EVALUATION OF IMPACT PROTECTION OF CRASH HELMETS

By

DR. C. A. VERGHESE,* FLT. LT. P. K. GHOSH** AND SHRI B. V. S. SHETTY***

Introduction

Protective helmet development and evaluation have received considerable attention in recent years because of an increased awareness of the role of head injury in accidents. Protective helmet being a complex system inspite of its apparently simple function and construction, requires evaluation of its various aspects. However, the most important function of a helmet is impact protection, *i.e.*, impact received during crash landings and buffeting.

Study of the variables involved in evaluating the impact protection qualities of helmets has been made by Ewing and Irving.[1] A mathematical analysis leading to the requirements of effective protection against concussion is given by Rayne and Maslen.[2] They also give the descriptions of the rigs constructed for the investigation of the dynamics of energy absorbing devices. The two rigs described by Rayne and Maslen and built at R.A.E. include a pendulum rig and a vertical drop rig.

The pendulum rig is similar to that developed by US AF.[3] The US AF tester consists of a pendulum weighing 12.5 lbs. which acts as the impact producing device giving a known impact to an aluminium head form of 9.97 lbs. and recording equipment. Strain gauge accelerometers are mounted in the pendulum and the head.

The R.A.E. vertical drop rig is similar to the one originally developed by the Road Research Laboratory.[4] We have also developed a vertical drop rig similar to the above rig for measuring shock absorption; the details of construction are discussed below.

Description of the Rig

The general arrangement of the test equipment is as in Fig. 1. The protective helmet to be tested is mounted on a head form which is fixed inclined so that when the striking block falls vertically the impact is received on the front side of the helmet which is the most likely site to receive an impact in actual crashes.

The wooden head form is mounted on a piezoelectric load gauge which is fixed on to a concrete base bedded in dry sand. The striker is a 11 lb. wooden block falling freely between two vertical guide wires. The impact shock received by the load gauge is transduced by the piezoelectric crystal amplified and recorded.

* Officer-in-charge, Department of Applied Physics, Institute of Aviation Medicine, Bangalore-17.
** Department of Applied Physics, Institute of Aviation Medicine, Bangalore-17.
*** Department of Applied Physics, Institute of Aviation Medicine, Bangalore-17.

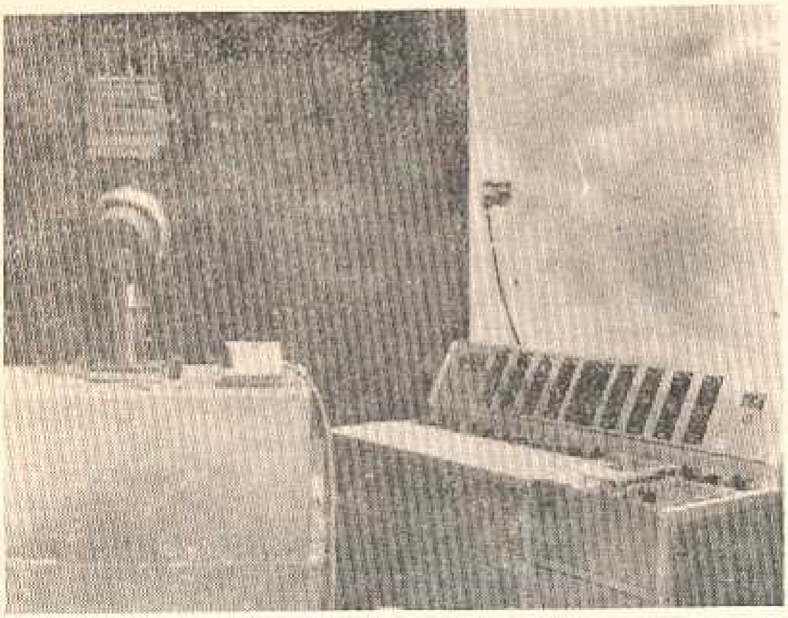

Fig. 1

Striker block is made out of laminated blocks of teak wood (Fig. 2). There are

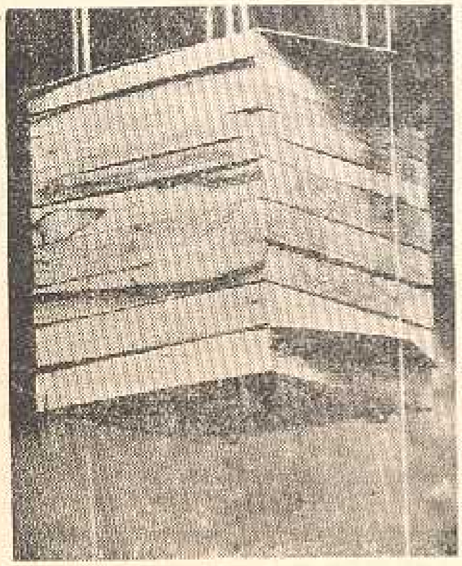

Fig. 2

two brass guide plates which pass through the striker block from one side to the other with two 3/32 inch diameter holes for passing the guide wires of 16 s.w.g. The striker block is suspended by a string passing over a pulley fixed to the roof. The other end of the string is attached to a moveable trolley. The striker block may be raised to any height by adjusting the trolley to and fro. The striker block can be released from any desired height by burning the cord.

A set of wooden headforms made out of teak are made to cover the different sizes of helmet as specified by Road Research Laboratory.[4]

Piezoelectric Load Gauge

Load gauges used for helmet testing should have large value of stiffness so as to keep the deflection of the gauge negligible compared to the material under testing. The minimum value for load gauge stiffness specified is 3×10^6 lbs./inch.[4] It is essential that the gauge should respond to rapidly applied force and the gauge response should be independent of the time of application within 0.1 m. sec. to 100 m. sec. A piezo-electric load gauge is therefore used for this purpose.

The load gauge has a cylindrical mild steel body 3.5 inches in diameter and 8" high so that stiffness is approximately 30×10^6 lbs./inch and the deflection of its upper surface under a uniformly distributed 20,000 lbs. is 0.0007 inch. The details of the gauge are given in Fig. 3. A quartz crystal ¾" square by 1" high is used and is housed in a tunnel bored up from the base of the gauge body No. 1. It is cemented with Araldite to mild steel end caps. The two surfaces of the crystal normal to the electric axis are gold plated, and fitted with fine flexible silver wires in sleeves. The crystal end caps are held in position by steel ball and cone seatings between the upper end of the tunnel and a loading screw (Part No. 9) which is threaded through a plug 6 screwed up against a tapered seating in the tunnel. The leading screw is adjusted to give an initial compressive load on the crystal and locked in position by a nut 11 and the lower end of the tunnel is closed by a second screwed plug 10. The silver wires are passed through an insulated side tunnel.

Shock Absorption Criteria

Current specifications for shock absorption, generally only define the maximum permissible transmitted force using certain standard tests.

In U.K., for various types of crash helmets a maximum force of 5,000 lbs. must not be exceeded in a standard drop test in which a 10 lb. weight, with kinetic energy from 75 to 150 foot lbs. (according to the role of the helmet) is dropped on to a rigidly mounted head helmet assembly.

In U.S.A., the requirement is that when a helmet mounted on a headform is struck with a 11 lb. weight having a kinetic energy of 100 ft. lbs., the acceleration of the striker shall not exceed—

150 g. for more than 4 m. sec.

200 g. for more than 1 m. sec.

400 g. at all

According to Rayne and Maslen,[2] there is little to show what relation these specifications bear to conditions actually obtained in crashes.

It has been shown that the level of linear impact likely to cause concussion to be between 15 ft./sec. & 25ft./sec. velocity change for short impacts. A mean value of 20 ft./sec. is taken by Rayne and Maslen.[4] Taking the weight of the head to be 10 lbs. this will correspond to a kinetic energy of impact of 62 foot pounds.

Kornhauser has used the sensitivity curve method for presenting G tolerance data as applied to man's impact tolerance. This consisted of a plot of Δ V (velocity change) against the accelerations of impact. Such a presentation which is applicable to any mass spring system; animate or inanimate, results in two asymptotes. This will mean that below a certain value of Δ V no damage will occur for any G application. Data from numerous sled tests and falls in the range of 30 to 200 g. which will correspond to whole body tolerances, can be plotted using sensitivity relationship. The average value of Δ V from these tolerance points for high value of G is approximately 45 ft./sec. Δ V of 45 ft./sec. will correspond to a kinetic energy for the head on impact of 320 foot pounds.

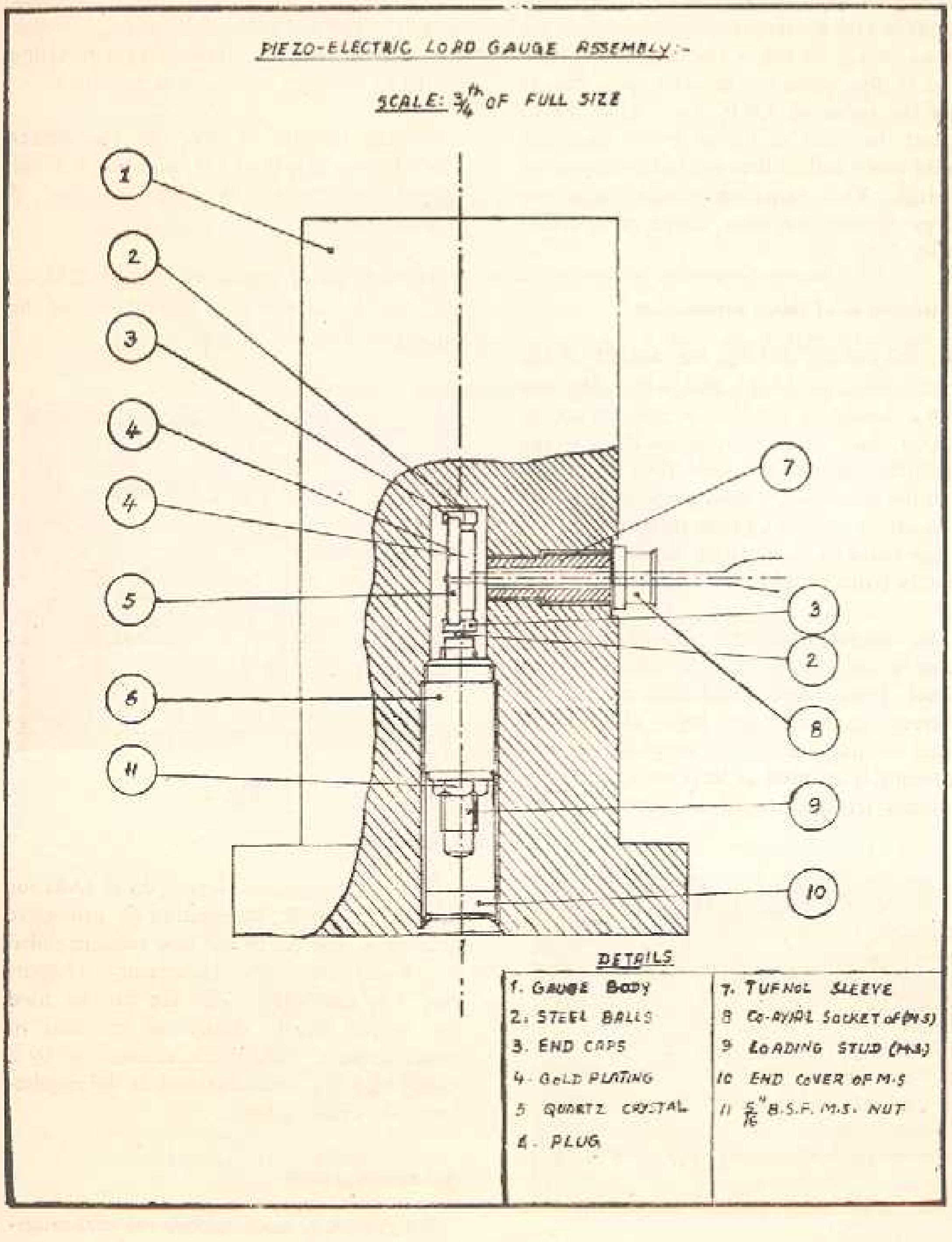
PIEZO-ELECTRIC LOAD GAUGE ASSEMBLY:-
SCALE: 3/4th OF FULL SIZE
1
2
3
4
4
5
6
11
7
3
2
8
9
10
DETAILS
1. GAUGE BODY
2. STEEL BALLS
3. END CAPS
4. GOLD PLATING
5 QUARTZ CRYSTAL
6. PLUG
7. TUFNOL SLEEVE
8 CO-AXIAL SOCKET of (M.S)
9 LOADING STUD (M.S.)
10 END COVER OF M.S
11 5/16" B.S.F. M.S. NUT

Fig. 3

It should seem reasonable to suggest that the protective helmets should attenuate the impact energy to below the concussion level of 62 ft. lbs. when the initial impact energy is of the order of 320 ft. lbs. Attempts to protect the head at higher levels than this would make little difference to the chance of survival. This criterion would mean an energy attenuation by a factor of approximately 5.5.

Measurement of shock attenuation

In the present test rig, the weight of the striker block is 11 lbs. and when dropped from a height of 5.5 ft. will give an energy of 55 ft. lbs. If the drop is made on to the headform fitted with helmet, then the output from the piezoelectric load gauge be less than or equal to the load gauge output when the striker block is dropped on to the headform directly from a height of 1 foot.

The output from the piezoelectric load gauge is fed on to an eight channel Grass Model EEG. The amplifications on the different channels are kept at different values so that linearity in amplification and recording is ensured at least on some of the channels irrespective of a certain degree of variation in the piezoelectric load gauge output. The piezoelectric load gauge output can then be read in millivolts by calibrating the EEG machine with known potentials.

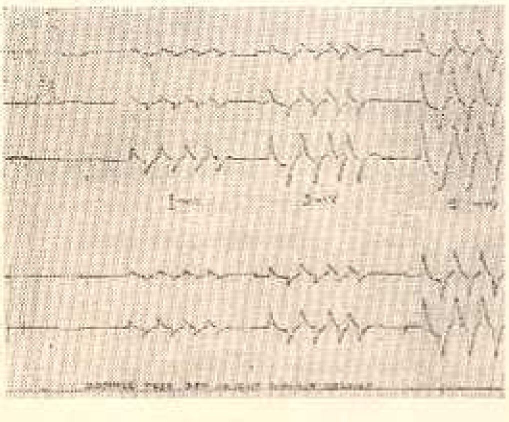

Fig. 4

Typical records of drop of the striker block from a height of 3 ft. with and without helmet is shown in Figs. 4 and 5 respectively.

The calibration signals of 5 M.V., 2 M.V., etc., are also seen next to the records of the impact of Figs. 4 and 5.

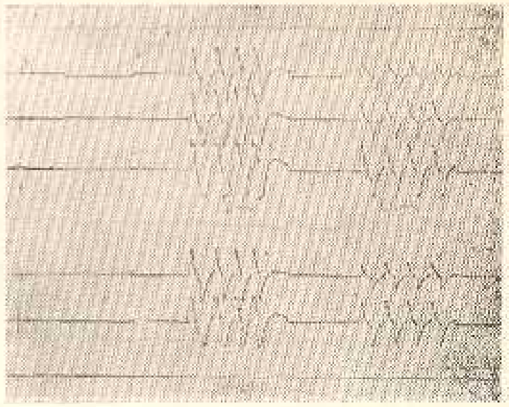

Fig. 5

Conclusion

The test equipment developed at IAM for measuring shock attenuation of protective helmets is similar to the one recommended by Road Research Laboratory (Report No. RN/3290/SJT). The rig can be used for testing shock absorption qualities of crash helmets. The shock attenuation by a factor of 5.5 is recommended as the requirement for crash helmets.

Acknowledgement

We gratefully acknowledge the encouragement and help given by Group Captain

J. H. F. Manekshaw, Officer Commanding, I.A.M. The authors have benefited from discussions with Wg. Cdr. S. K. Mukherjee. Technical help given by Sqn. Ldr. M. Bhaskar Rao and Flt. Sgt. R. K. Pillai is also acknowledged.

References

1. *Ewing, C. L.* and *Irving, A. M.*: Evaluation of head protection in aircraft. Aerospace Med., 40, 596, June 1969.

2. *Rayne, J. N.* and *Maslen, K. R.*: Factors in the design of protective helmets—Aerospace Med., 40, 631, June 1969.

3. *Strand, O. T.*: Protective helmet impact testing equipment U.S. A.F. Tech. Report 5820, May 1949.

4. *Thurlow, S. J.*: Apparatus for testing protective helmets Research note No. RN/3290/SJT, Road Research Laboratory, August 1958.

5. *Thompson, A. B.*: A proposed a new concept for estimating the limit of human tolerance to impact accelerations. Aerospace Med., 33, 1349, Nov. 1962.