LEGIBILITY DETERMINATIONS OF MULTIPLE CARBON COPIES

By

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I. INTRODUCTION

To manufacturers and users of multiple carbon forms, the legibility of multiple carbon copies is of great importance. The users of such forms are interested in obtaining those which will give the maximum over-all legibility for a specific number of parts (pages). The manufacturers of such forms are interested in producing those which will give maximum legibility, and, to them, the various factors entering into the production of such forms is very important. However, regardless of what factors enter into the production of maximum legibility for a certain number of carbon copies, unless it is possible to set up a standard of legibility and to compare copies produced under various conditions, as, for example, weight of paper, kind of paper, specific carbon used, thickness of carbon coating, et cetera, it will not be possible to determine either the factors or the extent of their contribution, except quite haphazardly.

It is, therefore, quite important to the manufacturers of these multiple carbon forms to be able to accurately compare the carbon copies produced under diverse circumstances, thus determining the extent to which various factors affect their legibility and, consequently, to be able to produce forms which do give greater legibility. Also, where a specific form is wanted for a specific job, it is of importance to the manufacturer to be able to easily and quickly compare different copies and to state definitely that, for the job wanted, one particular combination of carbon and paper will give the best results.

The subject of this research has been the investigation of a means of readily comparing multiple carbon copies and arriving at reproducible results.

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II. REVIEW OF LITERATURE

Electromagnetic radiations of wave lengths from approximately 3900 to 7800 Angstrom Units (10^{-8} centimeters) falling on the eye cause countless retinal-cortical connections to transmit electrical impulses to the brain, thus arousing the sensation of vision. Adrian[1] has diagrammed the steps between the stimulus and the mind, showing that change in stimulus produces an excitatory process in the retinal receptors which gradually declines, and that the neural currents thereby produced have one unique characteristic, that of frequency which decreases as the stimulus. High frequency results in high sensation intensity. These impulses travel at the rate of about two hundred and twenty miles per hour in the human nerve.[2]

The retina constituting the innermost structure of the eye may be thought of as a fine mosaic of tiny light-sensitive cells connected to the higher nerve centers. In the retina are found the rods and cones, so called because of their shape, which lie in the second of the ten retinal layers. The rods, of which there are about 130×10^6 (one hundred and thirty million) in the human eye, are 0.002 millimeters in diameter and from 0.04 to 0.06 millimeters in length. They function at low illumination levels under which neither color nor details may be discriminated. The cones, about 7×10^6 (seven million) in the human eye, vary from 0.022 to 0.085 millimeters in length and from 0.0025 to 0.0075

millimeters in diameter. They are responsible for color vision and the recognition of fine details.

It has been stated that eyes are functional over a range of stimulus energy ranging from ten billion to one.[3] There is, furthermore, no change in retinal sensitivity over the range of brightnesses usually encountered - thus, Weber's Law, that the just perceptible difference in sensation occurs when the stimulus is increased or decreased by a certain proportion of itself, the proportion being constant over limited ranges. When the eyes are required to change from a dark to light environment, it may be said in general that the time requirements for adaptation are much less than from light to dark environment.

It might be noted that pupil diameter varies from a diameter of two to eight millameters for brightness levels from one thousand to one-one thousandth millilambert. However, for very gradual changes in brightness the pupil size will remain constant for changes of as much as two hundred to one. Visual acuity improves as pupil diameter increases from a minimum to about two millameters, and thereafter remains essentially constant.[2]

Sensations of brightness and color do not grow to full or final value immediately when an image falls on the retina, nor do they decrease immediately to zero when the image is withdrawn.

It has been found that the "Parameters of the Visual Threshold"[2] are four in number: (1) the size of critical detail, that is the visual angle subtended by the detail at the eye, (2) the contrast

between the object and the background, (3) the brightness level to which the object is illuminated, and (4) the length of time the image of the object is allowed to remain on the retina. The fact that an object is visible is because of the fact that all of the variables above are equal to or greater than the threshold value. The magnitudes of these variables will, of course, depend on the biological characteristics of the observer, the characteristics of the physical environment, and upon the kind of visual recognition required. That is, to what perceptual threshold the recognition is to be carried. The three stages of visual perception are (1) the recognition of presence, (2) the bare perception of form, and (3) the certain perception of form of various shaped objects.[4] All forms appear alike and "formless" under conditions corresponding to the most elementary type of visual perception. Helson and Fehrer[4] have found that of various shapes viewed, (1) the rectangle requires least amount of light for perception, (2) the triangle is the form reported the most on the barely perceptible level, (3) the rectangle is confused the least number of times, and (4) the circle is the form appearing neither inferior nor superior by any criteria.

Among the factors of the Visual Threshold Parameters, time of duration of image on the retina is a factor of relatively small importance in perception, and size is of less importance than the factors of illumination and contrast, within ordinary limits.

Although the factors of illumination and contrast are complimentary, the influence of brighter illumination is inadequate to offset the disadvantages of low contrasts.[2]

Visual acuity is the ability to distinguish fine details. Theoretically the smallest space interval that can be distinguished is one such that one cone of the retina does not receive sufficient radiation to excite it. Then, since the average diameter of cones is of the order of 0.0032 millimeter, the average cone, for an eye having a focal length of fifteen millimeters, subtends an angle of forty-four seconds of arc. Thus two objects separated by less than this amount could not be resolved. Normal visual acuity is taken as that which is capable of discerning a black letter on a white background when the critical details of the letter subtend a visual angle of one minute. Visual acuity is the same substantially for black characters on white, red, and green backgrounds, but only about half as much for black characters on a blue background.

It has been found also that distractions may either inhibit or facilitate the visual reaction.[5] Data show however, that distractions of various kinds inhibit the reaction to a visual stimulus far more frequently than they facilitate the reaction.

Research has been made on the readability of various sizes and styles of type by means of statistical surveys run on groups of "well educated adults".[2] The criteria for these studies were psychological-physiological. The criteria proving of most consequence were the involuntary blink rate (being higher for poor

readability)[6], the pulse rate (being lower for poor readability)[7], and the involuntary muscular tension (which occured more often when reading under adverse circumstances.)[8]

Insofar as is known, the first study of legibility (readability) of carbon copies was done in 1942.[9] In that study the factor of illumination was the variable used for comparing samples. The copy and a rheostatically controlled electric lamp were placed in a light tight box and the sample viewed through a lens and a green filter (to eliminate color effects). The intensity of illumination was measured by a photoelectric cell. The results were inconclusive due to lack of precision inherent in the method. Later the same method was modified to include a standard sample. The apparatus was then essentially a double projector lantern, with the standard sample and the "unknown" being viewed side by side. The illumination on the standard sample was reduced to threshold conditions and then the illumination on the "unknown" was increased from zero until its legibility was equivalent with that of the standard. The results of this method were, however, inconclusive also.

Later another method, that of a recording densitometer, was used.[9] Since, other things being equal, two samples differed in legibility because they differed in contrast, and since contrast was determined by blackness of character and width of character (increasing with number of parts (copies)), it was thought that this could be measured with a densitometer. The copy was mounted

on a rotating drum and light passed through it to excite a photo-electric cell connected with a galvanometer. This apparatus was later modified but the densitometer principle was retained. However, it was impossible to correlate the blackness of the character and its width to obtain a satisfactory legibility scale. It was found at the time, however, that the difference in blackness between the first few and the last few parts was not great enough to affect the legibility as it was affected.

In 1946, another attack on the problem of legibility was made.[9] That time use was made of both the brightness and contrast factors of the Visual Threshold by use of a Luckiesh-Moss Visibility Meter. Although this showed more promise than anything tried to that date, the results were again not conclusive.

III. EXPERIMENTAL INVESTIGATION

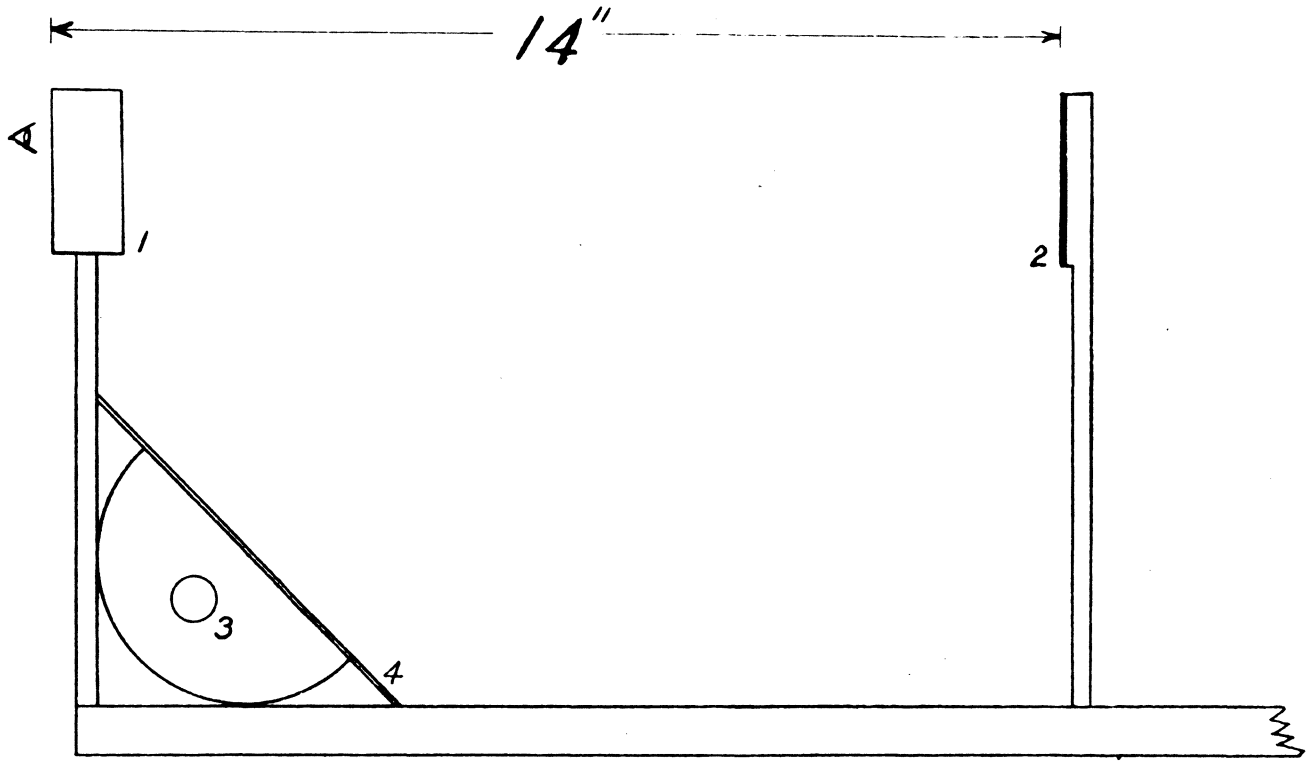
Object.

The object of this investigation has been to devise a means of measuring the legibility of multiple carbon copies and obtaining readily reproducible results.

Method of Procedure.

Since, as was mentioned in the Review of Literature, the two factors contributing most to the visibility of an object are its brightness and the contrast between the object and its background,[2] it was decided to use a method under which both of these factors could be simultaneously varied. A simple way of doing this has been incorporated in the Luckiesh-Moss Visibility Meter, which was designed to measure the illumination necessary for doing specific tasks in industry. This meter had been tried in legibility measurements earlier,[9] and though the results obtained were far from conclusive, they did not preclude the possibility of obtaining reproducible results with it.

The Visibility Meter was mounted at a distance of fourteen inches from and parallel to the copy to be measured, Figure 1. Fourteen inches was the distance used between meter and copy because of the fact that this is considered by ophthalmologists to be the normal reading distance.[2] (Not to be confused with the ideal reading distance, which is generally agreed to be twenty feet.)



Experimental Set-Up

1. L-M Visibility Meter 2. Copy to be measured 3. Flourescent Lamp 4. Opal Glass

Figure 1

The copy was furnished with an illumination of ten foot-candles as measured at the copy with a Weston Photovoltaic cell.

The only criteria for the legibility of printed or typed matter is whether or not it can be read. Consequently, due to the complexity of the functioning of eyes and brain when reading, all three stages of visual perception are encountered at once. That is, printed matter may be read when there is certain (definite) perception of the form of some of the characters while there may be but bare perception of form of others, and even only recognition of presence of still others, depending upon the word, sentence or paragraph one may be reading. That is to say, something may be read when all the characters in it are not completely visible, the brain filling in the characters that the eye fails to perceive, depending of course upon the conditioning of the brain and the matter being read.

Consequently, the question arises in making legibility measurements, as to what shall be taken as legible. This is quite different from the factors encountered in visibility measurements: there, you either wish to (1) recognize presence of an object, (2) barely perceive the form of the object, or (3) to have certain (definite) perception of the form of the object, and depending upon the factors contributing to threshold visibility, you either do so or you do not.

In the first measurements made with the Visibility Meter, the criteria used was that of "good" readability, that is, when there

was certain perception of the form of all the characters in the copy. This was found to give results quite erratic and unreproducible.

Then the criteria was changed to that of threshold legibility. That is, to the lowest amount of brightness and contrast under which the copy could be read, even though several of the characters could not be made out. It is obvious that using this criteria, some written matter will be more readable than others. As mentioned in the Review of Literature, rectangular shapes are most easily distinguished under adverse seeing conditions, while triangular shapes are most often confused, and circular shapes are more or less easily distinguished depending upon, in this case, other characters nearby.[4] Obviously then, if the various parts (carbon copies) of the test being measured contained the same written matter, very unreliable results would be obtained. In which case the results obtained would apply to only one text; and not only that, but, due to the memorizing ability of humans, after making several measurements the text would be memorized and the brain would do the work of the eyes. That is, when the form of the words is barely perceptible, and cannot be read, one will think that he is reading the text, when actually he is relying chiefly upon memory.

Therefore the test under consideration was made up of twelve different texts. (Twelve part forms were used throughout this investigation). That is to say, part one contained a certain paragraph, part two a different paragraph and so on throughout the copy. The text

was of such material as is usually encountered in industrial transactions. It was found that ten measurements per part were necessary and sufficient to rule out most random errors in the measurements due to fluctuations in visual acuity. Consequently, it was found that memory again entered into the picture and true readability measurements were not obtained if ten readings were made on the same part having the same text. Consequently, the ten readings for say, part one, were made on ten different texts. The readings were, however, made for one complete set of twelve parts at one time, to eliminate errors entering into any one part due to decreasing visual acuity caused by fatigue, etc. That is, part one containing one text was read, then part two containing another text, then part three containing still another text and so on through all twelve parts without interruption. It was found that one, or at times two, sets of twelve readings were all that could be done over a period of consecutive measurements due to the loss of visual acuity. Consequently, all sets of readings were made at random times, in a completely darkened room, always at night, to prevent any stray light from interfering with the copy or the observer, and because there would be (at night) no distractions such as undue noise, which has been found to affect eye performance considerably,[5] as mentioned previously.

Although measurements were made upon twelve parts consecutively, no two measurements were made in the same order. For the first set of measurements, say, part one was read first and part twelve last,

for the second set, part two was read first and part one last, for the third set, part three was read first and part two last, and so on. Though the order was not followed exactly, the method was, that is, the different set of readings were begun on different parts of the copy, for a total of ten sets of readings on all twelve parts.

In making the readings, the observer changed the contrast and brightness of the part being measured from that of very least contrast and very lowest brightness to that of threshold legibility. All measurements were made in this way because of the relatively rapid adjustment of dark adapted eyes to light, as opposed to the slower adjustment of light adapted eyes to darkness. Also, the change of brightness and contrast was done very slowly to allow time for this adaptation.

Apparatus.

The Visibility Meter was mounted in a regular clamp stand. The copy was supported fourteen inches away in a simple wooden stand. Illumination was furnished by a single fifteen watt flourescent bulb which was covered by a flat piece of flashed opal glass to diffuse the light and to give more uniform illumination on the copy.

The Luckiesh-Moss Visibility Meter, Figure 2, was used for the legibility measurements throughout this investigation. The instrument consists of two colorless photographic filters having precise

LUCKIESH-MOSS VISIBILITY METER

Figure 2

circular gradients in density. The meter is held the same as eyeglasses. A small disk at the top of the instrument rotates the filters before the eyes. The gradient filters reduce the apparent brightness of the print and at the same time, because of the slightly diffusing characteristics of photographic film, lower the contrast between the print and the paper. The brightness may be varied over a range sufficient to alter the threshold stimulus by a factor of two. Since the maximum range corresponds to twenty times threshold value, the meter is much more effective in reducing contrast than brightness.[2] The field of view for each eye subtends horizontal and vertical angles of thirty degrees and twenty-four degrees respectively.

The meter is provided with two scales, Relative Visibility, with a scale range of from one to twenty, and Relative Footcandles, with a scale range of from one to one thousand. The Relative Visibility Scale, which was used exclusively in this investigation, was calibrated using two parallel test bars whose critical detail subtended a visual angle of one minute at a distance of twenty feet. Although the meter could have been calibrated for any one of the visual threshold parameters, it was calibrated in terms of size, since in ophthalmology angular size is used as a criterion for appraising visual efficiency. Since a normal eye can distinguish, under favorable conditions, two objects separated by one minute of visual angle, this point on the scale of the meter was taken as unity. The scale value '2' indicates that the visibility of the

object viewed is equivalent to that of the test object when its critical detail subtends an angle of two minutes (at twenty feet), and so on.

IV. DISCUSSION OF RESULTS

Measurements were made on ten samples of copy, Test 1 through Test 10, as discussed in Experimental Investigation. The Tables of Legibility (Readability) are given in Appendix I, Table I through Table XXII, containing the values read on the Relative Visibility Scale. Since these values are all relative, any scale whatsoever, appropriate to the gradient filters used in the meter, would have sufficed.

Three sets of ten measurements per part were made on Test 1. The mean of each set of ten measurements per part, for the three sets is given in Table I-A, following. Since the values of the Relative Visibility Scale are not adapted for comparing tests, and because the visual acuity of the eyes varies more or less, from day to day, values of per cent legibility of each part have been determined for each set of measurements. The value obtained for Part 2 was taken as one hundred per cent. This was done because it was found the legibility of Part 1 varied quite considerably due to wear and tear on the typewriter ribbon and could not thus be used as a standard, and because the transfer of carbon to and the spreading of characters in Part 2 is practically constant, irrespective of the number of parts made. (With negligible variation, more or less depending on the kind of carbon and the kind of paper used.)

The per cent legibility of the mean values is given for each part for all three sets, as well as a column containing the mean per cent legibility.

T A B L E I-A

Test 1 Regular Tissue TW-12 Carbon

Part No.	Mean Legibility			% Legibility (Part 2 = 100%)			
	(a)	(b)	(c)	(a)	(b)	(c)	Mean %
1	5.9	6.2	5.8	134%	135%	135%	135%
2	4.4	4.6	4.3	100	100	100	100
3	3.8	3.8	3.8	86	83	88	86
4	3.5	3.6	3.4	80	78	79	79
5	3.2	3.2	3.0	73	70	70	71
6	2.9	2.9	2.8	66	63	65	65
7	2.8	2.7	2.5	64	59	58	60
8	2.5	2.5	2.4	57	54	56	56
9	2.3	2.4	2.3	52	52	53	52
10	2.2	2.2	2.3	50	48	53	50
11	2.3	2.1	2.1	52	46	49	49
12	2.1	2.3	2.3	48	50	53	50

The variation of the actual values obtained with the meter for the three sets is quite low. The deviation of the per cent legibility for any part of any set of measurements from the mean amounts in only one case to as much as four per cent. The deviation of all other parts being much less. That some variation should enter in is to be expected since, because of the method of making measurements, as discussed previously, it is impossible to select those values which are erroneous and discard them. Instead, they are averaged in and cause a fluctuation about the mean for the values obtained. It is to be noted that a very small variation in the actual measurements made on Part 2 can easily cause a variation of as much as several per cent, because of the small range of values covered. On Test 1, the maximum range covered is from 6.2 to 2.1 on the visibility scale, or 4.1. With the mean value obtained for Part 2, 4.4, a variation of 0.1, the smallest value that can be differentiated on the scale, leads to a difference of 2.3%.

Table II-A gives the actual measurements, the mean of three sets of ten each per part, made on Test 2, and also the per cent legibility of each part for the three sets of measurements, and the mean per cent legibility; the values of Part 2 being taken as one hundred per cent. Here again the maximum variation from the mean for any set on any one part amounts to but four per cent, and again this is true on only one part. The variation of the rest is less. Sets (a) and (b) show a decided variation in visual acuity. The per cent legibility of these two sets, however, is in close agreement.

T A B L E II-A

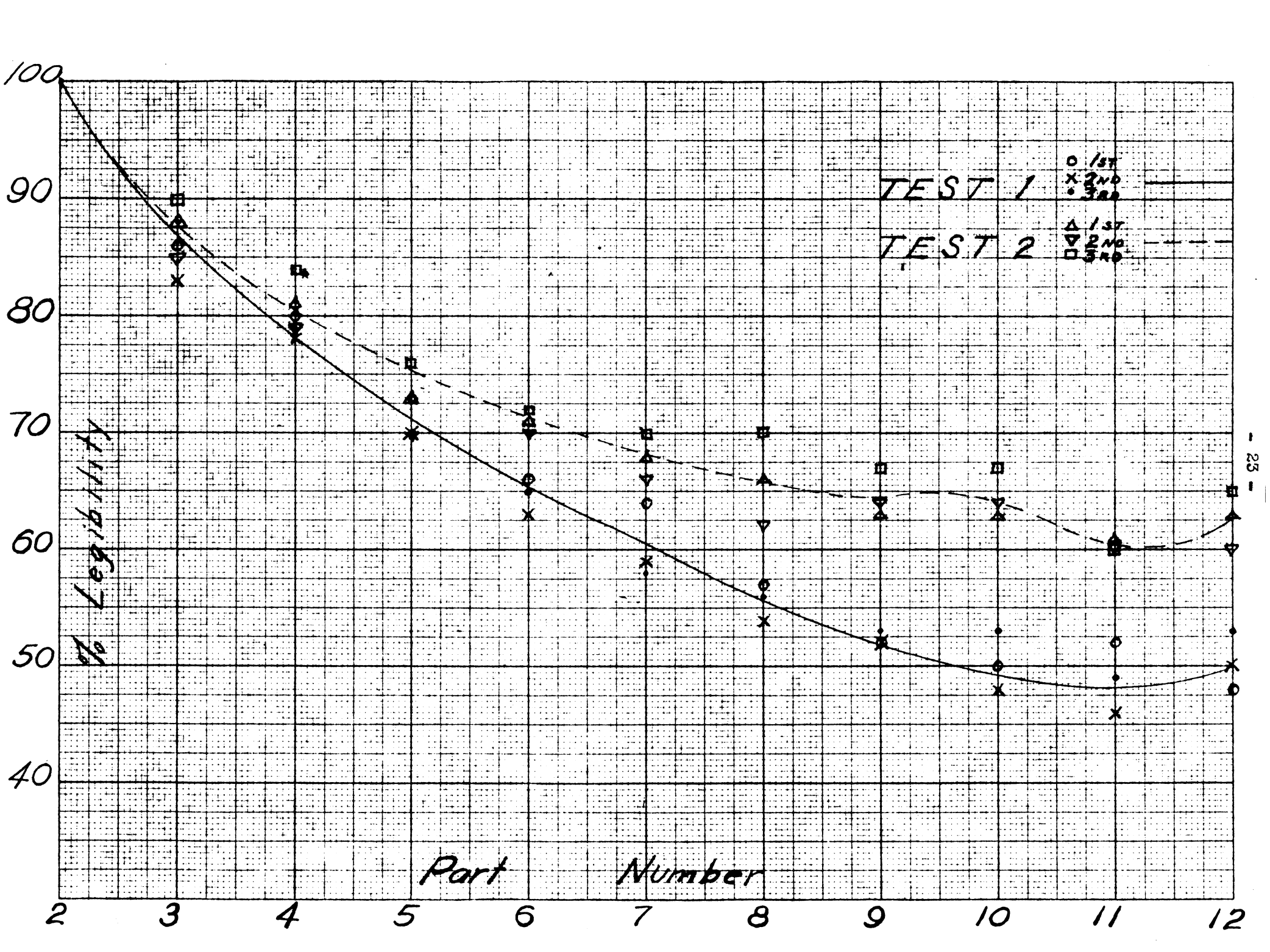
Test 2 Thin Tissue TW-12 Carbon

Part No.	Mean Legibility			% Legibility (Part 2 = 100%)			
	(a)	(b)	(c)	(a)	(b)	(c)	Mean %
1	5.4	6.0	5.9	132%	128%	132%	130%
2	4.1	4.7	4.3	100	100	100	100
3	3.6	4.0	3.9	88	85	90	87
4	3.3	3.7	3.6	81	79	84	81
5	3.0	3.3	3.3	73	70	76	73
6	2.9	3.3	3.1	71	70	72	71
7	2.8	3.1	3.0	68	66	70	68
8	2.7	2.9	3.0	66	62	70	66
9	2.6	3.0	2.9	63	64	67	65
10	2.6	3.0	2.9	63	64	67	64
11	2.5	2.8	2.6	61	60	60	60
12	2.6	2.8	2.8	63	60	65	63

A graph was plotted with the values obtained for each of the three sets of measurements made on Test 1 and Test 2. The curves for each test are the curves of the mean per cent legibility. It is to be noted from this graph that the variation of any one set from any other causes merely a slight lifting or lowering of the entire curve and does not affect the slope at all. In the case of Test 1, the curve for any set of values would be practically the same as that of the mean. In the case of Test 2, the maximum amount the curve could be lifted would be about two per cent, with a possible lowering of about one per cent. When error enters in, the values fall off of the smooth curve connecting the points; for example, in the second and third set of measurements made on Part 8, Test 2, there is obviously error in the per cent legibility, the values obtained being too high in one case and too low in the other. In making a comparison of tests, as is done here, these points will affect the comparison none at all; they will merely fall off of the curve.

Table III-A gives two sets of measurements made on Test 3. Here on one part, one set has a variation of five per cent from the mean. In all other cases the variation is less. It is to be noted that, in the case of the five per cent variation, this was caused by a difference in the two sets of values on this part, Part 8, of only 0.3.

Table IV-A gives two sets of measurements made on Test 4. In this case the maximum variation in per cent legibility of the two sets from the mean amounts to only two per cent.


100
90
80
70
60
50
40
Legibility %
2
3
4
5
6
7
8
9
10
11
12
Part Number
TEST 1
1ST
2ND
3RD
TEST 2
1ST
2ND
3RD

T A B L E III-A

Test 3 Thin Tissue TW-10 Carbon

Part No.	Mean Legibility		% Legibility (Part 2 - 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	5.2	5.0	130%	128%	129%
2	4.0	3.9	100	100	100
3	3.7	3.6	93	92	93
4	3.4	3.3	85	85	85
5	3.1	3.0	78	77	78
6	2.7	2.8	68	70	69
7	2.5	2.6	63	67	65
8	2.2	2.5	55	64	60
9	2.1	2.4	53	61	57
10	2.0	2.1	50	54	52
11	1.9	2.1	48	54	51
12	2.1	2.2	53	56	55

T A B L E IV-A

Test 4 Regular Tissue TW-10 Carbon

Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	5.4	5.7	132%	136%	134%
2	4.1	4.2	100	100	100
3	3.5	3.6	85	86	86
4	3.1	3.3	76	79	78
5	2.7	2.9	68	69	69
6	2.4	2.6	59	62	61
7	2.2	2.3	54	55	55
8	2.0	2.2	49	52	51
9	1.9	2.0	46	48	47
10	1.7	1.9	42	45	44
11	1.6	1.7	39	40	40
12	1.7	1.9	42	45	44

Table V-A gives two sets of measurements made on Test 5. The greatest variation in per cent legibility on any test in this investigation was found in the measurements on this test. On one part, the two sets of measurements experience a maximum deviation of six per cent; however, the variation for all other parts is much less. Obviously, error entered into the measurements of the first set here, although the actual difference in the values obtained in the first and second sets of measurements on this part, Part 7, amounts to only 0.2. In any comparison of tests this value of per cent legibility would simply fall off of the curve.

Table VI-A gives two sets of measurements made on Test 6. Here there is a maximum variation of per cent legibility of the two sets from the mean of only two per cent. It is to be noted here that, with the exception of the first three parts, the values obtained on the two sets of measurements are identical.

Table VII-A gives two sets of measurements made on Test 7, made with Red Carbon. There is a maximum variation between that of the two sets and the mean per cent legibility, of only four per cent on only one part. The variation on other parts is two per cent or less.

Table VIII-A gives two sets of ten measurements each on each part made on Test 8. Here there is found a maximum deviation of per cent legibility, of the two sets from the mean, of only two per cent.

Table IX-A gives two sets of measurements made on Test 9. In this case, values obtained for six parts are identical for the two

T A B L E V-A

Test 5 Regular Tissue X-75 Carbon

Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	4.8	4.5	114%	108%	111%
2	4.2	3.8	100	100	100
3	3.6	3.2	86	84	85
4	3.2	3.0	76	79	78
5	3.0	2.7	71	71	71
6	2.6	2.5	62	66	64
7	2.2	2.4	52	63	58
8	2.2	2.2	52	58	55
9	2.0	2.1	48	55	52
10	2.0	2.1	48	55	52
11	2.0	2.1	48	55	52
12	2.2	2.1	52	55	54

T A B L E VI-A

Test 6 Thin Tissue X-75 Carbon

Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	4.6	4.5	112%	115%	114%
2	4.1	3.9	100	100	100
3	3.5	3.4	85	87	86
4	3.2	3.2	78	82	80
5	2.8	2.8	68	72	70
6	2.6	2.6	63	67	65
7	2.5	2.5	61	64	63
8	2.3	2.3	56	59	58
9	2.2	2.2	54	56	55
10	2.1	2.1	51	54	53
11	2.1	2.1	51	54	53
12	2.3	2.3	56	59	57

T A B L E VII-A

Test 7 — Red Carbon

Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	6.3	5.9	166%	160%	163%
2	3.8	3.7	100	100	100
3	3.3	3.3	87	89	88
4	2.8	2.9	74	78	76
5	2.5	2.6	66	70	68
6	2.4	2.4	63	65	64
7	2.1	2.3	55	62	59
8	2.1	2.0	55	54	55
9	1.9	1.9	50	51	51
10	1.9	1.9	50	51	51
11	1.8	1.8	48	49	49
12	1.9	1.9	50	51	51

T A B L E VIII-A

	Test 8		Special P Carbon		
Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	5.8	5.5	153%	141%	158%
2	3.8	3.9	100	100	100
3	3.4	3.3	89	85	87
4	3.0	3.0	79	77	78
5	2.7	2.8	71	72	72
6	2.6	2.5	68	64	66
7	2.4	2.4	63	59	61
8	2.4	2.3	63	59	61
9	2.3	2.2	61	56	58
10	2.1	2.2	55	55	55
11	2.0	2.0	53	51	52
12	2.2	2.2	58	55	57

sets of measurements. There is a maximum deviation of per cent legibility of only two per cent from the mean of the two sets.

Table X-A gives two sets of measurements made on Test 10. Here also is found a maximum deviation from the mean of per cent legibility of only two per cent for the two sets. The actual readings differ by only 0.1 for seven parts and are identical for the rest.

T A B L E IX-A

Test 9 Regular Tissue Special Q Carbon

Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	6.1	5.9	149%	144%	147%
2	4.1	4.1	100	100	100
3	3.5	3.6	85	88	87
4	3.3	3.2	81	78	80
5	3.1	3.0	76	73	75
6	2.9	2.9	71	71	71
7	2.7	2.6	66	63	65
8	2.5	2.5	61	61	61
9	2.4	2.4	59	59	59
10	2.3	2.3	56	56	56
11	2.2	2.2	54	54	54
12	2.5	2.4	61	59	60

T A B L E X-A

Test 10 Thin Tissue Special Q Carbon

Part No.	Mean Legibility		% Legibility (Part 2 = 100%)		
	(a)	(b)	(a)	(b)	Mean %
1	6.1	6.0	145%	140%	143%
2	4.2	4.3	100	100	100
3	3.6	3.7	90	86	88
4	3.4	3.4	81	79	80
5	3.2	3.1	76	72	74
6	2.8	2.9	67	67	67
7	2.7	2.7	64	63	64
8	2.6	2.6	62	61	62
9	2.4	2.5	57	58	58
10	2.3	2.3	55	54	55
11	2.2	2.2	52	51	52
12	2.4	2.5	57	58	58

V. CONCLUSIONS

It is to be concluded that through the use of the Luckiesh-Moss Visibility Meter, and the method of making measurements used in this investigation, that it is possible to get reproducible results. That it is possible, when the values are interpreted as per cent legibility, Part 2 being taken as one hundred per cent, to have a normal deviation of no more than two per cent.

It cannot be expected, however, that exact reproducibility of results is to be achieved by this or any other method since the question of legibility (readability) is such a personal item, and when in this method of measuring legibility, the "human error" enters in such an elementary manner.

However, it has been found in this investigation that the greatest amount of deviation from the mean amounted to but six per cent and that but in one case. It is to be concluded then that a deviation of as much as five per cent will be encountered only as a rarity.

Deviations of even as much as six per cent, however, have no effect when making comparisons of various tests. This is especially true when the comparing is done by means of legibility curves, as is done in Appendix II, since such erratic values will simply fall off of the smooth curve connecting the points.

VI. ACKNOWLEDGEMENTS

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VIII. APPENDIX I

Following are twenty-two tables of measurements made on ten samples of multiple carbon forms. Three sets of measurements were made on Test 1, three on Test 2, and two on each of the other tests. All measurements were made a column at a time, though not necessarily in order. The values are the values read on the Relative Visibility Scale of the L-M Visibility Meter.

T A B L E I

Test 1 Regular Tissue TW-12 Carbon

(a)

Part No.	Readability										Mean
1	6.0	5.6	5.8	5.4	6.6	6.4	6.4	6.0	6.0	5.0	5.9
2	3.6	4.0	5.0	4.0	5.2	4.8	3.5	5.0	4.4	4.8	4.4
3	3.0	3.6	3.8	3.6	3.0	4.8	3.9	4.9	4.0	3.8	3.8
4	3.6	4.0	2.8	3.5	3.4	4.0	3.2	3.6	3.6	3.4	3.5
5	3.1	3.1	3.4	3.3	3.0	3.2	3.6	3.0	3.0	3.2	3.2
6	2.6	3.0	3.0	3.4	3.0	2.7	2.6	2.5	2.8	3.2	2.9
7	3.0	2.8	2.7	3.0	2.9	2.4	3.0	2.8	2.7	2.9	2.8
8	2.1	2.3	2.4	2.6	2.3	2.3	2.6	2.4	2.7	2.8	2.5
9	2.1	2.2	2.6	2.6	2.7	2.0	2.3	2.0	2.3	1.9	2.3
10	1.7	1.9	2.1	2.0	2.3	2.4	2.4	1.9	2.2	2.4	2.2
11	2.9	2.7	1.9	1.9	2.2	2.4	2.4	2.3	2.0	2.1	2.3
12	1.9	1.9	2.1	2.4	2.4	1.9	1.8	2.3	2.3	2.1	2.1

T A B L E II

Test 1 Regular Tissue TW-12 Carbon

(b)

Part No.	Readability										Mean
1	5.4	6.5	6.8	7.2	6.9	6.4	6.5	5.5	6.0	4.9	6.2
2	3.9	3.8	5.7	4.4	4.9	5.2	4.9	5.1	4.4	4.0	4.6
3	3.8	3.5	3.4	4.0	4.0	3.8	4.4	3.7	4.0	3.4	3.8
4	3.7	3.6	3.1	3.6	3.8	3.4	3.7	3.4	3.8	3.4	3.6
5	3.4	3.1	3.2	2.8	3.4	3.5	3.2	3.4	3.0	3.2	3.2
6	3.0	3.0	2.6	3.0	2.4	3.3	3.0	2.7	2.8	2.8	2.9
7	2.9	2.5	2.8	2.6	3.0	2.6	2.8	2.5	2.6	2.6	2.7
8	2.5	2.7	2.4	2.4	2.4	2.8	2.2	2.4	2.3	2.5	2.5
9	2.3	2.4	2.3	2.4	2.6	2.3	2.6	2.2	2.3	2.3	2.4
10	2.2	2.4	2.4	2.2	2.2	2.3	1.9	2.1	1.9	2.2	2.2
11	1.9	2.1	2.3	2.7	2.2	1.9	2.4	2.0	1.8	1.9	2.1
12	2.0	2.4	2.3	2.7	2.4	2.3	2.6	2.4	2.2	2.1	2.3

T A B L E III

Test 1 Regular Tissue TW-12 Carbon

(c)

Part No.	Readability										Mean
1	6.0	6.6	5.6	6.0	6.2	5.6	5.6	6.2	5.5	5.0	5.8
2	4.1	4.3	5.0	4.8	4.2	4.4	4.4	4.2	3.8	3.8	4.3
3	4.0	3.1	4.0	4.0	3.9	3.8	3.8	3.8	3.4	3.7	3.8
4	3.6	3.3	3.4	3.6	3.5	3.4	3.2	3.4	3.4	3.5	3.4
5	3.5	2.9	2.8	2.7	3.2	3.2	2.6	3.1	2.9	3.3	3.0
6	2.6	2.7	2.4	2.8	2.6	2.7	2.7	3.0	2.9	3.2	2.8
7	2.6	2.3	2.6	2.2	2.7	2.4	2.7	2.5	2.6	2.5	2.5
8	2.7	2.4	2.2	2.3	2.4	2.3	2.3	2.5	2.7	2.2	2.4
9	2.4	2.6	2.4	2.3	2.3	2.1	2.2	2.1	2.3	2.3	2.3
10	2.2	2.4	2.4	2.3	2.0	2.2	1.9	2.4	2.2	2.5	2.3
11	2.3	2.1	2.3	2.1	2.2	2.0	2.0	2.1	2.2	1.9	2.1
12	2.4	2.2	2.2	2.4	2.3	2.3	2.2	2.4	2.2	2.0	2.3

T A B L E IV

Test 2 Thin Tissue TW-12 Carbon

(a)

Part No.	Readability										Mean
1	6.0	5.6	5.0	4.8	5.0	5.4	5.1	5.0	6.6	5.0	5.4
2	3.7	4.0	3.6	4.8	3.6	3.5	3.2	4.2	4.6	5.4	4.1
3	3.6	4.2	4.0	3.6	3.2	3.6	3.3	3.6	3.6	3.4	3.6
4	4.0	3.6	3.0	3.2	3.5	3.1	2.7	3.4	3.2	3.4	3.3
5	3.3	3.0	3.4	3.4	2.8	3.0	2.9	2.9	2.6	3.1	3.0
6	3.6	3.7	3.0	2.8	2.8	2.5	2.7	3.1	2.9	3.0	2.9
7	2.6	2.7	2.7	2.9	2.6	2.8	2.6	2.4	2.9	3.5	2.8
8	3.0	2.8	2.7	2.5	2.8	2.8	2.2	2.9	2.2	2.8	2.7
9	2.4	3.2	2.4	2.8	2.5	2.7	2.4	2.3	2.2	2.9	2.6
10	3.6	2.7	2.6	2.5	2.2	2.4	2.8	2.3	2.6	2.6	2.6
11	2.3	2.3	2.5	3.0	2.5	2.5	2.7	2.2	2.6	2.5	2.5
12	3.0	2.3	2.4	2.6	2.5	2.5	2.2	2.7	2.8	2.9	2.6

T A B L E V

Test 2 Thin Tissue TW-12 Carbon

(b)

Part No.	Readability										Mean
1	6.5	6.8	5.4	5.4	6.4	5.4	6.0	5.8	5.8	6.1	6.0
2	5.6	4.2	5.4	3.8	4.8	4.8	4.2	5.0	5.2	4.8	4.7
3	3.8	4.0	3.8	4.0	3.7	3.8	3.8	4.6	3.8	4.4	4.0
4	3.4	3.8	3.6	3.8	3.3	3.1	4.4	3.8	4.3	3.6	3.7
5	2.9	2.7	2.9	3.0	3.5	3.4	3.0	3.7	4.4	3.4	3.3
6	3.6	2.9	2.7	2.8	3.6	3.7	3.3	3.4	3.4	3.8	3.3
7	2.9	3.2	2.7	2.8	3.0	3.5	3.2	3.5	3.3	3.0	3.1
8	3.0	2.8	2.7	2.6	2.9	3.4	3.0	2.5	2.9	3.2	2.9
9	3.0	3.0	2.6	2.9	2.6	2.9	2.9	3.0	3.5	3.4	3.0
10	2.4	3.2	2.9	2.7	3.2	3.2	2.9	2.6	3.0	3.7	3.0
11	2.5	2.6	3.2	2.7	3.0	3.2	2.6	2.5	3.1	3.0	2.8
12	2.4	2.7	2.3	2.9	3.0	2.8	3.0	2.8	3.1	3.4	2.8

T A B L E VI-

Test 2 Thin Tissue TW-12 Carbon

(c)

Part No.	Readability										Mean
1	6.3	7.0	5.8	5.2	6.5	5.6	5.5	6.2	5.2	6.0	5.9
2	5.2	4.2	4.6	3.8	3.8	4.8	4.2	4.0	4.1	3.8	4.3
3	4.8	3.8	3.9	4.2	3.6	3.4	3.8	3.6	3.7	3.8	3.9
4	3.8	3.9	3.3	3.6	3.2	3.4	3.6	3.4	3.8	3.5	3.6
5	3.8	3.4	3.2	3.2	3.0	3.2	3.2	3.2	3.4	3.5	3.3
6	3.4	2.9	2.8	3.2	3.2	3.1	3.2	3.0	2.9	3.4	3.1
7	3.6	3.2	2.7	2.7	3.0	2.9	2.9	3.4	3.0	3.0	3.0
8	3.6	2.9	3.0	2.5	2.8	3.0	3.0	3.1	3.4	3.0	3.0
9	3.0	3.0	2.7	2.7	2.8	2.7	2.9	2.9	3.1	3.0	2.9
10	2.7	3.0	3.0	2.9	2.7	2.5	2.4	2.9	2.9	2.8	2.9
11	3.0	2.6	3.0	2.6	2.6	2.4	2.4	2.6	2.6	2.5	2.6
12	3.2	2.5	2.6	2.9	2.7	2.6	2.8	2.9	2.8	3.0	2.8

T A B L E VII

Test 3 Thin Tissue TW-10 Carbon

(a)

Part No.	Readability										Mean
1	5.6	5.4	5.5	4.8	5.6	6.1	5.0	4.6	4.7	4.8	5.2
2	4.0	3.8	3.8	3.9	3.8	3.9	3.7	4.6	4.0	4.2	4.0
3	4.0	3.8	3.8	3.4	3.8	3.7	4.0	3.3	4.1	3.0	3.7
4	3.4	3.2	3.4	3.4	3.2	3.0	3.2	3.0	4.8	3.1	3.4
5	3.2	3.2	2.9	3.0	2.8	2.5	3.7	3.4	3.4	3.0	3.1
6	2.6	2.3	2.8	3.4	2.3	2.5	3.0	2.7	2.7	2.5	2.7
7	2.2	2.9	2.7	2.6	2.4	2.5	2.4	2.4	2.4	2.1	2.5
8	2.4	2.1	2.0	2.3	2.0	2.6	2.0	2.2	2.3	2.3	2.2
9	2.0	2.1	2.1	2.0	2.2	2.2	2.0	2.3	2.3	1.8	2.1
10	2.2	2.3	1.9	1.9	1.9	2.2	2.0	2.2	1.8	1.9	2.0
11	1.9	1.8	2.1	2.0	1.8	2.0	1.8	1.9	1.8	1.7	1.9
12	2.2	2.3	2.2	1.9	2.8	2.1	2.0	1.9	2.0	1.6	2.1

T A B L E VIII

Test 3 **Thin Tissue** **TW-10 Carbon**

(b)

Part No.	Readability										Mean
1	5.0	4.8	4.2	4.6	4.8	5.6	6.0	5.0	4.6	5.0	5.0
2	4.4	3.8	3.6	4.2	3.7	3.9	4.3	3.6	3.7	3.8	3.9
3	3.6	3.8	3.8	3.5	3.6	3.3	4.0	3.5	3.5	3.5	3.6
4	3.8	3.4	3.2	3.0	3.5	3.0	2.7	3.3	3.0	3.8	3.3
5	3.3	3.0	2.8	3.0	3.0	3.2	3.4	2.5	2.5	3.0	3.0
6	2.8	2.8	2.8	2.8	2.7	2.7	2.8	3.2	2.8	3.1	2.8
7	2.9	2.9	3.0	2.4	2.2	2.3	2.6	2.5	2.7	2.8	2.6
8	2.2	2.7	2.5	3.1	2.3	2.1	2.5	2.6	2.3	2.4	2.5
9	2.4	2.3	1.9	2.3	2.3	2.5	2.6	1.9	2.3	2.3	2.3
10	2.1	2.2	2.4	2.1	1.9	2.0	2.1	1.9	2.3	2.1	2.1
11	2.0	2.1	2.2	2.2	2.3	2.1	2.1	2.1	2.0	2.2	2.1
12	2.2	2.3	2.5	2.2	2.2	1.9	2.2	2.4	2.1	2.1	2.2

T A B L E IX

Test 4 Regular Tissue TW-10 Carbon

(a)

Part No.	Readability										Mean
1	5.8	5.6	5.8	5.4	5.2	5.0	5.2	6.0	5.0	5.2	5.4
2	4.0	4.5	3.4	3.8	5.2	3.9	4.3	3.7	4.1	4.2	4.1
3	3.5	3.1	4.0	2.8	3.6	3.5	3.5	3.9	3.6	3.5	3.5
4	3.1	3.0	3.9	3.1	3.0	3.4	2.7	2.8	3.2	3.0	3.1
5	2.7	2.5	2.9	2.5	2.6	2.4	2.8	2.9	3.0	3.1	2.7
6	2.5	2.3	2.2	2.5	2.2	2.4	2.5	2.4	2.5	2.4	2.4
7	2.2	2.1	2.7	2.1	2.0	1.8	2.0	2.4	2.1	2.2	2.2
8	2.2	2.0	1.8	2.0	2.0	2.0	1.9	2.0	1.9	2.2	2.0
9	2.4	1.8	1.8	2.1	1.9	1.9	1.5	1.6	1.9	1.9	1.9
10	1.8	1.6	2.0	1.9	1.7	2.0	1.4	1.7	1.6	1.6	1.7
11	1.5	1.7	1.6	1.7	1.4	1.5	1.6	1.5	1.7	1.5	1.6
12	1.9	1.8	1.8	1.4	1.8	1.6	1.5	1.7	1.7	1.8	1.7

T A B L E X

Test 4 Regular Tissue TW-10 Carbon

(b)

Part No.	Readability									Mean
1	5.6	5.8	5.6	5.7	5.7	6.4	5.6	5.8	5.2	5.8	5.7
2	3.6	4.4	4.3	4.0	4.2	4.0	4.3	4.3	4.4	4.0	4.2
3	3.6	3.3	3.6	3.8	3.2	3.8	4.0	4.0	4.0	3.6	3.6
4	3.0	3.3	3.0	3.2	3.1	3.5	3.6	3.6	3.4	3.2	3.3
5	2.7	2.7	3.0	2.6	2.8	3.1	3.4	2.8	2.6	2.8	2.9
6	2.4	2.8	3.0	2.4	2.2	2.8	2.4	2.8	2.6	2.5	2.6
7	2.2	2.1	2.4	2.3	2.6	2.0	2.3	2.4	2.6	2.4	2.3
8	1.9	2.0	2.2	2.1	2.3	2.5	2.3	2.1	2.3	2.1	2.2
9	1.9	1.9	1.9	2.2	1.9	1.8	2.4	1.9	1.8	1.8	2.0
10	1.8	2.0	2.1	1.8	2.0	1.7	1.7	1.9	1.9	1.8	1.9
11	1.8	1.8	1.7	1.6	1.6	1.7	1.8	1.7	1.8	1.7	1.7
12	2.2	1.8	1.9	2.0	1.9	1.8	1.9	1.6	2.3	1.8	1.9

T A B L E XI

Test 5 Regular Tissue X-75 Carbon

(a)

Part No.	Readability										Mean
1	5.2	4.6	5.2	4.4	4.8	5.1	4.7	4.2	4.8	4.8	4.8
2	3.4	4.2	4.0	3.8	4.2	5.0	4.8	4.6	3.8	3.9	4.2
3	3.6	3.8	3.3	3.8	3.8	3.4	3.7	3.2	3.5	3.9	3.6
4	3.5	3.2	3.2	2.8	3.4	3.0	3.3	2.9	3.6	2.8	3.2
5	2.9	3.3	3.2	2.9	3.4	2.7	3.1	2.8	2.7	2.7	3.0
6	2.4	2.4	2.5	3.4	2.5	2.5	2.6	2.6	2.6	2.7	2.6
7	2.7	2.1	2.0	2.3	2.2	2.0	2.4	2.6	1.9	2.2	2.2
8	2.1	1.9	1.9	2.5	2.1	2.2	2.3	2.7	2.2	2.4	2.2
9	2.0	2.1	2.0	2.1	1.9	2.5	2.0	2.0	1.8	2.0	2.0
10	2.0	2.1	2.3	1.9	2.0	1.9	2.0	1.9	2.0	1.7	2.0
11	2.2	2.1	2.1	1.8	2.0	1.8	1.9	2.0	2.1	1.9	2.0
12	2.0	2.0	2.1	2.0	2.6	2.3	1.9	2.9	2.0	2.0	2.2

T A B L E XII

Test 5 Regular Tissue X-75 Carbon

(b)

Part No.	Readability										Mean
1	4.4	4.3	3.7	4.6	4.2	5.4	4.2	5.2	4.7	4.6	4.5
2	3.4	3.4	3.5	3.7	3.4	3.2	3.9	4.4	4.3	4.4	3.8
3	3.1	3.1	3.2	3.3	2.9	3.0	2.9	3.2	3.6	3.3	3.2
4	3.4	3.2	2.9	3.0	2.9	2.8	2.9	2.8	2.8	2.7	3.0
5	2.4	2.4	3.2	2.3	2.5	2.6	2.6	2.5	2.9	3.2	2.7
6	2.3	2.6	2.4	2.4	2.3	2.4	2.7	2.4	2.8	3.2	2.5
7	2.4	2.0	2.2	2.5	2.3	2.5	2.9	2.2	2.2	2.4	2.4
8	2.0	2.3	2.4	2.4	2.3	2.5	1.8	2.2	2.2	2.1	2.2
9	2.0	1.9	2.2	1.7	2.4	2.1	1.9	2.0	2.5	1.9	2.1
10	1.7	1.8	2.2	1.8	1.9	2.4	2.3	2.0	2.1	2.3	2.1
11	1.6	2.1	1.7	2.0	1.8	2.0	2.3	2.3	2.0	2.1	2.0
12	2.2	1.7	2.0	2.3	2.2	1.8	2.4	2.0	2.2	2.6	2.1

T A B L E XIII

Test 6 **Thin Tissue** **X-75 Carbon**

(a)

Part No.	Readability										Mean
1	4.7	4.6	4.7	4.6	4.3	4.8	4.6	4.6	4.5	4.6	4.6
2	5.2	3.8	3.9	3.9	3.8	3.7	4.2	3.7	3.9	4.4	4.1
3	3.2	4.1	4.2	3.5	3.4	3.2	3.5	3.1	3.4	3.5	3.5
4	3.7	3.3	3.2	2.9	3.5	3.2	3.0	3.6	2.7	2.6	3.2
5	3.1	2.6	2.8	3.0	3.0	2.9	2.6	2.4	2.5	2.9	2.8
6	3.1	2.6	2.3	2.8	2.7	2.6	2.4	2.5	2.4	2.7	2.6
7	2.8	3.0	2.4	2.4	2.3	2.5	2.2	2.0	2.7	2.3	2.5
8	2.1	2.2	2.6	2.4	2.1	2.3	2.3	2.3	2.0	2.3	2.3
9	2.3	2.2	1.9	2.6	2.1	1.9	2.3	1.9	2.4	2.0	2.2
10	2.1	1.9	1.8	2.0	2.7	2.1	2.0	1.9	2.0	2.0	2.1
11	2.1	2.0	1.9	2.0	1.9	2.6	2.0	1.8	2.0	2.2	2.1
12	2.3	2.0	2.1	2.1	2.3	2.2	2.8	2.3	2.4	2.3	2.3

TABLE XIV

Test 6 Thin Tissue X-75 Carbon

(b)

Part No.	Readability										Mean
1	5.5	4.2	4.3	4.7	4.8	4.1	4.4	5.2	4.1	3.9	4.5
2	4.4	3.9	3.8	4.1	3.9	3.8	3.6	4.4	3.6	3.4	3.9
3	3.6	3.6	3.5	3.2	3.5	3.2	3.2	3.3	3.4	3.1	3.4
4	3.1	3.5	3.2	2.7	2.8	2.7	3.9	2.9	3.7	3.0	3.2
5	2.9	3.0	2.5	2.7	2.7	2.3	2.6	3.4	2.9	2.5	2.8
6	2.4	3.0	2.5	2.4	2.6	2.4	2.2	2.4	3.2	2.6	2.6
7	2.3	2.8	2.6	2.4	2.4	2.6	2.3	2.3	2.4	2.6	2.5
8	1.9	2.1	2.7	2.5	2.2	2.0	2.3	2.3	2.6	2.3	2.3
9	1.8	2.0	2.2	2.5	2.2	2.2	2.0	2.4	2.1	2.1	2.2
10	2.2	1.8	1.9	2.1	2.5	2.1	2.4	2.0	2.1	2.2	2.1
11	2.1	1.9	1.9	2.0	2.1	2.3	1.8	2.0	2.5	2.0	2.1
12	2.3	2.1	2.2	2.1	2.4	2.2	2.5	2.3	2.3	2.2	2.3

T A B L E XV

Text 7 Red Carbon

(a)

Part No.	Readability										Mean
1	6.4	6.2	7.3	6.0	5.4	6.6	5.6	5.7	6.5	6.9	6.3
2	4.3	3.9	3.6	3.9	3.7	4.0	3.4	3.6	3.8	3.6	3.8
3	4.0	3.4	2.9	3.3	3.1	3.0	3.0	3.5	2.9	3.5	3.3
4	3.2	3.1	2.8	2.6	2.3	2.7	2.8	2.5	3.1	3.0	2.8
5	2.9	2.2	2.7	2.3	2.0	2.4	2.5	2.8	2.5	2.6	2.5
6	2.7	2.1	2.0	2.3	2.2	2.3	2.4	2.4	2.7	2.5	2.4
7	2.1	2.2	1.9	2.2	2.0	2.3	1.8	2.4	2.4	2.1	2.1
8	2.2	2.0	1.8	1.8	2.0	1.8	2.2	2.5	2.2	2.1	2.1
9	1.9	1.8	1.6	1.8	1.8	2.2	2.2	1.8	2.0	1.9	1.9
10	1.9	1.8	1.6	1.8	1.9	2.1	1.8	1.9	2.1	1.7	1.9
11	1.8	1.6	1.5	1.7	1.8	1.8	1.9	1.8	1.7	1.7	1.8
12	1.8	1.7	1.6	1.9	1.8	1.8	2.0	1.8	2.0	1.9	1.9

T A B L E XVI

Test 7 Red Carbon

(b)

Part No.	Readability										Mean
1	5.6	6.8	6.8	6.0	5.2	6.0	5.4	5.6	5.6	5.8	5.9
2	4.0	3.8	4.1	3.5	3.6	3.7	3.4	3.8	3.8	3.7	3.7
3	3.9	4.0	3.0	3.0	3.2	3.8	3.0	3.4	3.2	3.7	3.3
4	2.9	3.3	2.7	2.8	2.6	2.6	3.0	2.8	3.1	2.8	2.9
5	2.5	2.9	2.4	2.3	2.3	2.6	2.6	2.8	2.6	3.1	2.6
6	2.4	2.3	2.2	2.2	2.3	2.2	2.7	2.2	2.7	2.8	2.4
7	2.4	2.3	1.9	2.1	2.2	2.2	2.2	2.5	2.9	2.4	2.3
8	1.9	1.8	2.3	1.9	1.9	1.7	2.3	2.2	2.0	2.2	2.0
9	2.2	1.8	1.9	1.8	1.7	2.0	2.0	1.8	1.9	2.3	1.9
10	2.0	1.8	2.0	1.5	1.9	2.3	2.0	1.8	2.1	1.9	1.9
11	2.0	1.8	1.8	1.7	1.8	1.6	1.7	1.8	1.8	1.7	1.8
12	1.9	1.9	1.9	1.9	2.0	1.9	2.0	1.8	1.8	2.1	1.9

T A B L E XVII

Test 8 Special P Carbon

(a)

Part No.	Readability										Mean
1	5.0	5.6	6.0	4.8	6.3	6.2	5.4	5.4	6.5	6.6	5.8
2	3.4	3.8	3.7	3.6	3.6	3.5	4.6	3.7	3.9	4.2	3.8
3	3.2	3.4	3.2	3.4	3.4	3.0	3.4	4.2	3.6	3.5	3.4
4	2.9	3.0	2.9	2.8	2.9	2.7	2.9	2.8	3.6	3.2	3.0
5	2.8	2.7	2.6	2.6	2.4	2.7	2.7	2.6	2.7	3.4	2.7
6	2.3	2.6	2.6	2.8	2.3	2.6	2.7	2.9	2.3	2.8	2.6
7	2.4	2.4	2.4	2.7	2.6	2.6	2.2	2.4	2.2	2.3	2.4
8	2.4	2.1	2.3	2.5	2.3	2.5	2.1	2.5	2.5	2.5	2.4
9	2.0	2.4	2.4	2.1	2.3	2.3	2.2	2.1	2.3	2.8	2.3
10	1.8	1.9	2.3	1.8	1.9	2.1	2.0	2.1	2.3	2.3	2.1
11	1.8	1.7	1.9	2.2	2.0	1.8	2.0	1.9	2.2	2.2	2.0
12	2.3	1.8	2.0	2.4	2.3	2.2	2.2	2.2	2.3	2.3	2.2

T A B L E XVIII

Test 8 Special P Carbon

(b)

Part No.	Readability										Mean
1	6.0	5.8	5.4	5.4	5.4	5.5	6.3	5.4	4.8	5.4	5.5
2	3.6	4.8	4.6	3.6	3.6	3.9	3.4	3.6	4.1	3.8	3.9
3	2.9	3.2	3.6	3.2	2.9	3.7	3.1	3.4	3.3	3.2	3.3
4	3.2	2.6	2.6	3.4	3.1	3.5	2.9	2.7	2.5	3.1	3.0
5	2.9	3.0	2.2	2.7	3.0	2.8	2.6	2.8	2.9	2.7	2.8
6	2.3	2.7	2.5	2.1	2.4	2.8	2.7	2.5	2.4	2.6	2.5
7	2.1	2.5	2.3	2.2	2.3	3.0	2.6	2.1	2.5	2.4	2.4
8	2.2	2.2	2.3	2.2	2.1	2.6	2.4	2.2	2.3	2.3	2.3
9	2.5	2.4	2.2	2.2	2.0	2.1	2.2	2.1	2.0	2.4	2.2
10	2.2	2.7	2.2	1.9	1.9	2.0	2.1	2.3	2.2	2.3	2.2
11	1.8	2.3	2.0	2.0	1.8	2.1	1.8	2.0	2.5	1.9	2.0
12	2.2	2.2	2.3	2.4	2.1	2.2	2.1	1.9	2.1	2.2	2.2

T A B L E XIX

Test 9 Regular Tissue Special Q Carbon

(a)

Part No.	Readability										Mean
1	6.0	6.0	6.0	5.8	6.1	6.0	6.1	6.6	6.4	5.8	6.1
2	3.8	3.8	4.2	3.8	4.1	4.4	3.9	4.2	4.8	3.8	4.1
3	2.9	3.4	3.8	3.4	3.2	3.6	3.8	3.6	3.4	3.8	3.5
4	3.2	3.2	3.2	3.3	3.2	3.0	3.6	3.6	3.2	3.4	3.3
5	2.9	3.0	3.1	3.0	3.4	2.8	3.1	3.3	3.2	2.8	3.1
6	3.1	2.6	2.9	2.5	3.2	3.0	2.7	2.9	3.0	2.7	2.9
7	2.4	3.3	2.9	2.9	2.6	2.6	2.8	2.5	2.3	3.0	2.7
8	2.6	2.4	2.7	2.3	2.6	2.3	2.5	2.3	2.4	2.5	2.5
9	2.3	2.1	2.4	2.8	2.6	2.4	2.6	2.3	2.4	2.3	2.4
10	2.1	2.4	2.3	2.2	2.6	2.1	2.5	1.9	2.4	2.3	2.3
11	2.0	2.5	2.2	2.2	2.1	2.5	2.2	2.1	2.1	2.2	2.2
12	2.1	2.3	2.6	2.5	2.3	2.5	3.0	2.3	2.7	2.3	2.5

T A B L E XX

Test 9 Regular Tissue Special Q Carbon

(b)

Part No.	Readability										Mean
1	6.0	6.1	5.8	6.2	6.6	5.4	5.2	6.0	5.6	6.4	5.9
2	4.3	3.9	4.6	4.0	4.3	3.9	3.7	3.7	4.9	4.0	4.1
3	3.4	3.4	3.8	3.4	3.6	3.7	3.9	3.3	3.4	3.8	3.6
4	3.2	3.0	3.4	3.2	3.5	3.0	3.2	3.2	3.2	3.4	3.2
5	3.2	2.9	3.1	3.2	2.7	2.7	2.9	3.0	3.2	3.4	3.0
6	3.0	3.0	2.9	3.2	2.7	2.5	2.7	3.1	3.0	3.0	2.9
7	2.6	2.9	2.5	2.8	2.5	2.4	2.7	2.6	2.6	2.7	2.6
8	2.5	2.5	2.9	2.7	2.4	2.3	2.4	2.7	2.4	2.5	2.5
9	2.5	2.0	2.2	2.7	2.4	2.3	2.2	2.3	2.5	2.4	2.4
10	2.6	2.3	2.3	2.3	2.6	2.2	2.3	2.1	2.4	2.3	2.3
11	2.2	2.1	2.4	1.9	2.3	2.4	2.1	2.3	2.2	2.2	2.2
12	2.4	2.3	2.3	2.3	2.4	2.3	2.6	2.1	2.6	2.4	2.4

T A B L E XXI

Test 10 Thin Tissue Special Q Carbon

(a)

Part No.	Readability										Mean
1	5.4	5.6	6.0	6.0	6.2	6.6	6.5	5.8	6.0	6.4	6.1
2	4.0	3.9	3.9	4.6	3.8	4.0	5.0	3.7	4.2	5.0	4.2
3	3.6	3.6	3.4	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.6
4	3.2	3.2	3.5	3.6	3.2	3.3	3.1	3.2	3.5	2.9	3.4
5	3.4	3.1	3.0	3.0	3.1	3.5	3.4	3.0	3.0	3.0	3.2
6	2.9	2.8	2.7	2.7	3.1	2.6	2.7	3.1	2.8	2.8	2.8
7	2.3	2.5	3.1	2.9	2.7	2.9	2.5	2.8	3.0	2.6	2.7
8	2.5	2.3	2.5	3.1	2.5	2.0	2.7	2.3	2.6	2.5	2.6
9	2.0	2.4	2.2	2.6	2.6	2.7	2.6	2.5	2.4	2.3	2.4
10	1.9	2.1	2.3	2.2	2.4	2.5	2.4	2.3	2.5	2.2	2.3
11	2.0	2.0	2.2	2.3	2.0	2.4	2.5	2.2	2.3	2.2	2.2
12	2.1	2.4	2.3	2.0	2.3	2.2	2.7	2.6	2.5	2.5	2.4

T A B L E XXII

Test 10 Thin Tissue Special Q Carbon

(b)

Part No.	Readability										Mean
1	5.4	6.0	5.4	6.0	6.0	6.4	5.8	7.0	6.0	6.4	6.0
2	3.8	4.1	4.0	3.8	3.6	4.3	5.0	4.3	4.8	5.0	4.3
3	3.4	3.5	3.4	3.8	3.5	3.6	4.2	4.0	3.8	4.0	3.7
4	3.4	3.3	3.4	3.3	3.3	3.5	3.5	3.0	3.5	3.5	3.4
5	3.2	3.0	2.9	3.0	3.0	3.4	3.6	3.0	3.0	3.2	3.1
6	2.7	3.0	3.0	2.8	2.9	2.8	3.2	2.9	2.5	2.8	2.9
7	2.5	2.8	2.9	2.7	2.9	2.6	2.7	2.8	2.7	2.5	2.7
8	2.5	2.3	2.4	2.7	2.7	2.9	2.9	2.9	2.5	2.7	2.6
9	2.2	2.6	2.2	2.2	2.8	2.6	2.8	3.2	2.5	2.3	2.5
10	2.2	2.2	2.3	2.1	2.3	2.4	2.5	2.5	2.5	2.3	2.3
11	2.0	2.2	1.9	2.0	2.2	2.2	2.6	2.5	2.1	2.6	2.2
12	2.2	2.5	2.2	2.1	2.6	2.5	2.7	3.0	2.4	2.8	2.5

IX. APPENDIX II

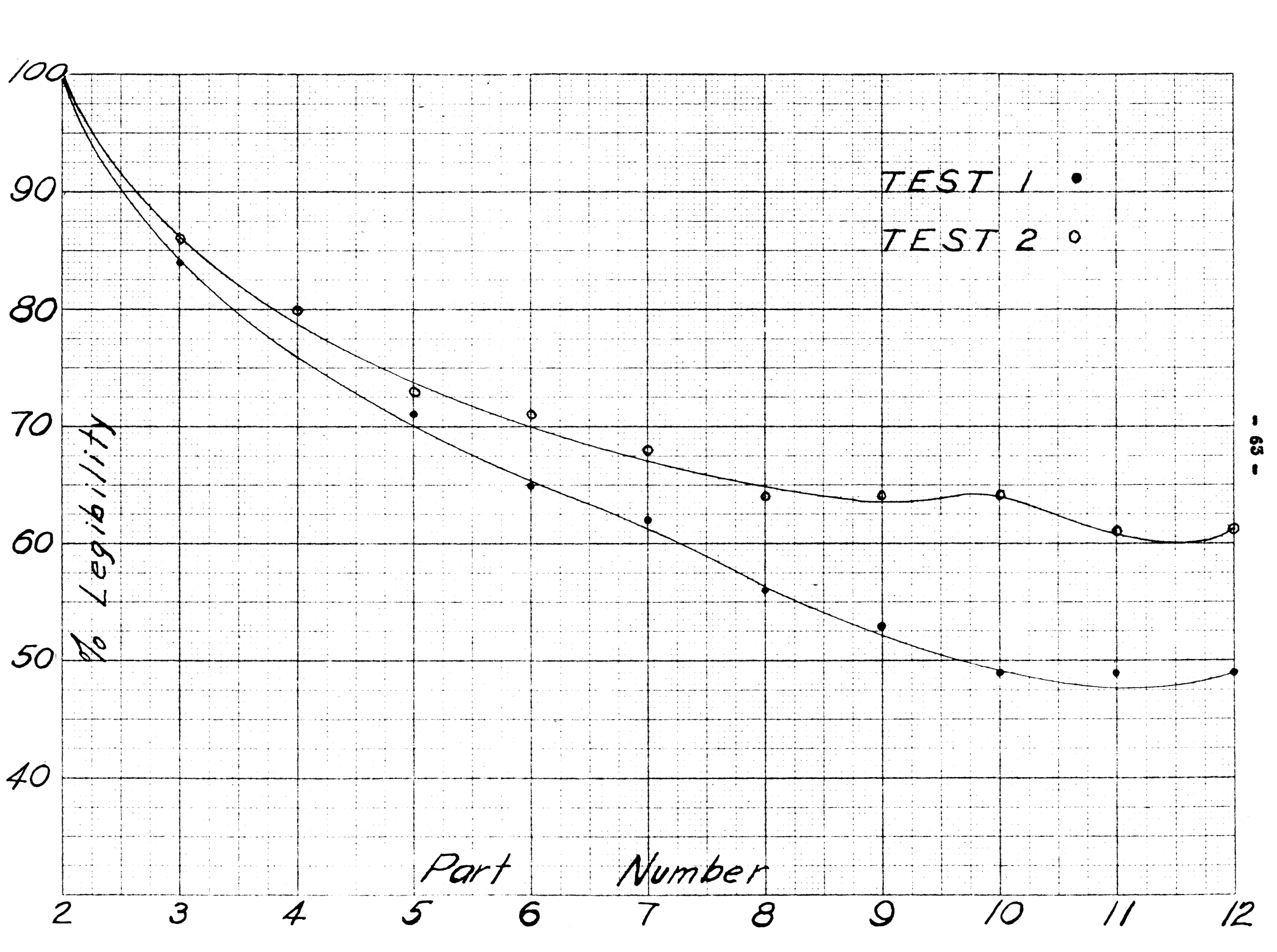
Following are eleven graphs of legibility curves, plotted with the per cent legibility versus the part number, comparing the various tests used in this investigation. The basis of comparison is the carbon used, since the side of the paper, the paper itself, and the setting of the electromagnetic typewriter used in making the samples, were all held constant.

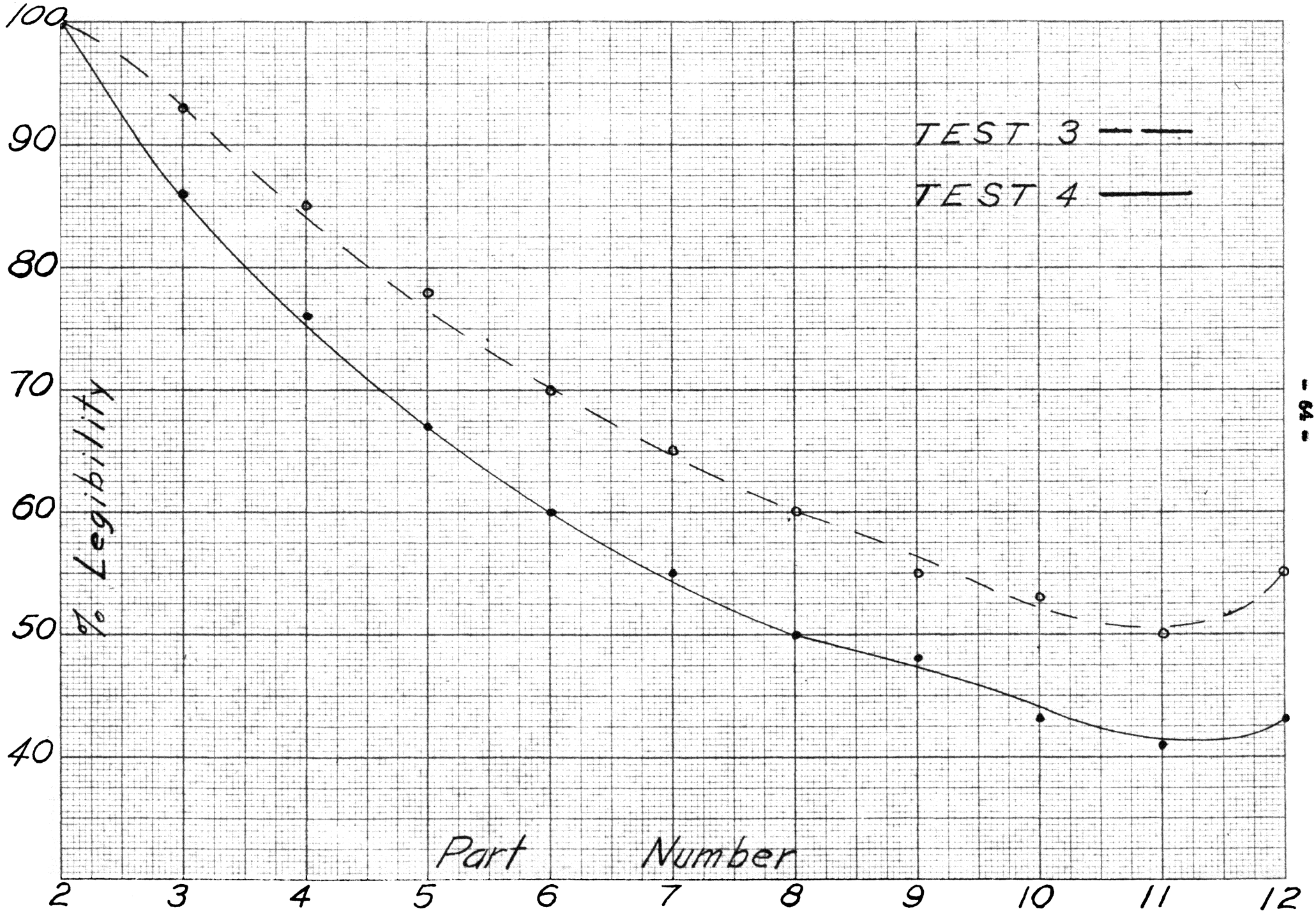
The first graph of Test 1 and Test 2 was plotted from the per cent legibility of the mean values of sets (a) and (b). These values were used in making comparisons with other tests through Test 6, which were also plotted from the per cent legibility of the mean values.

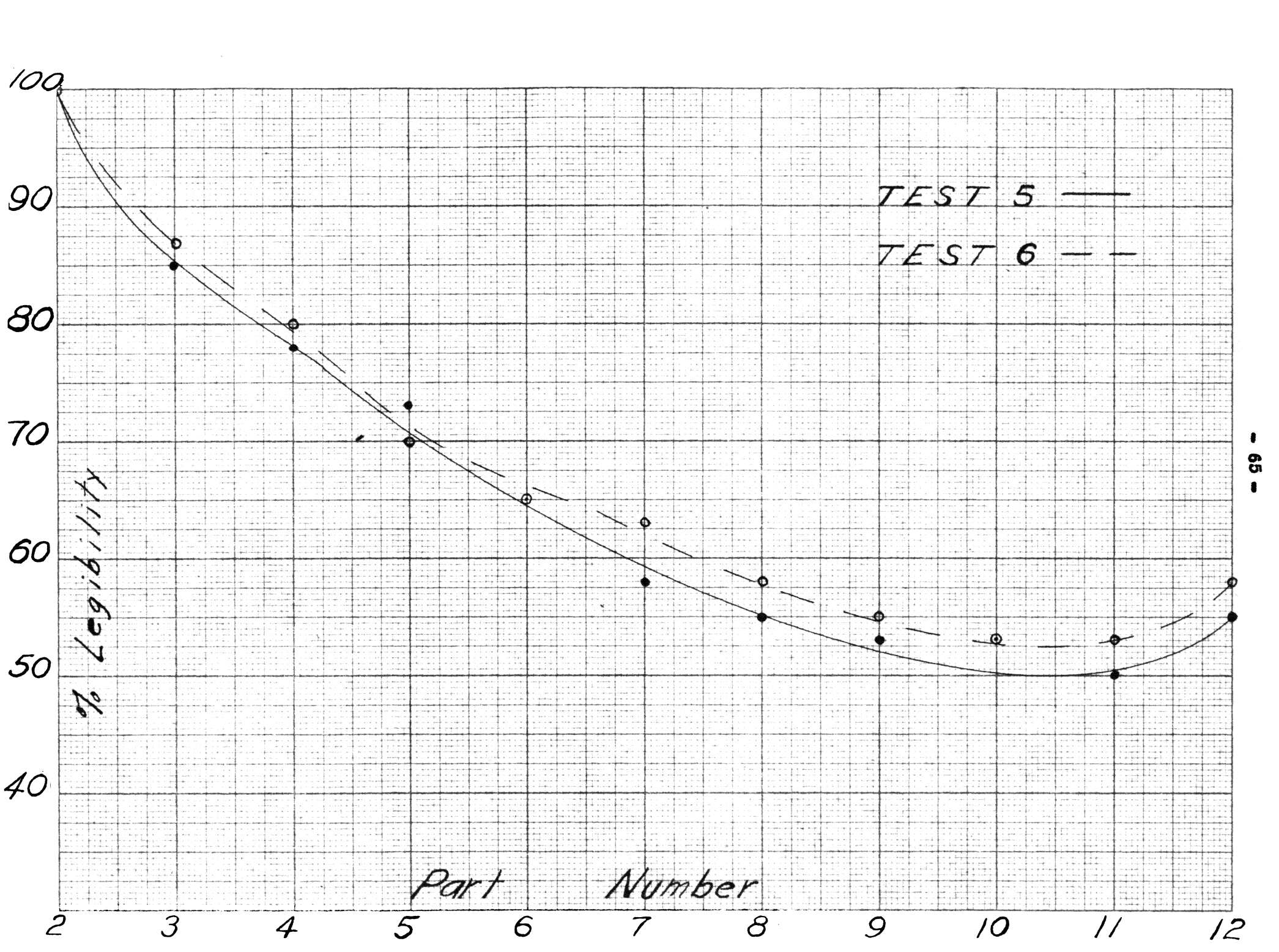
The second graph of Test 1 and Test 2 was plotted from the mean per cent legibility of sets (a), (b), and (c). These values were used in making comparisons with Tests 7 through 10; Tests 8 through 10 were also plotted from the mean per cent legibility.

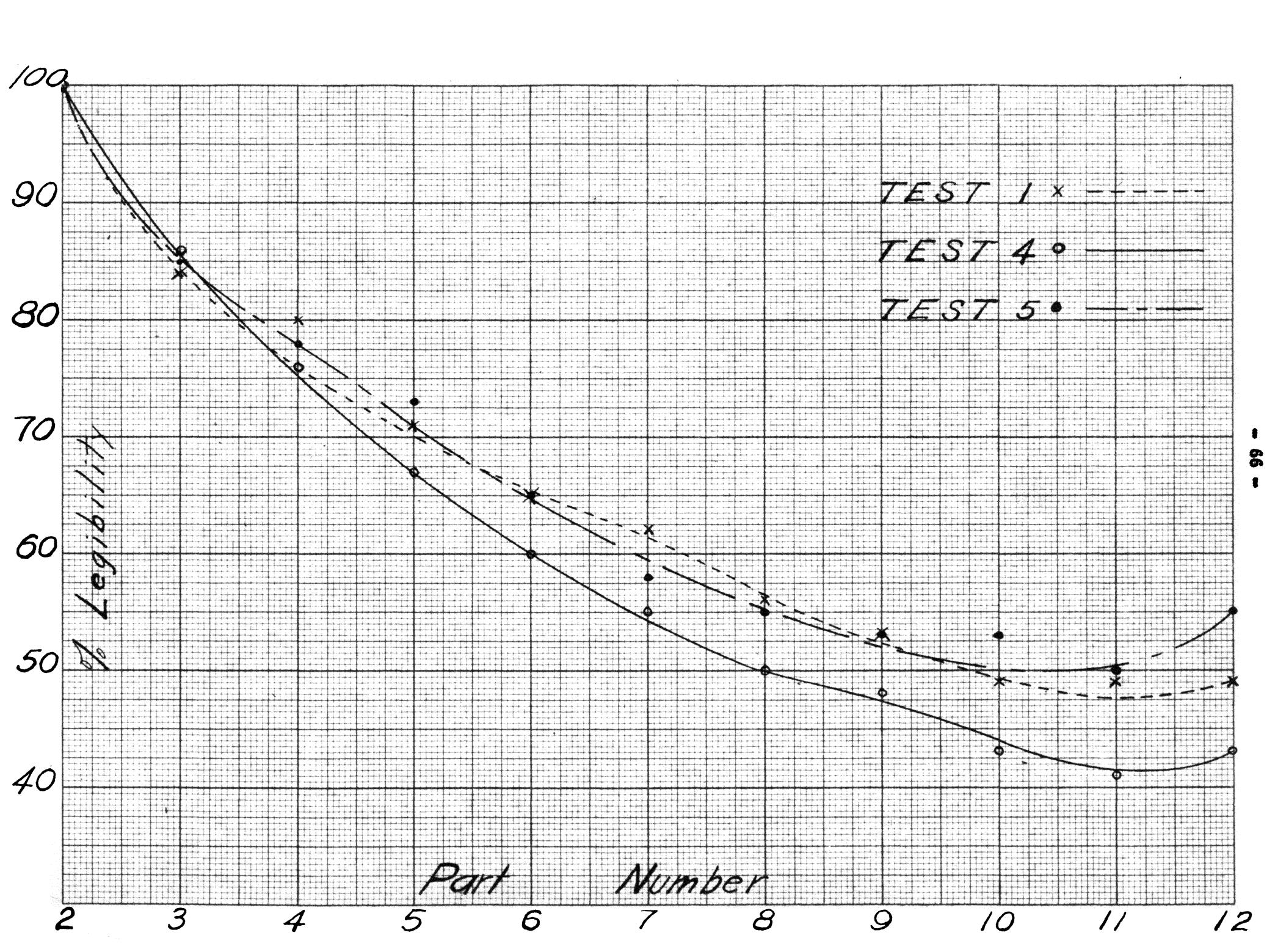
Part 1 was not plotted on the graphs since Part 2 was taken as one hundred per cent legible, and also because of the fact that its (Part 1) legibility was not pertinent to this investigation.

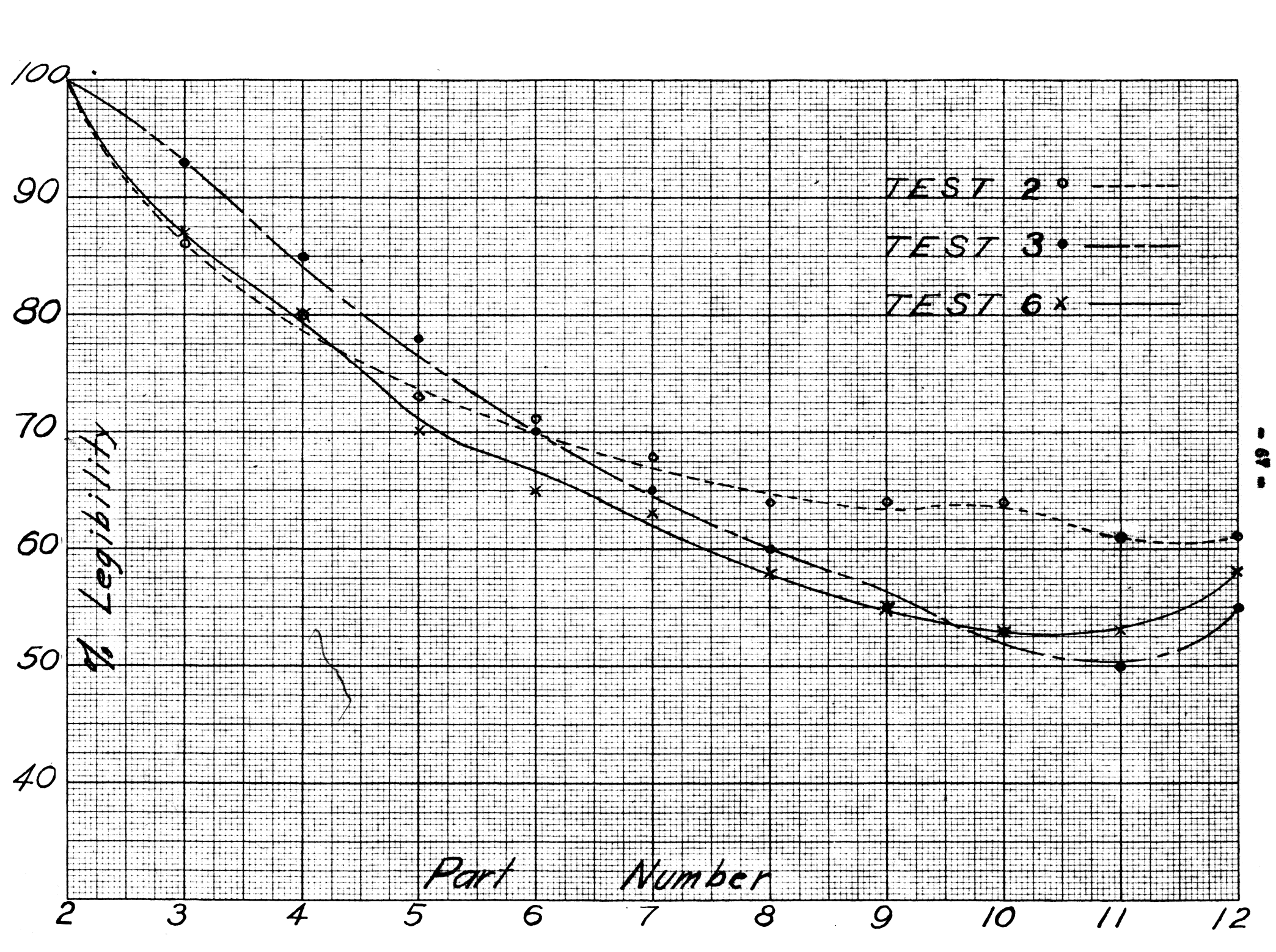
Test 7 is a sample made using Red Carbon. It is interesting to note that it is, overall, more legible than one of the black carbon samples.

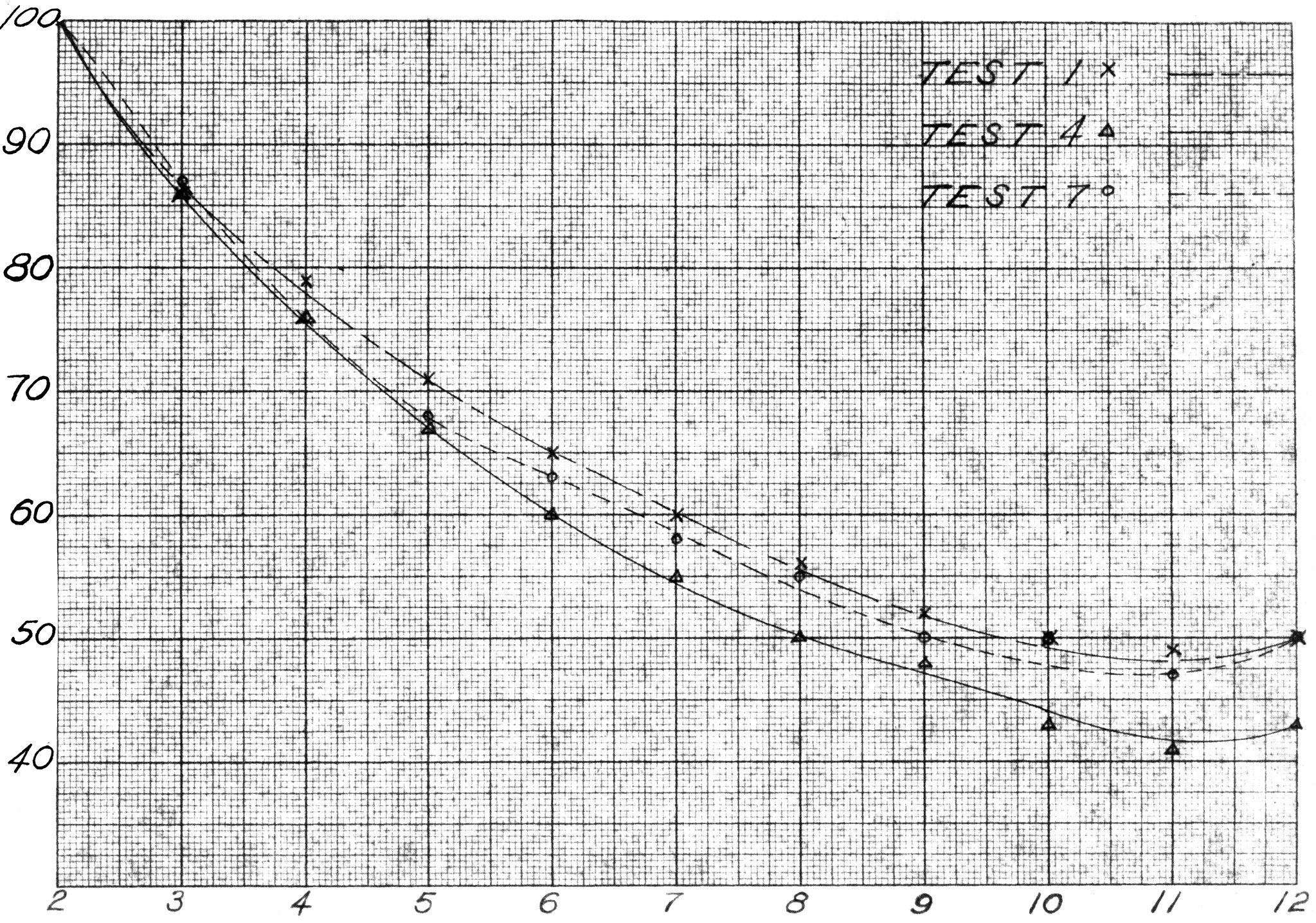

100
90
80
70
60
50
40
% Legibility
TEST 1 •
TEST 2 ○
Part Number
2
3
4
5
6
7
8
9
10
11
12


100
90
80
70
60
50
40
% Legibility
TEST 3
TEST 4
Part Number
2
3
4
5
6
7
8
9
10
11
12


100
90
80
70
60
50
40
% Legibility
TEST 5 ——
TEST 6 — —
Part Number
2
3
4
5
6
7
8
9
10
11
12


100
90
80
70
60
50
40
Legibility %
TEST 1 ×
TEST 4 ○
TEST 5 ●
Part Number
2
3
4
5
6
7
8
9
10
11
12


100
90
80
70
60
50
40
% Legibility
TEST 2°
TEST 3•
TEST 6×
Part Number
2
3
4
5
6
7
8
9
10
11
12


100
90
80
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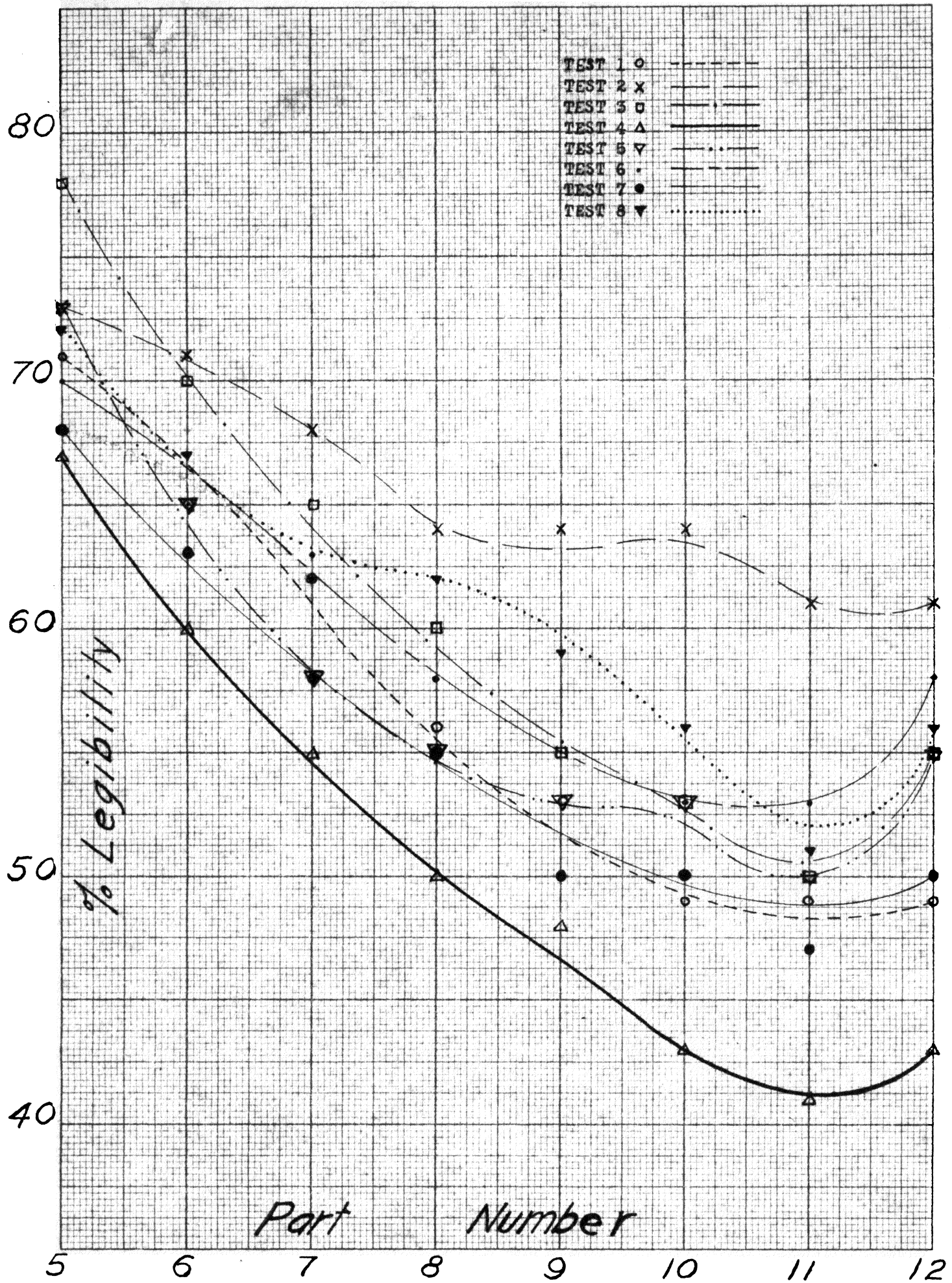
11
12
TEST 1 ×
TEST 4 △
TEST 7 ○


TEST 1
TEST 2
TEST 3
TEST 4
TEST 5
TEST 6
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TEST 8
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% Legibility
Part Number
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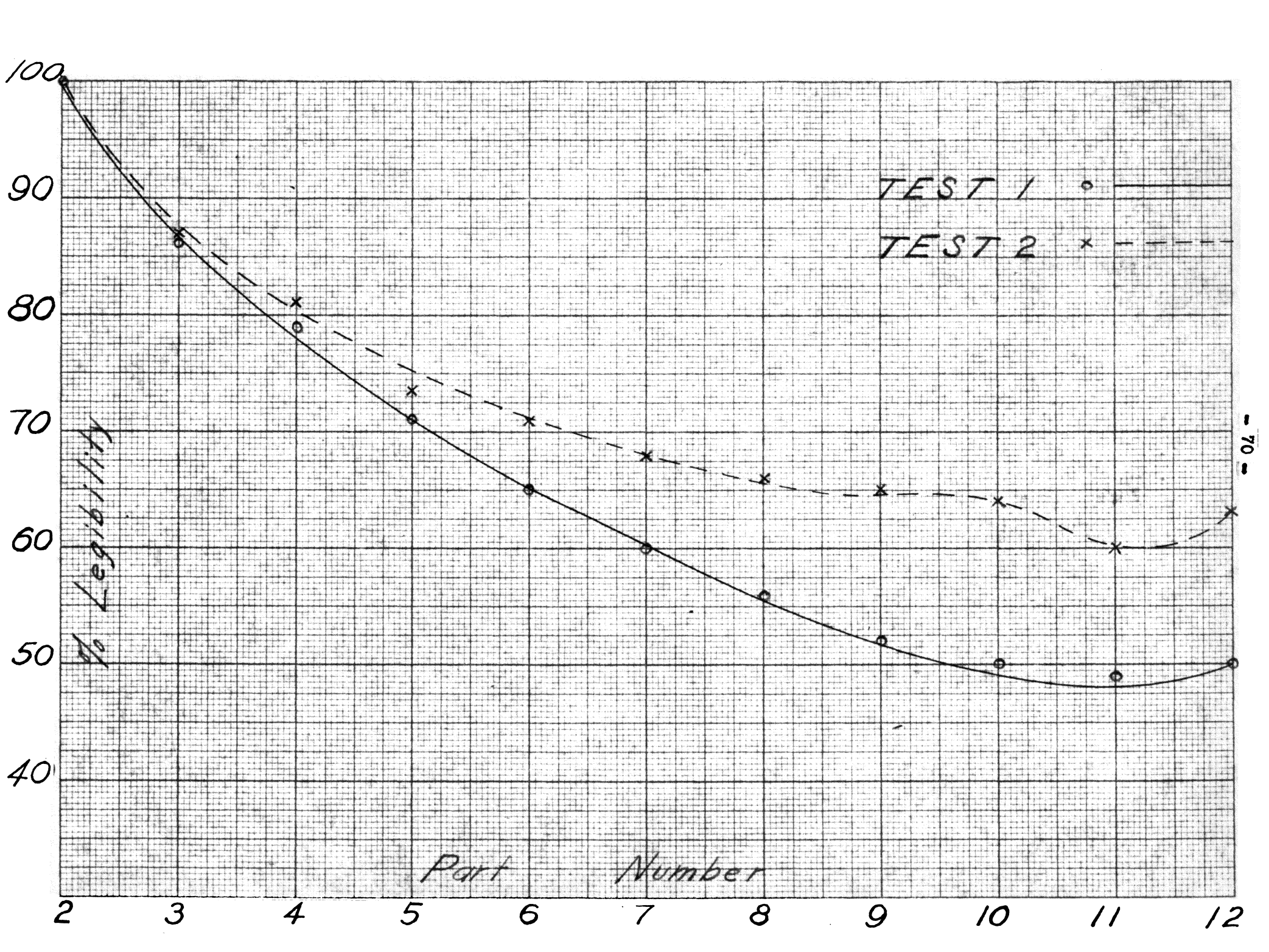
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Legibility %
TEST 1
TEST 2
Part Number
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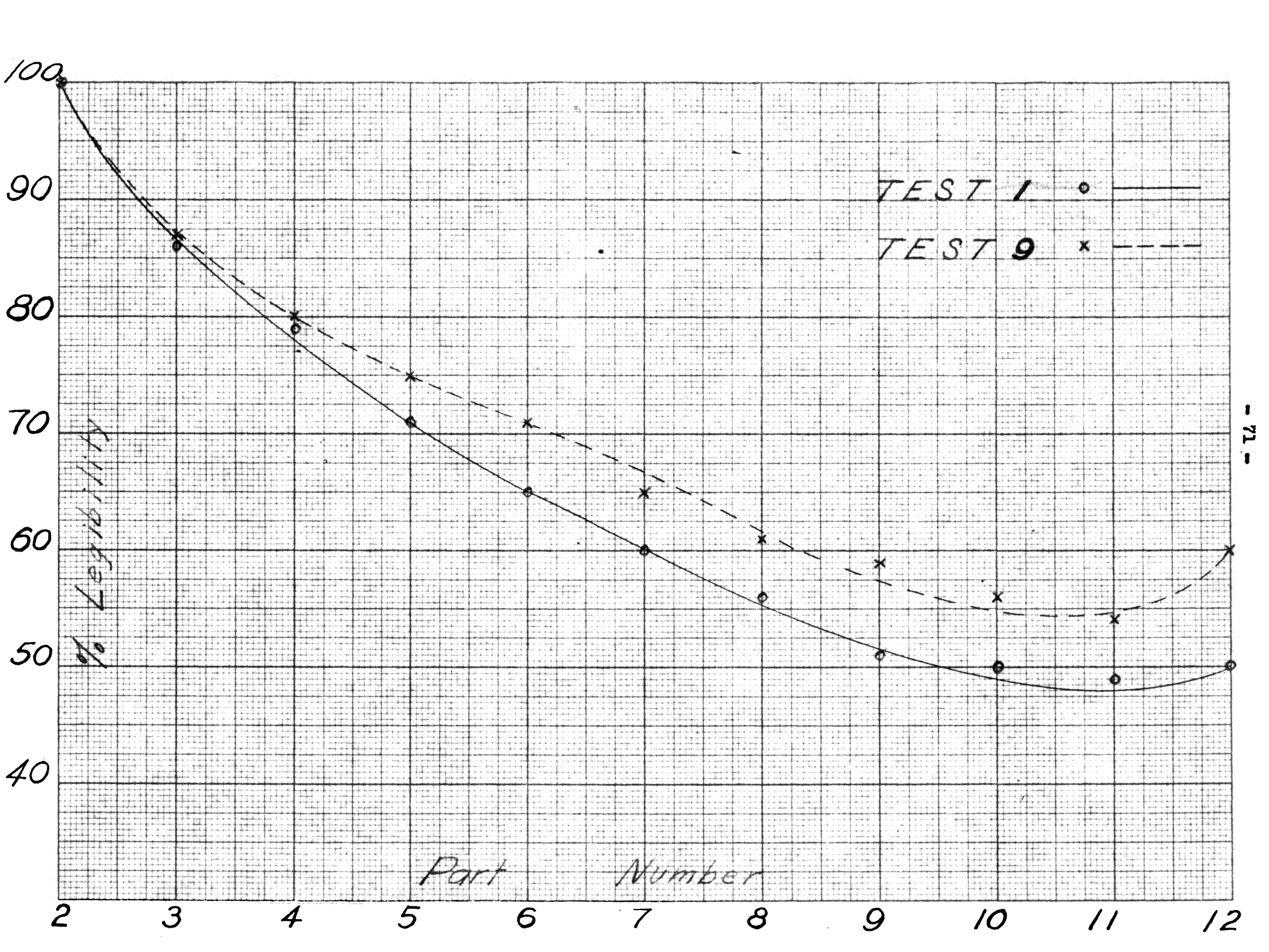
100
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80
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% Legibility
TEST 1
TEST 9
Part Number
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4
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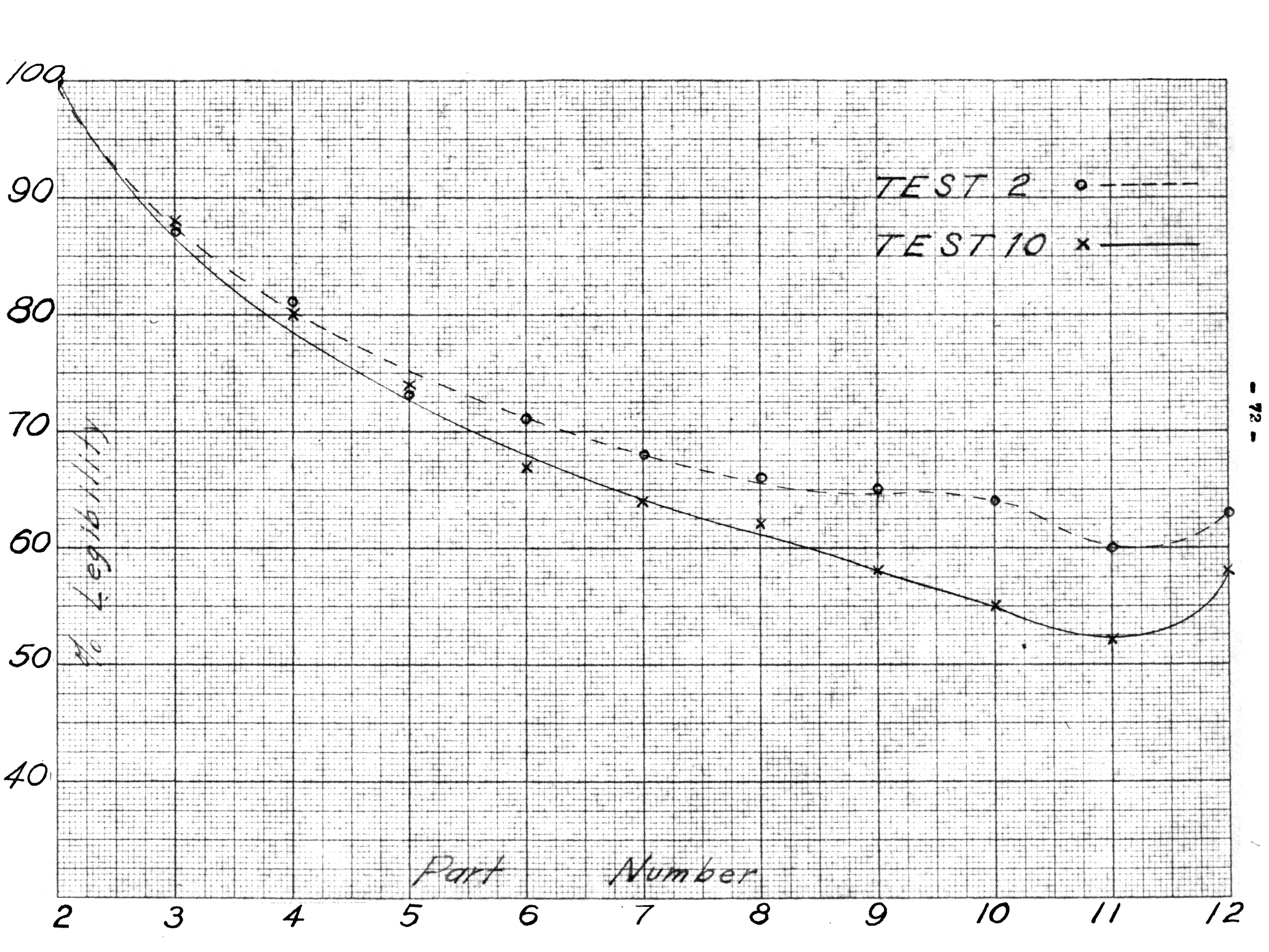
100
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Legibility
%
TEST 2
TEST 10
Part Number
2
3
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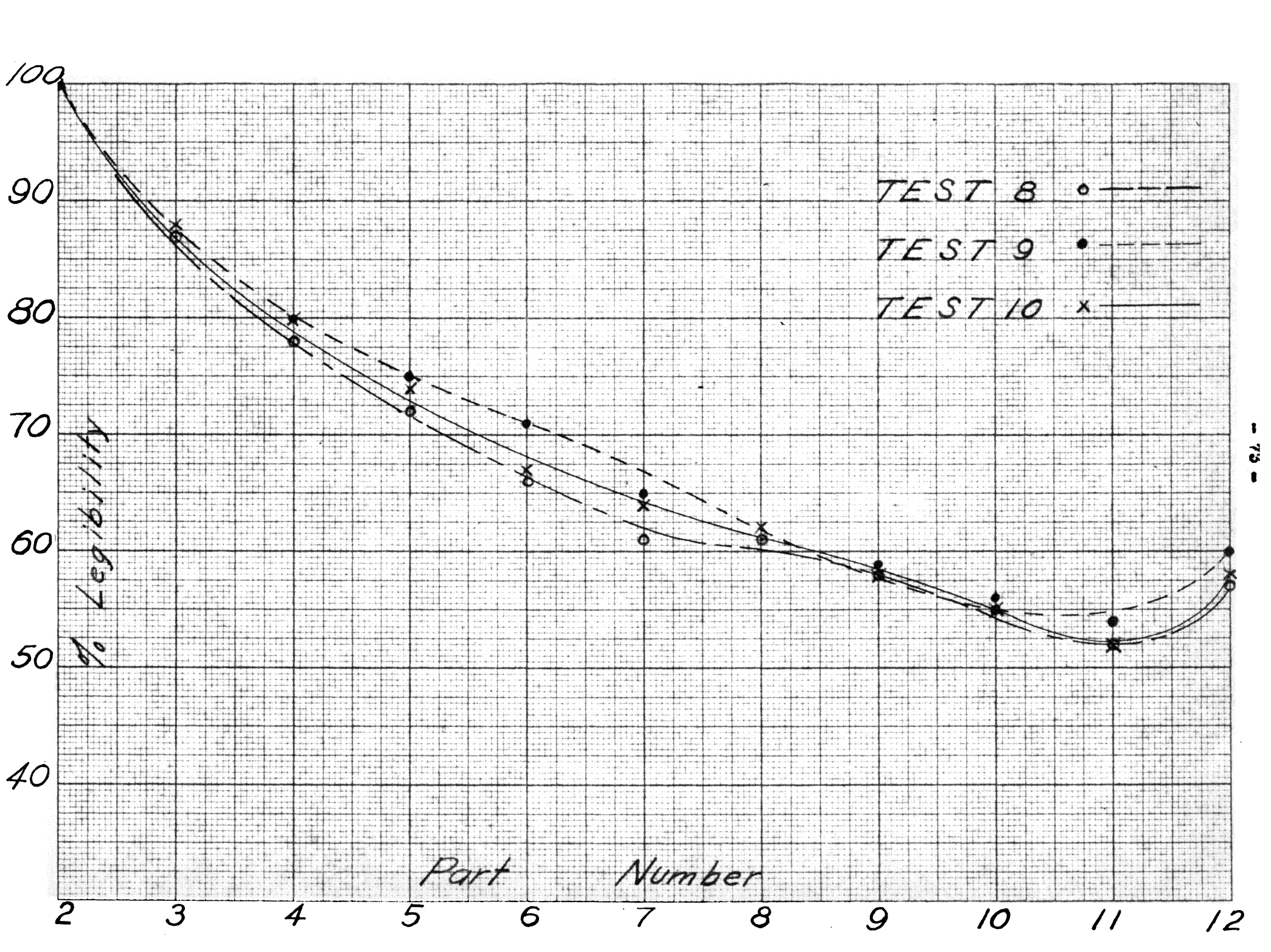
11
12


100
90
80
70
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% Legibility
TEST 8
TEST 9
TEST 10
Part Number
2
3
4
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