A NEW DROP TESTER

By J. E. HOLT, M.E., and D. SCHOORL, B.Agr.Sc.

SUMMARY

A new drop tester, suitable for the impact testing of fruit and vegetable packages, has been designed and built. Extensive experimentation has proven the reliability and repeatability of the machine. The design was based on the following criteria:—

(1) Drop height range 0·5 in. to 4 ft.

(2) Repeatability of impact conditions.

(3) Readily changed severity of impact.

(4) Accommodation of all common fruit package sizes and weights.

(5) Simple and inexpensive construction and operation.

I. INTRODUCTION

There is no doubt that undue proportions of fruit and vegetables are damaged *en route* from grower to consumer. Schoorl has unpublished data to show that the average percentage of bruised apples is 10–15 in tray packs and 15–24 in pattern-packed cases. After a journey of 1,000 miles and six handling operations, tomatoes exhibited an 18% bruising rate and strawberries suffered 97% bruising.

Schoorl and Williams (1973) have shown that a significant part of the bruising suffered by fruit and vegetables occurs due to impacts during handling. They have demonstrated a clear relationship between package type, drop height and the number of drops the package receives.

The study of package design and handling procedures, with the aim of prediction and control of fruit bruising, requires reliable means of package impact simulation. This simulation can readily be performed on a suitable drop tester.

A drop tester for use in this packaging field needs to satisfy the following conditions.

(1) *Drop height range.*—Schoorl and Williams (1973) reported on a critical minimum drop height of 2 in. which produced bruising in apples. For other fruits it is likely that lower critical heights exist. At the other end of the range it has been found necessary to drop packages through 3–4 ft in order to fully illuminate the relationship between impact and bruising. On these bases a drop height range of 0·5 in. to 4 ft is desirable.

(2) *Package size and weight.*—A package size 24 in. long, 15 in. wide and 12 in. high must be provided for and a maximum package weight of 100 lb expected. Further, any means of supporting, locating or holding the package prior to impact must not alter the conditions within the package.

(3) *Repeatability of impact conditions.*—In order to compare the performance of packages under impact they must be subjected to the same shock conditions. The package must be dropped in a reproducible manner, either flat or at any desired angle, with the fruit in its normal position. The drop machine must be sufficiently robust to withstand repeated impacts without wear so as not to alter the shock conditions.

(4) *Variable severity of impact.*—It is necessary to be able to change the nature of the shock so that the effects of dropping packages on different surfaces (concrete, wood, earthen floors, etc.) may be investigated.

Many different types of machines are currently in use for impact testing of packages. Several exhibit major limitations as regards the drop tester requirements previously described.

Guillou, Sommer and Mitchell (1962) reported on a drop impacter consisting of a cam-operated master container into which the package is inserted. The container travels through an arc, thus giving undesirable horizontal motion. Further, no provision is made for variable severity of impact.

Stam (1970) described a drop tester in which the package is supported by arms which fall and separate when dropping the package. Major limitations are the minimum drop height of 30 cm and the inability to prevent rotation of falling unguided packages.

Drop testers in common use in laboratories such as those of PIRA (Leatherhead, U.K.) also employ the free-falling package arrangement and suffer from the last-mentioned defect. These testers use a variety of quick-release mechanisms such as hooks, collapsing leaves and spring-loaded arms.

Gordon and McPhail (1969) described a dropping rig where the package is held at the sides by pads which release just before package impact. These pads necessarily deform soft packages and hence alter internal conditions.

One of the authors (Schoorl) recently visited the Michigan State School of Packaging which uses a drop tester where the package is supported on a rail-guided platform. A shock programmer provides for variable impact conditions. This drop tester, supplied by M.T.S. (Monterey), while fulfilling the requirements listed in the previous section, was considered too complicated and costly for our purposes of fruit package testing.

II. DESCRIPTION OF NEW DROP TESTER

A new drop tester has been designed and constructed in the Mechanical Engineering Laboratories of the University of Queensland. The initial design was carried out under the authors' supervision by three final year Mechanical Engineering students, Messrs. Cusack, Kahler and Whitmore. Development and extensive testing has resulted in a machine of proven reliability and repeatability. The drop tester is shown in Figure 1.

The package is supported on a rigid platen guided down by rails onto a solid rubber shock programmer. An arrester mechanism prevents secondary impacts. The platen is raised to the required height using a manual winch, and a simple quick-release mechanism provides safe and repeatable drop conditions. The major components of the machine will be briefly described.

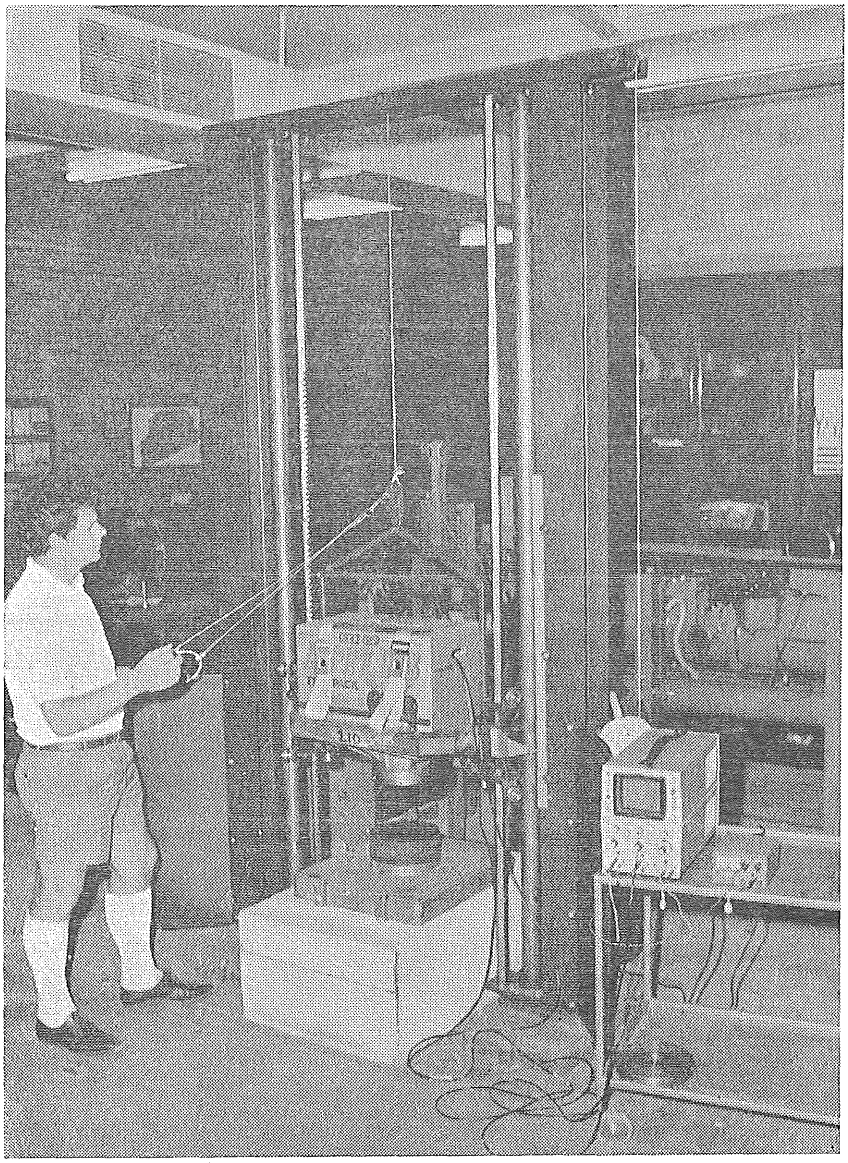

Fig. 1.—General view of the drop tester.

The platen is designed to give rigid support to the package during impact. A webbed construction in spheroidal graphite cast iron provides this rigidity without an excessive weight. The base of the platen consists of a heavy steel insert associated with the shock programming of the machine. The platen can accommodate packages 61 cm long, 43 cm wide and 43 cm high. The package is held firmly in place on the platen by means of automobile safety belts.

B

Impact conditions of differing severity are obtained by using an extremely simple and effective technique. A thick unconstrained rubber block cushions the impact of the platen. The base of the platen can be fitted with interchangeable steel inserts, each of which has the bottom face machined to a different spherical radius. The smaller this spherical radius the less severe is the deceleration or impact. The hardness of the rubber block also affects the severity of impact.

The platen is guided by rollers running on vertical rails. The rails are precision straight steel tubing accurately set up and dowelled in the vertical position. The rollers consist of standard ball bearings mounted on eccentric shafts which allow initial alignment of the platen. The large vertical spacing of the rollers minimizes fore and aft and sideways tilt of the platen. In addition, if sideways tilt does occur the rail and roller system subjects the platen to a restoring torque.

A rack and pawl arrangement is used to arrest the platen at the top of the free rebound, thus preventing secondary impacts. Two spring-loaded horizontal pawls are released on impact and contact two vertical racks, one on each side of the platen. The shape of the pawls allows free upward movement of the platen but ensures positive engagement at the top of the rebound. When the platen is again supported by the hoisting wire the pawls are reset by cocking levers ready for the next drop.

The drop tester is mounted on a concrete block weighing approximately 3·2 tonnes which is isolated from the surroundings by expanded cork inserts. The cork inserts have been designed to damp out high frequency vibrations, while the concrete itself acts as a seismic mass in absorbing the relatively small frequency low impact energies involved.

Records of rebound height, or more accurately arrested height, for over 1,500 individual drop tests afford a direct and reliable measurement of reproducibility. For each drop height used the corresponding arrested height was remarkably consistent at the 95% level. For the remaining 5%, variations from the normal did not exceed one rack spacing (approximately 19 mm).

As a further check on the reproducibility of the machine acceleration, measurements have been made on the platen and inside the fruit pack. These preliminary readings show satisfactory repeatability of behaviour in terms of peak acceleration and rise time.

III. EXPERIMENTAL RESULTS

Package drop testing studies have been conducted on two varieties of apples (Jonathan and Delicious), on pears and on strawberries. As an example, the experiment design for the Jonathan trial was as follows.

Packaging.—Tray pack cartons, pattern-packed cases

Height and number of drops.—

Height (in.)	No. of Drops
6	1, 3, 9, 27
12	1, 3, 9, 27
18	1, 3, 9
24	1, 3
48	1

Each drop treatment was duplicated giving a total, for this experiment, of 392 drops involving 56 packages. Four packages of each type were set aside as controls for bruise assessment before dropping.

The detailed results of this experiment, together with the results of trials on Delicious apples and pears, are reported by Schoorl and Williams (1973).

IV. CONCLUSION

Extensive testing of the drop tester has shown that the machine is suitable for fruit package impact testing. It overcomes major weaknesses apparent in most drop testers in current use. Its robustness and repeatability have been demonstrated.

V. ACKNOWLEDGEMENTS

The authors are indebted to Messrs. P. Cusack, R. Kahler and J. Whitmore, final year students in Mechanical Engineering in 1971, for their work on the initial design of the machine. Thanks are also due to the staff of the Mechanical Engineering Laboratories, in particular Messrs. D. Duncan, G. Dick and G. Dodd.

REFERENCES

GORDON, G. A., and MCPHAIL, A. (1969).—A dropping rig for carrying out controlled flat and edge drops. *PIRA Internal Report* No. 15.

GUILLOU, R., SOMMER, N. F., and MITCHELL, F. G. (1962).—Simulated transit testing for produce containers. *Tappi* 45:176-9.

SCHOORL, D., and WILLIAMS, W. T. (1972).—Prediction of drop-testing performance of apple packs. *Qd J. agric. Anim. Sci.* 29:187-97.

SCHOORL, D., and WILLIAMS, W. T. (1973).—Robustness of a model predicting drop-testing performance of fruit packs. *Qd J. agric. Anim. Sci.* (in press).

STAM, R (1970).—De technische uitrusting van een verpakkings—laboratorium. *T.N.O., Delft.*

(Received for publication November 1, 1972)

Mr. J. E. Holt is a Lecturer in Mechanical Engineering at the University of Queensland, Brisbane. Mr. D. Schoorl is an officer of the Horticulture Branch, Queensland Department of Primary Industries, stationed at Redlands Horticultural Research Station, Ormiston.