Agriculture Canada

August 1973

Engineering Research Service

REPORT NUMBER: 6820-6

The Interchangeability Of Instruments Used To Measure Pea Tenderness

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Contribution No. 394 from Engineering Research Service, Research Branch, Agriculture Canada, Ottawa K1A 0C6.

THE INTERCHANGEABILITY OF INSTRUMENTS USED TO MEASURE PEA TENDERNESS

Peter W. Voisey

SUMMARY

The interchangeability of 3 instruments was investigated by various methods. While pea tenderometers can be made to read the same within close limits a typical difference between 2 instruments is 8 T.U. Ottawa Pea Tenderometer cells show differences of 1.8 to 2.7 T.U. over the part of the tenderness scale used to apply marketing agreements. The Food Technology Corp. shear compression cell appears to have a similar performance but may be prone to wear changing its standardization.

There are thus machines available to replace the Pea Tenderometer that can improve the degree of standardization in measuring pea tenderness to establish the price paid for peas.

1.0 INTRODUCTION

It is a well-known fact that it is difficult to standardize the F.M.C. Pea Tenderometer (P.T.) The author's experience over a number of years (see references in section 4.0) indicates that it is practically impossible to standardize a group of these instruments, particularly when they are dispersed over a wide area. This is because of a) the way the instrument is designed precludes making the critical parts of all machines precisely the same; b) a suitable material (including peas) has yet to be found that can check the tenderometer reading under operating conditions. It appears that for administering pea marketing agreements the P.T. should be replaced with a better instrument. The instrument used as a replacement should not introduce the same standardization problems.

Two instruments are available as replacements: The Food Texture Test Tenderometer System (Food Technology Corp., Rockville, Maryland) developed from the Kramer Shear Press, which consists of a hydraulically powered press which operates a shear-compression cell (Cat. No. CS-1) and indicates the shearing force on a dial gauge (Cat. No. TG-3 Tenderometer Gauge) in tenderometer units. The Ottawa Texture Measuring System consists of a motorized press which operates a wire extrusion cell and indicates the force on an electronic readout in Kg. The comparative merits of these instruments have already been discussed (4). The main advantages offered by both are:

a) the force indicating system can be separated from the machine and calibrated independently or in situ under operating conditions;
b) the test cell containing and shearing the pea sample is a removable, easily replaced component.

Bracketed numbers cite references listed in Section 4.0.

The purpose of the work here was to examine the interchangeability of the test cells of the two instruments that could replace the P.T. so that the feasibility of standardization could be determined.

2.0 EXPERIMENTAL METHODS AND OBSERVATIONS

2.1 F.M.C. Pea Tenderometer (P.T.)

2.1.1 Comparison of P.T.

P.T. that are in the same location so that they can be compared regularly and that are properly maintained will give nearly the same average reading over a very large number of samples. For example within 7 T.U.:

P.T. No.	Reading T.U.	
	1971	1972
1	114	120
2	117	124
3	120	127
4	118	124

Thus if readings are taken on each batch with these 4 instruments and an average result used it is reasonable to expect repeatable accurate results. However the majority of processors only use one P.T. Two such P.T. were compared and found different as follows comparing the means of 10 readings:

Pea Tenderometer	A	B
Reading T.U.	90	82
c.v.%	2.2	3.8
Motor RPM	1725	1725
Gearbox output RPM	72	79
Calibration full scale T.U.	200.5	199.5
Calibration at zero T.U.	0	0
Friction at pivot g	70	1500

The difference in this particular case was 8 T.U. even though both machines calibrated correctly at zero and full scale. Observation showed that the rotation speed of the shearing blades was different because different gearboxes were installed, which theoretically introduces a difference in reading. Also the friction in the pendulum pivot of one machine was much higher than the other and was equivalent to the 8 T.U. reduction in reading.

2.1.2. An Observation on the Use of an Independent Instrument for Calibration.

If an independent instrument is used to serve as a standard the weights on the pendulum can be moved until readings from the P.T. and standard agree. Unfortunately it is then no longer possible to check the balance of the pendulum by the accepted method. Because results have shown that large errors exist in some tenderometers it was necessary to establish the total range of adjustment available at the P.T. pendulum.

Ten samples of peas were tested with the large pendulum weight at the minimum possible radius. This was then repeated moving the pendulum weight in 0.5 in increments up to the maximum possible radius. The entire test was repeated with two pea varieties.

The results in Figure 1 shows that the maximum range of adjustment was about 9 T.U. This may be insufficient to bring some P.T. up to standard in their present poorly maintained condition. The slop of the relationship between radius and reading was not the same for the two varieties tested indicating a varietal effect.

2.1.3. An Observation on the Use of Wax Wafers as a Standardizing Material.

Wax wafers have been used to measure differences between tenderometers (2,3,9). Readings at different points on the scale were obtained by using one, two or three wafers per test. Ideally, the reading should be directly proportional to the number of wafers used. This was investigated by testing 10 replicates of 1 to 12 wafers. The results (Fig. 2) showed that the relationship was definitely non-linear. This can be attributed to compression and flow of the wax since the wafers do not cover 100% of the shearing blade area.

2.1.4. Improvements to the Electronic Tenderometer.

A P.T. was converted (10) to record electronically by installing a transducer (T, Fig. 3) in place of the pendulum. This overcame some of the problems of the original instrument. The Transducer was calibrated against a proving ring (10). If this instrument was selected to serve as a transportable independent standard a more reliable method of calibrating the transducer is required. This can be done by using weights to apply force directly to the transducer via a cable (Fig. 3B).

The calibration weight required is calculated as follows:

Torque at full scale reading (200 T.U.) = 2464 in.lb.

= 2839 cmKg

Radius of transducer from center of rotation = 25 cm

Force at full scale at this radius = 113.56 Kg.

Thus if 113.56 Kg is applied horizontally at the transducer the electronic readout can be adjusted to read 200 and the instrument will read directly in T.U.

2.2. Shear Compression Cell of the Food Technology Corp. Tenderometer System.

The method that has been adopted for calibrating this instrument is to compare it with an independent standard (of the same type). The sensitivity of the tenderometer gage is adjusted (same as moving weights on P.T.) until the same pea tenderness is indicated by the instrument and standard. As with the P.T. the force indicating system (Tenderometer Gauge) then cannot be checked for accuracy independently using a proving ring or weights to show that a standard force produced a given reading. However, unlike the P.T. after standardization, by comparing with the independent standard, the actual gauge reading for a given force could be measured and noted on the instrument for future checks. In effect the method involves altering the force indicating system to compensate for differences between the shear-compression cells.

It would be preferable to have the cells interchangeable so that all the Tenderometer Gauges could be adjusted to the same standard. The following measurements were made to check the interchangeability of these cells (K.S.) using the cells listed in Table 1 which were made at various stages of the instrument's development. In effect three cell designs were involved differing in the materials used, the method of assembly and the shape at the end of the shearing blades (angled or square) but nominally made to the same dimensions.

The results (Table 2) show that two cells made to the latest specifications (1 & 2) were the same within 0.5% in testing frozen and thawed peas but the two earlier designs (3 & 4) gave readings that were 3 to 13% different. In other words, old cells should not be incorporated into the standardization system. In testing canned corn the difference between cells 1 and 2 was 5% indicating that the test material used may have an effect on the apparent differences. The same effect was apparent for fresh peas but the magnitude of the differences between cells 1 and 2 or cells 1,2,3 and 4 were not consistent. That is, if a particular comparison of 2 cells shows a difference in reading there is no means of knowing that this difference is constant especially if different pea varieties must be used.

2.3. Ottawa Pea Tenderometer (O.P.T.) and its Wire Extrusion Cells.

The O.P.T. has an electronic readout system that could be adjusted to compensate for differences between cells. However, the instrument is not intended to operate in this way. The objective was to use a standardized force indicating system (100 Kg = 400 units) and provide interchangeable cells. For example, from the first batch of cells manufactured 5 were found to give the following average readings on 10 samples of peas from the same batch.

Cell	Reading Kg
A	188
B	188
C	190
D	190
E	189

Thus the cells all read within 0.5% of each other.

A total of 8 cells were tested, these were made at different times and by different manufacturers (Table 3). Preliminary tests (Table 4) with small numbers of samples showed that the cells made by one manufacturer were approximately interchangeable with baked beans and fresh peas, however there were differences up to 9%. Further testing of fresh peas (Table 5) showed that 6 cells made by one manufacturer over 2 years were interchangeable within 1.5 to 2.5% of reading but early prototype cells (7 and 8) were quite different. Based on these tests 4 cells (3,4,5 and 6) made by one manufacturer were selected for further tests.

The 4 cells were operated using two O.P.T. presses. Five pea samples from one batch were tested in each cell in each of the two presses. This simulated the use of two O.P.T. each equipped with 2 cells. The test was performed on several batches of several varieties. The results (Table 6) show that within machines the readings were the same within close limits, the majority being within about ±1% of the mean reading for the four cells (Table 7). The maximum difference was 3.7%. These differences must be evaluated taking into account that the peas within a batch vary and the small differences between cells may be true readings of differences in the peas tested.

There was a consistent difference between machines (Table 6) which averaged 8.8%. This was attributed to the 4% difference in speeds between the two available O.P.T. presses. The higher speed press produced higher readings which agrees with the expected difference. The differences appeared to depend on the batch of peas tested.

Thus it appears feasible to make interchangeable test cells and providing the presses used are the same the systems should also be interchangeable.

3.0 DISCUSSION AND CONCLUSIONS

It appears feasible to make shear-compression or Ottawa Pea Tenderometer cells interchangeable within acceptable limits. The O.P.T. cells appear to give the same readings within less than ±2% of reading. Thus in operation the errors that would be expected are as follows:

Pea Tenderness T.U.	Error ± T.U.
90	1.8
120	2.4
135	2.7

The data also indicates that shear-compression cells are interchangeable. However it is more prone to wear and changing its performance than the O.P.T. cell.

It is concluded that the shear compression or Ottawa Pea Tenderometer cells could be used to replace the Pea Tenderometer and achieve a much better degree of standardization among instruments. This was proved in a practical way by transporting peas from one batch to two plants and testing them simultaneously in a P.T. and O.P.T. at each plant with the following result:

	P.T. T.U.	O.P.T. T.U.	P.T. T.U.	O.P.T. T.U.
Plant A	87	92	111	112
Plant B	82	94	101	113

4.0 REFERENCES

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Table 1. Description of shear compression cells

Cell No.	Serial No.	Year Purchased	Material	Blade type
1	500-412D-12101	1970	Aluminum	Pinned-angle
2	500-412D-12112	1973	Aluminum	Pinned-angle
3	C257	1960**	Stainless steel	Welded-square
4	C334*	1962**	Stainless steel	Pinned-angle

*Modified from square blades

**Approximately

Table 2. Comparison of readings (means of 10 samples) from different shear compression cells at 10 cm/min

Test Product	Cell No.*	Mean Reading	Coefficient of variation
		Kg	%
Frozen and thawed peas	1	223	3.4
	2	222	4.0
	3	249	2.0
	4	230	3.0
Canned whole kernel corn	1	225	5.4
	2	213	6.4
	Mean	219	5.1
Fresh peas (Trumpet)	1	413	3.4
	2	403	2.4
	Mean	408	
Fresh peas (4683)	1	403	1.9
	2	402	2.4
	3	403	1.6
	4	374	3.2
	Mean	396	
Fresh peas (Trumpet)	1	313	2.0
	2	310	2.5
	3	315	1.7
	4	304	1.7
	Mean	311	

*Modified from square blades

Table 3. Ottawa Pea Tenderometer cells tested (30 cm^2 wire extrusion type)

Cell Number	Manufacturer*	Year Manufactured	Remarks
1	CML	1973	
2	CML	1973	
3	CML	1973	Shortened
4	CML	1973	Shortened
5	CML	1972	Shortened
6	CML	1972	Shortened
7	ERS	1971	
8	ERS	1971	

*Canners Machinery Ltd., Simcoe, Ont.
Engineering Research Service

Table 4. Comparison of readings from different Ottawa Pea Tenderometer cells

Product:	Baked Beans*		Fresh Peas**		Frozen and Thawed Peas	
Samples per cell:	6		4		4	
	Mean Kg	C.V. %	Mean Kg	C.V. %	Mean Kg	C.V. %
Cell Number						
1			360	5.3	129	2.8
2			382	2.6	128	4.7
3	35	4.8	368	1.8	131	6.7
4	34	3.6	365	4.0	126	3.6
5	33	7.3				
6	32	4.3				
Mean	33		369			
C.V. %	6.8					

* Rinsed with cold water

** 142 T.U. on standard P.T. and 119 (C.V. 1.2%) on E.T.

Table 5. Comparison of Ottawa Pea Tenderometer readings using fresh peas. 10 samples per cell per batch means in Kg

Cell Type	Variety	Cell No.	1	2	3	4	5	6	7	8	Mean
O.P.T.	4683	Mean	213	217	217	217	220	218	211	215	216
		C.V.	3.2	2.6	2.0	3.0	2.0	1.9	1.5	1.4	
	Trumpet	Mean	-	-	276	272	274	274	261	254	269
		C.V.	-	-	2.3	2.5	3.3	3.6	2.5	2.2	
	Trumpet	Mean	251	246							248
		C.V.	3.9	2.6							
	4683	Mean	248	254					251	248	250
		C.V.	1.5	2.4					3.1	2.9	
	4683	Mean	-		265	267	268	266			267
		C.V.			3.4	2.0	2.8	3.0			

Table 6. Comparison of readings from 4 cells used in two Ottawa Pea Tenderometers in Kg (Means of 5 samples)

Machine:	A ("white") 18.0 cm/min					B 18.75 cm/min					Mean
Cell No.	3	4	5	6	Mean	3	4	5	6	Mean	A & B
Variety											
D.S.P.	310.4	307.9	297.4	300.5	304.1	332.4	327.7	319.7	320.0	325.0	314.5
D.S.P.	249.4	249.9	241.1	243.2	245.9	255.1	259.5	257.9	272.1	261.2	253.5
—	248.8	245.6	244.4	240.2	244.7	252.6	255.9	260.8	262.7	258.0	251.4
—	239.7	235.2	233.4	237.5	236.5	243.8	246.8	245.0	248.4	246.0	241.2
Med. 303	259.9	256.0	254.8	254.1	256.2	284.1	280.4	284.3	291.1	285.0	270.6
Perf. 213	196.3	192.4	198.3	194.0	195.2	209.2	204.8	212.6	219.4	211.5	203.4
D.S.P.	290.8	284.2	280.8	281.4	284.3	299.9	294.3	295.7	298.5	297.1	290.7
Perf. 213	276.2	275.9	274.4	276.6	275.8	301.5	294.6	297.3	301.2	298.7	287.2
					C.V. %						
D.S.P.	3.91	2.05	2.00	3.10	3.20	3.23	1.11	0.71	2.93	2.70	4.45
D.S.P.	2.63	3.20	0.35	3.51	2.97	3.63	4.89	3.02	4.00	4.44	4.85
—	1.90	2.83	4.51	2.10	3.05	3.40	3.33	4.60	3.26	3.74	4.31
—	2.98	2.77	2.33	4.73	3.23	4.12	2.34	2.75	1.51	2.70	3.55
Med. 303	3.95	1.25	1.88	3.19	2.72	1.73	2.65	4.12	2.81	3.05	6.10
Perf. 213	4.23	1.01	1.41	2.04	2.59	3.44	1.68	2.26	1.77	3.38	5.05
D.S.P.	1.32	4.65	4.26	4.49	3.86	2.24	3.25	1.74	1.64	2.25	3.80
Perf. 213	4.52	2.69	2.58	1.76	2.83	3.41	0.57	1.82	1.36	2.15	4.73

Table 7. Differences* among 4 cells used in 2 Ottawa Pea Tenderometers in %

Machine:	A				B				A and B**
Cell No.	3	4	5	6	3	4	5	6	
D.S.P.	+2.1	+1.3	+2.2	-1.2	+2.3	+0.6	-1.6	-1.5	- 6.6
D.S.P.	+1.4	+1.6	-2.0	-1.1	-2.3	-0.7	-1.3	+4.2	- 6.0
—	+1.7	+0.4	-0.1	-1.8	-2.1	-0.8	+1.1	+1.8	- 5.3
—	+1.4	-0.5	-1.3	+0.4	-0.9	+0.3	-0.4	+1.0	- 3.9
Med. 303	+1.4	-0.1	-0.5	-0.8	-0.3	-1.6	-0.2	+2.1	-10.6
Perf. 213	+0.6	-1.4	+1.6	-0.6	-1.1	-3.2	-0.5	+3.7	- 8.0
D.S.P.	+2.3	0.0	-1.2	-1.0	+0.9	-0.9	-0.5	+0.5	- 4.4
Perf. 213	+0.1	0.0	0.5	+0.3	+0.9	-1.4	-0.5	+0.8	- 8.0
Mean+	1.4	0.6	1.2	0.9	1.4	1.2	0.8	1.9	8.8

* $\frac{\text{Reading} - \text{Mean}}{\text{Mean}} \times 100\%$

** $\frac{\text{Mean A} - \text{Mean B}}{\text{Mean (A + B)}} \times 100\%$

\+ Neglecting sign

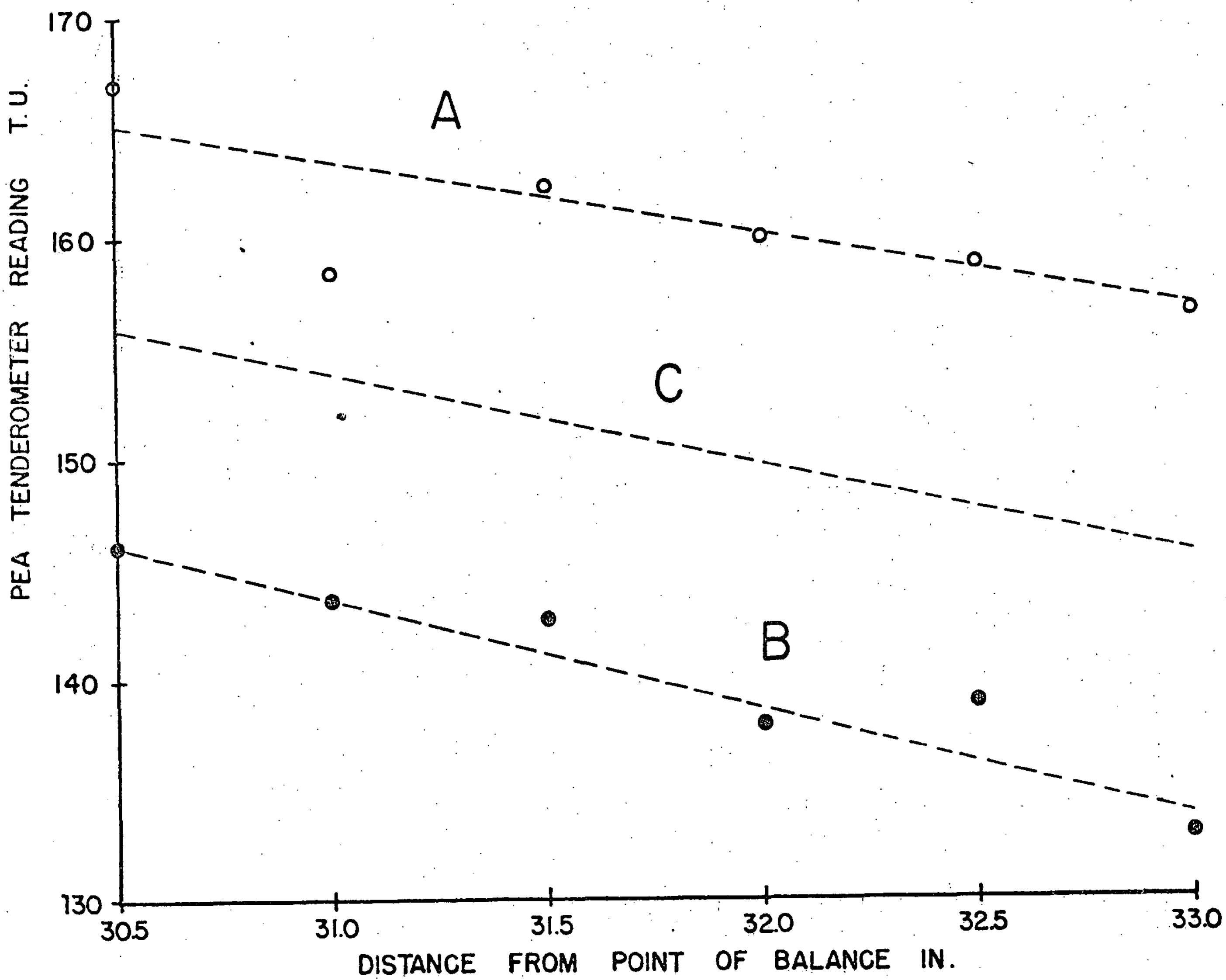


Fig. I

Figure 1. Plot of tenderometer reading against radius (R) of pendulum weight.
A. Dark skin perfection P.T. = -3.21R + 263.0 (r = -0.732);
B. Small sieve freezers P.T. = -4.82R + 293.5 (r = -0.941);
C. A and B pooled P.T. = -4.02 + 278.2 (r = -0.309).

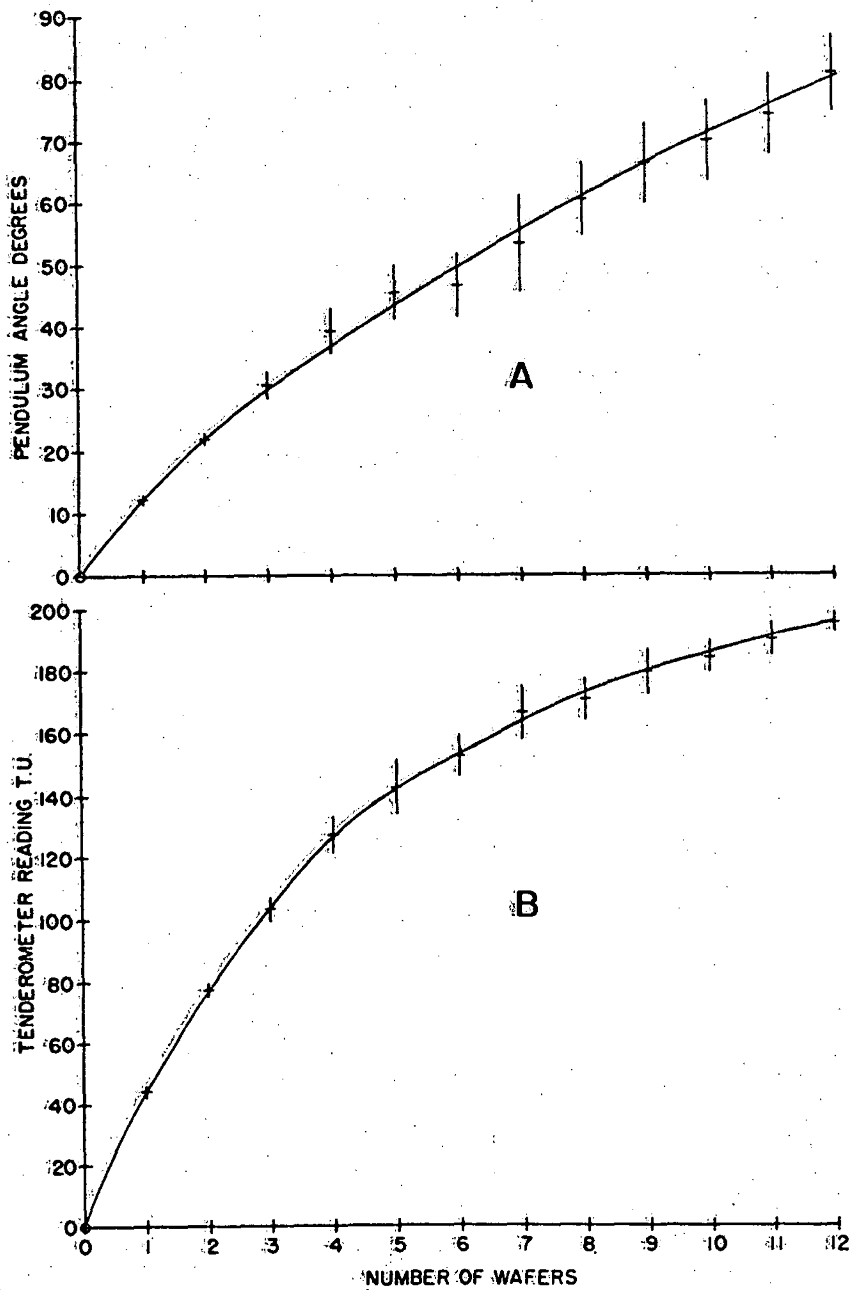


Figure 2. Plots of A. pendulum angle and B. tenderometer reading against the number of wax wafers (i.e. thickness) used. Each point is the mean of 10 replicates at 24°C, and the vertical lines represent one standard deviation.

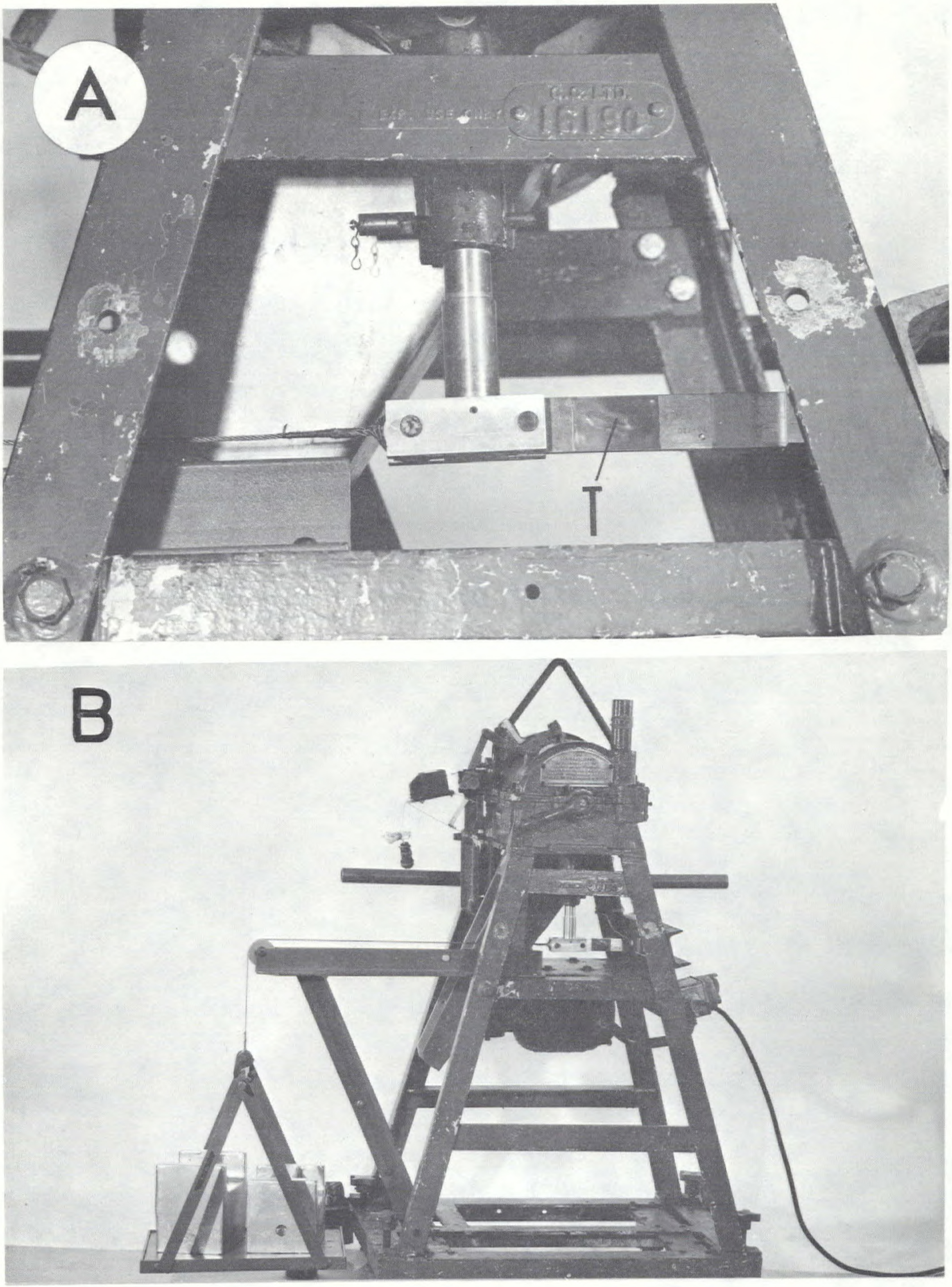
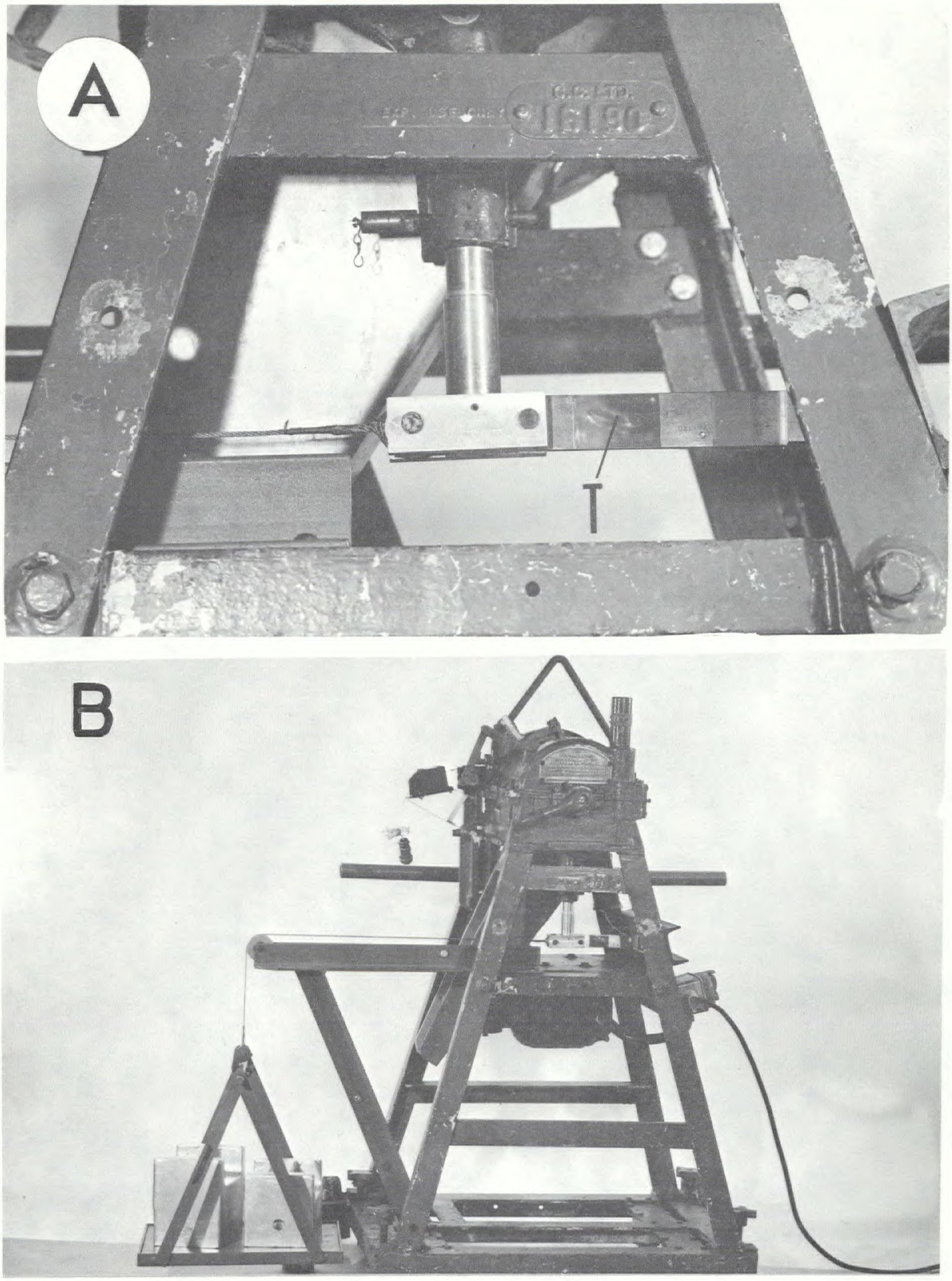


Figure 3. Electronic tenderometer. A. transducer (T) installation; B. improved method of calibrating transducer to read directly in T.U.



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