extremely brittle substance and the large strength variation (Figs. 3 and 4) is consistent with the theory of brittle solids proposed by Griffith (13). Dollimore and Gregg (14) have shown that the ratio of the theoretical strength, R_m, to the practical strength, R, is given by:

$$\frac{R_m}{R} = \left(\frac{\pi c}{a}\right)^{\frac{1}{2}}$$

where a is the range of the attractive forces, and $2c$ is the length of a crack in the brittle solid. Taking $a \approx 3 \times 10^{-8}$ cm., and $c \approx 1 \times 10^{-4}$ cm., then a crack of only 2 μ in the binder would cause a 100-fold reduction of strength. The strength of the granules would also be expected to vary due to irregularities in their shape and the presence of localized powder or binder voids.

CONCLUSION

Griseofulvin can be granulated by the bowl method and the strength of the granules formed has been shown to be dependent on both their size and on their PVP content.

It appears to be more difficult to prepare smooth, rounded granules with good flow and storage characteristics from the fine grade than from the coarse grade, although the former is preferred for therapeutic reasons.

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Keyphrases

Griseofulvin
Granulation, griseofulvin—bowl, dish methods
Polyvinylpyrrolidone solution—binder
Granule strength, porosity, sizing, flow rate
Density, bulk, tapped—granules
Centrifugal force—granule diameter
Pendular bond strength—particle size

"Crushing-Strength" of Compressed Tablets I

Comparison of Testers

By DAVID B. BROOK and KEITH MARSHALL

By means of a piezo-electric force transducer the actual compressional load exerted at certain scale readings by four types of commercially available "crushing-strength" instruments has been determined. The results indicate that variations in crushing-strength values between instruments are due in part to inaccuracies in instrument scale values, zero errors and varying methods of applying the load. Calibration is therefore necessary for accurate measurements using one instrument or when comparing results from more than one tester.

THE MECHANICAL strength of medicinal tablets is an important property of this form of drug presentation and plays a significant role in development and control procedures. It has been described by various terms including "fracture resistance" (1), "friability" (2), "hardness" (3), "bending strength" (4), and "crushing-strength" (5). Measurement of the latter is probably the most widely used technique and may be precisely defined as "that compressional force which, when applied diametrically to a tablet, just fractures it." In most cases the tablet is placed upon a fixed anvil, and the force is transmitted to it by means of a moving plunger.

Crushing-strength is widely employed in commercial production as a control procedure and has been compared by several authors with other properties of the tablet (5–9). Many individual instruments for crushing-strength determinations have been described (3, 9–12) and comparisons between commercially available testers made (3, 11, 13).

In the present investigation a comparative study, against an absolute standard has been made on four commercially available instruments, "Strong-Cobb," "Monsanto," "Pfizer," and "Erweka" hardness testers.

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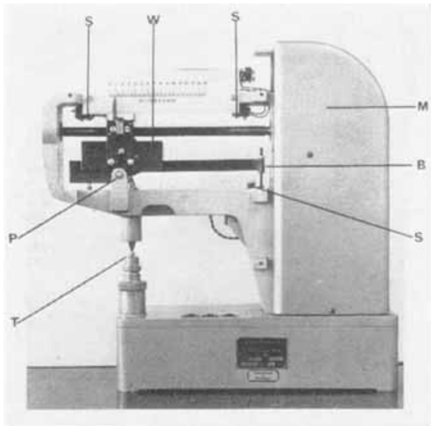

Fig. 1—The Erweka tablet hardness tester, type TBT. (Cover and attached zero light removed.) Key: B, beam; M, motor housing; P, beam pivot; S, microswitch; T, tablet; W, sliding weight.

The first three of these testers are adequately described elsewhere (3, 11, 12). In the "Erweka" tablet hardness tester (type TBT) the compressional force is applied by a loaded beam. The loading is produced by a sliding weight moved along the beam by an electric motor, which is stopped automatically, immediately the tablet fractures (see Fig. 1). The initial zero position is indicated by a red warning light. Hence, errors associated with a nonuniform rate of loading and varying zero adjustment are minimized. A recent report (14) using this instrument suggests that a more realistic test is to apply the force axially to the tablet, a procedure suggested by other authors (1) for the Strong-Cobb hardness tester.

In fact almost all the published work on the crushing-strength of tablets refers at some point, to discrepancies between readings obtained by different techniques. The work described endeavors to correlate results and explain the observed variations in crushing-strength values.

EXPERIMENTAL

Calibration of Force Transducer—In order to ascertain the absolute load transmitted to a tablet by the four instruments at certain scale readings, a small load washer was substituted for the tablet. The transducer employed (Kistler, type 901A) was based on the piezo-electric effects of a quartz crystal. Compressional loads on these cause a re-orientation of electrons within the crystal, giving rise to an electrostatic charge on it. The transducer was coupled to a piezo-charge amplifier (Kistler, type 568) which precisely converted this charge into a voltage output signal which was registered on a digital voltmeter (Weyfringe, type 4NP).

Although conversion data were supplied with the transducer, it was felt desirable to calibrate the instrument accurately over the intended range of loading. This was carried out by two methods: (*a*) by placing known weights at fixed distances from the fulcrum of a simple, freely pivoted beam (illustrated diagrammatically in Fig. 2) which rested on one of the transducer's sensitive surfaces, and (*b*) using an accurate compression/tension testing machine (Instron, floor model TT-C).

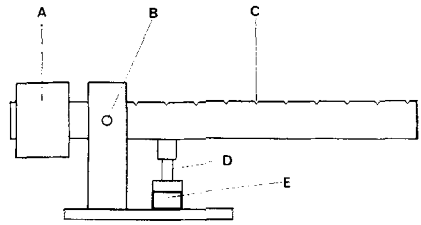

Fig. 2—Diagram of simple beam used to calibrate the load transducer. Key: A, counterbalance weight; B, beam pivot; C, beam graduated in exact 2-cm. divisions; D, plunger fixed to beam and resting on transducer surface; E, load transducer.

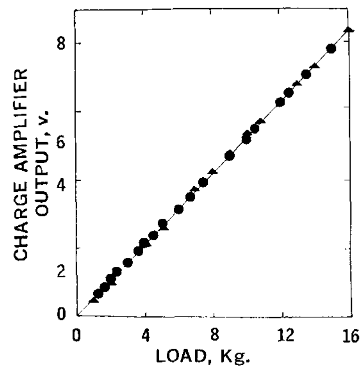

Fig. 3—Calibration curve for load transducer. Key: ●, reading obtained by loaded beam; ▲, reading obtained on Instron testing machine.

The results summarized in Fig. 3 indicated that the relationship between compressional load and voltage output was substantially linear over the range tested; *i.e.*, compressional load (Kg.) was equal to 1.925 $\times$ voltage output. This relationship was used in the subsequent experiments.

Calibration of Instrument Scales—The four testers were then taken in turn and with the load transducer in place of a tablet, loads were applied to fixed scale intervals, the resulting voltage being noted. Each series of readings was repeated to give a total of 25 at each level of loading. The arithmetic mean of these was then converted into Kg. using the above relationship. The values obtained are plotted against instrument scale readings in Fig. 4. Calibration values were only obtained up to actual loads of about 15 Kg. since in normal use the testers are unlikely to be operated beyond this point.

The Monsanto hardness tester is probably the most well known and it was therefore decided to compare five instruments of this type to ascertain the individual variation. In addition to the tester in the authors' laboratory, three new testers were donated by the manufacturers and a well used instrument was obtained from an industrial source. The results of calibration tests similar to those described above on these testers are given in Table I and Fig. 5.

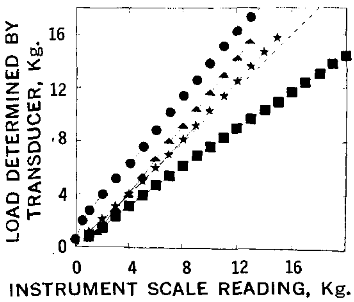

Fig. 4—Relationship between instrument scale reading and actual load being exerted as determined by load transducer. Key: ●, Erweka tablet hardness tester; ▲, Pfizer tablet hardness tester; ★, Monsanto tablet hardness tester; ■, Strong-Cobb tablet hardness tester. Dotted line is theoretical ideal of slope one.

TABLE I—RESULTS OF CALIBRATION BY LOAD TRANSDUCER OF FIVE MONSANTO TABLET HARDNESS TESTERS

Monsanto Scale Reading (Kg.)	Load in Kg. Determined by Transducer				
	A[a]	B	C	D	E
1	1.100	0.960	1.009	1.125	0.820
2	2.263	1.974	2.000	2.086	1.528
3	3.050	2.983	3.157	2.981	2.599
4	4.220	4.140	4.299	3.976	3.451
5	5.370	5.370	5.493	4.997	4.624
6	6.720	6.623	6.680	5.966	5.518
7	7.890	7.853	7.918	7.024	6.527
8	8.970	8.950	9.087	8.171	7.530
9	10.150	10.193	10.221	9.200	8.511
10	11.362	11.461	11.440	10.222	9.507
11	12.625	12.734	12.671	11.422	10.519
12	13.902	13.950	13.943	12.530	11.693
13	15.180	15.117	15.250	13.595	12.796
14				14.634	13.799
15				15.705	14.696
16					15.797

[a] Testers A, B, and C were new. Tester D had been used in the authors' laboratory for 3 years and tester E was a well used instrument obtained from an industrial source.

DISCUSSION

The results shown in Figs. 4 and 5 indicate discrepancies between the load as registered on the instrument scales and the actual load as determined by load transducer. The graphs approximate to straight lines over most of the range studied, and it is therefore convenient to utilize the slopes S (which were determined graphically) of these plots as a means of comparison with the ideal line of slope one. Since all lines should ideally pass through the origin, S is the correction factor necessary to adjust instrument scale readings so that they lie on the theoretical line.

Strong-Cobb—This tester registers the air pressure required to crush the tablet and has a scale graduated in Kg./sq. in. Comparison with other results is therefore only possible if these readings are converted to compressional load in Kg. The manufacturer of the instrument specifies a conversion factor based upon piston dimensions of 0.780. In this investigation the value of S was found to be 0.728 and Table II gaves the values of instrument scale readings corrected by this factor.

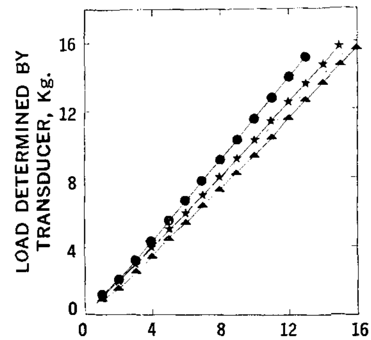

Fig. 5—Relationship between instrument scale reading and actual load being exerted as determined by load transducer for 3 Monsanto testers. Key: ●, Monsanto A (new); ★, Monsanto D (authors); ▲, Monsanto E (well used). Dotted line is theoretical ideal of slope one.

TABLE II—COMPARISON OF CORRECTED SCALE VALUES FOR CRUSHING STRENGTH AND ACTUAL LOAD EXERTED BY STRONG-COBB AND ERWEKA TABLET HARDNESS TESTERS

Strong-Cobb		Erweka	
Actual Load (Kg.)[a]	Corrected Scale Reading (Kg.)[b]	Actual Load (Kg.)[a]	New Scale Reading (Kg.)
0	0		
0.650	0.728	0.493	0.500
1.508	1.456	2.033	2.000
2.369	2.184	2.689	2.700
3.147	2.912	3.918	4.000
3.919	3.640	5.154	5.200
4.722	4.368	6.271	6.250
5.438	5.096	7.515	7.500
6.201	5.824	8.728	8.750
6.905	6.552	10.090	10.000
7.616	7.280	11.314	11.300
8.311	8.008	12.503	12.500
9.003	8.736	13.742	13.750
9.702	9.464	15.108	15.000
10.395	10.192	16.048	16.000
10.910	10.920	17.260	17.250
11.748	11.648		
12.499	12.376		
13.095	13.104		
13.800	13.832		
14.536	14.560		

[a] Actual loads determined by load transducer. [b] Scale reading × 0.728.

Monsanto—The results for these testers appear to indicate that the springs applying the load become fatigued with prolonged use, *i.e.*, S values falling, although when new they exert loads which are consistent but in excess of the scale reading.

McCallum, Buchter, and Albrecht compared the Monsanto and Strong-Cobb hardness testers and calculated a conversion factor of 0.625 for Monsanto to Strong-Cobb units (3). The results reported here gave a factor of 0.627 (new Monsanto) and 0.697 (well used).

Pfizer—This tester was found to exert loads in excess of the scale readings (S value 1.260), and since the instrument was comparatively new it is probable that, as with new Monsanto testers, the spring does not match the scale graduations initially. In addition it was noted that at loads below 3.0 Kg. the load was less than the scale reading, probably due to frictional losses.

TABLE III—DIFFERENCES IN TABLET HARDNESS TESTER CONSTRUCTION WHICH MAY CONTRIBUTE TO VARIATION IN CRUSHING-STRENGTH VALUES BETWEEN INSTRUMENTS

Loading Mechanism	Monsanto Coil Spring	Strong-Cobb Hydraulic Pressure	Pfizer Coil Spring	Erweka Loaded Beam
Scale length/Kg.	0.3 cm.	0.79 cm.	0.88 cm.	0.935 cm.
Scale graduated in:	1.0 Kg.	0.728 Kg.[a]	0.2 Kg.	0.25 Kg.

[a] One scale unit is equal to 0.728 Kg.

Erweka—Examination of this tester revealed a zero error because at the moment the zero warning light became activated the instrument was already exerting a load of about 0.5 Kg. Furthermore, as soon as the sliding weight began to move along the beam there was a sudden increase in load to about 1.4 Kg. Subsequent increase in loads of one scale division resulted in an increase in true load of 1.211 Kg.

The initial errors were traced to an incorrect zero adjustment and frictional losses in the pivot. Utilizing the principle of moments it was possible to calculate the theoretical load from the known scale dimensions (0.935 cm./division) and the magnitude of the sliding weight (1.925 Kg.). The distance of the plunger from the fulcrum was accurately measured as 1.425 cm. From these readings a value of 1.262 Kg./scale division was obtained. The difference between this and the observed reading (1.211 Kg./scale division) was thought to be due to frictional effects.

From these experiments a true zero position was attained by adjustment of the zero light trip switch position and a new scale was constructed. These modifications were entirely successful in producing true response to actual loads (see Table II).

Krowczynski (13) compared the Monsanto and Erweka hardness testers and found that the results from the two instruments differed widely. This author calculated a conversion factor of 1.6 for Erweka to Monsanto units. In the present investigation it was impossible to determine such a simple factor because a large constant zero error in the Erweka tester results in a factor which increases as the crushing-strength values decrease. This may well account for the difficulty reported by Krowczynski in determining his conversion factor.

Other Differences in the Testers—Any comparison of these four types of testers must take into account the additional factors due to the inherent differences in design summarized in Table III.

For example the variations in scale length for 1-Kg. units of loading are significant enough to introduce considerable errors in estimation of the load. The different methods of applying the load might also be expected, as is shown here, to give rise to differing values of crushing-strength for different instruments.

Since the initial load applied to grip a tablet is, in three types of instruments, subject to operator variation this must also lead to discrepancies. In the Monsanto and Pfizer hardness testers it was found that with extreme care the initial load required to grip the transducer could be as little as 0.1 Kg., but unless the operator exercized this care, loads of 0.3 to 0.5 Kg. were more likely. In the Strong-Cobb hardness tester it appeared that the setting for zero was less critical. Although the pressure gauge needle was sluggish in leaving the zero mark, the load applied at a scale reading of 1 unit was reasonably constant irrespective of the initial "gripping load." Before adjustment of the Erweka hardness tester the average zero load applied to a tablet, when the zero light was activated, was found to be 0.5 Kg. Any slight overshooting of the zero position resulted in initial loads up to 1.3 Kg. which of course were not accounted for in the subsequent crushing strength indicated on the instrument scale. Even after adjustment any overshooting still applies large initial loads.

Finally, it may be noted that all instruments were less accurate at crushing-strengths below about 2.0 Kg. and it is doubtful if values below this figure have any significance.

CONCLUSIONS

Variations in crushing-strength values obtained from different types of tester have been shown to be due in part to inaccuracies in instrument scale values, zero errors, and varying methods of applying the load. Calibration is therefore necessary where a high degree of accuracy is desired or when comparing results from different types of testers. The physical dimensions and shape of the tablet as well as other physical properties must also contribute to the property of crushing-strength. The results reported here are now being used to study these additional factors.

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Keyphrases

Tablets, compressed—crushing-strength
Hardness testers—comparison
Monsanto hardness testers, new, used—variation
Force transducer—scale calibration
Load, initial gripping—hardness tester accuracy