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Fowler, H. S.; Levy, G. G.

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FIELD NOTE NO. 28

ASSOCIATE COMMITTEE ON BIRD HAZARDS TO AIRCRAFT

A SPECIFIC PROPOSAL FOR BIRD-IMPACT TESTING OF AIRCRAFT PARTS

H.S. Fowler and G.G. Levy

Introduction.

In a previous note* various methods of impacting birds on aircraft parts were discussed. It was concluded that while true simulation could be obtained by placing a stationary bird in the path of a rapidly moving aircraft part ("target"), this was technically difficult and costly. If the impact could be properly simulated by hurling a bird at a static target, this would be a far more convenient and economic method. The present note examines the relative merits of these two simulations, the so-called "sled" (moving target) and "gun" (moving bird) methods.

Comparison of "Sled" and "Gun" techniques.

2.a. Behaviour of Bird.

In the first place, we have to decide whether a bird hung static on a light string and a bird fired from a gun behave in the same way on impact. This depends on two things, the dynamics of the bird, and the qualities which determine its manner of deformation in high rate impact. the projectile dynamics depend on the function MV^2 (where M = projectile mass, and V = relative velocity between projectile and target). Either method is therefore adequate simulation, provided bird weight and relative impact velocities are correct.

The deformation of the bird in high-speed impact is a less simple matter. From careful observation of remains, and the details of damage to structures, it is reported by McNaughtan that the bird behaves as a thick fluid, and in fact "flows" over the surface of the target. This action again depends upon the relative motion of bird and target, irrespective of which one is moving.

It is however necessary to pack a bird in a nylon sack, paper bag, or foam-plastic sabot for gun-firing, otherwise it disintegrates in midair, and it has been argued that the sack or bag alters the impact-"flow" of the bird. It ahs also been suggested that the initial high g-loading on the bird in the gunbarrel might compact it into a layer of homogeneous "pressed meat" at the back of the sack.

However, careful observation of the damage caused, on both vertical metal panels and on sloping windshields and panels, in the UK and the US, has convinced observers that the wrapping does not affect the "flowing" characteristics of the bird on impact. Also, a number of birds have been fished out of a pond after a series of gun-firings in which a target was not impacted, and these were still in bird-like form in their sacks, showing that compaction under firing-g had not occurred. It is therefore concluded that the behaviour of the bird during impact is adequately simulated by either sled or gun experiment.

*(Field Note No. 26)

2.b. Behaviour of Target.

The behaviour of the target in resisting impact is a function of the forces imposed on it, and the resistive strength of the target. The strength of the target is the quality we wish to examine in the experiment, and is assured by using an actual specimen, truly mounted, as a target. It therefore remains to see whether the forces on the target are properly simulated in both tests.

While the energy of the bird in motion relative to the target is represented by 1/2 MV^2 (1/2 x mass of bird x relative velocity^2 of bird), tests* have shown that for penetration of a given windshield, MV^3 is a constant. Thus, provided the bird mass and the relative velocity are both truly simulated, then both projectile dynamics and penetrative criteria will be correct.

We are assuming impact to occur in straight, level constant speed flight. There are therefore no acceleration forces on the target, or by one mounted on a sled moving at constant speed.

The air loading on the aircraft may be high, and apply a stress to it. This is applied truly in the sled test. except that a sled run at sea-level at true velocity to simulate the impact MV^3 requirement will subject the target to a dynamic airloading (o)f 1/2 x density x velocity^2, where the sea-level density experienced will be too high if we wish to simulate an altitude case. It would be possible to blow an airjet over the specimen while using the gun, if calculations of a particular case showed that the air-load stress was of importance compared with the impact stresses. This has not in fact been done to date.

Another factor, of prime importance is the temperature of the specimen. particularly in the case of windshields which incorporate glass and plastic, the strength-temperature relation is very critical, especially as part of the window is often heated during operation.

It is therefore now realized that for windshield tests it is essential to duplicate the proper temperature (and temperature gradients) on the target. While this would be extremely difficult to achieve on a sled running on an outdoor track, it should be a reasonable task on a static target in some sort of enclosure in which radiant and conductive heating could be installed.

In the case of bird-ingestion tests on engines, rather more demanding conditions prevail. In the first place, the size of the larger engines makes it more difficult than ever to put them on sleds. Furthermore, the exact observation of damage which may result in a chain of failures and disintegration of the engine in a matter of seconds is next to impossible unless lights and high-speed movie cameras can be set up around the engine. This makes the gun and stationary-target system almost inevitable. However, it is often considered important to have reasonably true airflow conditions at the engine intake, which implies a flight-speed stream over the nose of the engine. It is thought that this could be adequately simulated when required by putting a shroud round the engine, and using its exhaust jet to induce the required flow over the nose.

The remaining difficulty which has been found in engine ingestion tests is that the blast from a gun fired into the intake at close range(say 20 ft.) can sometimes cause a flame-out on its own. The present writers believe that some form of blast deflector, such as is used on modern military guns, could at least reduce this effect to acceptable proportions.

* Tests by Kangas and Pigman, quoted by McNaughtan (Aircraft Engineering, Dec. 1964).

We may therefore conclude that either sled or gun techniques can give proper simulation of bird impact on aircraft, but that the nature of the target may call for particular auxiliary equipment, such as heater banks over a windshield, or ejector shroud round an engine, etc.

2.c. Instrumentation.

It is easily seen that while the instrumentation of the target is basically similar in both sled and gun tests, the problems of mounting the instruments and recording their output are vastly magnified if the target is to be on a moving sled, acceleration and deceleration at upwards of 5 g and moving over at least half mile of track. The problems of getting high speed still or movie records, with adequate lighting, are also much more difficult in the sled technique.

2.d. Comparison of Costs.

The cost of bird and target specimen are common to both sled and gun techniques, and will not be considered here, beyond saying that a 4 lb. bird, at about $2.00 a shot, is the cheapest part of the experiment, however it is done.

2.d.1. The sled experiment which is delt with fully in Field Note No. 26 previously referred to, - is very roughly estimated as follows, for 400 ft/sec tests. For higher speeds the track length. rocket costs, and general engineering, will rise at least in proportion to the speed.

Track	(half mile length only including brake installation)	$20,000
Sled	(without target, rockets, or instruments)	$ 2,000
Rockets	(4 per run to suit the short track)	$ 1,100/run
Quonset-Hut	for onsite work and storage	$21,000
Instrumentation		$15,000

From which we see a Capital Cost of $58,000, and a Propellant Cost of $1,100 per run. This estimate is, if anything optimistic, and does not allow for bringing electric and road services to the remote rail track site.

2.d.2. Gun tests.

It is understood that the compressed air gun at RAE cost about $10,000, but that certain firms in the UK have built very practical guns for about $5,000.

An estimate of $5,000, including air-compressor and target-mounting, seems adequate.

The recommended firing system, using a diaphragm and a detonator, is likely to cost less than $10 per shot.

A sand and concrete emplacement to mount the gun and protect the target area should cost about $5,000.

The whole installation could be mounted in a large Quonset Hut, for all-weather operation, and to enable the target to be temperature controlled, for an expenditure of $21,000 on the hut.

The gun proposed in the following section is deliberately designed so that for engine-ingestion tests the gun could be moved into an engine test-cell, to use an existing engine test beds.

Instrumentation is again estimated at $15,000. The Capital Cost is therefore estimated at $46,000, with an Operating Cost of $25 per shot, (including bird, diaphragms, plastic sabot.).

Neither Gun nor Sled estimates include wages. The gun method would need far fewer operators, and could be done near an existing laboratory, whereas a sled track is an outstation job, which is always unduly costly.

2.e. Conclusions.

From this above discussion, the present writers conclude that bird-impact tests should be conducted using the gun technique, on the grounds of its greater convenience, lower capital and operating cost, ability to control the target temperature, and ease of recording details of the impact.

3.a. Specific Proposal for a Compressed-Air Gun.

Having studied the features and performance of various guns at present in operation, and the design proposal of Peake (NAE), the writers put forward the following preliminary design of a gun, capable of firing a 4 lb. chicken at 400 ft./sec., using air at 30 psig, or at up to 800 ft./sec. using higher air pressures. The gun is portable to enable it to be placed in an engine test-cell, or in any other firing-bay. A simple blast-arrestor should be incorporated in the muzzle. A general layout of the gun is shown in Fig. 1, with key details shown in Fig. 2. Although the initial requirement is a muzzle-velocity of 400 ft./sec. (270 mph), the gun is to be stressed for use with air pressures of up to 200 psig, which will give a muzzle velocity of over 800 ft./sec., - as shown in Fig. 3. Higher velocities would need a longer barrel.

The gun consists of a 30 ft. long 6" dia. smooth-bore steel tube, mounted in the centre of a light triangular-section girder fabricated of steel tubing. At the breech end, the reservoir is mounted on rollers on a short track, to enable it to be run back for loading. The reservoir is 5 1/2 ft. long x 30" bore steel pipe, with a domed rear end, and carrying a bellmouth nozzle on its front end. This nozzle clamps into the rear end of the barrel by a strong but simple quick-release clamp ring. The gun is fired by splitting a single rupture-diaphragm with a detonator taped to the diaphragm. This system of loading and firing is adopted for reasons of simplicity, strength, and reliability. The clamping-ring breech appears very simple, strong, and easy to manufacture, using only plain turned parts. the use of a single diaphragm and detonator is preferred to the double-diaphragm used in some guns., as being much less sensitive to pressure or diaphragm strength. The present writers also consider the diaphragm and detonator much preferable to the servo-operated cone valve proposed for such a gun, as experience has shown that such valves tend to instability. It is understood that a device of this nature was tried in the RAE gun, and abandoned in favour of the diaphragm system after much fruitless labour.

The operation of the gun is as follows. The gun assembly is lined up to the target by jacking at three support points under the triangular girder frame, with a projector-light in the breech and a cross-wire on the muzzle, to produce an image on the target. The gun is then tied down, using hydraulic dashpots rather than recoil springs.

The reservoir is rolled back to open the breech, the sightline light removed, and the bird in its plastic sabot is loaded. The rupture-diaphragm is put in place behind the bird, the detonator taped on, the reservoir run forward to close the breech, and the clamping ring secured.

Warning signals are run up, the range cleared, and the crew retire to the firing post. The reservoir is then charged to the required pressure, and firing the detonator blows the diaphragm and the bird is shot at the target.

If the detonator should missfire, the compressor is stopped, and the reservoir-pressure released via a remotely controlled dump valve.

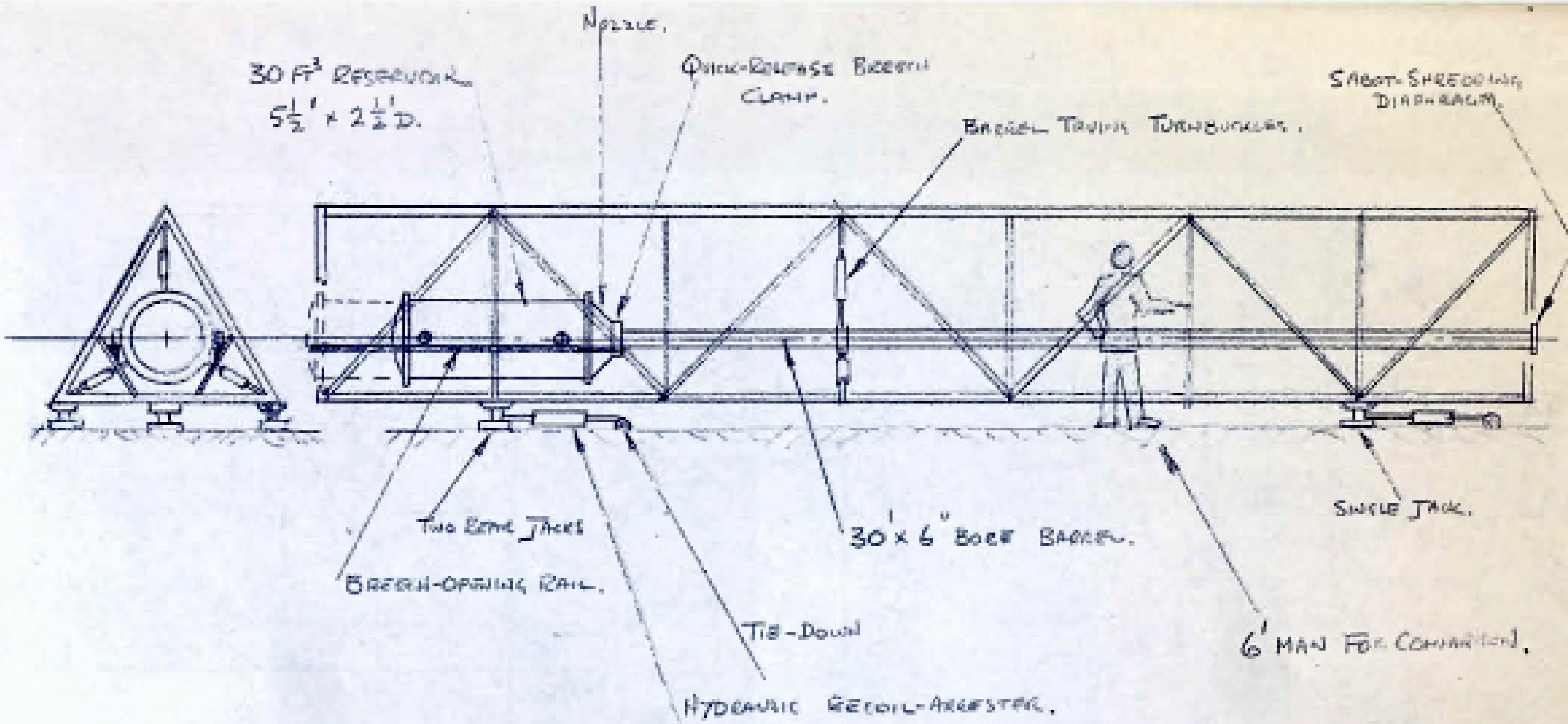
Range danger-signals should be connected in parallel to the air-compressor power supply and a pressure switch in the reservoir, so that both these switches must be dead before the range is "safe".

The estimated cost of the gun system isas follows-

Material for gun	$1200	
Manufacturing labour costs	2500	
Therefore Complete Gun		$3700
Target stand (angle iron structure)		400
Air Compressor (200 psig, 20 ft^3/min)		500
Emplacement		
Concrete wall ($100/$yd^3$)	$2300	
" floor ($65/$yd^3$)	2500	
Sand and earth backing ($2/$yd^3$)	450	
Therefore Complete Emplacement		5250
Quanset Hut to enclose this installation,		
Insulated, heated, lighted, 30' wide, 15' high,		
70' long, floor area 2100 ft2 at $10/$ft^2$		21,000
Instrumentation		
Berkelay Counter - (Muzzle Velocity)		
Oscilloscope and camera - (transient records)		
Two standard movie cameras		
One fastax camera		
Lights, (spot, flood, and Microsec flash)		
Strain gauges, thermocouples		
Self balancinmg potentiometers		15,000
Total Capital Cost		$46,150
Operating Cost		$25 per shot

3.b Conclusion.

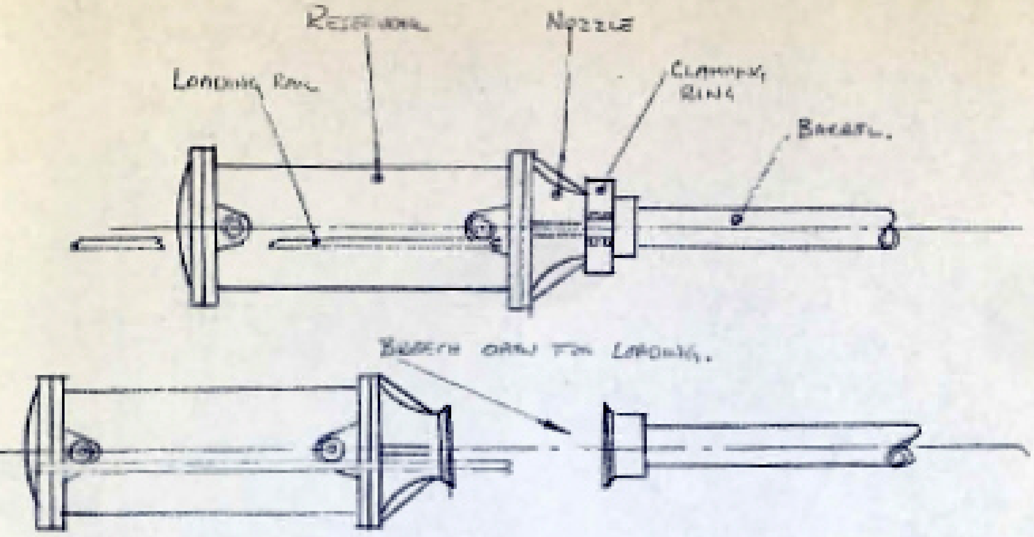
A design for a gun for firing birds at aircraft components has been presented. It is estimated that such a gun installation should cost approximately $46,000, and $25 per shot to operate (excluding crew cost.) The gun is designed for muzzle velocities of 400 ft/sec, but can be operated at up to 800 ft/sec. targets could be temperature-controlled, and the installation operated on a year-round basis.



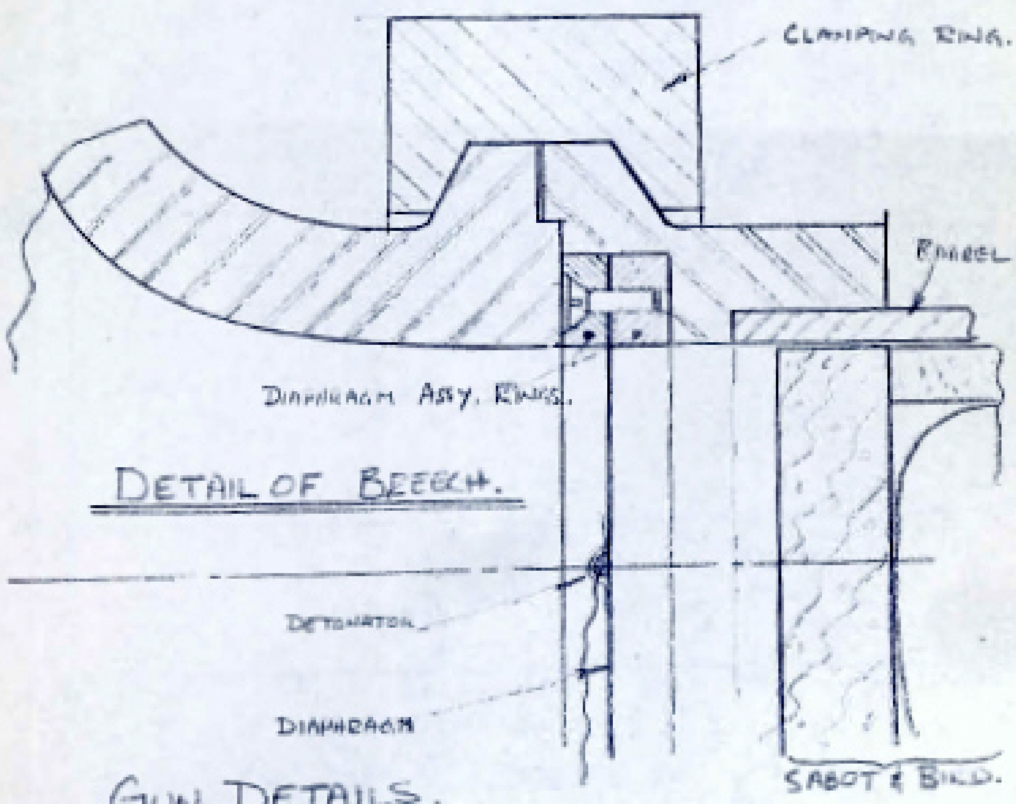
SCALE :- 5' = 1"

LAYOUT OF PROPOSED GUN.

FIG. 1.



LOADING MECHANISM.



DETAIL OF BEECH.

GUN DETAILS.

FIG. 2.