MEASURING THE TENDERNESS OF MEAT
BY MEANS OF A MECHANICAL SHEAR

by

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INTRODUCTION

Tenderness in meat may be defined as the state of being easily masticated, broken or cut. Meat is often referred to as being tender, very tender, and conversely, tough or lacking in tenderness. The boundaries of this classification are at best vague and indefinite.

A wide variation in tenderness may occur between carcasses and even between different cuts of meat from the same carcass. Tenderness in the cooked meat may also vary as a result of the method of cooking. It is believed by some that the kind and amount of connective tissue fibers present in meat influences the tenderness or lack of tenderness, as the case may be. It is of paramount importance that some method of measuring variation in tenderness be devised in order that the factors which cause this variation may be studied.

Three general methods have been employed to determine differences in tenderness between two or more samples of meat. These are the palatability method, chemical analyses, and the physical or mechanical method.

In brief, the palatability method consists of serving samples of meat prepared under standard conditions to a group of individuals who are experienced in the detection of differences which occur within and between the various samples. A chart, or score sheet, is employed on which the members of the committee record their reactions to such factors as aroma, flavor, tenderness, etc., both as to intensity and desirability. Such a group of judges is able to detect variations in tenderness very readily. Individual tastes and standards are eliminated when a number of judges are employed which makes it possible to secure a true composite value for tenderness. It is very important that the judges know nothing of the history of the samples as this knowledge may influence their judgment to a marked degree. Comparisons between two committees, working independently at different stations but under similar conditions and on comparable meat samples, show a fairly high correlation (7). The main objections to the above method are the time, expense, and the difficulty of standardizing the factors involved.

Mitchell (4) and his colleagues have devised a method for the determination of collagen and elastin, and offer this as a means of measuring tenderness chemically. Their work indicates that different cuts from the same carcass vary in the content of these two constituents (5). For example, the shank of beef contains more collagen nitrogen expressed as percentage of total nitrogen of the lean than the rib cut. Duplication of results is possible in one laboratory but it is doubtful whether these results should or can be compared directly with those obtained in another laboratory as the technic of the chemist plays a very important part in this analysis. The question of the relation of the two proteins, collagen and elastin, to tenderness in meat is still debatable, and there may be other constituents of meat which influence tenderness.

Apparently the first work with a mechanical or physical means of measuring tenderness of meat was that done by Lehmann (3) and his pupils. His research was begun in 1897 and his findings were published in 1907. The Lehmann method consisted of a simple lever type of machine in which a weight, applied at one end of a lever arm to force a knife-like blade through a sample of meat arranged at the other end of the lever, was taken as a measure of the tenderness of that sample. Undoubtedly, the sharpness of the blade would be an important factor in the operation of this machine and it would be difficult to standardize.

Since the work done by Lehmann, different types of machines have been employed. Tressler et. al. (6) describe two mechanical means for measuring tenderness of meat. One is a cutting gauge by which the pressure necessary to cut through the meat sample is measured by a Shrader tire gauge. The other method is a penetrometer device by means of which the penetration into meat of a plunger under definite pressure and through a fixed period of time is measured in millimeters. The data secured from trials with this machine were used in an attempt to show that quick-freezing and storage under low temperatures increases the tenderness of meat. The conclusions of Tressler et. al. have not been accepted by all meat investigators.

Warner (8) describes the mouse trap, or miter box, type of machine. This is in principle a mechanical shear, with a blade moving through a stationary guide, or miter box. The sample of meat is placed in an opening of the blade and the force required to shear the sample is measured by a self-recording spring dynamometer.

Of the various mechanical methods mentioned, that of the mouse trap type has received the most attention. This instrument is used by the Animal Husbandry Division, Bureau of Animal Industry, United States Department of Agriculture, and several Experiment Stations engaged in experimental work relating to quality and palatability of meat. This machine tends to duplicate itself as shown by the significant correlation of .79 on raw samples from more than 200 pairs of beef rib cuts (8). The variation in tenderness measured by this machine is similar to that measured by mastication as demonstrated by the fact that the same approximate correlation was obtained between shearing values realized on cooked samples and the grading of the same samples by a palatability committee.

At the present time results secured at the different stations using this type of machine are not entirely comparable. No two instruments are identical in their specifications, some vary in shape and size of opening in the blade, others vary in thickness of blade, and still others vary in the type of cutting edge used. For these reasons it seemed advisable to analyze the shearing type of machine in use and attempt its standardization.

With this in mind an experiment was inaugurated at the Kansas Agricultural Experiment Station in cooperation with the Animal Husbandry Division of the Bureau of Animal Industry, United States Department of Agriculture, enabling the author, working under the Departments of Animal Husbandry and Physics, to make such a study.

OBJECT OF THE EXPERIMENT

1. To develop a physical means of measuring the tenderness of meat:

a. By making a thorough analysis of the miter box type of machine now used in testing the shearing strength of meat tissues.

b. By attempting improvements upon this type of machine.

c. By studying the value of the suggested improvements as means of measuring the tenderness of meat.

EXPERIMENTAL METHODS AND OBSERVATIONS

The machine used in this experiment is a modification of instrument now in use at several experimental stations. The modified instrument was built by the Shop Practice Department of Kansas State College. Plates I and II give detailed specifications of the modified machine and of four different blades used in this work.

Plate III illustrates the type of machine which was previously used at the Kansas Agricultural Experiment Station and is typical of machines used at other stations. This machine lacks in machining, in uniformity of clearance between blade and miter box and in hardness of steel. These defects have been corrected in the new machine.

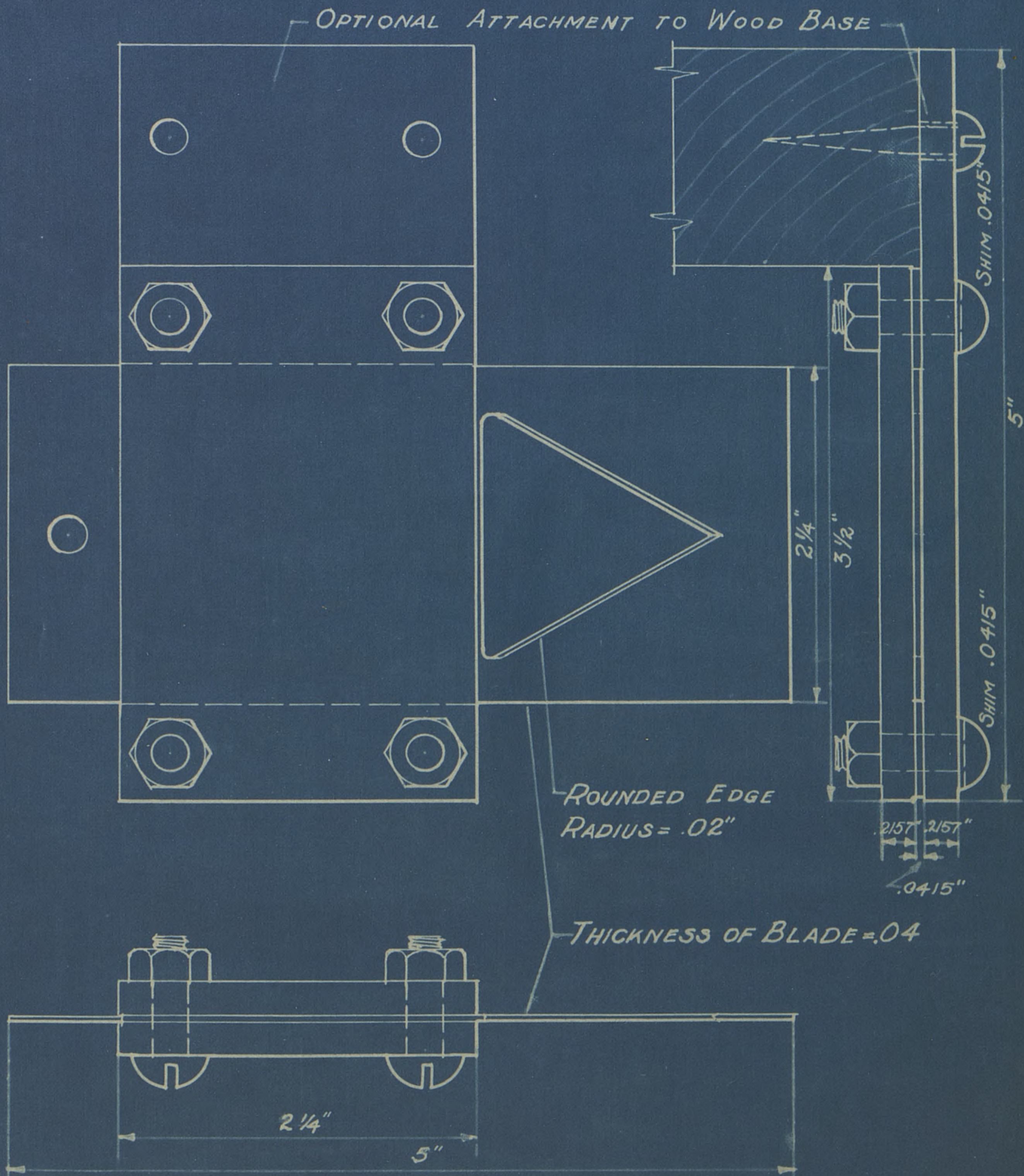

OPTIONAL ATTACHMENT TO WOOD BASE
SHIM .0415"
5"
2 1/4"
3 1/2"
SHIM .0415
ROUNDED EDGE
RADIUS = .02"
.2157" .2157"
.0415"
THICKNESS OF BLADE = .04
2 1/4"
5"

PLATE I.

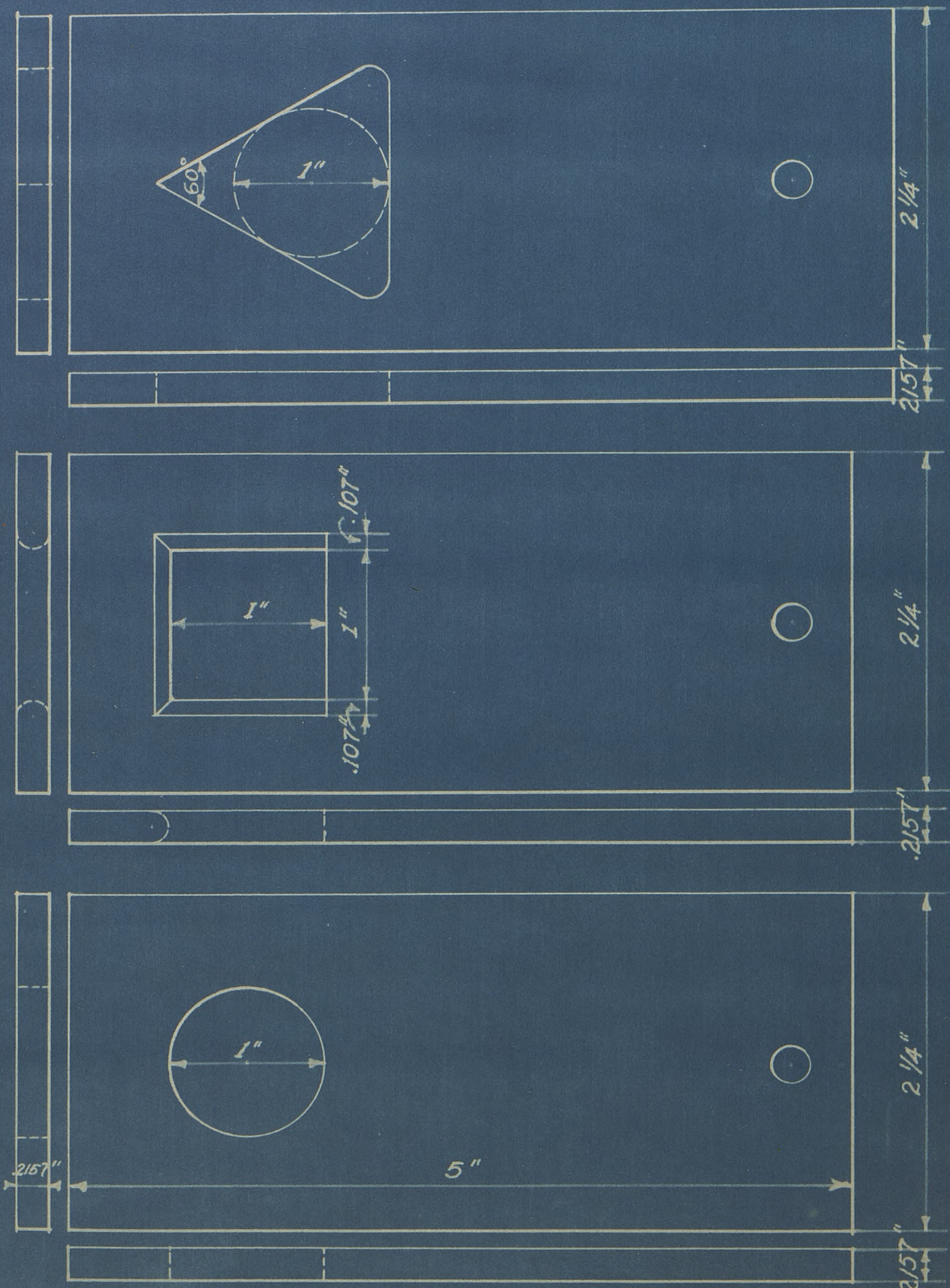


PLATE II.

PLATE III

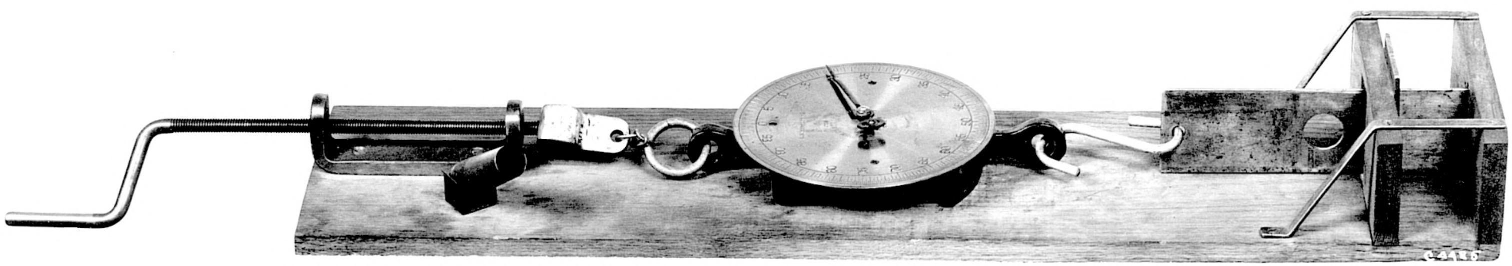


Table I lists all the various blades used in this study and the nomenclature adopted for each blade. The variations of the blade tested were as follows; size and shape of opening in the blade, thickness of blade, and type of cutting edge of the blade.

The sizes of openings used, namely, one inch and one and one-half inch, were chosen in order to determine the effect that they have on the precision of any blade when shearing a sample one inch in diameter. This range in size includes all sizes of openings embodied in the machines used at other stations. The shapes of openings chosen were those which seemed practical and could be duplicated with a high degree of mechanical accuracy. The two thicknesses of blades, .2157 inch and .040 inch, embrace in their range practically all of the blades used at other institutions. In this discussion, blades .2157 inch in thickness will be referred to as thick blades, and blades .040 inch in thickness will be designated as thin blades.

In order to measure differences in precision due to variations in the blades used, it was necessary to employ some material which was homogeneous. A compound composed of beeswax, ten parts; vulcanized rubber, six parts; lump rosin, five parts; and paraffin, two parts, was used. These ingredients melted and mixed together produced a substance

TABLE I

Identification of the blades used and the average force necessary to shear a one inch sample of a homogeneous substance.

Blade No.	Thick-ness	Type of Opening	Type of Edge	Average Shearing Force in Pounds
1	.2157"	1" circle	Square	39.88
2	.2157"	$1\frac{1}{2}$" circle	Square	35.23
3	.2157"	$1\frac{1}{2}$" circle	Square	35.52
4	.2157"	1" square	Square	33.55
4-b	.2157"	1" square	Rounded Radius .1079"	32.32
5	.2157"	Equilateral triangle circumscribed about 1" circle	Square	27.24
5-b	.2157"	Same as (5)	Rounded Radius .1079"	27.38
1-a	.040"	1" circle	Square	16.16
2-a	.040"	$1\frac{1}{2}$" circle	Square	16.71
3-a	.040"	$1\frac{1}{2}$" square	Square	15.51
4-a	.040"	1" square	Square	16.03
4-c	.040"	1" square	Rounded Radius .020"	16.03
5-a	.040"	Equilateral triangle circumscribed about 1" circle	Square	14.08
5-c	.040"	Same as (5-a)	Rounded Radius .020"	13.50

that was cohesive and solid at room temperature. It appeared to be homogeneous and could be remelted innumerable times without materially changing its consistency.

The compound was made up in sufficient quantity to provide twenty-four feet of cylindrical shapes one inch in diameter. These samples were made by pouring the melted substance into forms of brass tubing one foot in length and having an inside diameter of one inch. The forms were placed in a water bath of boiling water to insure even and uniform cooling of all samples.

The homogeneous mixture proved to be materially affected by changed in temperature. This effect of temperature on the material was minimized by taking all readings in a room equipped with temperature and humidity control.

At seventy degrees Fahrenheit the compound sheared in a manner similar to meat. It was necessary to keep a thin film of oil on all movable parts of the shearing machine to eliminate excessive friction due to the cohesiveness of the material. The cylindrical sticks of the compound were allowed to become acclimated to room temperature and humidity for twenty-four hours before using.

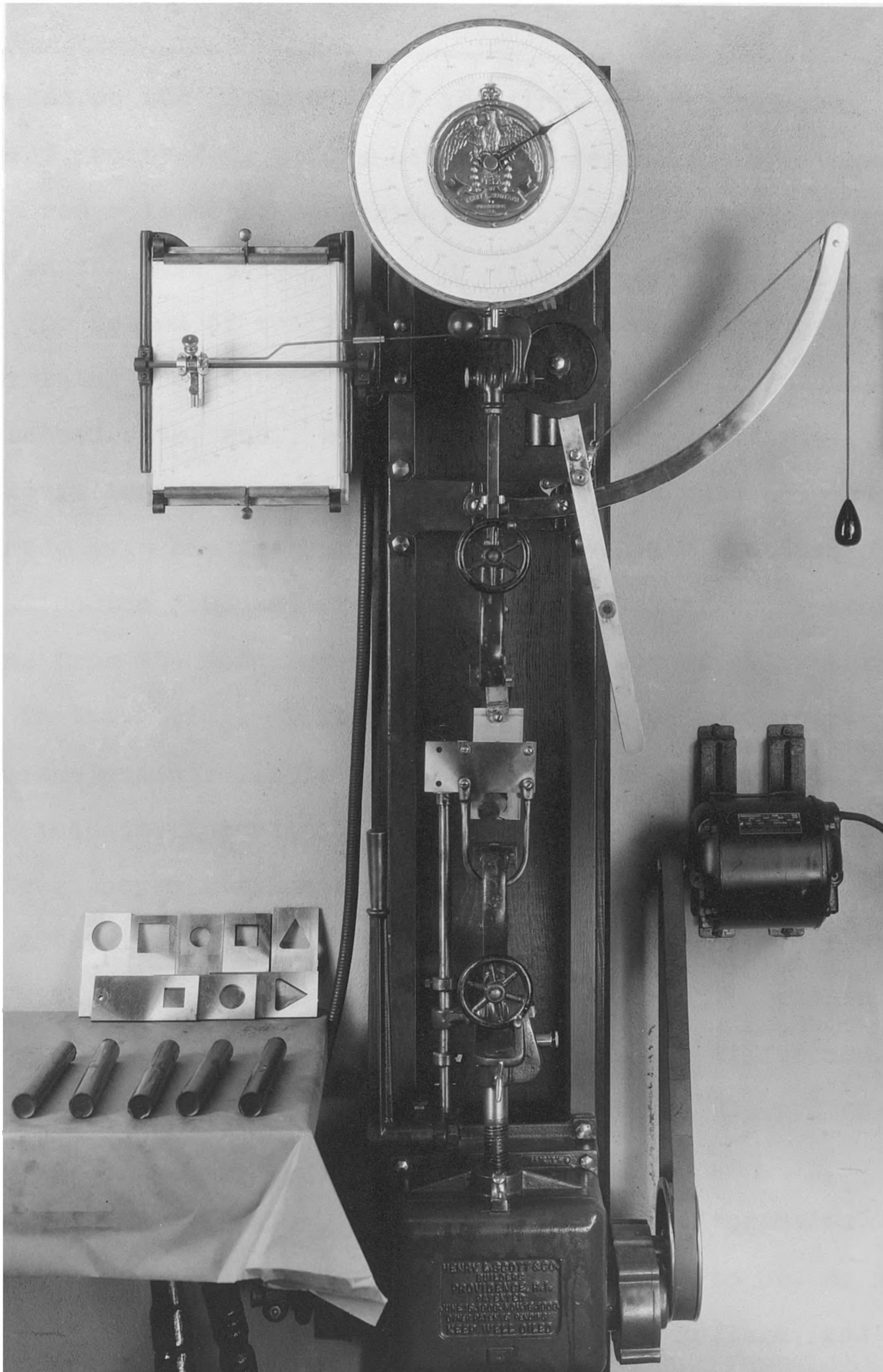
The modified model of the shearing machine had an attachment (not shown in the plates) which made it possible to use it in connection with the Henry L. Scott Combination

Tensil Strength Tester, Model D[1], which is owned by the Division of Home Economics at Kansas State College. Plate IV shows this machine with the shearing attachment in position for operation. The Tensile Strength Tester is of the dead weight type, with an automatic recording device. The jaw moves at a uniform speed of twelve inches per minute, which is comparable to that attainable with the hand operated type.

Comparisons were made between only two blades at a time. In most cases twenty to twenty-four sticks of the compound were used in one trial. One blade was employed to make all first cuts on each stick. The blade was then changed and all second cuts were made with the other blade of the pair that was being tested. Following this procedure, it was possible to secure an average of ten cuts per stick, or five with each blade. This method of comparison was followed in all instances with one exception when four blades were compared directly, each blade making every fourth cut on the same sample. Electric fans were used to keep a rapid movement of air over the samples in order to eliminate any possible heating effect which shearing may

1. Manufactured by Henry L. Scott and Company, Providence, Rhode Island.

PLATE IV


BUILDERS
PROVIDENCE, R.I.
PATENTED
OTHER PATENTS PENDING
KEEP WELL OILED

have had on the material. As the first cut was taken on each of twenty-four sticks before the second cut was taken, there was a lapse of approximately fifteen minutes between cuts on the same stick.

The method of analysis for variation consisted of determining the average shearing value for all first cuts, all second cuts, etc., of the sticks used in that trial. The deviations from these mathematical means were computed and made into one frequency distribution. The standard deviation was computed from such a frequency array of deviations from the mean for each particular cut of all sticks used in that trial. This method was followed as it appeared that some uncontrollable factors entered into the operations which made it impractical to place all shearing values in one frequency distribution.

A total of 12,168 observations was secured for the work done with the homogeneous material. The variation within a comparison was considered significant when the difference between the standard deviations was four times the probable error.

Relative variation, or the coefficient of variation, was not employed. A set of data was submitted to Dr. R. A. Fisher of the Rothamsted Experiment Station, England, and his statement as to relative variance is as follows (2):

"In relative variance, blade 2 still has a slight advantage, but I attach no importance to this, for I do not see that this method of comparison has any logical basis, except on the assumption that the difference in average reading for any blade between two different materials is proportional to the average reading for that blade. This seems to me a pure assumption, and leads to the most interesting point in the whole enquiry, namely, that your measure of precision needs to be supplemented (not by the mean readings), but by a measure of dispersion of the mean readings of the two blades, on really different materials."

Table I gives the nomenclature used in designating the various blades and also the average force required for each blade to shear the homogeneous material at seventy degrees Fahrenheit. It will be noted that in all cases the circular openings required the most force, whereas the triangular holes required the least force. This difference is accentuated in the case of the thick blades. The freedom with which the material could expand during shearing evidently accounts for the difference in shearing values between blades 1 and 2 and between blades 3 and 4.

The results of comparisons with the thick blades are given in Table II. It appears that blades 4, 4-b, 5 and 5-b are more precise than the remaining blades. It is also

TABLE II

Results of comparisons made with blades 1, 2, 3, 4, 4-b, 5 and 5-b on a homogeneous substance.

Blade No.	Number of Observations	Standard Deviation	Probable Error	Significance
1	426	.8584	±.0198	
2	441	.6239	±.0144	+
2	400	.746	±.0178	
5	396	.558	±.0134	+
3	639	.5860	±.0111	
5	639	.4815	±.0091	
4	610	.3563	±.0069	
5	609	.3257	±.0063	?
4-b	365	.3422	±.00854	+
4	365	.4098	±.01023	
5-b	335	.3372	±.00879	−
5	335	.3199	±.00834	
5	326	.3476	±.00918	+
4-b	326	.4284	±.01131	

evident from these data that differences in variation between the round and square edged blades could not be efficiently determined with the homogeneous substance used in this study. The rounded edge seemed to function as a sharpened knife and therefore required the same or less shearing force than the square edged blades when shearing the wax-like substance. This might not be true with a material containing fibers.

Table III gives the results of comparisons made with the thin blades. Of the seven blades tested, it was found that blades 4-a, 4-c, 5-a and 5-c were the most precise. Comparisons between blades 4-a, 4-c, 5-a and 5-c were made at one trial, with each blade making every fourth cut on each stick of the homogeneous material. The lowest standard deviation in the final trial was secured with blade 5-c, and, therefore, this blade was used in the tests with meat. This blade was .040 inch in thickness with a triangular opening made by circumscribing an equilateral triangle about a one inch circle. The cutting edge of the blade was rounded and had the curvature of a circle with a radius of .020 inch. The guide box against which the meat was sheared had a square edge.

A final selection between blades 4-a, 4-c, 5-a and 5-c should be made only after their precision has been checked

TABLE III

Results of comparisons made with blades 1-a, 2-a, 3-a, 4-a, 4-c, 5-a, and 5-c on a homogeneous substance.

Blade No.	Number of Observations	Standard Deviation	Probable Error	Significance
1-a	609	.426	±.0082	−
2-a	609	.417	±.0081	
2-a	549	.4501	±.00916	
5-a	549	.3551	±.00723	+
4-a	567	.3901	±.00781	+
3-a	567	.4507	±.00903	
4-a	509	.22138	±.00468	
5-a	509	.24398	±.00516	?
5-a	372	.3135	±.00775	
4-a	372	.2809	±.00695	?
5-c	372	.2720	±.00673	
4-c	372	.2819	±.00697	

by using one or more different substances. An additional reason for selecting blade 5-c for use with samples of meat was that it was observed during the trials that a triangular opening was apparently more sensitive to changes in material than any of the other shapes of holes tested.

The Scott Tensile Strength Tester was equipped with an attachment which made it possible to secure curves of the shearing process. Figures 1, 2, 3, and 4 show the consistency with which the homogeneous material sheared and also portray differences in shearing due to variation in the blades.

Cuts of meat showing marked variation in grade and quality were selected for the tests on meat. The standard rib cut (6th to 12th ribs inclusive) was used for comparisons between the observations of a competent palatability committee and the shearing values of the raw and cooked samples.

The 6th, 7th and 8th ribs were cooked according to the standard method (9). The sample used for shearing was taken by means of a cork borer type of sampler one inch in diameter. These samples were removed from the center of the cooked eye muscle of the rib (longissimus dorsi) parallel to the muscle fibers. They were comparable in uniformity and were taken while the roast was still hot, and allowed to

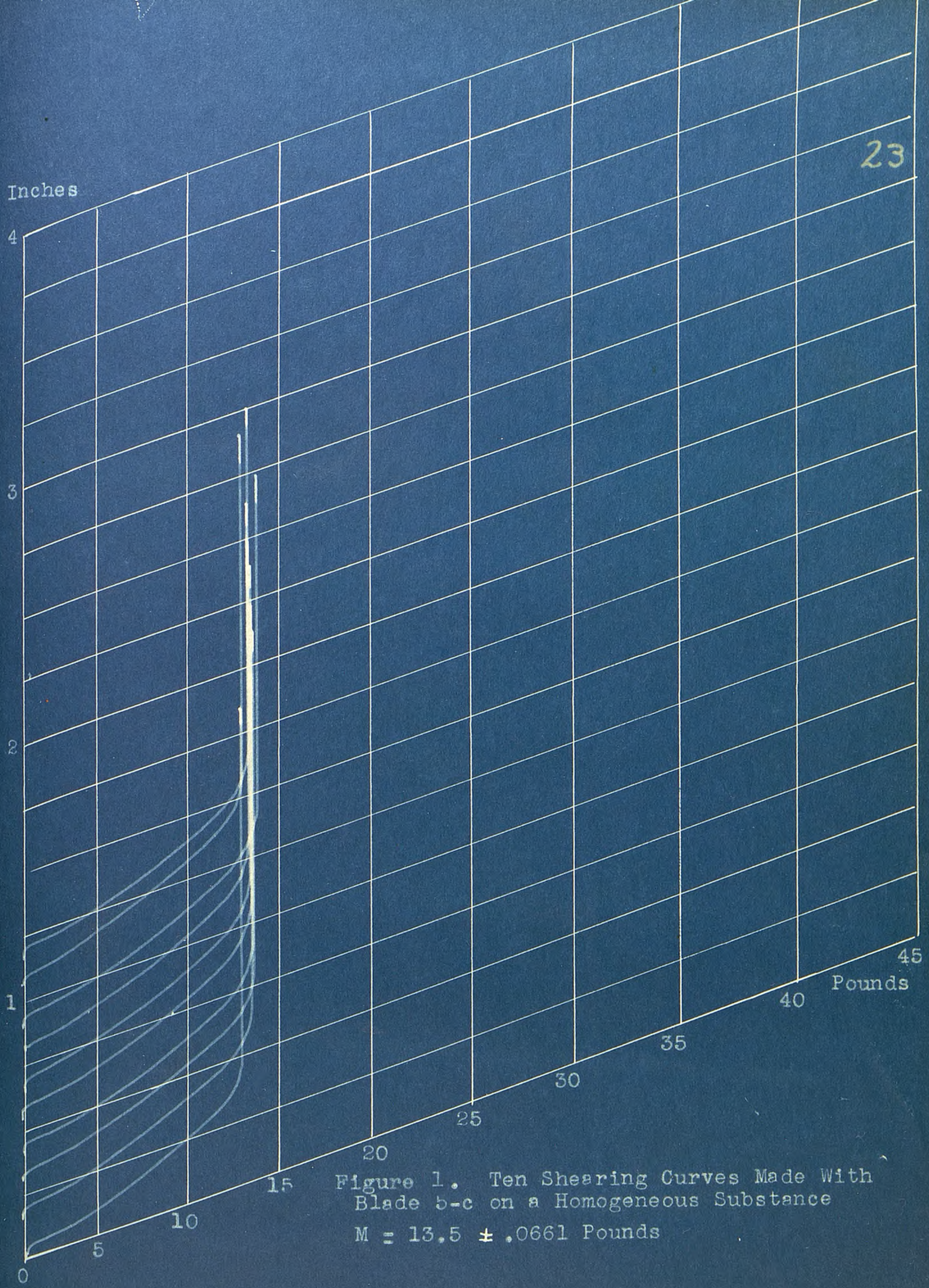


Figure 1. Ten Shearing Curves Made With Blade 5-c on a Homogeneous Substance

M = 13.5 ± .0661 Pounds

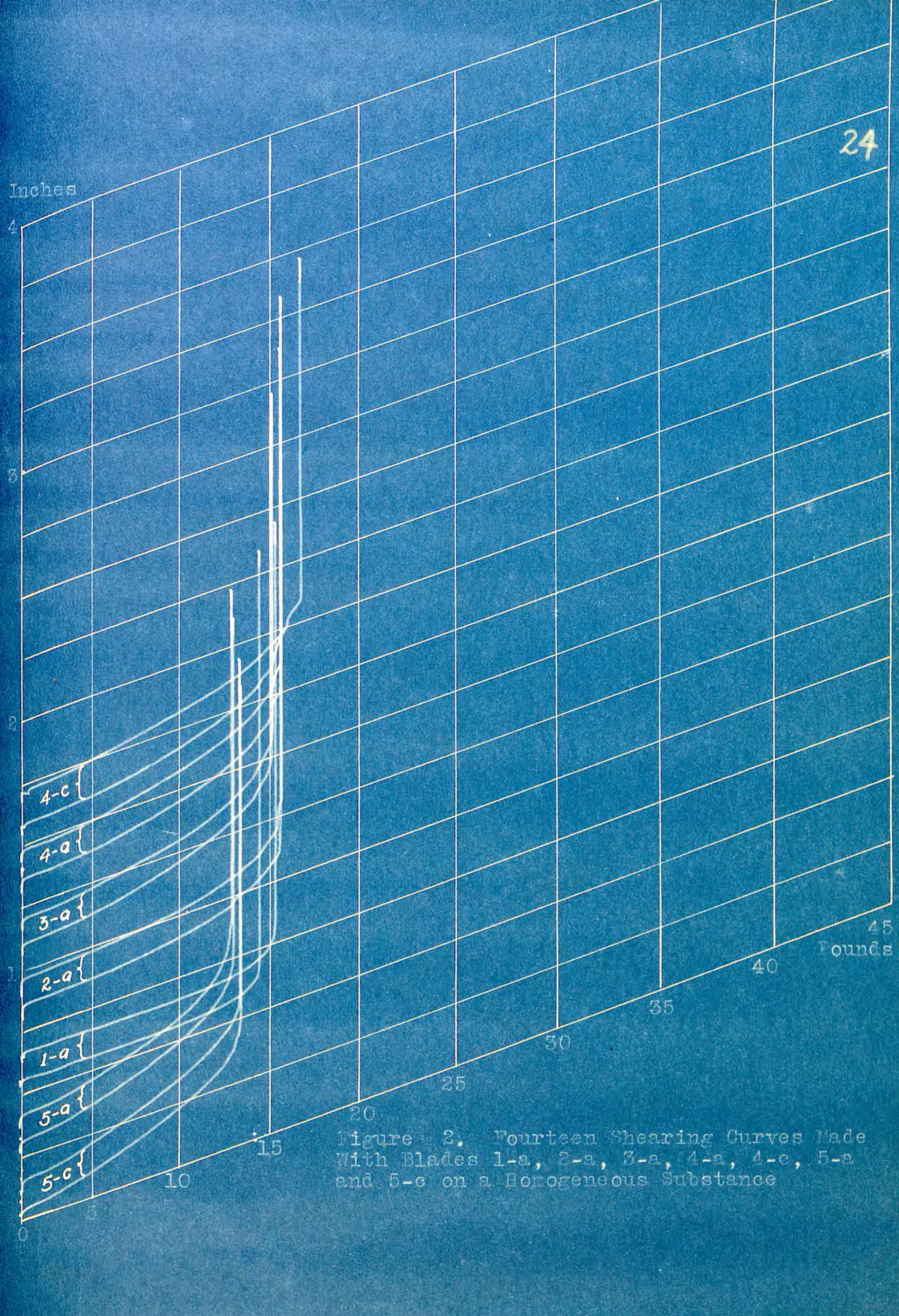


Figure 2. Fourteen Shearing Curves Made With Blades 1-a, 2-a, 3-a, 4-a, 4-c, 5-a and 5-c on a Homogeneous Substance

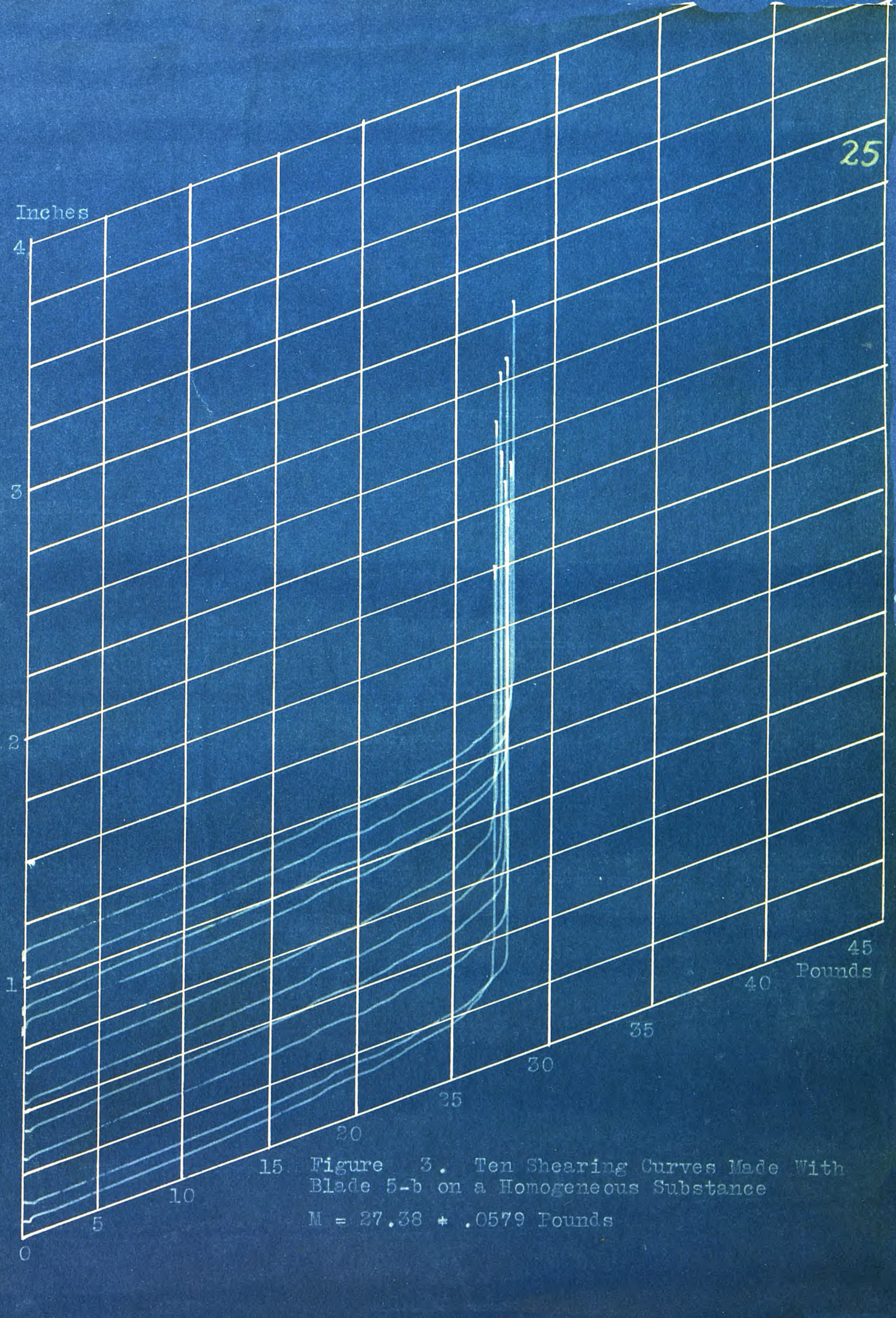


Figure 3. Ten Shearing Curves Made With Blade 5-b on a Homogeneous Substance

M = 27.38 ± .0579 Pounds

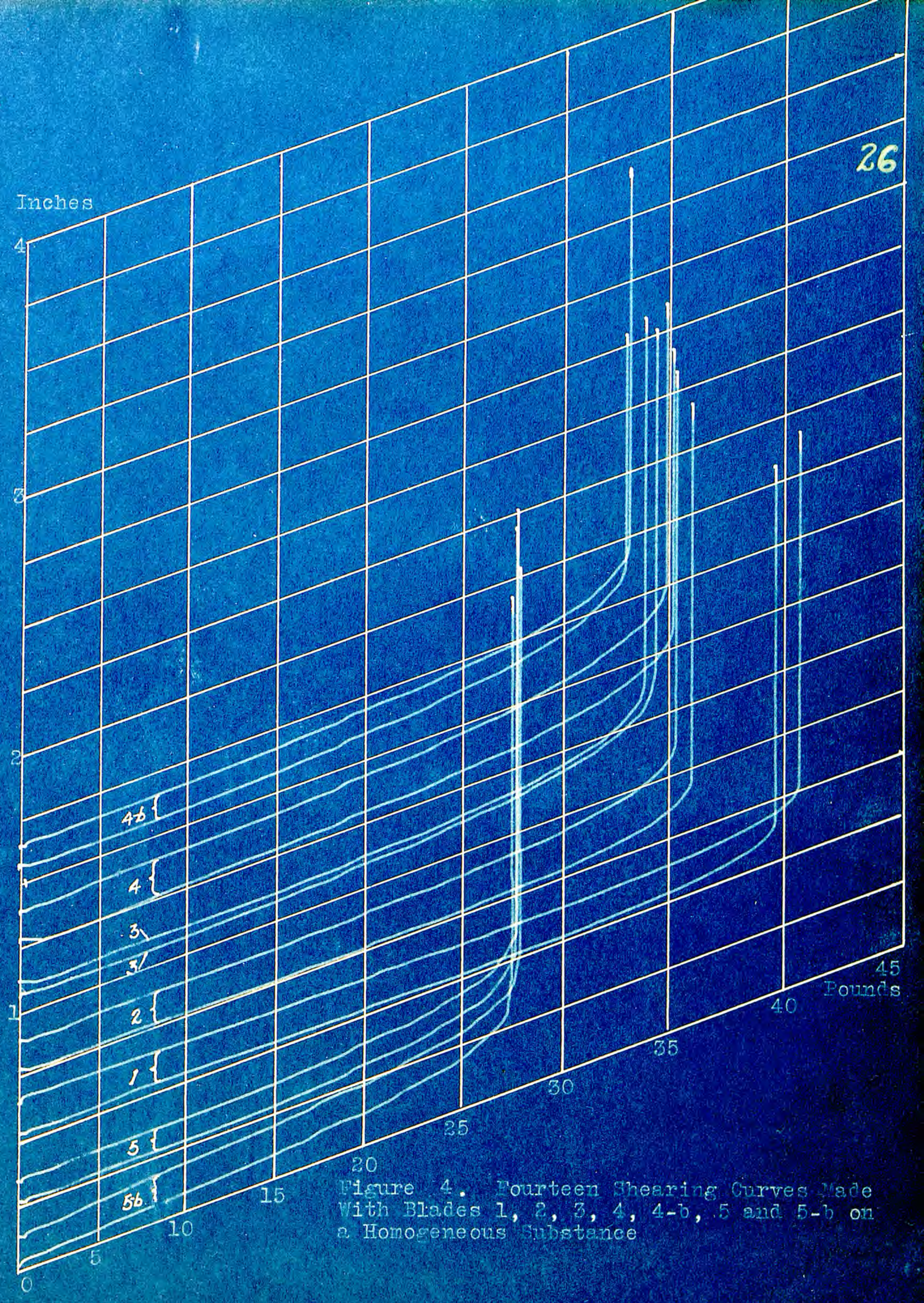


Figure 4. Fourteen Shearing Curves Made With Blades 1, 2, 3, 4, 4-b, 5 and 5-b on a Homogeneous Substance

cool to eighty degrees Fahrenheit before shearing.

The palatability committee was comprised of the same personnel as the committee which functions in connection with the cooperative meat investigations conducted at the Kansas State Agricultural Experiment Station. Comparable samples were served each member and these samples were scored for all factors on the official scoring chart.

Figure 9 shows the official scoring chart for palatability tests.

The samples of raw meat were taken from the lateral portion of the longissimus dorsi from the region of the 9th, 10th, 11th and 12th thoracic vertebrae. These were removed parallel to the muscle fibers with the same sampler as was used in sampling the cooked samples, and were comparable in size and location in the longissimus dorsi. All samples were sheared at a temperature of eighty degrees Fahrenheit.

The rib cuts compared and tested were of the following classes and grades: one cow rib (grade common) from a sixteen year old cow; one steer rib (grade good) from a two year old steer; one heifer rib (grade low choice) from a long yearling heifer; one cow rib (grade medium) from an aged cow; one cow rib (grade good) from an aged cow; and one bull rib (grade cutter) from an aged bull.

MEAT COOKING RECORD

Grading Chart for Cooked Meat

Cooking Laboratory No._____ Sample No._____ Kind_________ Date______________

FACTOR	PHASE	7	6	5	4	3	2	1	REMARKS
Aroma	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	Neutral	undes.	undes.	
Texture	Intensity	very fine	fine	m. fine	s. coarse	coarse	very coarse	ext. coarse	
Flavor of fat	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	Neutral	s. undes.	undes.	
Flavor of lean	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	Neutral	s. undes.	undes.	
Tenderness	Intensity	very tender	tender	m. tender	s. tough	tough	very tough	ext. tough	
Juiciness	Quantity of Juice	very juicy	juicy	m. juicy	s. dry	dry	very dry	ext. dry	
	Quality of Juice	very rich	rich	m. rich	s. rich	per	s. per.	imper.	

Color of Lean		Color of Fat	
1. light red	4. pinkish brown	1. white	4. yellowish brown
2. dark pink	5. light brown	2. creamy white	5. yellow
3. light pink	6. dark brown	3. grayish cream	6. amber

Key to Abbreviations

pro. - pronounced	des. - desirable	imper. - imperceptible
m. - moderately	undes. - undesirable	per. - perceptible
s. - slightly	ext. - extremely	

____
(Signature of Judge)

Figure 9.

Grading Chart for Cooked Meat.

Table IV summarizes the tests made on the various rib cuts. With the exception of one case, there was very little difference between the raw shearing values and the cooked shearing values. It will be noted that in all cases, with the exception of one, the average and standard deviation were less for the cooked samples than for the raw samples. This is also true of the range within one sample. There is a tendency for both the raw and cooked shearing values to correlate with the grading of the palatability committee. Unfortunately, the number of rib cuts tested is too small to conclude definitely that the machine used in this analysis measures variation in tenderness, but this conclusion seems to be indicated.

Figures 5, 6, 7, and 8 show the reaction of meat to the shearing process, and also the variation in shearing values.

Further comparisons were made between the carcass of a sixteen year old cow (grade common) and the carcass of a one year old bull (grade choice). The carcass designated as a "choice" bull carcass would have graded "choice" steer at most packing establishments. Comparisons made between these two carcasses were made on the three major muscles of the round (semimembranosus, semitendinosus and biceps femoris). Shearing tests were made on the raw samples taken from a first cut round steak four inches thick from each round.

TABLE IV

Results of shearing tests made on raw and cooked samples of the longissimus dorsi from six different beef rib cuts.

Description	Number of Observations	Mean	Standard Deviation	Average Deviation	Range Within Sample	Palatability Grade
Common Cow Rib 16 yr. old cow. Raw.	10	13.33 ± .5059	2.3715	1.936	10.1-18.1	
Common Cow Rib. 16 yr. old cow. Cooked.	9	16.33 ± .4755	2.1151	1.909	12.9-18.7	5.86 (Tender)
Good Steer Rib. 2 yr. old steer. Raw.	11	23.79 ± .8892	4.3727	3.390	19.0-32.6	
Good Steer Rib. 2 yr. old steer. Cooked.	9	12.90 ± .4077	1.8135	1.533	9.8-15.5	5.47 (Tender)
Common Cow Rib. Aged cow. Raw.	16	24.12 ± .6479	3.842	3.09	18.5-31.1	
Common Cow Rib Aged cow. Cooked.	13	29.12 ± .7453	3.9845	3.48	22.6-35.0	3.86 (Slightly Tough)
Good Cow Rib Aged cow. Raw.	16	22.66 ± .6403	3.797	3.02	15.1-28.3	
Good Cow Rib Aged cow. Cooked.	11	18.66 ± .3026	1.488	1.11	16.1-21.0	5.00 (Tender)
Choice Heifer Rib Raw.	15	17.56 ± .5594	3.212	2.74	11.3-20.9	
Choice Heifer Rib Cooked.	9	17.03 ± .4548	2.023	1.82	14.8-20.4	5.43 (Tender)
Cutter Bull Rib Raw.	13	34.15 ± 1.0456	5.590	4.22	28.0-44.6	
Cutter Bull Rib Cooked.	9	34.33 ± .7723	3.435	2.94	28.9-38.6	1.71 (Very Tough)

Figure 5. Eleven Shearing Curves Made With Blade 5-c on a Sample of the Raw Longissimus Dorsi Taken From the 9th, 10th and 11th Ribs of a Good Steer Carcass
M = 23.79 ± .8892 Pounds

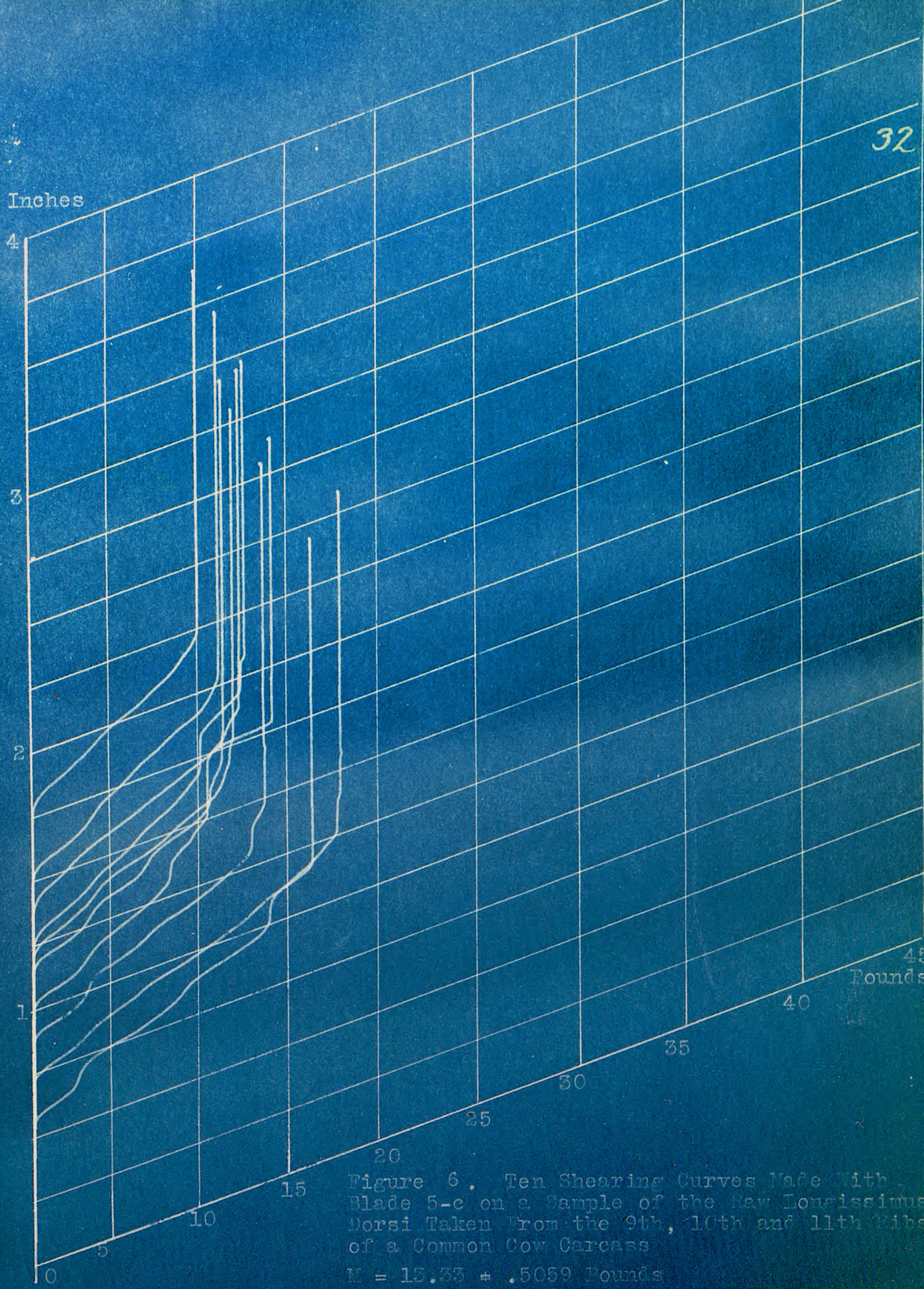


Figure 6. Ten Shearing Curves Made With Blade 5-c on a Sample of the Raw Longissimus Dorsi Taken From the 9th, 10th and 11th Ribs of a Common Cow Carcass

M = 13.33 ± .5059 Pounds

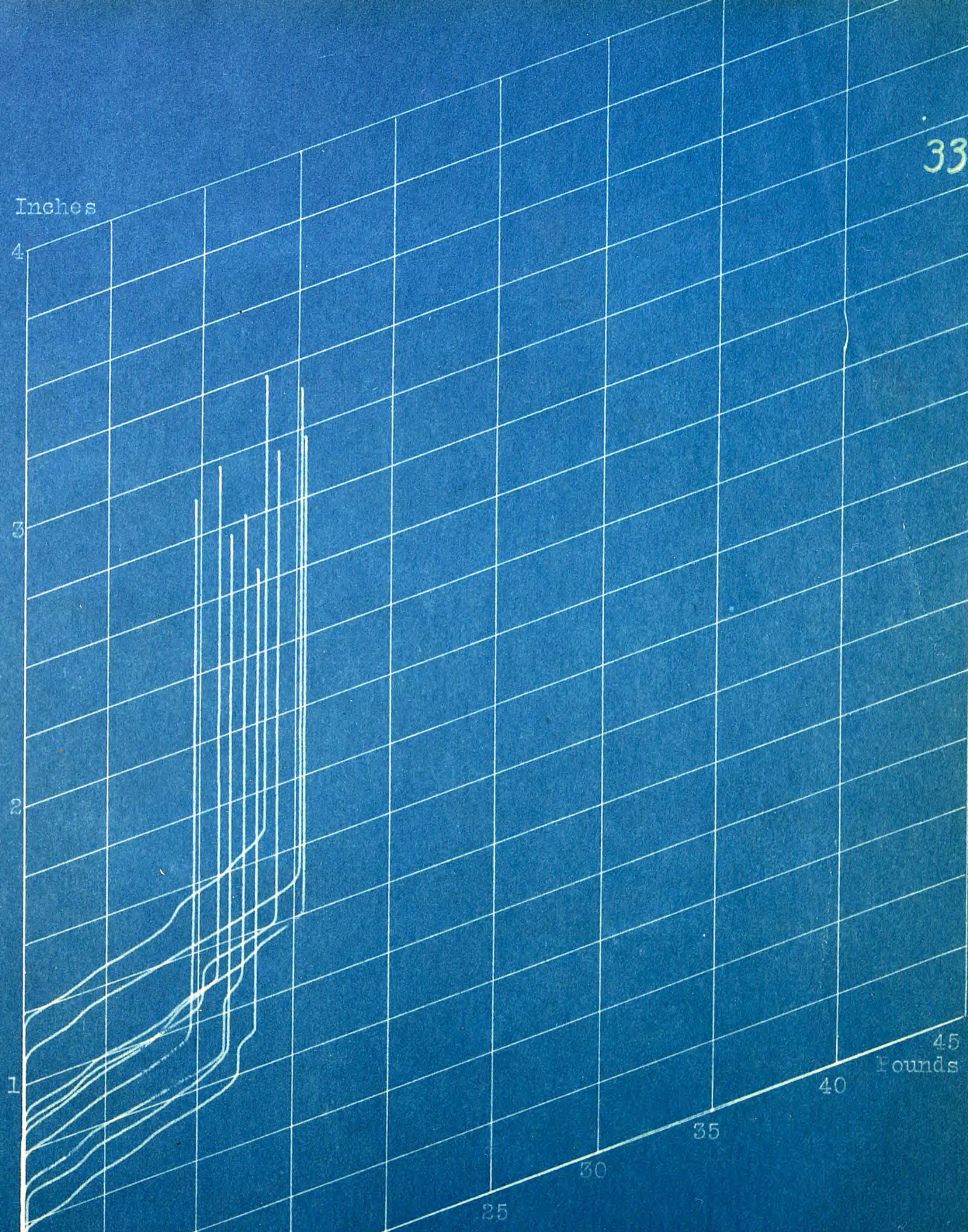


Figure 7. Nine Shearing Curves Made With Blade 5-c on a Sample of the Cooked Longissimus Dorsi Taken From the 6th, 7th and 8th Ribs of a Good Steer Carcass

M = 12.9 + .4077 Pounds

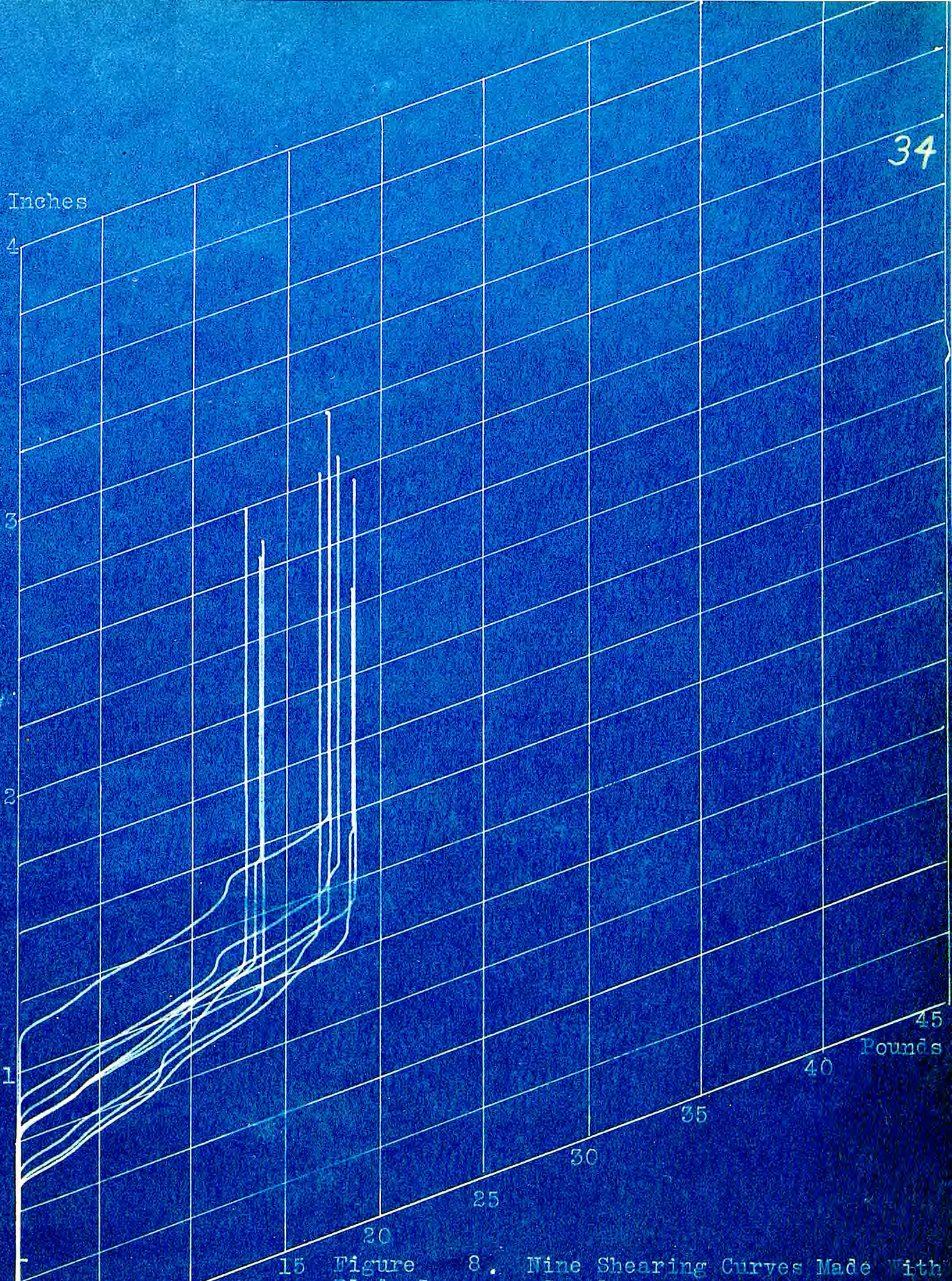


Figure 8. Nine Shearing Curves Made With Blade 5-c on a Sample of the Cooked Longissimus Dorsi Taken From the 6th, 7th and 8th Ribs of a Common Cow Carcass

M = 16.33 ± .4755 Pounds

TABLE V

Results of shearing tests made on various raw muscles from the carcass (grade common) of a 16 year old cow and from the carcass (grade choice) of a one year old bull.

Description	Number of Observations	Mean	Standard Deviation	Average Deviation	Range Within Muscle
Semimembranosus Common cow carcass.	36	23.7 ± .8721	7.758	6.38	8.9-43.3
Semitendinosus Common cow carcass.	23	28.9 ± .8170	5.809	5.01	17.0-38.7
Biceps femoris Common cow carcass.	26	32.2 ± .8242	6.231	5.05	23.0-44.2
Semimembranosus Choice bull carcass.	44	31.1 ± 1.273	12.516	11.09	10.9-52.0
Semitendinosus Choice bull carcass.	29	30.2 ± .7855	6.271	5.12	17.5-39.2
Biceps femoris Choice bull carcass.	32	30.0 ± .5819	4.88	4.29	21.0-38.7
Psoas major Common cow carcass.	12	9.42 ± .4187	2.151	1.517	4.8-14.1
Longissimus dorsi 13th thoracic vertebra - 5th lumbar vertebra inclusive. Common cow carcass.	20	11.31 ± .5556	3.6839	3.02	6.2-18.9

Tracings were made of each cut in order to insure comparable location of each sample. The cork borer type of sampler was employed. The raw longissimus dorsi from the region of the 13th thoracic vertebra to the 5th lumbar vertebra and the tenderloin muscle (psoas major) from the common cow carcass were also tested for shearing values.

The results of these comparisons are presented in Table V. It will be noticed that there is no consistent correlation between the semimembranosus, semitendinosus and biceps femoris of the two carcasses. Shearing values indicate that the psoas major is the most tender muscle of those studied. This concurs with the results obtained on cooked meat at the Missouri Experiment Station (1). The psoas major also appears to be the most homogeneous.

CONCLUSIONS

1. Shape of opening:
   a. The blades ranked in order of increasing variation as follows: triangular, square and circular.
   b. Blades with circular openings required the greatest force to shear the homogeneous

substance and blades with triangular openings required the least.

2. Size of opening:

   a. The one inch square was more precise than the one and one-half inch square.

   b. The one and one-half inch circle was more precise than the one-inch circle.

3. Thickness of blade:

   a. The thin blades (.040 inch) had less apparent variation than the thick blades (.2157 inch).

4. Cutting edge of blade:

   a. The substance used was not suitable for measuring variation between the rounded and square cutting edge. It is believed that a fibrous material would be necessary for this phase of the investigation.

5. There was an indication of a definite correlation between the shearing values of raw and cooked samples and the grading of a palatability committee for the tenderness factor.

6. The psoas major is apparently the most tender muscle of those studied.

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