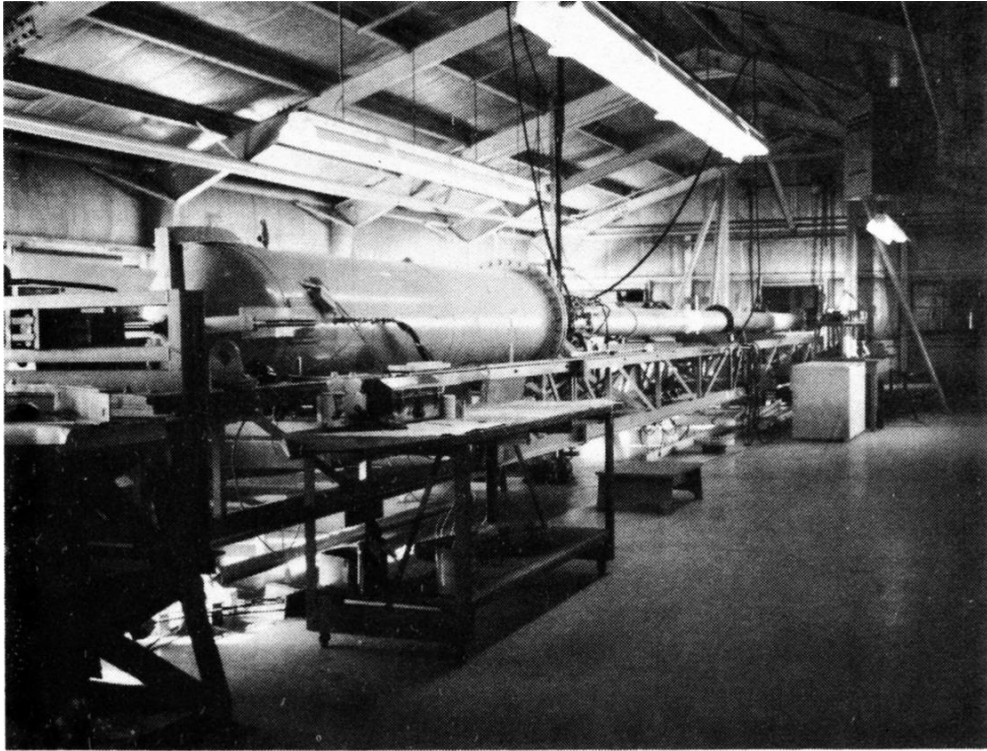


Fig. 2. Compressed Air Powered Gun

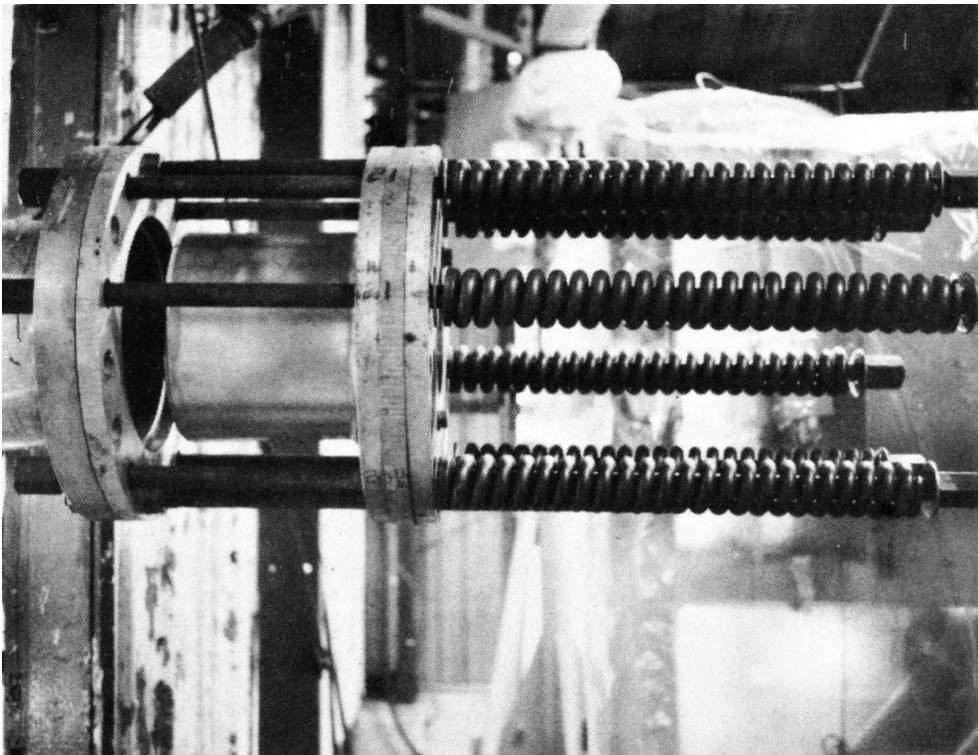


Fig. 3. Sabot Arrestor

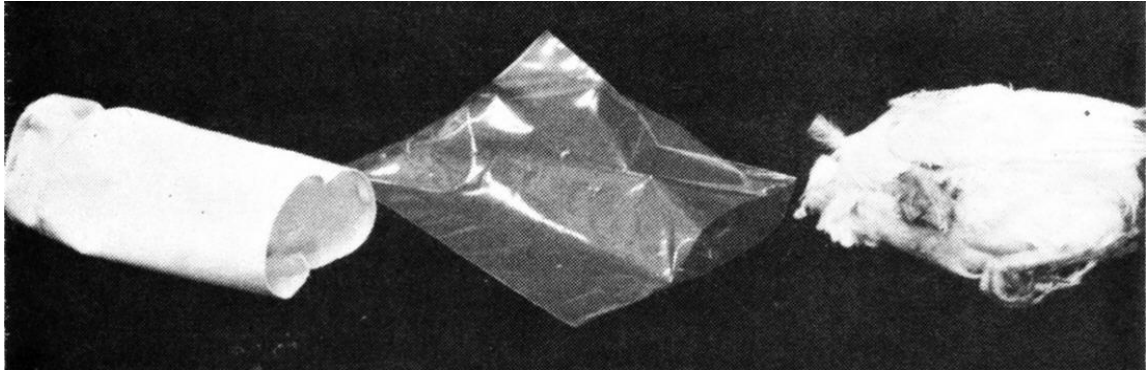


Fig. 4. Bird and packaging material

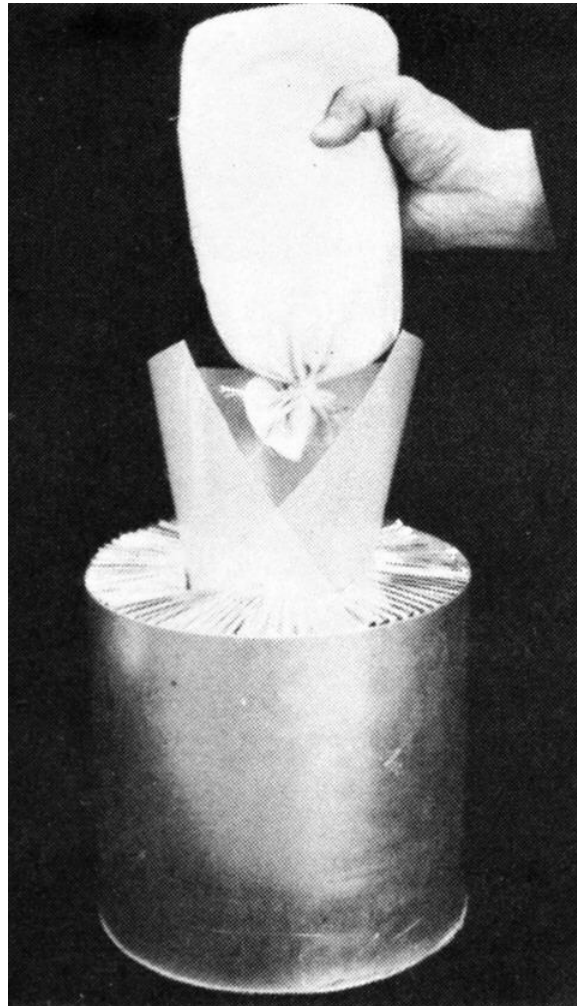


Fig. 5. Packaged bird being inserted into a sabot

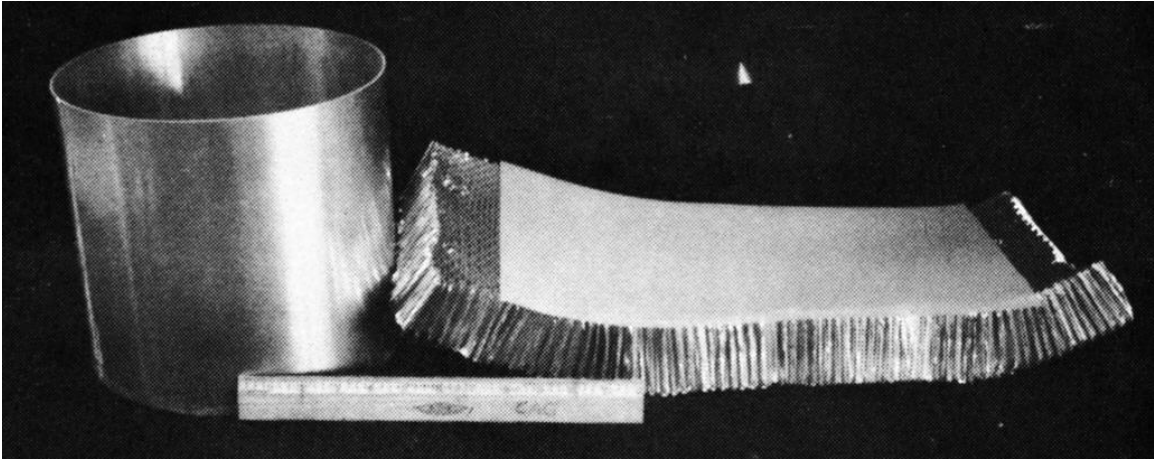


Fig. 5. Sabot components

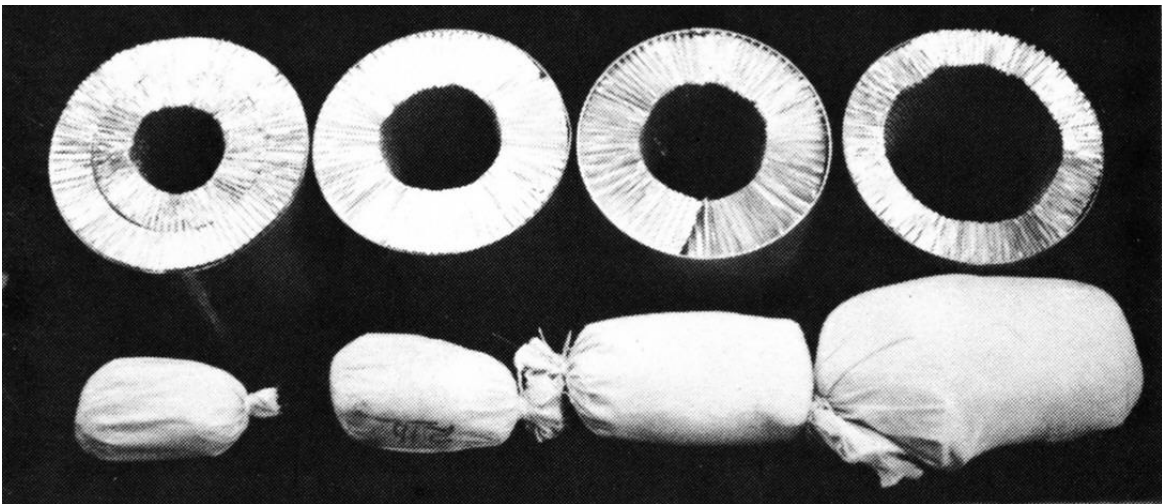


Fig. 6. Assembled sabots for different bird weights (1, 2, 4, 8 pounds)

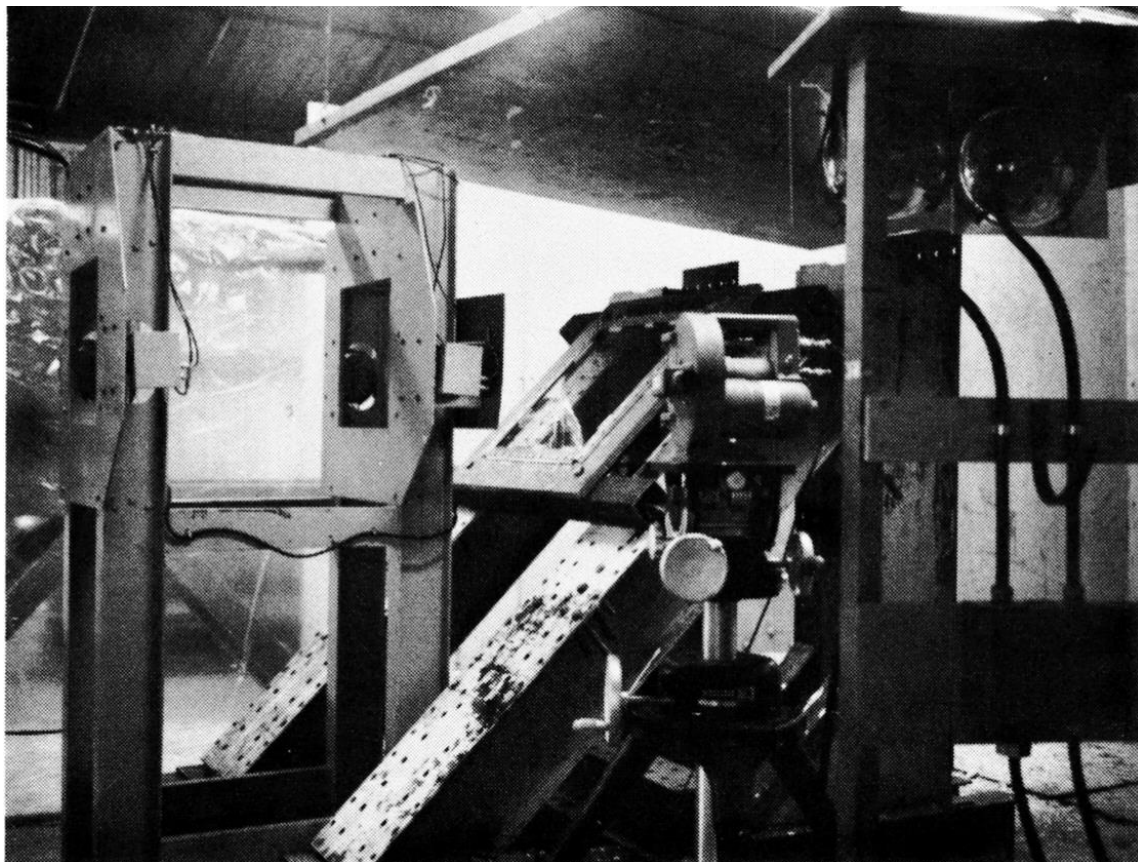
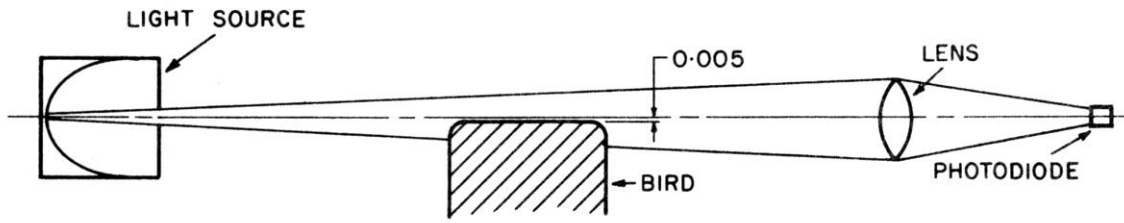
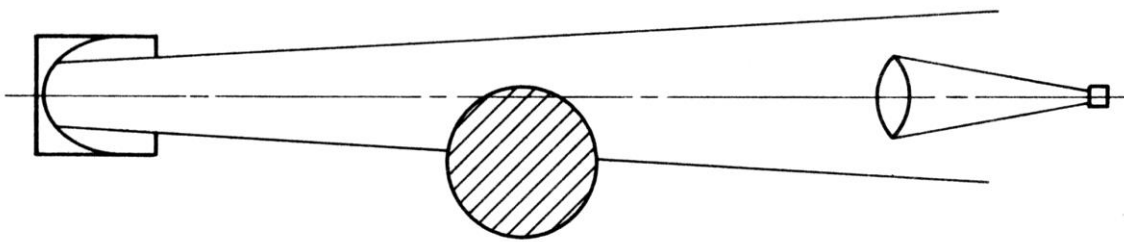


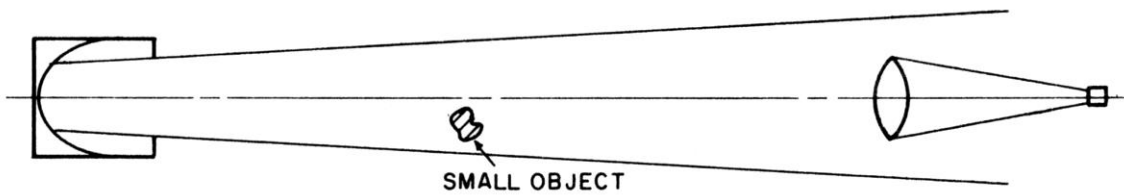
Fig 8. Velocity timing rack (45° support frames, flat panel mounting fixture and Fastax 16mm high-speed film cameras)



(a) TRIP BAND SHOWN IN VERTICAL PLANE



(b) MINIMUM OF 50 % LIGHT OBSCURED TO TRIGGER SIGNAL



(c) LESS THAN 50 % DOES NOT TRIGGER SIGNAL

Fig. 9. Velocity measuring device (operating principal)



Fig. 10. Gun breech (being loaded).

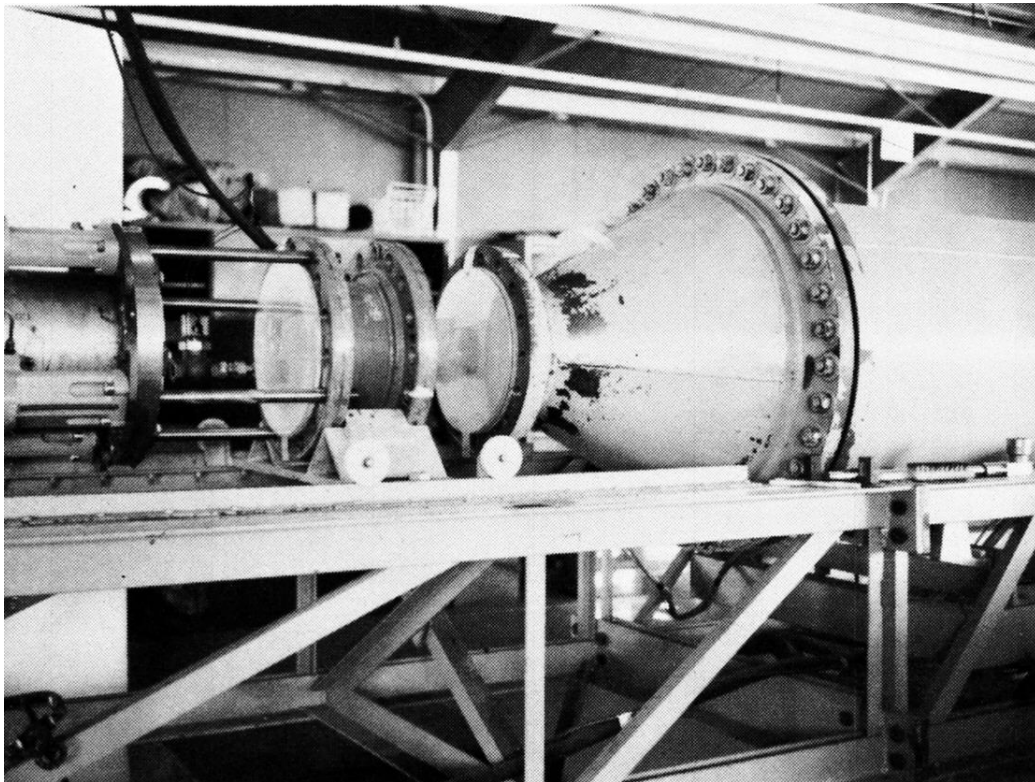


Fig. 11. Step Chamber (diaphragms installed)

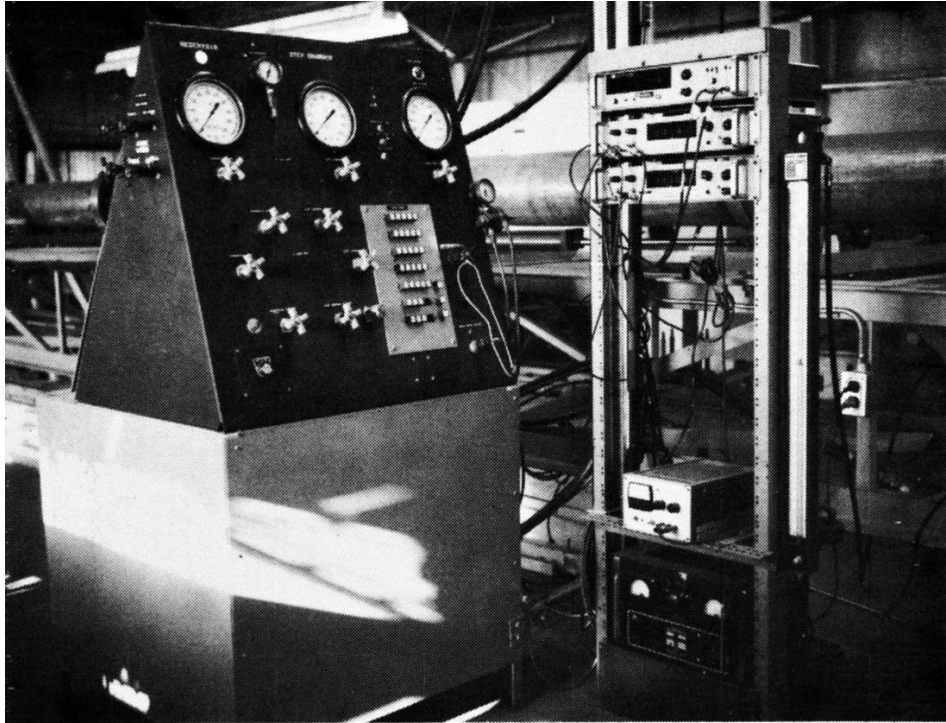


Fig. 12. Control Panel and velocity timer-counters

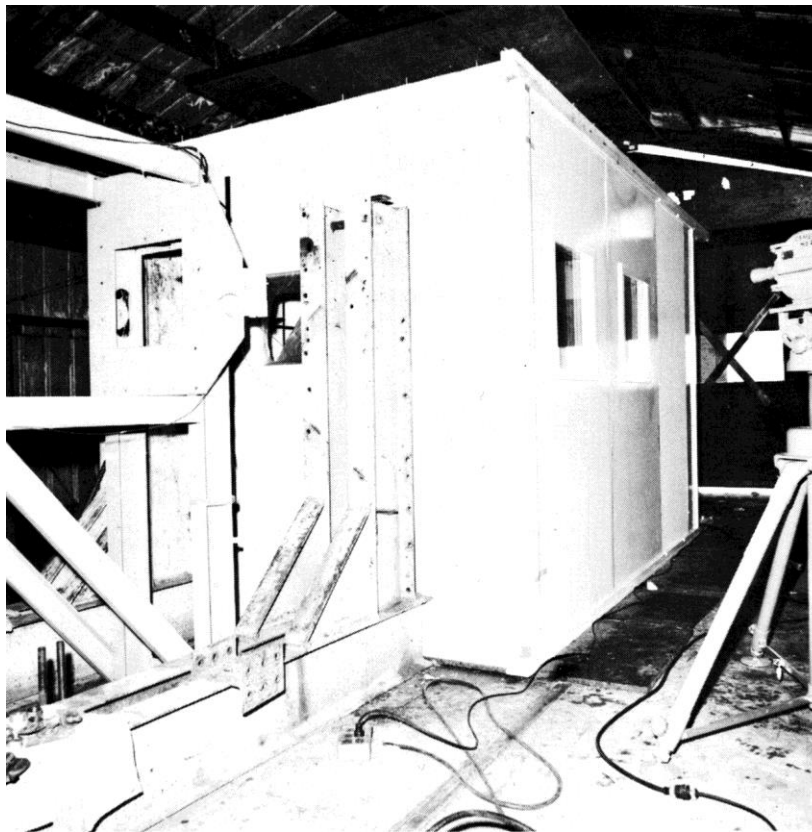


Fig. 13. Erected Environmental Chamber