DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS
OF THE
BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 194

A PRELIMINARY STUDY OF TEARING INSTRUMENTS AND TEARING TEST METHODS FOR PAPER TESTING

BY

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Bureau of Standards

JULY 27, 1921

PRICE, 5 CENTS

Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

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By Paul L. Houston

ABSTRACT

In this technologic paper a study is made of the relative effect of different sizes of test samples on the tearing strength of paper. A great number of samples of commercial papers are torn on three different instruments, using different sizes of test samples and also the same sizes of test samples. Data are collected, accordingly, to show that the larger the test sample the greater are the values of tearing strength. The reason for this is brought out as fabric assistance, which is of considerable importance in the textile industry.

The three instruments used in this study are a tensile-strength instrument and two types of instruments for determining the tearing strength of paper. These two types of instruments are called type I and type II. Type I is a recording instrument, while type II is a nonrecording instrument. A study is then made of these two types of tearing instruments for the purpose of investigating their accuracy and reliability, so that the results of this investigation may benefit the paper industry.

Conclusions are drawn up to show that the type II nonrecording instrument is the more reliable of the two and is within a 5 per cent error on the majority of papers.

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I. INTRODUCTION

1. STATEMENT OF PROBLEM

For some time it has been a recognized fact in the paper industry that there is a need for an instrument that will give numerically the tearing strength of paper. Considerable work has been done along this line at different laboratories. The result has been that two types of tearing instruments have been invented and are used to some extent. One of these types is a recording instrument, giving a curve showing the maximum and minimum tearing strength of paper and the results of five initial tears. The other type gives merely the maximum tearing strength by weighing or measuring the load applied to the paper to tear it. Both types have their good and their bad points, which will be brought to light in the following study.

II. DISCUSSION OF TEST METHODS

1. PRACTICAL TESTS WITH DIFFERENT SIZE TEST SAMPLES

Before taking up a study of the instruments themselves it must be remembered that the tearing strength of paper depends a great deal on the size of the test sample. For instance, a series of bag papers that had previously been tested for weight (in pounds) of the standard size ream 25×40—500 and for bursting strength were torn on the tensile-strength instrument described in Bureau's Circular No. 107, pages 15–17, and on the two types of tearing instruments mentioned above. For convenience, let the recording instrument be called type I and the nonrecording instrument type II. The test samples were cut 1 by 8 inches for the tensile-strength machine, 2¾ by 1⅛ inches for type I instrument, and 4 by 10 inches for type II instrument. All samples were torn the machine direction, beginning at a point just halfway across the width of the test sample, and an average of 10 tests was taken for each result. The results in Table 1 were obtained. It might be well to mention here that all tests in this study were conducted in a constant-temperature and humidity room, where all test samples before they were used were conditioned for two hours at a temperature of 70° F and a relative humidity of 65 per cent. From these data it is to be noted that the larger the test samples are in size the higher are the values of tearing strength.

TABLE 1.—Relative Effect of Different Size Test Samples on Tearing Strength of Bag Paper, Using Tensile Strength, Type I, and Type II Instruments

[Test samples: Tensile strength, 1 by 8 inches; type I, $2^3/_4$ by $1^1/_8$ inches; type II, 4 by 10 inches]

Bag paper identification numbers	Weight of the standard-size ream, 25×40—500	Bursting strength	Tearing strength		
			Tensile strength	Type I	Type II
	Pounds	Points	Grams	Grams	Grams
16 081	32	11	30.8	15.75	33.6
16 082	44	23	58.3	34.80	76.4
16 083	52	18	47.5	38.40	68.4
16 084	49	29	86.6	58.80	96.2
16 085	53	36	91.6	59.80	113.2
16 086	61	36	108.3	63.40	128.6
16 087	32	32	50.0	33.50	64.0
16 088	46	36	100.0	43.20	118.0
16 089	77	54	133.3	90.60	179.2
16 090	77	31	97.5	55.50	149.2
16 091	110	94	270.8	188.00	338.4
16 092	147	125	433.3	256.50	471.4
16 093	39	21	38.3	22.40	60.6
16 094	45	25	43.3	30.80	73.2
16 095	62	33	83.3	62.80	135.6
16 096	45	28	79.1	52.80	94.6
16 097	38	22	101.6	73.10	84.0
16 098	51	33	116.6	74.60	121.6
16 099	65	47	165.6	108.00	179.2
16 100	43	24	78.3	63.50	85.2
16 101	51	28	61.6	39.50	83.0
16 102	72	46	136.6	116.50	186.6
16 103	52	30	73.3	49.90	96.2
16 104	76	41	129.1	88.50	166.8

In order to illustrate this point further, a series of writing papers that had already been tested for weight (in pounds) of the standard size ream 25×40—500 and for bursting strength was torn on the tensile-strength machine and type II nonrecording instrument. Test samples were cut 1 by 8 inches for the tensile-strength apparatus and 4 by 10 inches for the type II instrument, and an average of 10 tests was taken for each result. The data in Table 2 show the same results as in Table 1.

TABLE 2.—Relative Effect of Different Size Test Samples on Tearing Strength of Writing Paper, Using Tensile Strength and Type II Instruments

[Test samples: Tensile strength, 1 by 8 inches; type II, 4 by 10 inches]

Writing paper identification numbers	Kind of writing paper	Weight of standard-size ream 25×40—500	Bursting strength	Tearing strength		Ratio of tensile strength to type II
				Tensile strength	Type II	
		Pounds	Points	Grams	Grams	Per cent
14 731	Bond	86	55	156.9	181.7	86.4
14 732	Writing	46	19	32.4	54.5	59.5
14 733	Copying	24	10	29.0	34.2	84.8
14 734	Printing	55	27	50.2	77.8	64.5
14 735	do	44	19	23.5	44.8	63.6
14 736	Manifold	10	5	13.8	16.8	82.2
14 737	Ledger	98	72	167.2	230.4	72.6

2. PRACTICAL TESTS WITH SAME SIZE TEST SAMPLES

On the other hand, if the test samples are cut the same size, very good check results will be obtained. Note the following results in Table 3 on the above series of long-fibered bag papers when test samples were cut 1 by 8 inches for both tensile-strength and type II instruments. An average of 10 tests was taken for each result.

TABLE 3.—Relative Effect of Same Size Test Samples on Tearing Strength of Bag Paper, Using Tensile Strength and Type II Instruments

[All test samples were 1 by 8 inches]

Bag paper identification numbers	Weight of the standard-size ream 25X 40—500	Bursting strength	Tearing strength		Ratio of tensile strength to Type II
			Tensile strength	Type II	
	Pounds	Points	Grams	Grams	Per cent
16 081	32	11	20.8	21.0	99.0
16 082	44	23	58.3	58.0	100.2
16 083	52	18	47.5	49.6	95.8
16 084	49	29	86.6	90.2	96.1
16 085	53	36	91.6	93.8	97.7
16 086	61	36	108.3	113.0	96.0
16 087	32	22	50.0	50.0	100.0
16 088	46	35	100.0	92.0	108.6
16 089	77	54	133.3	142.2	93.8
16 090	77	31	97.5	104.8	93.0
16 091	110	94	270.8	271.0	99.7
16 092	147	125	433.3	442.8	97.8
16 093	39	21	38.3	41.2	93.0
16 094	45	25	43.3	44.8	96.6
16 095	62	33	83.3	90.4	92.3
16 096	45	28	79.1	74.2	106.6
16 097	38	22	101.6	96.6	102.6
16 098	51	33	116.6	113.4	102.7
16 099	65	47	166.6	160.0	104.0
16 100	43	24	78.3	70.6	110.8
16 101	51	28	61.6	66.8	92.3
16 102	72	46	136.6	139.6	97.8
16 103	52	30	73.3	74.0	99.1
16 104	76	41	129.1	129.6	99.7

3. FABRIC ASSISTANCE

After studying the action of the paper as it was torn on each instrument it became evident that each fiber in the path of the tear received assistance from all the fibers adjoining as far as the edges of the test samples. Also, it was noted that the larger the test sample was the greater was the amount of assistance that the fibers in the path of the tear received from the adjoining fibers, provided, of course, that the beginning of the tear was always the same distance from the end of the test sample and just halfway across the width of the test sample. In the textile industry this effect is called fabric assistance and is of considerable importance.

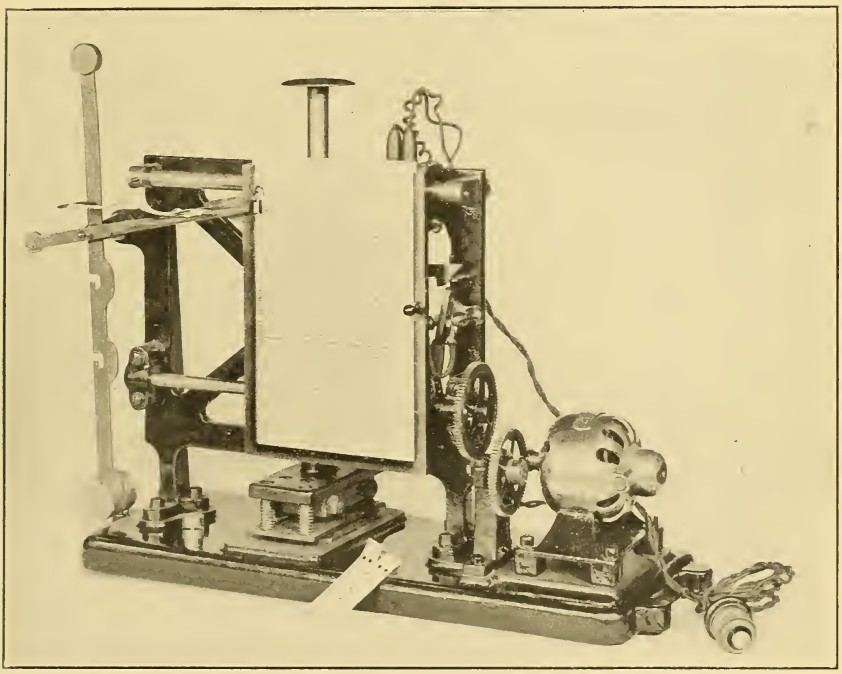

FIG. 1.—*The recording instrument, type I*

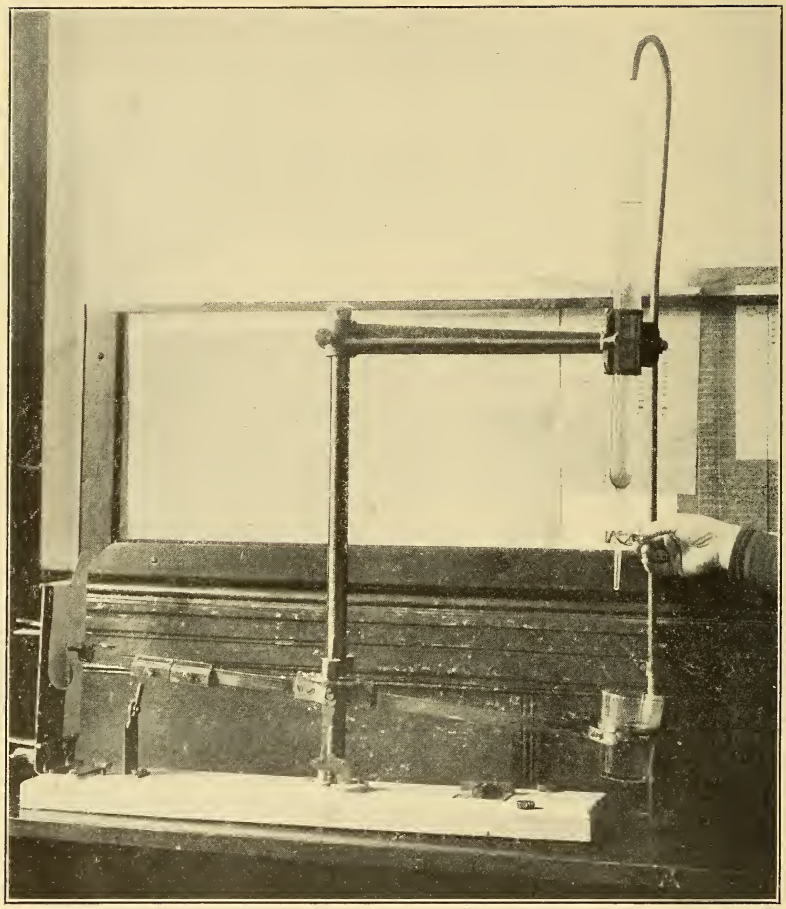

FIG. 3.—*The nonrecording instrument, type II*

III. DISCUSSION OF A RECORDING INSTRUMENT

1. DESCRIPTION OF INSTRUMENT

Since it is found that it is necessary to cut test samples the same size in order to compare the tearing strength of papers, it is now best to proceed to a study of the instruments themselves. The recording instrument, type I, Fig. 1, is the type of instrument preferred for laboratory use. However, such an instrument should be very delicate, sensitive, and accurate. There should be the least possible amount of friction between the chart and pen point. The recording arm should move freely, with as little friction as possible in the bearing. However, there seems to be no instrument of this caliber on the market to-day. The instrument under study has the appearance of a delicate, sensitive, and accurate little machine, but has certain defects which will be discussed later. It is composed of a sliding plate on which the chart rests and a recording arm which moves on a pin-slot bearing and holds a small glass capillary pen with a platinum point. The test sample of paper is cut by means of a die in such a way as to give five initial tears and a curve showing the maximum and minimum tear. Small angular slits in the path of the tear make possible these five initial tears, and a slit down the center of one end of the sample makes it possible for the starting point of the tear to be always the same distance from the edges of the paper. The test sample is placed on the instrument so that one half of the slitted end is fastened to a pin on the sliding plate, while the other half is fastened to a pin on the recording arm. The instrument is motor driven, and as the plate slides to one side the paper is torn and the recording arm is forced down to register on the chart the load in grams necessary to tear the paper. Two different weights may be suspended at three different positions on the projection of the recording arm as factors or multiples of the gram readings on the chart.

2. CALIBRATION TEST

Before operating any instrument of this kind it is always best to calibrate it to determine its accuracy. This was done by hanging dead-weights on the recording arm. With pen point barely touching the chart, there was so much friction in the pin-slot bearing that it was almost impossible to calibrate the instrument at all, as the swinging pen point would stop almost anywhere. However, the following correction curves, Fig. 2, were obtained

for factors, 5, 10, 20, 50, and 100, but they are not reliable for reasons mentioned above. It was impossible to calibrate the instrument for any factor below 5.

3. PERFORMANCE TEST

After attempting to calibrate this instrument it was thought best to tear on it a number of samples of paper, using the different weights to represent factors. The same bag papers were used as before, and from them three identical sets of test samples (numbered 1, 2, and 3) were cut 2¾ inches long and 1⅛ inches wide. Each test sample was torn in the machine direction, and the average of the five initial tears was taken as the tearing strength of the paper. In the following data, Table 4, it is to be noted that different results were obtained for different factors used. The values which are given in this table were directly observed and have not been corrected by use of the calibration curves of Fig. 2.

TABLE 4.—Relative Effect of Different Factors on Tearing Strength of Bag Paper, Using Three Identical Sets of Test Samples and Type I Instrument

[All test samples were 2¾ by 1⅛ inches]

Bag paper identification numbers	Set 1		Set 2		Set 3	
	Factors	Tearing strength	Factors	Tearing strength	Factors	Tearing strength
		Grams		Grams		Grams
16 081	2	15.7	5	17.8	10	18.6
16 082	5	30.0	10	34.8	20	33.6
16 083	5	29.1	10	35.3	20	38.4
16 084	5	41.7	10	58.8	20	53.2
16 085	5	42.3	10	59.8	20	54.2
16 086	10	64.2	20	63.4	50	80.0
16 087	5	33.5	10	24.5	20	30.8
16 088	5	41.6	10	43.2	20	38.8
16 089	20	90.6	50	105.5	100	115.0
16 090	20	54.6	50	55.5	100	72.0
16 091	20	177.2	50	188.0	100	189.0
16 092	50	256.5	100	283.0	.....	.....
16 093	5	22.4	10	30.8	20	22.2
16 094	5	29.6	10	30.8	20	36.7
16 095	20	62.8	50	65.5	100	75.0
16 096	5	43.1	10	52.8	20	46.2
16 097	10	73.1	20	61.0	50	76.0
16 098	10	74.6	20	74.0	50	72.5
16 099	20	108.0	50	114.0	100	152.0
16 100	10	63.5	20	37.2	50	60.8
16 101	10	39.5	20	44.6	50	56.0
16 102	20	101.2	50	116.5	100	146.0
16 103	10	49.9	20	41.2	50	49.0
16 104	20	96.2	50	88.5	100	101.0

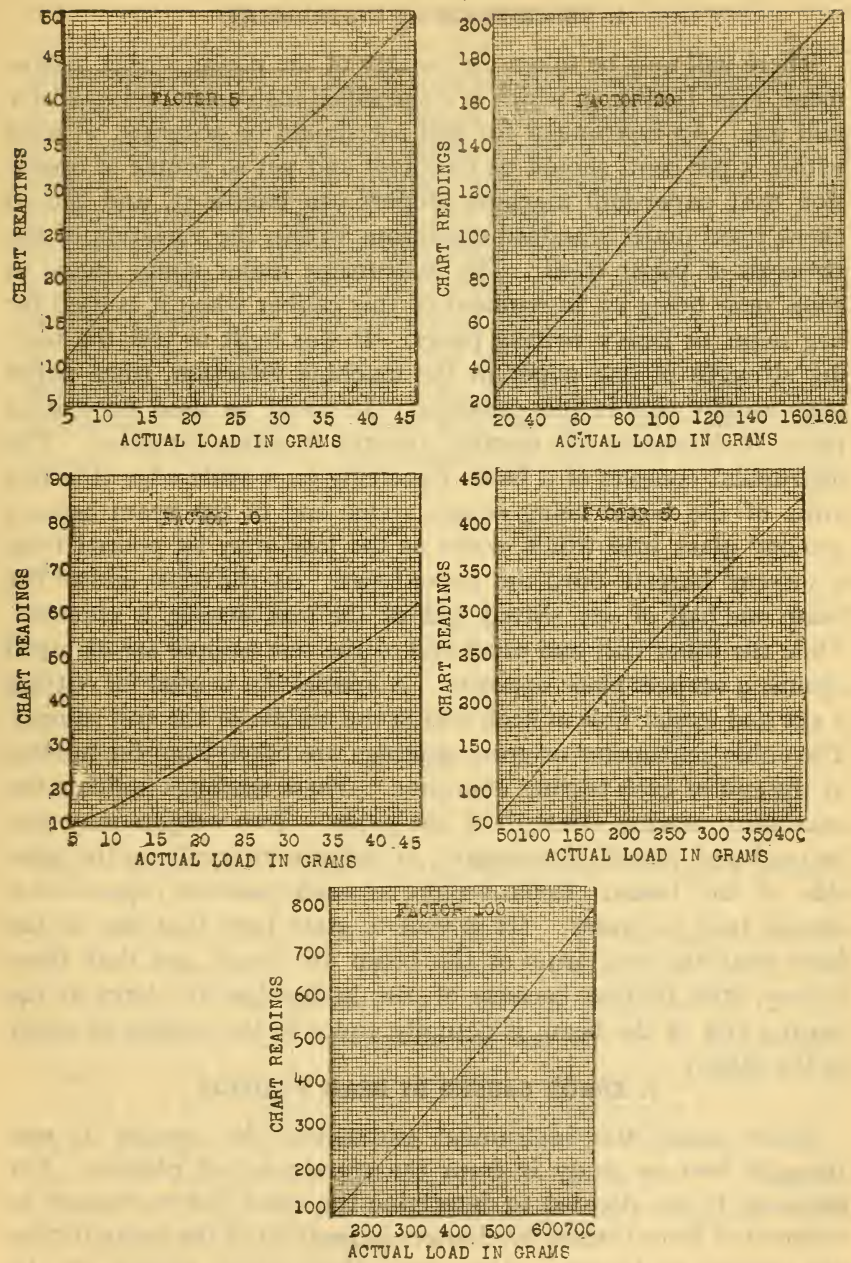

FIG. 2.—*Diagrams showing correction curves for different factors (recording instrument, type I)*

IV. DISCUSSION OF A NONRECORDING INSTRUMENT

1. DESCRIPTION OF INSTRUMENT

There will now be taken up a study of the nonrecording instrument, type II, Fig. 3, which is a simplified instrument adapted for mill use. An instrument for mill use should be accurate, at least within 5 per cent, should be foolproof and yet so simple of operation that paper-mill machine tenders can handle it, and should check itself under standard conditions within the variation of the strength of paper itself. The instrument under study seems to come near being an instrument of this caliber when it is used for bag paper or heavy writing paper. It was built to test the tearing strength of bag paper in the machine direction, since paper bags usually tear in this direction. It could be used on writing paper to determine the tearing strength in either direction. The instrument consists of a beam balancing on a knife-edge (the two arms of the beam being equal). One end of the beam holds a 300-cm^3 glass into which water as the load may be poured from a 500-cm^3 burette until the paper tears. At the other end of the beam one half of one slitted end of the test sample is clamped, while the other half and other end of the test sample are clamped against a vertical plate opposite. A special die is used for cutting a slit and eyelet hole at each end in the middle of the test sample. The cubic centimeter or gram readings are taken from the burette at the end of each tearing operation. These readings indicate the maximum tearing strength of the paper. Two weights may also be used and placed, if necessary, at definite intervals on the glass side of the beam. Each weight at each position represents a certain load in grams. (It is well to state here that due to the facts that the two arms of the beam are equal, and that there is very little friction because of the knife-edge, the force at the tearing end of the beam is actually equal to the weight of water in the glass.)

2. ERROR CAUSED BY BEAM POSITION

Before using this instrument extensively for tearing it was thought best to study it from the standpoint of physics. For instance, it was decided to determine the error due to changes in moment of force caused by changes in position of the beam during the process of tearing. Also, were there errors caused by the force exerted by the falling stream of water? Let there first be made a study of the different moments of force caused by different positions of the beam. Note the following diagram of beam, Fig. 4.

Let BC represent the beam and AR represent a pointer which is fastened at the center A of the beam and at right angles to it, and which determines by its position in respect to the graduations below, numbered 0, 1, and 2, whether the beam is balanced (and in this case horizontal) or is one or two graduations off balance. It is evident that when the beam is one or two graduations off balance the moment of applied force decreases as the number of graduations off balance of the beam increases. In order to find the amount of the error introduced by the changes in moment of force caused by changes in position of the beam, the moment of the applied force was calculated for three different positions of the beam, using 100 g as the weight of water in the glass. Referring to the diagram, Fig. 4, let MF and NG represent the two positions of the beam BC when it is one and two graduations off balance, as indicated by the pointer AR, which at the same time

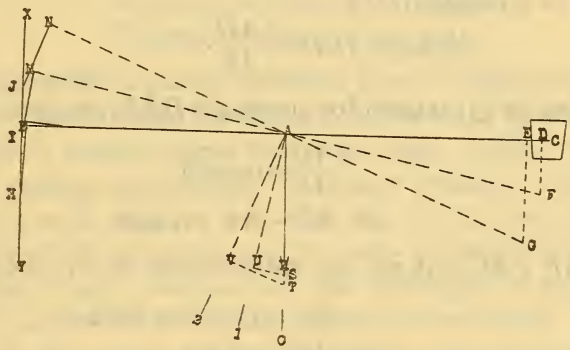

FIG. 4.—*Diagram showing change in effect of weight of water with change in position of beam (nonrecording instrument, type II)*

takes the respective position AU and AV. By drawing the dotted line US perpendicular to AU at point U and dotted line VT perpendicular to AV at point V, and by extending line AR to intersect dotted line US at S and dotted line VT at T, right-angled triangles AUS and AVT are formed. By drawing dotted lines GE and FD from points G and F and perpendicular to AC, right-angled triangles ADF and AEG are formed. Of these triangles angle DAF = angle SAU, and angle EAG = angle TAV. Distances AR, US, VT, and AC have been measured very carefully on the type II apparatus, as follows:

$$AR = AU = AV = 8.9 \text{ cm};$$
$$US = .48 \text{ cm};$$
$$VT = .96 \text{ cm};$$
$$AC = 35.56 \text{ cm}.$$

Referring to triangle AUS,

$$\frac{US}{AU} = \text{tan angle } SAU. \tag{1}$$

Substituting in (1) 0.48 for US and 8.9 for AU, we get:

$$\frac{0.48}{8.9} = \text{tan angle } SAU;$$

$$\text{or, } 0.0539 = \text{tan angle } SAU.$$

Referring to a table of trigonometric functions, it is found that if tan angle $SAU = 0.0539$,

$$\text{cos angle } SAU = 0.9986. \tag{2}$$

Since angle SAU = angle DAF, by substituting in (2) cos angle DAF for cos angle SAU, we get:

$$\text{Cos angle } DAF = 0.9986.$$

Referring to triangle ADF,

$$\text{cos angle } DAF = \frac{AD}{AF}. \tag{3}$$

Substituting in (3) 0.9986 for cos angle DAF, we get:

$$\frac{AD}{AF} = 0.9986;$$

$$\text{or, } AD = AF \times 0.9986. \tag{4}$$

Since $AF = AC = 35.56$, by substituting in (4) 35.56 for AF, we get:

$$AD = 35.56 \times 0.9986;$$

$$\text{or, } AD = 35.51.$$

When the beam is in the position represented by MF and the pointer is at the position of graduation, number 1, the moment of force is represented by the formula:

$$\text{Moment of force} = AD \times \text{weight of water}. \tag{5}$$

Since 100 g were taken as the load in this case, by substituting in (5) 100 for weight of water and 35.51 for AD, we get:

$$\text{Moment of force} = 35.51 \times 100 = 3551.$$

Referring to diagram, Fig. 4, when the beam is in the position represented by NG and the pointer is at the position of graduation, number 2, the moment of force is represented by the formula:

$$\text{Moment of force} = AE \times \text{weight of water}. \tag{6}$$

By using the triangles AVT and AEG and angles TAV and EAG the determination of AE is exactly the same as for AD and is found to be 35.35.

Since 100 g were taken as the load in this case, by substituting in (6) 100 for weight of water and 35.35 for AE, we get:

$$\text{Moment of force} = 35.35 \times 100 = 3535.$$

Referring to the diagram, Fig. 4, when the beam is in the horizontal position represented by BC and the pointer is at zero graduation, the moment of force is represented by the formula:

$$\text{Moment of force} = AC \times \text{weight of water.} \qquad (7)$$

Since $AC = 35.56$ and since 100 g were taken as the load in this case, by substituting in (7) 100 for weight of water and 35.56 for AC, we get:

$$\text{Moment of force} = 35.56 \times 100 = 3556.$$

Consequently, there are the following moments of force at zero graduation and at graduations numbered 1 and 2:

Moment of force at 0 = 3556;
Moment of force at 1 = 3551;
Moment of force at 2 = 3535.

From these results it can be seen that the error due to the different moments of force caused by different positions of the beam during the process of tearing is less than 1 per cent, which is very small. Very few testing instruments of greater accuracy than this are built. It is well to state here that due to the fact that at the tearing end of the beam the pull can not be exactly perpendicular to the beam in any position and that the angle of pull will vary with the position of the beam, another error exists. However, this error is very small, for the reason that the vertical plate XY (Fig. 4) which holds the test specimen of paper is situated so close to the end of the beam that there is very little clearance between the end of the beam and the vertical plate. Consequently, due to this fact and due to the fact that the angular displacement of the beam during the process of tearing is never more than 10° because the beam is so long, the angle of pull is always very close to the perpendicular. In this connection note the angles of pull, JNA, IMA, and HBA (Fig. 4), which are very close to right angles. H represents the starting point of tear, which is halfway between the end B of the beam in initial position and the lower end Y of the test sample.

3. ERROR DUE TO IMPACT OF WATER.

Let there now be taken up the second question: Are there errors caused by the force exerted by the falling stream of water? In practically all cases the paper began to tear at the balancing

position of the beam, and the water was shut off immediately by turning of the stopcock which closed the outlet from the burette, and the reading from the burette was taken. Consequently, it was decided to measure the distance from the end of the burette to the surface of the water in the glass at different applied volumes, as indicated by the graduations on the burette. This was done because the different velocities caused by the falling of the water from the burette through different distances to the surface of the water in the glass were the controlling factors in determining the error due to the impact of water. During this operation the beam was held firm in balancing position and a piece of aluminum attached to a thread was used to make the measurements. The following measurements were obtained:

Volume applied, cm^3	Distance, cm	Volume applied, cm^3	Distance, cm
25	16.5	175	11.4
75	14.6	225	10.2
125	13.0	275	8.9

Then a small piece of aluminum about the size of a 10-cent piece was attached by means of very small wires to the end of the beam in place of the glass. This was done in such a way that the water from the burette fell directly on the aluminum. The small size of the aluminum prevented any water from remaining on its surface. The forces were then measured experimentally by placing small laboratory weights on the other end of the beam to balance the force of the water from the burette on the aluminum. The forces were obtained for heads of water in the burette at different graudations (on the burette) corresponding to the above applied volumes (since the applied volumes are determined by the graduations on the burette), and the burette was lowered at the end of each experimental operation so that the distances between burette and aluminum were the same as the above at the respective applied volumes. The same operations were repeated continuously until close checks were obtained. Ten readings were taken at each head of water and an average of the 10 made. The results which were obtained are shown in Table 5. (It might be added here that the force of impact on the aluminum disk is not exactly the same as the force of impact on the water in the glass, because the energy dissipated is not the same in both cases. However, the use of the aluminum disk would seem to give results that are sufficiently accurate for a study of an instrument of this type.)

TABLE 5.—Forces at Different Heads

Readings	Forces in grams for heads at graduations of—					
	25 cm³	75 cm³	125 cm³	175 cm³	225 cm³	275 cm³
1	4.80	4.30	3.80	3.50	3.30	3.10
2	4.80	4.30	3.80	3.50	3.30	3.10
3	4.80	4.40	3.80	3.50	3.20	3.00
4	4.85	4.40	3.80	3.50	3.20	3.10
5	4.90	4.45	3.80	3.50	3.30	3.00
6	4.90	4.45	3.80	3.40	3.20	3.00
7	4.90	4.40	3.80	3.40	3.20	3.10
8	4.95	4.30	3.80	3.40	3.30	3.00
9	4.95	4.40	3.80	3.40	3.20	3.00
10	4.95	4.40	3.80	3.50	3.20	3.10
Average	4.88	4.38	3.80	3.46	3.24	3.05

From the above results a correction curve was drawn, which is presented in Fig. 5.

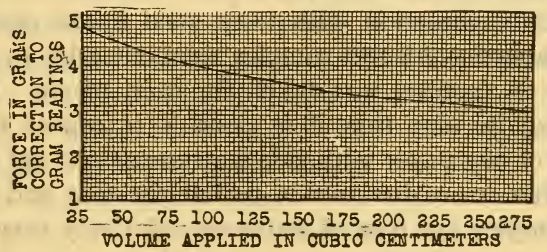

FIG. 5.—*Diagram showing positive corrections at different applied volumes as indicated by head graduations in Table 5 (nonrecording instrument, type II)*

It can easily be seen from Fig. 5 curve, by dividing the ordinates by the corresponding abscissas, that the errors caused by the force exerted by the falling stream of water are as follows:

Volume applied, cm³	Error, per cent	Volume applied, cm³	Error, per cent
25	19.52	175	1.97
75	5.84	225	1.44
125	3.04	275	1.10

Practically all the samples of bag paper that were tested on this instrument tore above the 75 g load when the test samples were cut 4 by 10 inches, which is the size recommended and specified by the inventor. This has previously been presented in Table 1. Consequently, the instrument is within the 5 per cent error on the majority of these grades of bag paper. For writing paper, such as manifold, lightweight printings, and lightweight writings, and for all lightweight short-fibered papers, the error is greater than 5 per cent, as is shown in Table 2. The term "lightweight' here indicates that the weight in pounds of the standard

size ream 25×40—500 is less than 50. For practically all writing papers that are heavier than 50 pounds, and for practically all weights of bonds and ledgers, the error would be less than 5 per cent. These errors might be decreased somewhat if the burette were lowered nearer the glass than was the case in the above experiments. However, the decrease would be very small and the results would be comparatively the same.

4. PERFORMANCE TEST

After studying this instrument from the standpoint of physics a number of samples of paper were torn on the machine in order to discover whether the instrument would check itself under standard conditions within the variation of the strength of the paper itself. Two sets of test samples, numbered 1 and 2, were prepared from the same bag papers as were used before and torn in the machine direction with very good check results, as are shown in Table 6. All test samples were cut 4 by 10 inches, and an average of 10 tests was taken for each result. From these results it can be seen that it is possible to repeat tests on the same grade of bag paper with this instrument and get check averages, and that errors due to side pull at the tear and to personal errors in stopping the flow of water are relatively very small.

TABLE 6.—Relative Effect of Use of Two Identical Sets of Test Samples on Tearing Strength of Bag Paper, Using Type II Instrument

Bag paper identification numbers	Tearing strength		Ratio of set 1 to set 2	Bag paper identification numbers	Tearing strength		Ratio of set 1 to set 2
	Set 1	Set 2			Set 1	Set 2	
	Grams	Grams	Per cent		Grams	Grams	Per cent
16 081	33.6	32.4	103.7	16 093	60.6	56.8	106.7
16 082	76.4	74.0	103.2	16 094	73.2	73.0	100.2
16 083	68.4	69.0	99.2	16 095	135.6	132.4	102.2
16 084	96.2	96.6	99.6	16 096	94.6	92.2	102.6
16 085	112.2	110.0	102.0	16 097	84.0	85.4	98.4
16 086	128.6	128.6	100.0	16 098	121.6	122.0	99.6
16 087	64.0	64.0	100.0	15 099	179.2	176.8	101.4
16 088	118.0	117.4	100.4	16 100	85.2	83.6	101.8
16 089	179.2	185.6	96.6	16 101	83.0	83.2	99.8
16 090	149.2	147.8	101.0	16 102	186.6	186.8	99.9
16 091	338.4	335.4	101.0	16 103	96.2	96.0	100.1
16 092	471.4	477.0	99.8	16 104	166.8	167.8	99.4

V. CONCLUSIONS

Conclusions to be drawn from this study of type I and type II instruments are that neither one of them has been perfected enough for general commercial use. Type I, the recording instrument as now manufactured, is neither a delicate, a sensitive, nor an accurate piece of apparatus, since the amount of friction in the pin-slot bearing and the friction between the pen point and the paper chart do not allow careful accurate calibration. Since the test results obtained by using different factors will not check, it would indicate also that there is a defect in the mechanism of the instrument. Type II, the nonrecording instrument, is a fair instrument for bag paper, since most bag papers tear above the 75 cm^3 or gram mark. However, many recommendations could be made, such as stronger clamps, a better device for cutting test samples an exact size, a better device to control the distance of tear of each sample and to keep the distance the same for all samples, and the elimination of the use of weights on the glass side of the beam, by which the force is immediately applied instead of being gradually applied as in the case of the water. The general idea of both instruments is good. The type I recording instrument gives a curve showing the maximum and minimum tearing strength of paper as well as five peaks in the curve showing the results of five initial tears. No fault can be found with a curve that represents the maximum and minimum tearing strength, and the initial tearing strength is just what is wanted for writing papers. However, there is great doubt whether the five peaks in the curve of type I instrument actually represent five initial tears. The fibers very near the edge of an angular slit in the test sample (or perhaps halfway between two angular slits between which the paper is torn) may be stronger than those fibers at the very edge. In such a case the result would be a rising curve and the peak would not represent the initial tear but the tearing strength of the fibers near the edge or halfway between two slits in the paper. During the work on this instrument it was noticed that some peaks in the curves were double-toothed or double-peaked. In this case the first peak probably more nearly represents the initial tear. This may be a very fine distinction, and yet if this recording instrument is going to be used as a laboratory instrument it must be accurate to the highest degree. The type II nonrecording instrument, on the other hand, gives merely the maximum tearing strength of paper, which is all that is necessary for a

mill test. All tests on the two instruments were made in the machine direction of the paper (the direction in which paper moves on the paper machine) for the reason that better comparative results could be obtained in this way. Most papers are much stronger in the cross direction than they are in the machine direction. Since this is true, if you attempt to tear these papers in the cross direction, the direction of the tear as a rule turns to the machine direction soon after the beginning of the tear. This change in the direction of the tear never occurs when the paper is torn in the machine direction. Since in practically all grades of paper a good tearing strength in the machine direction is just as essential as a good tearing strength in the cross direction, and since better comparative results are obtained by tearing paper in the machine direction, it would seem that all tearing tests should be made in the machine direction.

WASHINGTON, January 5, 1921.