6-1-1977

An investigation into the effects of gloss and smoothness on legibility

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Certificate of Approval--Master's Thesis

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's Thesis of

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with a major in Printing Technology
has been approved by the Thesis Committee as
satisfactory for the thesis requirement for the
Master of Science degree at the convocation of
June, 1977

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AN INVESTIGATION INTO THE EFFECTS OF GLOSS AND SMOOTHNESS ON LEGIBILITY

by

Donald J. Perlman

A thesis submitted in partial
fulfillment of the requirements for the
degree of Master of Science in the School of Printing
in the College of Graphic Arts and Photography
of the Rochester Institute of Technology

June, 1977

Thesis advisor: Werner Sobotka

ACKNOWLEDGEMENT

The completion of this thesis would have been impossible without the many people that have helped.

To Werner Sobotka, visiting professor from Austria-- My sincere thanks. Without your guidance I would never have been able to complete this thesis.

To the Thesis Committee-- Your suggestions and time are greatly appreciated.

To Chester Daniels-- I greatly appreciate the time you spent with me, showing and explaining the instruments I used.

To Michael Jones-- Your help and friendship will be long remembered.

To Craig, Anne, and Barbara-- We came in together but will be leaving separately. Thanks for all the help you guys have given me. Best wishes for your future endeavors.

Finally, I'd like to thank the faculty of RIT for giving me the skills that I will use in my future career.

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AN INVESTIGATION INTO THE EFFECT OF GLOSS AND SMOOTHNESS ON LEGIBILITY

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An Abstract

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ABSTRACT

This study on legibility takes a different approach than the studies that precede it. Standardized test targets (ISO Characters) were used as the measurement device instead of the various means used previously. This was done to keep the test more objective.

Twelve papers of different gloss and smoothness values were tested with two groups--college students and senior citizens.

These experiments were done under controlled conditions with the only variable being the paper.

The average results from the legibility readings were correlated against the physical properties of the paper samples.

The results of this study showed a 2 and 4% correlation between college students and smoothness and gloss respectively.

No correlation could be obtained between senior citizens and gloss and smoothness. Here the ISO Characters did not work as a test of legibility but rather as a test of visual acuity.

Abstract approval _____, Thesis advisor

_____, Title and Department

_____, Date

I. INTRODUCTION

Most research on legibility has been oriented toward typography and little else has been studied with any great concern.

One of the most important influences on legibility, besides the type face, is the substrate on which the word is printed. Paper is the substrate most often used by the major printing processes. This is because paper has the ability to provide an adequate surface for reproduction at a reasonable cost.

The printer has many types of paper from which to choose. His choice of paper stock may be based on economics or the appearance of the finished product. However, this choice should be weighed against the reader's need for legible print and the purpose of the printing (i.e. books versus newspapers).

The reader needs a stock that will help increase legibility. This need should be an important consideration in choosing the type of paper. Paper that detracts from legibility hinders the reader after long periods of reading compared to paper of better legibility quality.

Definition of terms

Legibility-- This deals with the reader's ability to perceive words and letters in a rapid and easy manner. With continuous text, legibility would deal with the coordination of the many factors to produce the optimum reading condition.

Objectives

There are certain properties of paper that have some effect on legibility. Throughout the years very little research was done on the effects of legibility. Most research in the area of legibility has been done in typography.

Since research has been lacking in this area, there are two things this study tried to accomplish. First, an attempt is made to generate new interest in this area among researchers. Secondly, this study will provide the printer, printing salesmen, and printing purchasers with the knowledge of the effects of paper on legibility so they can choose the most legible paper.

Since paper has many properties it would be difficult to study all these properties and get significant results.

The printer has a choice of many papers. Gloss of paper is one variable the printer can control by using coated or uncoated paper. Ordinarily, smoothness and gloss are closely related since the smoothness of paper seems to affect the level of gloss. Therefore, both smoothness and gloss were chosen to be studied in this investigation.

In the past, few experiments have been done in this area. The few experiments already done tend to be subjective. All but one of the test methods used in the past require the use of the printed word. Results from such studies would then be affected by the participants knowledge of individual letters or words.

In this study, unlike other legibility studies, a test target was used to help make the test more objective. This method has been unavailable to those who study typefaces since the test target is a standard symbol that is not changed by type design.

Another fault of past experiments is the age of the participants chosen in the experiments. Paterson and Tinker used mostly college students. Carmichael and Dearborn used both college and high school students in their experiments.[1] High school and college students are only a small part of our population.

Pyke at first used students but later switched to using a full time paid staff which he believed was better. Luckiesh and Moss used the technical and clerical staff which worked in their labs.[2]

Tinker points out that the use of a full time staff can affect the results. People who take tests "repeatedly in a given field gradually learn what is expected of them", and they will unintentionally react to produce the results expected in the experiments.

A literature search indicated that the few researchers who had conducted studies in this area did not use groups of observers who were really representative of the population. For this reason, it is necessary to study the effects in legibility of certain paper properties on senior citizens to see if paper affects them the same way it affects college students.

College students and senior citizens are not representative of the whole population but rather two polarized groups.

In the future, other studies should be done to test the effects of paper legibility on other age groups. However, for this investigation I have chosen these two groups.

Hypothesis

1-- There is a good correlation between gloss and legibility of paper read by college students.

2-- There is a good correlation between smoothness and legibility of paper read by college students.

3-- There is a good correlation between gloss and legibility of paper read by senior citizens.

4-- There is a good correlation between smoothness and legibility of paper read by senior citizens.

5-- There will be a higher correlation for paper legibility with senior citizens than thereis with paper legibility for college students.

FOOTNOTES FOR CHAPTER ONE

1. Zachrisson, Bror, Studies in Legibility of Printed Text (Almquist and Wiksells Boktryckeri AB Sweeden 1965) page 70.

2. Ibid., page 70.

3. Tinker, Miles A., Validity of Frequency of Blinking as a Criteria of Readability (Journal of Experimental Psychology Vol. 36 October 1946) page 458.

II. LITERATURE REVIEW AND THEORETICAL BASIS

Little research has been done on the effect of paper on legibility. During the late nineteenth and early twentieth centuries, many people ventured to give their opinions on this subject; however, none was based on experimental data.

Basically, these writers suggested that the paper should be a white uncoated matte surface with enough opacity to prevent show-through or print-through.[1]

Since that time, some research has been done, mostly by ophthalmologists and psychologists interested in physiology.[2]

In 1878, F. Javal,[3] an ophthalmologist, conducted the first scientific study dealing with reading and eye movements.[3] Javal suggested the tint of paper should not be of a color found on the extremes of the visible spectrum. He goes on to suggest that green would be the ideal tint but is "ugly." Instead, a yellow tint would be preferred for its aesthetics and it's ability to absorb blue light.

Since that time a number of methods have been used to test legibility. In "WIE Sollen Bucher Und Zeitungen Gedrucht Werden" by Cohn and Rubencamp,[4] Weber[5] is cited as having used the rate of reading test to determine the effect of letter size on legibility.

Two of the strongest proponents of the rate of reading method are Paterson and Tinker.[6] By standardizing the test and using a comprehension control, they made this method a scientific tool.

Paterson and Tinker used the Chapman-Cook[7] speed of reading test. This test has two forms, A and B. Both forms are considered to be of equal difficulty.

The test is divided into sixty paragraphs of thirty words each. In each paragraph there is one word that does not belong in the context. By marking this word, the subject indicates comprehension. This is done within a short predetermined time limit.

The vocabulary used in these paragraphs is scaled to a fourth grade reading level. Eighty per cent of the words used were taken from a list of the five hundred most frequently used words in the English language. Ninety-five per cent of the vocabulary is from a list of the five thousand most frequently used words.[8]

The accuracy of the Chapman-Cook test is questionable. One question that has been raised about this test is whether forms A and B are really equal in difficulty.

Paterson and Tinker tested this and found there is a small difference when form B is read before form A. However, when form A is read before form B, no real difference was found.

Paterson and Tinker found form B to be slightly more

difficult than form A. When form A was read first the reader had enough practice to compensate for the increased difficulty.

The Chapman-Cook speed of reading test also raises questions regarding its use in legibility studies. A scrupulous reader who can find the "crazy word" is considered to be the ideal reader. The speed reader or skimmer will be at a disadvantage to the careful reader even though the skimmer or speed reader's comprehension may be greater.[10]

Carmichael and Dearborn[11] also used the rate of reading as a test of legibility in their research. In their studies on fatigue, they measured the number of lines read during an allotted period of time.

Another method of measuring legibility is by measuring eye movement. The study of the movement of the eyeball is a good indicator of reading ability. In 1922 Buswell[12] said this significance "... goes beyond the mechanics of reading. The use of eye movement records in the analysis of reading rests primarily upon the fact that they furnish an objective symptom of the character of the reading process. Unless the attention of the reader is specifically directed to them, he is entirely unconscious of their nature".[13]

Fixation is one method used to measure the eye ball movement. Researchers have found that the length of fixation of the eye ball is based on the reader's maturity, habits, and interest in reading. The time of each fixation will

remain approximately constant for any given person. The number of fixations will increase as reading material becomes difficult to read, poorly printed, of poor contrast or too light. The number of fixations also increase (or decrease) according to the size and shape of the typographical arrangement.

Carmichael and Dearborn also studied fixations. In 1947 they concluded that "the duration of the pauses is relatively unaffected by the conditions which either increase or decrease the number of fixation pauses.... the general conclusion to be drawn is that fixations are rather constant in duration but vary much more in frequency in a given unit of reading."[14]

A second method of measuring eye movements is by studying the rate of blinking. It is generally believed, but not yet proven, that involuntary blinking is a sign of fatigue. People blink to cleanse the cornea, massage the eye, aid in tear drainage, increase pressure to the eye, and help resolve blurred images.[15]

Luckiesh and Moss[16] have used the rate of blinking as a method for measuring legibility. As subject matter, they used H.G. Wells's The Outline of History. They chose this book because they felt it had a low emotional value and a uniform level of interest.

In 1947 they conducted a study with eighteen single, educated people from twenty to thirty-five years of age.

Under controlled illumination, they found that paper with more gloss will increase the rate of blinking. Luckiesh and Moss also noted that greater illumination will decrease the rate of blinking.

Luckiesh and Moss also used this method to study the affect of type face and size on legibility.

Tinker, an advocate of the rate of reading technique, questioned whether the rate of blinking is an accurate measure.

During 1945 and 1946, Tinker undertook some studies on this subject. In one study, he compared a text of all capital letters with a text of all lower case letters.

Tinker first used the rate of reading method. He found that the text with all capitals reduced the reading speed compared to the text of all lower case letters. He then repeated the experiment, but this time he used the rate of blinking test. With this method, he found that there was no real difference between capital and lower case letters.

Tinker with Paterson also conducted studies with capital and lower case letters. They studied eye fixations by photographing the subjects' eye movements while reading capital and lower case letters. They found that the text with all capitals required "significantly more fixations and longer pause duration than the text in lower case".[17]

Though Tinker indicates that the rate of blinking is a poor index when studying type faces or size, he does point out that there may be some special situations where this

method would be acceptable. He indicates that this method may be applicable in a study of the affects of contrast between the print and the paper.[18]

Theoretical Basis

Paper has certain inherent properties that can affect legibility. These properties can affect legibility either in a positive or negative way.

These properties can be classified into two categories.

1. Optical Properties

These are the properties that can either aid or hinder the readers visual senses. Properties such as gloss, color, and brightness will be discussed.

1-1 Gloss is associated with the burnished or shiny appearance of paper. It is the measurement of the percentage of light reflectance of paper.[19]

A mirror will reflect light in a predictable way. The angle at which the light hits the mirror will be equal to the angle that the light will bounce off the mirror. This is called specular reflection.

Paper is not a perfect reflector of light because of its uneven surface. We attempt to make the surface smoother by calendering or coating the paper. Even with smoother paper light is still scattered. This is called diffuse reflection.

The measurement of the amount of light reflected at the proper angle and the loss of light that is scattered and cannot be measured is called gloss.

Since gloss helps lengthen the density range between ink and paper, it should aid in legibility. This is because legibility will increase as the density difference between the ink and paper increases.

Glossy paper may also be undesirable for text matter because of the increased glare.[20]

1-2 Color is used to enhance the aesthetic quality of paper. Paper can be colored or tinted to any color. But not all colors are good for the reproduction of text matter if legibility is considered.

For text, the ideal paper would be slightly off-white. A color such as blue-white or cream-white is often used.

The problem with tinted or colored paper is it lowers the contrast between the paper and ink. As long as the tint is not too strong it will not reduce the contrast enough to make a notable difference.

1-3 Brightness is the paper's ability to appear white. The brighter the paper, the lighter or whiter it will appear.

Brightness deals with the measurement of blue-violet light that is reflected from the paper. It differs from gloss in that the angle of reflectance is not important. A bright paper will look bright regardless of the angle you look at the paper.

Brightness, unlike gloss, is increased with paper that scatters light. A mirror, even though it is a perfect reflector of light, would have virtually no brightness value since it does not scatter any light.

Coated paper is often brighter than uncoated. This is caused by the pigment particles in the coating that increases the reflecting surface.

Even though brightness is the measure of blue-violet light, it is considered to be the whiteness of the paper as it appears to the eye.

Since brightness will add contrast between the paper and the ink, legibility should be aided.

2. Physical Properties

Physical properties cannot be discussed separately from optical properties. Physical properties such as smoothness, opacity, and absorbtion can "... affect the level and variation of the optical properties..."[21]

2-1 Smoothness is an important factor of paper. A smooth paper will help to increase the gloss of paper.

If the paper is not smooth enough, a heavier layer of ink will have to be put down to reach the same density of a smoother paper. If an excessively heavy layer of ink is put down, drying problems will occur. If the layer of ink is not thick enough, the ink will not fill the valleys of the paper with enough density, and the printing will appear grainy.

2-2 Opacity of paper plays an important part in the legibility of printed matter. Papers are opaque to varying degrees. Opacity is a physical characteristic that will help prevent the image on the reverse side of the paper from showing through. This is called show-through. Greater opacity will also prevent the printing on adjacent sheets from being seen through the top sheet.

Lack of opacity, produces excessive show-through and reduces contrast between the paper and the type face. This will reduce legibility.

2-3 Absorbtion deals with the paper's ability to absorb oils and water. If the paper absorbs the oils from the ink too fast, there may be a loss of print quality. On coated papers, this can cause powdering or chalking of the ink.

Statistical Investigation

In this study there are a number of variables that will be studied. It is important to know how strong a relationship one variable has to a second.

By studying the correlation, a single number, between 1 and -1, can be derived to show the degree to which change in one variable is related to the change in a second. The numerical value we get from this correlation, called the correlation coefficient, will not only tell us the strengths but will also give us an easy means for comparing the strength of the different relationships.[22]

The closer the correlation coefficient is to 1 or -1, the stronger the relationship becomes. The closer to zero, the weaker the relationship.

To determine the strength of the relationship in a percentage, the r value should be squared. For example, if r= .85, there would be a 72% correlation ($.85^2$).

FOOTNOTES FOR CHAPTER TWO

1. Tinker, Miles A., Legibility of Print (Iowa State University Press, Ames, Iowa 1963) page 154.
2. Zachrisson, Bror, Studies in Legibility of Printed Text (Almquist and Wiksells Boktryckeri AB Sweeden 1965) page 27.
3. Ibid., page 27.
4. As Cited in Zachrisson Ibid., page 45.
5. Zachrisson, Op. Cit., page 45.
6. Ibid., page 46
7. Ibid., page 46
8. Paterson, Donald G. and Tinker, Miles A., How to Make Type Readable (Harper and Brothers New York, 1940) page 27.
9. Ibid., page 164.
10. Zachrisson, op. cit., page 28.
11. Ibid., page 47.
12. Ibid., page 48.
13. Ibid., page 48.
14. Ibid., page 57.
15. Ibid., page 57.
16. Ibid., page 58.
17. Tinker, Miles A., Validity of Frequency of Blinking as a Criteria of Readability, Journal of Experimental Psychology, Vol. 36, October 1946, page 458.

18. Ibid., page 453.

19. Reed, Robert F., What the Printer Should Know about Paper (Graphic Arts Technical Foundation, Inc., 1970) page 167.

20. Ibid., page 53.

21. Karttunen, Simo, Printability and the Surface Structure of Paper (Reprinted from Paperi ja Puu No. 11, 1971) page 4.

22. Nie, Norman H. and others., Statistical Package for the Social Science (McGraw Hill Book Company 2nd edition 1975) page 276.

III. METHODOLOGY

Plate

A 3M type R lithographic plate was used. This is a negative working additive plate.

The plate was exposed on a NuArc plate-burner with a carbon arc light source. To insure that the plate was properly burned in and developed, the Kodak fourteen step control (grey) scale t-14 was used. The plate was exposed to the manufacturers specifications using this grey scale.

For developing the plate, 3M's three-step process was used-- desensitizer, laquer, and gum.

Ink

Van Son black ink number 40904 was used for the entire press run.

Paper

The paper that was used in the testing consists of three different types--coated, uncoated and calendered. (Normal papers for offset jobs). These papers are varied enough to give a wide spectrum of gloss and smoothness values.

To get results of overall paper qualities for book

production, both the wire and felt side of each paper was tested. This yielded twelve printed samples (six papers, both sides).

The different papers were labeled consecutively one through six. Both sides of each paper were labeled ("A" or "B"). No attempt was made to label the wire or felt side with a specific letter.

A list of the papers can be found in table one.

Paper Samples

paper number	type	Company
1	uncoated	Consolidated
2	Patina coated matte	Warren
3	Lustro offset enamal	Warren
4	Blade coated Modern gloss	Consolidated
5	Patina coated glossy	Warren
6	Blade coated fortune gloss	Consolidated

Table 1.

Samples of the papers used can be found in Appendix A.

Press

The test targets were printed on an A.B. Dick 360 press. This is a lithographic offset press. A photograph of the press can be seen in Figure one.

A.B. Dick 360
Offset Press

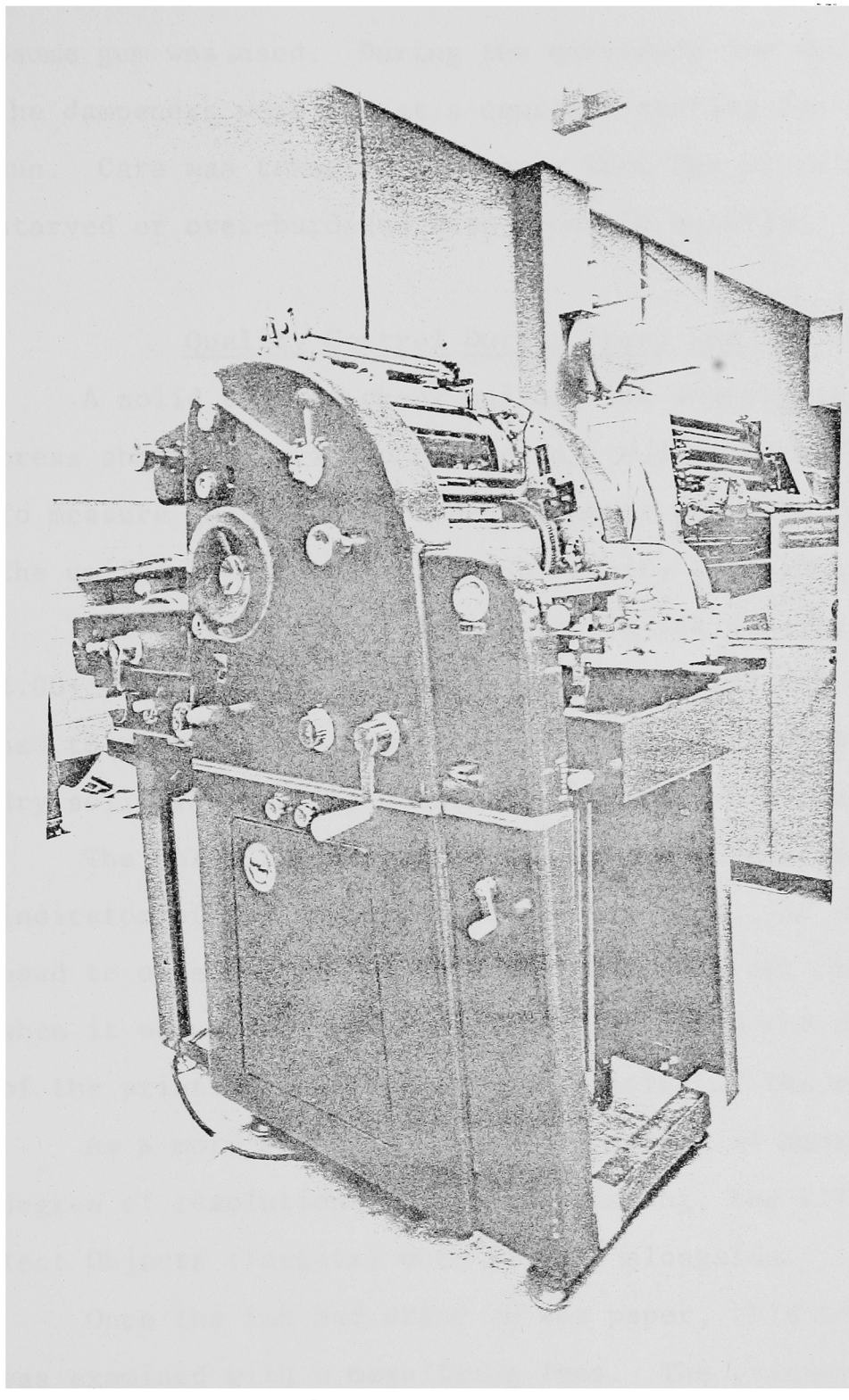


Figure 1.

Foutain Solution

Anchor Concentrate III fountain solution with 14° Baume gum was used. During the makeready for each paper, the dampeners were set at a constant setting for the entire run. Care was taken to make sure that the plate was neither starved or over-burdened with fountain solution.

Quality Control During Press Run

A solid area to check uniform ink density for the press sheet was printed on the tail end of each sheet. To measure the results, a densitometer was used to check the uniformity of the solid ink density throughout the run.

The specifications for the solid ink density was 1.00+ 0.05. During the press run, the solid ink density had to go above the upper density range of 1.05 to get a dry solid ink density within the parameters already set.

The GATF Star Target on the form worked as a visual indicator of the sharpness of the printing. It was also used to observe fill-in or slur and to correct it immediately when it occurred. This was important since the resolution of the printing could affect the results of the experiments.

As a more exact and objective method of measuring the degree of resolution during the printing, the RIT Alphanumeric Test Objects (Targets) were printed alongside.

Once the ink had dried on the paper, this test target was examined with a magnifying lens. The printed alphanumeric

characters were recognizable to the smallest line (line number 25).

According to the instruction booklet for the use of this test target, the printing had a resolution of at least 18.0 lines per millimeter.[1]

Physical Testing of Paper

All papers were tested for gloss and smoothness on both the wire and felt sides of the paper. Fifteen readings on each side of the paper were taken. The results are found in tables two and three (respectively).

For measuring gloss the Hunter Lab model D16 Multi-purpose Glossmeter was used. (Photograph in Figure two).

This glossmeter is a photoelectric instrument that measures the percentage of light that is specularly reflected off the specimen (paper).

This model glossmeter has a choice of two angles at which the light can be measured. The light source that would be beamed at a 75 degree angle to the paper was used. Since gloss is a measurement of specular reflection, rather than diffused reflection, the specimen phototube that is used to measure the amount of light being reflected is located at a 75 degree angle, also.

Since the light source may fluctuate due to variations in electric current or life of the bulb, a comparison photo-tube is used to compare the amount of light it receives directly from the original light source to the amount of

Hunterlab Model D16

Multipurpose Glossmeter

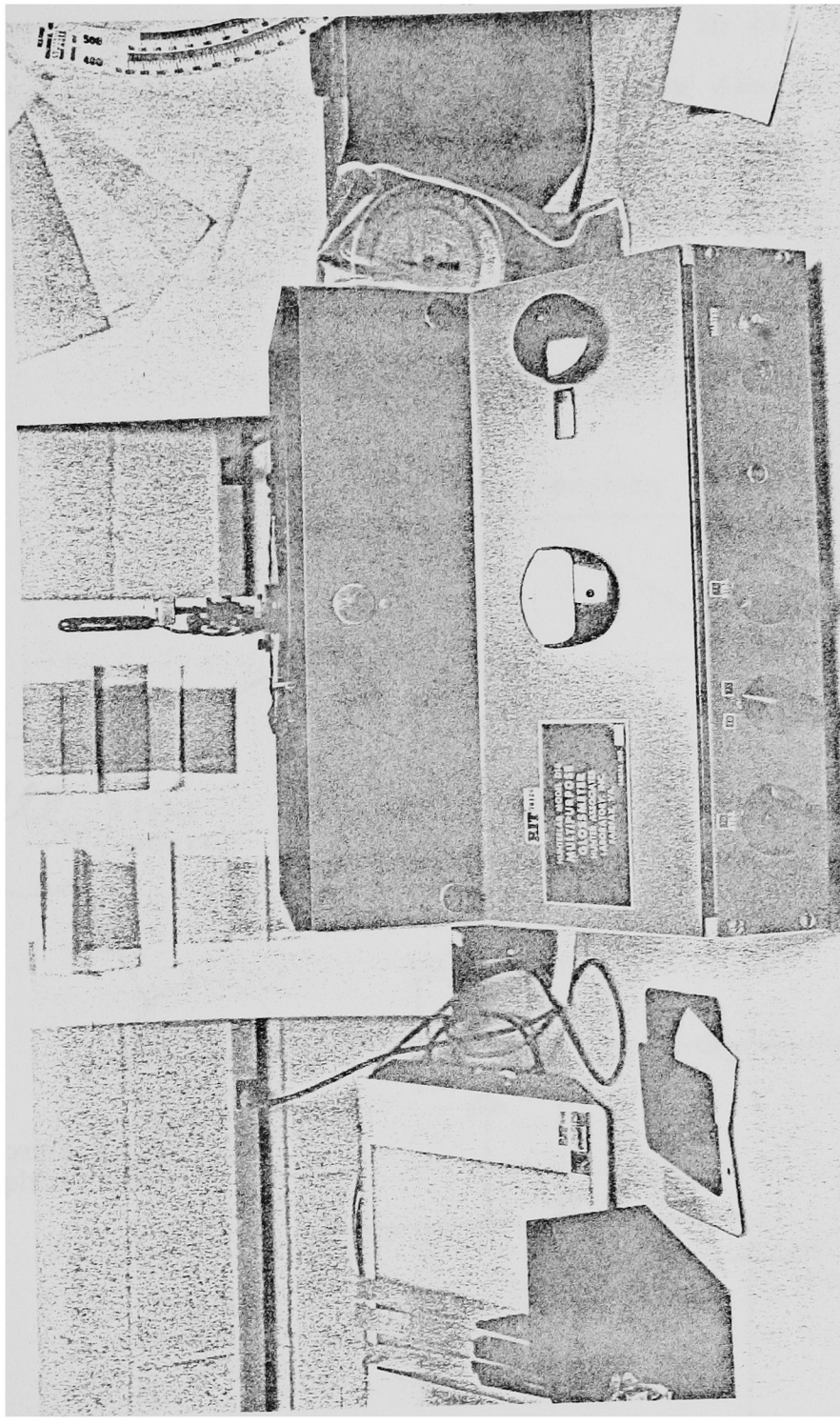


Figure 2.

light the specimen phototube is receiving.

In order to get the digital read-out of the percentage of light reflected, the digital read-out knob is turned until the needle of the null meter is in the null position (centered). The gloss reading is then displayed in the digital counter. This is a four digit number with a decimal point after the first two numbers. The read-out is read directly as a percentage. This is represented in figure three.

Diagram of Glossmeter

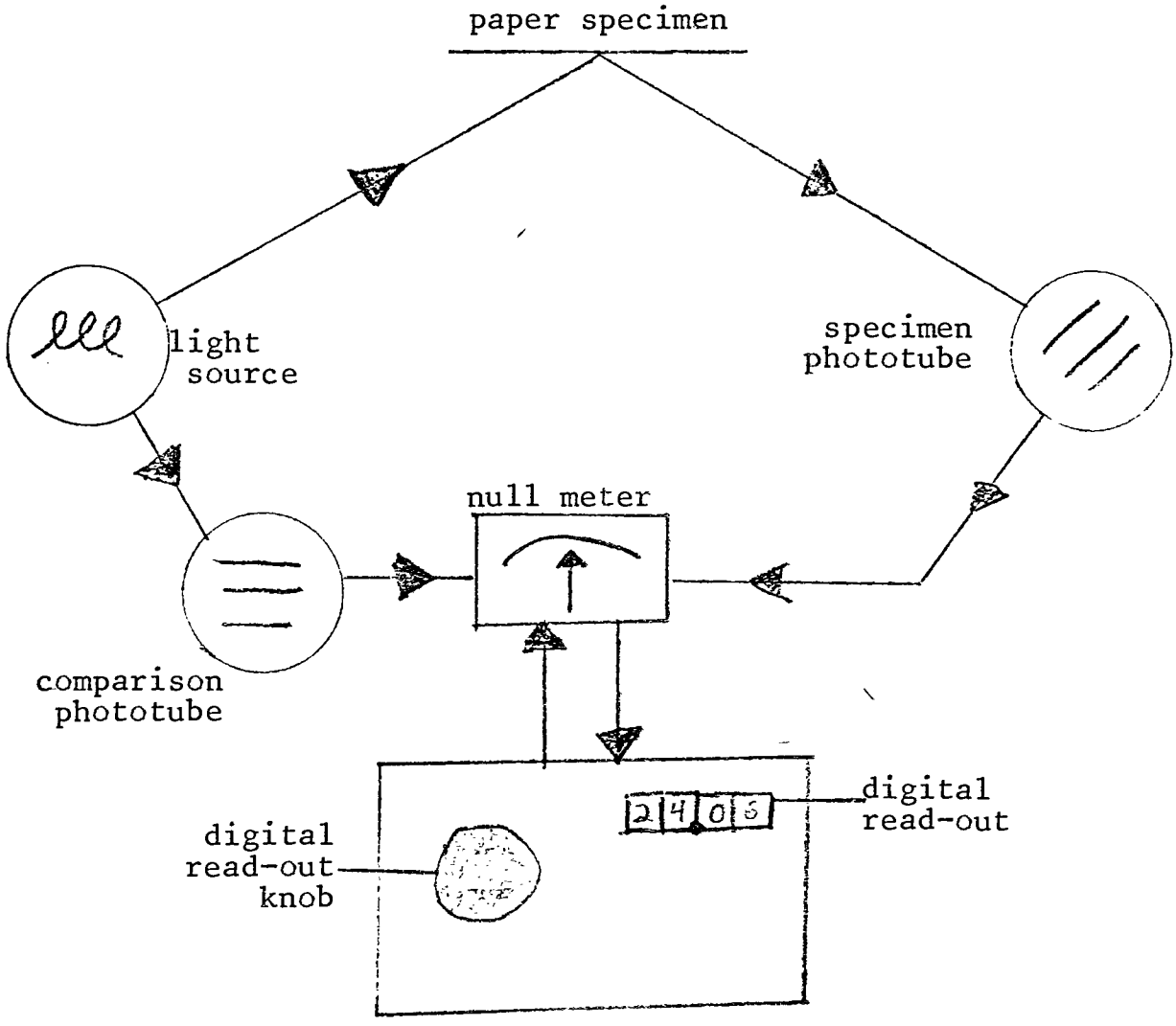


Figure 3.

GLOSS READINGS

1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
1.96	10.45	17.82	20.30	80.83	79.74	57.05	49.54	9.04	8.01	52.68	53.90
1.88	10.50	18.86	19.86	79.48	77.45	56.89	52.02	8.85	7.93	50.63	53.58
1.97	10.05	19.26	20.08	78.19	76.33	56.58	51.20	8.50	8.00	51.37	54.47
1.96	10.30	18.82	18.92	80.50	77.10	54.81	51.78	8.90	7.77	51.64	55.21
1.94	10.74	19.48	18.74	78.19	79.14	56.11	49.70	9.14	7.87	49.72	53.68
1.94	10.50	18.29	18.62	79.88	80.32	55.46	50.09	9.17	8.44	52.26	54.85
1.90	10.11	17.70	18.14	78.70	78.08	57.60	53.36	8.82	7.94	51.98	53.76
2.00	10.28	19.73	18.97	78.26	78.80	56.88	50.62	8.62	7.76	53.50	53.48
1.93	9.60	18.37	18.16	82.46	79.02	58.01	48.47	9.25	7.70	52.81	51.83
1.95	9.68	18.77	19.01	81.66	76.80	56.55	49.89	8.48	7.96	53.25	54.82
1.96	10.17	18.75	19.12	80.96	75.45	58.09	51.20	8.75	7.72	51.91	53.21
1.95	9.60	19.74	18.90	82.17	78.40	58.08	53.48	9.13	8.13	53.68	52.99
1.98	10.23	19.70	19.57	82.52	79.93	58.84	53.41	9.01	7.80	52.71	53.53
1.96	10.32	19.62	20.82	80.60	79.62	57.25	50.95	9.14	8.12	54.60	53.86
1.92	9.98	18.99	19.22	81.41	77.62	55.89	51.34	8.64	8.22	52.81	55.28
$\bar{x}$ 1.947	10.167	18.927	19.229	80.387	78.253	56.939	51.137	8.896	7.958	52.366	53.897
s 0.030	0.340	0.672	0.765	1.544	1.438	1.093	1.500	0.255	0.206	1.222	0.917

Table 2.

The Sheffield Smoothchek paper tester was used to test the paper smoothness. (Photograph in Figure five). This instrument uses the air leak method of testing.

With this method, the paper specimen is put on top of a glass plate. The test head, which has two metal concentric rings, is lowered onto the paper specimen. (Illustration in Figure four).

Air is pumped from an air pump through the rotometer columns which produces a specific amount of air pressure to the test head. The air will try to escape between the concentric rings and the paper.

So the amount of air which is leaking out is an integrated measurement of the roughness or smoothness of the paper.

An illustration of the Sheffield Smoothchek is shown in Figure six.

With the gloss and smoothness data, two curves were drawn.

The first curve (Figure seven) was made by superimposing curves of the average reading of smoothness and gloss for each individual paper.

The second curve (Figure eight) is a curve of smoothness versus gloss.

Measuring Head of Smoothness Tester

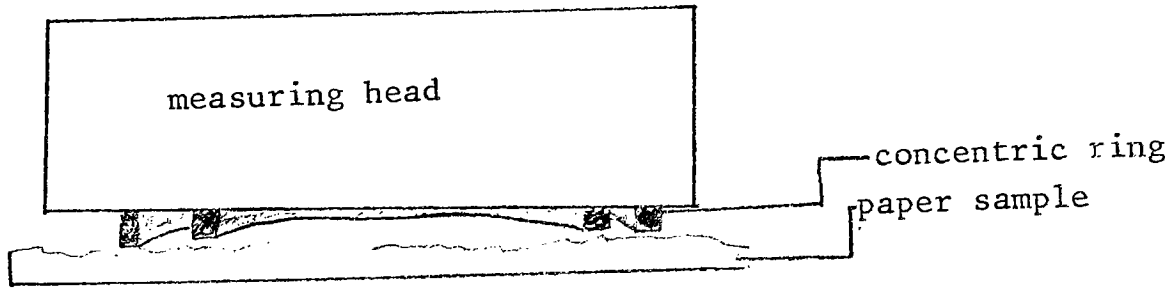


Figure 4.

Sheffield Smoothchek

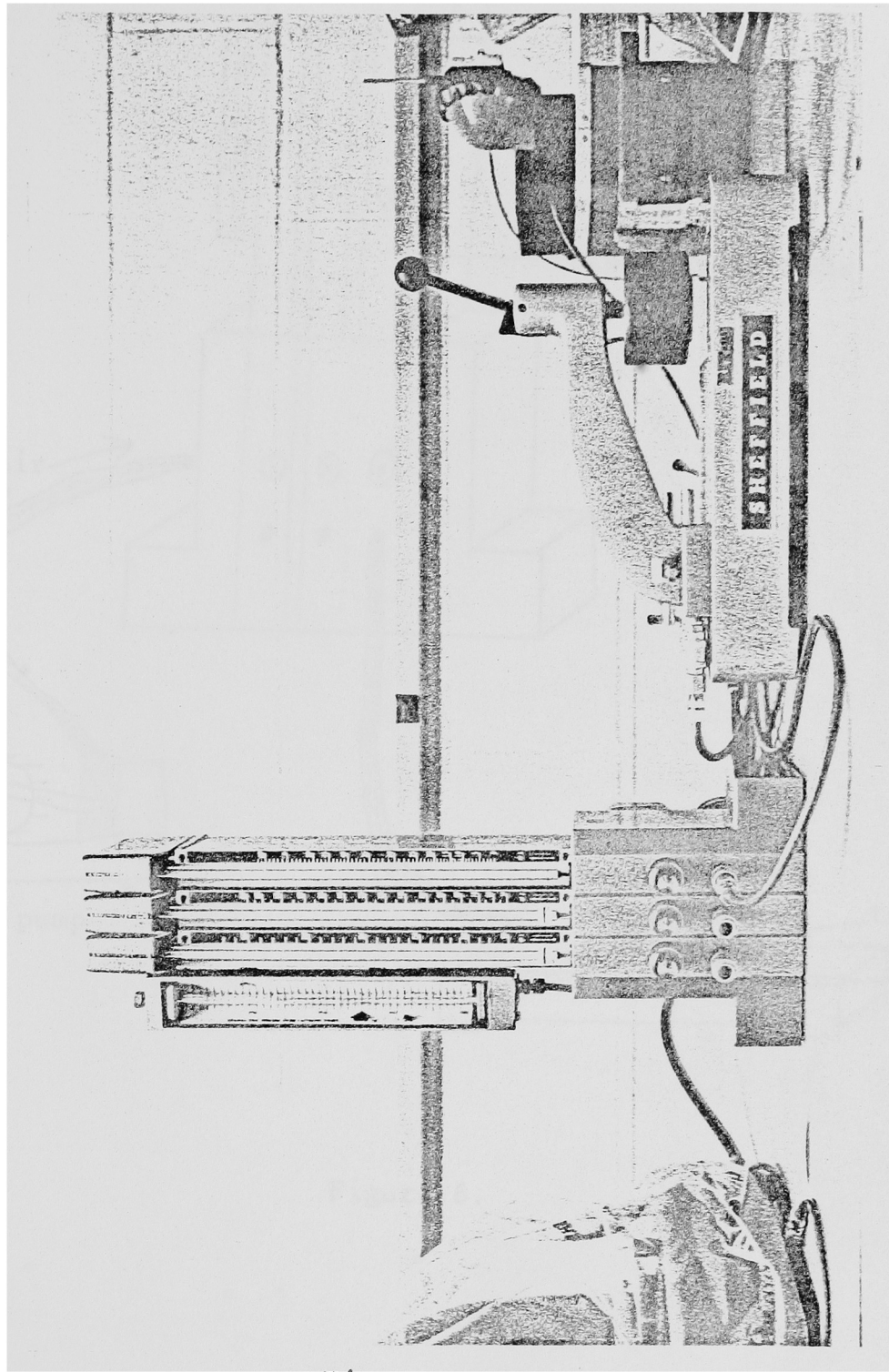


Figure 5.

Diagram of Sheffield Smoothchek

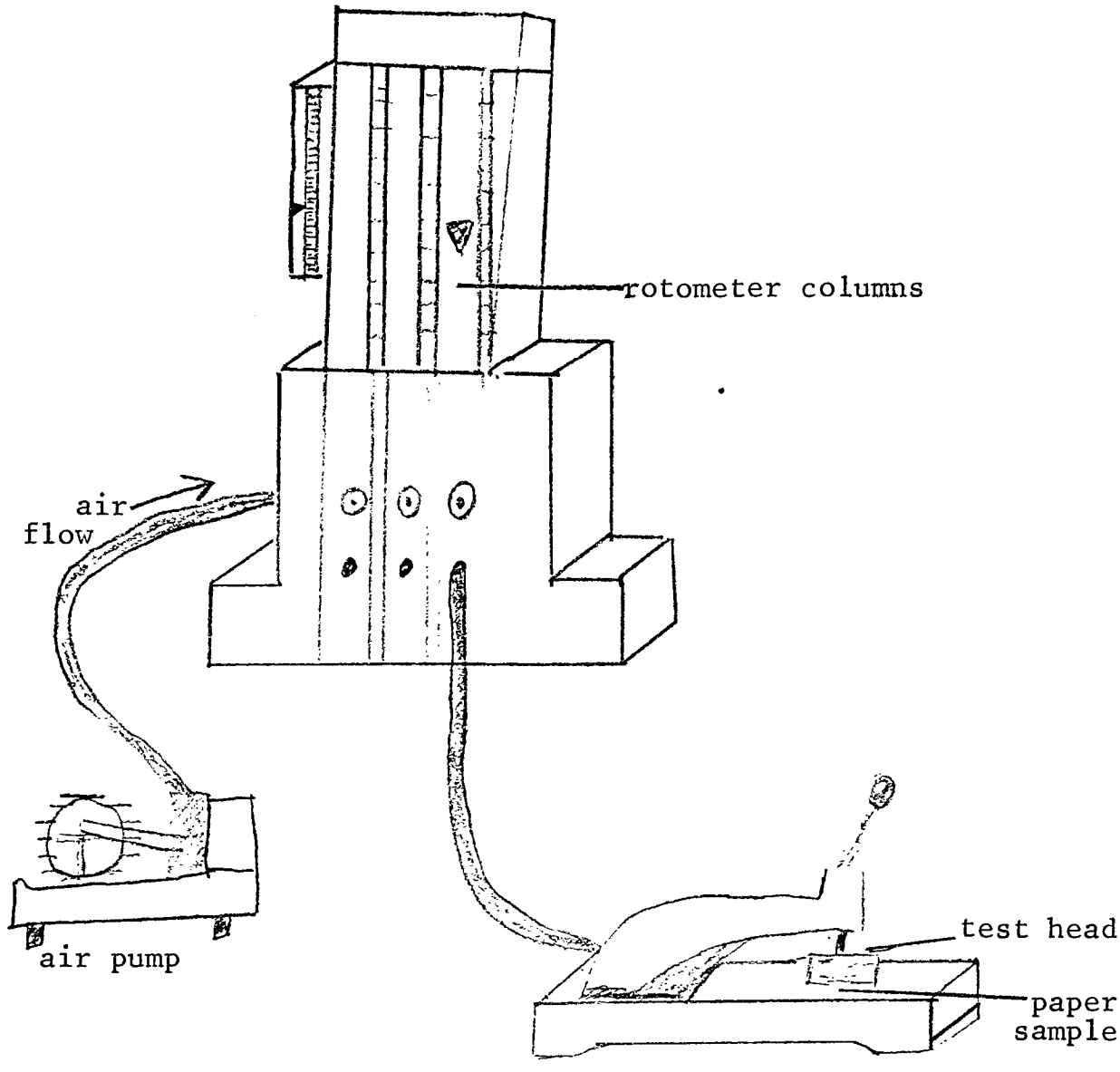


Figure 6.

SMOOTHNESS READINGS

1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B
175	74	32	33	29	34	26	28	37	49	13	13
165	75	36	37	22	27	21	35	50	52	18	12
163	73	31	39	26	39	18	22	46	54	22	18
163	70	41	37	22	20	17	27	43	52	23	23
160	75	37	43	24	17	27	22	47	52	26	20
170	73	44	40	18	38	30	22	38	51	20	13
172	66	42	39	16	29	26	31	43	51	24	16
153	72	43	38	18	26	30	37	39	53	18	23
166	74	38	40	26	31	28	30	50	52	25	14
160	73	39	40	31	23	33	31	48	50	26	14
168	70	39	41	35	19	35	22	42	56	32	21
157	65	30	38	16	40	25	26	43	53	26	25
164	67	38	20	31	26	32	29	47	49	19	18
163	73	35	41	34	32	24	29	44	54	18	17
164	69	35	36	24	26	20	28	40	47	20	23
$\bar{x}$ 164.2	71.3	37.3	38.8	24.8	28.5	26.1	27.9	43.8	51.7	22.0	18.0
s 5.6	3.3	4.2	2.4	6.3	7.2	5.4	4.7	4.2	2.3	4.7	4.3

Table 3.

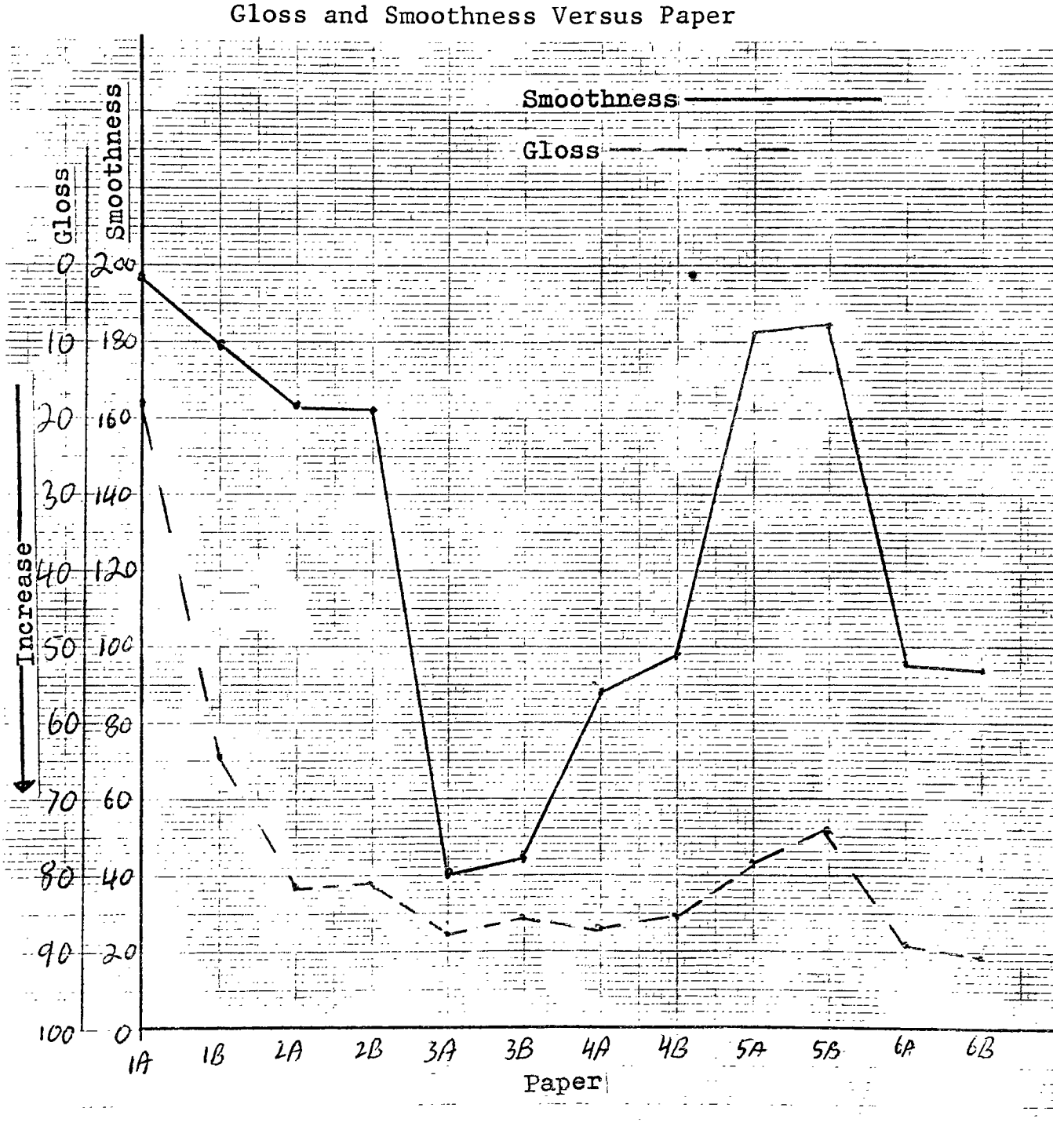

Gloss and Smoothness Versus Paper
Smoothness
Gloss
Gloss
Smoothness
Increase
0
10
20
30
40
50
60
70
80
90
100
200
180
160
140
120
100
80
60
40
20
0
1A
1B
2A
2B
3A
3B
4A
4B
5A
5B
6A
6B
Paper

Figure 7.

Gloss Versus Smoothness

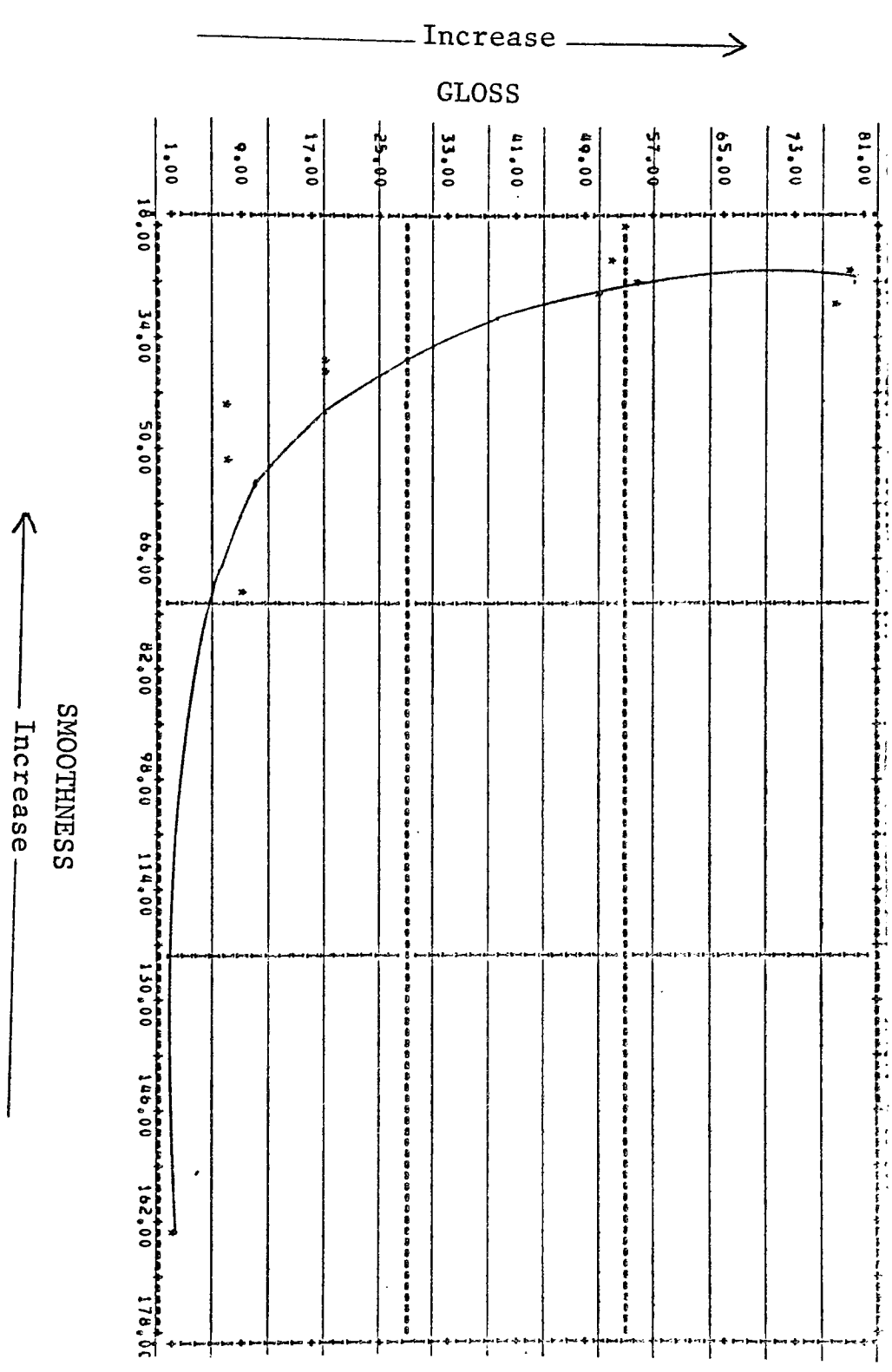
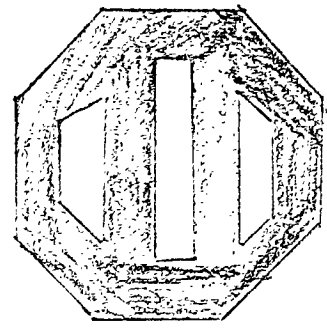


Figure 8.

Test Target

The primary test target used in the experimentation was the ISO (International Standard Organization) Conventional Typographic Character for Legibility tests.

The ISO Characters are made to appear similar to conventional typographic characters. It is designed as an octagon with two parallel lines inside. (Figure 9.)



ISO Character

Figure 9.

In order to test legibility, the direction of the parallel lines on a group of these characters had to be recognizable. The octagon was tilted so the parallel lines appeared horizontal, vertical, or at a 45 degree angle to the right or left.

These octagonal characters were grouped into word units. Each "word" contained four ISO Characters. There were two word groups per line. This two word group was considered legible when seven of the eight characters could be correctly identified as to the angle of the parallel lines.[2]

Experimental Procedures

This study used two groups of observers. The first group consisted of nine senior citizens 65 years or older. The second group consisted of college students 18 to 25 years of age.

Each observer tested was given instructions before they began. First they were shown an enlarged diagram of the ISO Character and given an explanation of how the symbol was suppose to work.

They were then given the sample sheets of paper. They were instructed to hold the paper at their normal reading distance and to look at the left hand side of the paper. There were two vertical columns of word units which decreased in size toward the bottom of the sheet.

They were told to start at the top of the column with the rectangle labeled "200" and to visually descend down the column looking at the octagon shapes which were located around the numbered boxes.

When they reached the smallest group of octagons in which they could still detect the direction of the parallel lines, they were told to read aloud the number found within the black rectangular box in that group of octagons. They were then asked to read across a line and describe the direction of the parallel lines by the following:

 Vertical

 Horizontal

 Left

 Right

A constant check was kept to see if the reading distance remained the same. At regular intervals the observer would be asked if he/she was reading the smallest group they were capable of reading.

The printed sheets were shown in a random order. Each time the sheets were reshuffled before they were shown to the next person. The results of the legibility tests, for senior citizens and college students, are found in tables four and five (respectively).

Curves of legibility readings of senior citizens and college students versus gloss and smoothness were made. (Figures ten to thirteen).

Statistical Correlation

Linear correlation of two different variables (i.e., gloss and smoothness) was used for the statistical study. To make the correlation coefficient more significant, the log of one of the two numbers studied was used. This compressed the line to produce a more linear fit.

Below is the list of the correlation coefficients that were used for the conclusions of these experiments.

Gloss vs. Smoothness..... r=-.86

Gloss vs. College Student Legibility..... r=-.86

Smoothness vs. College Student Legibility.... r= .85

Gloss vs. Senior Citizen Legibility..... r=-.21

Smoothness vs. Senior Citizen Legibility..... r= .09

College Student Legibility vs. Senior Citizen Legibility..... r= .47

College Student Legibility of felt side vs. College Student Legibility of wire side..... r= .56

SENIOR CITIZENS LEGIBILITY READINGS

	1	2	3	4	5	6	7	8	9	$\bar{x}$	s
1A	120	120	120	100	120	140	140	140	100	122.2	15.6
1B	120	120	120	100	120	140	170	140	100	125.6	21.9
2A	140	120	120	100	120	140	140	140	84	122.7	20.1
2B	140	140	120	100	120	140	140	140	100	126.7	17.3
3A	120	120	100	100	120	140	140	140	100	120.0	17.3
3B	120	120	120	100	100	140	120	140	84	116.0	18.5
4A	120	100	120	100	120	140	140	140	100	120.0	17.3
4B	140	120	140	120	120	140	120	170	84	128.2	23.4
5A	120	100	120	100	100	100	140	140	100	113.3	17.3
5B	140	120	120	100	120	140	140	140	100	124.4	16.7
6A	120	120	140	100	120	140	140	140	84	122.7	20.1
6B	120	120	120	120	120	140	140	140	84	122.7	17.4
$\bar{x}$	126.7	118.3	121.7	103.3	116.7	136.7	139.2	142.5	93.3		
s	9.8	10.3	10.3	7.8	7.8	11.5	12.4	8.7	8.2		

Table 4.

Gloss Versus Senior Citizen Legibility Readings

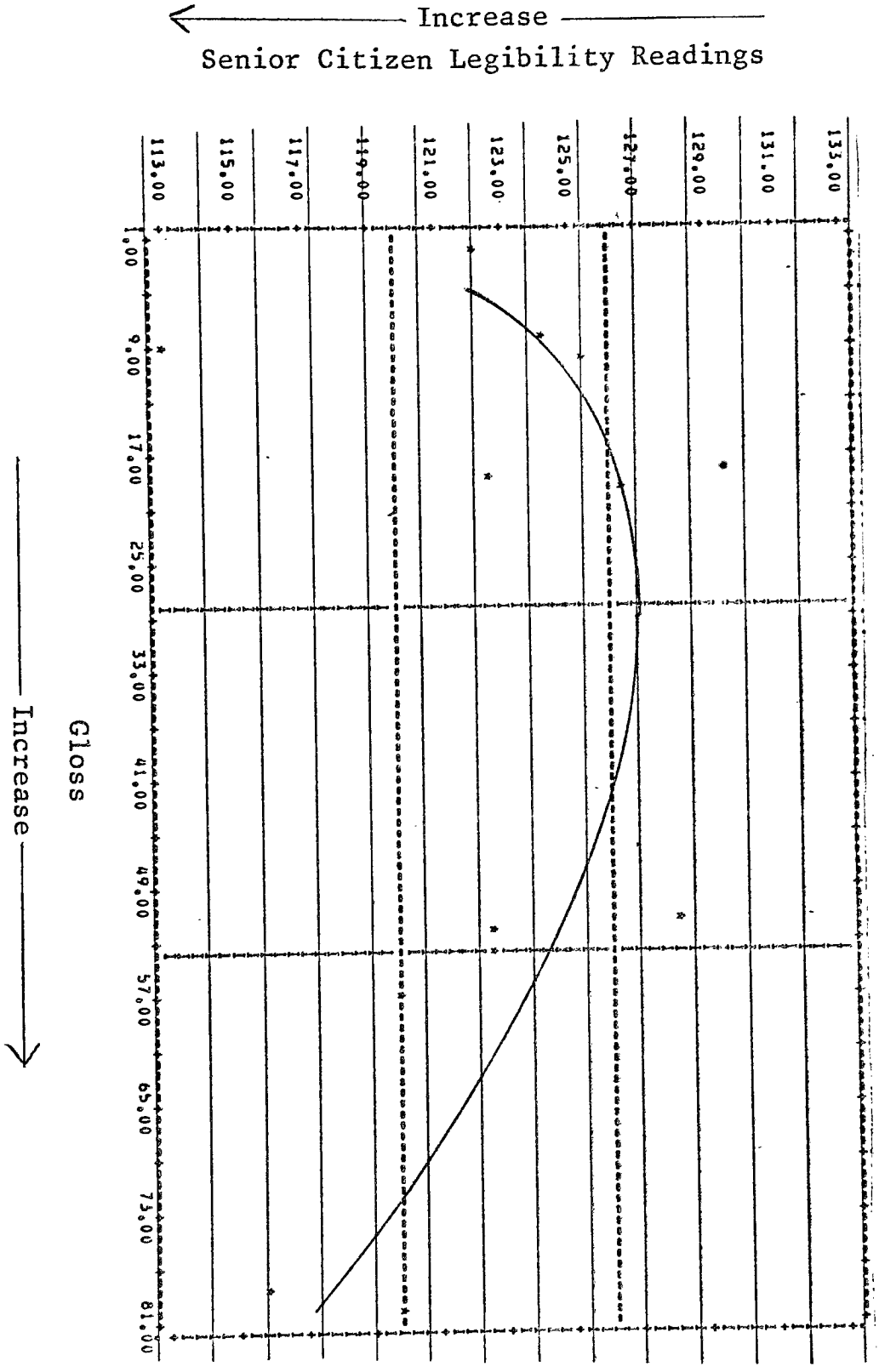


Figure 10.

Smoothness Versus Senior Citizen Legibility Readings

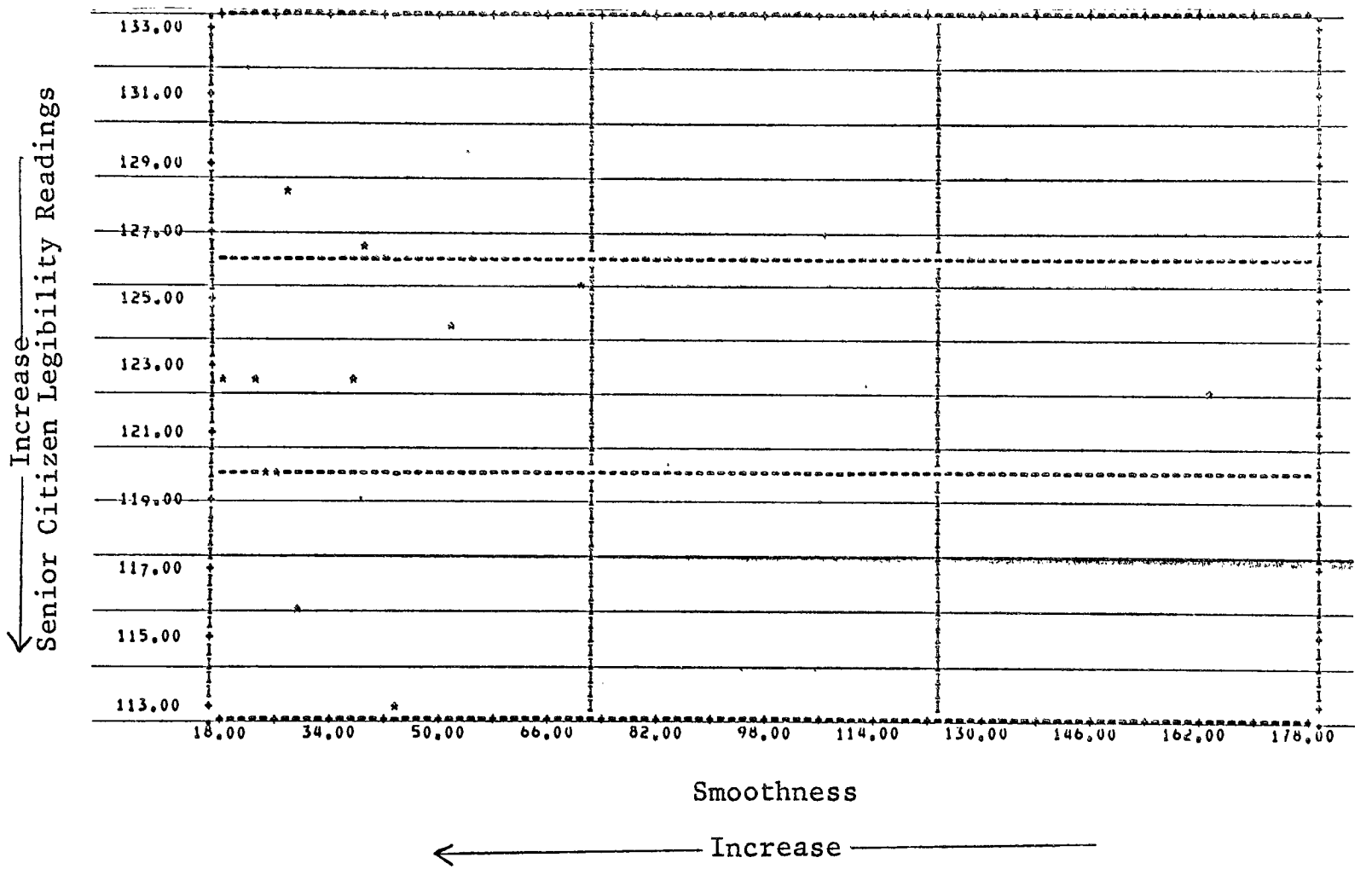
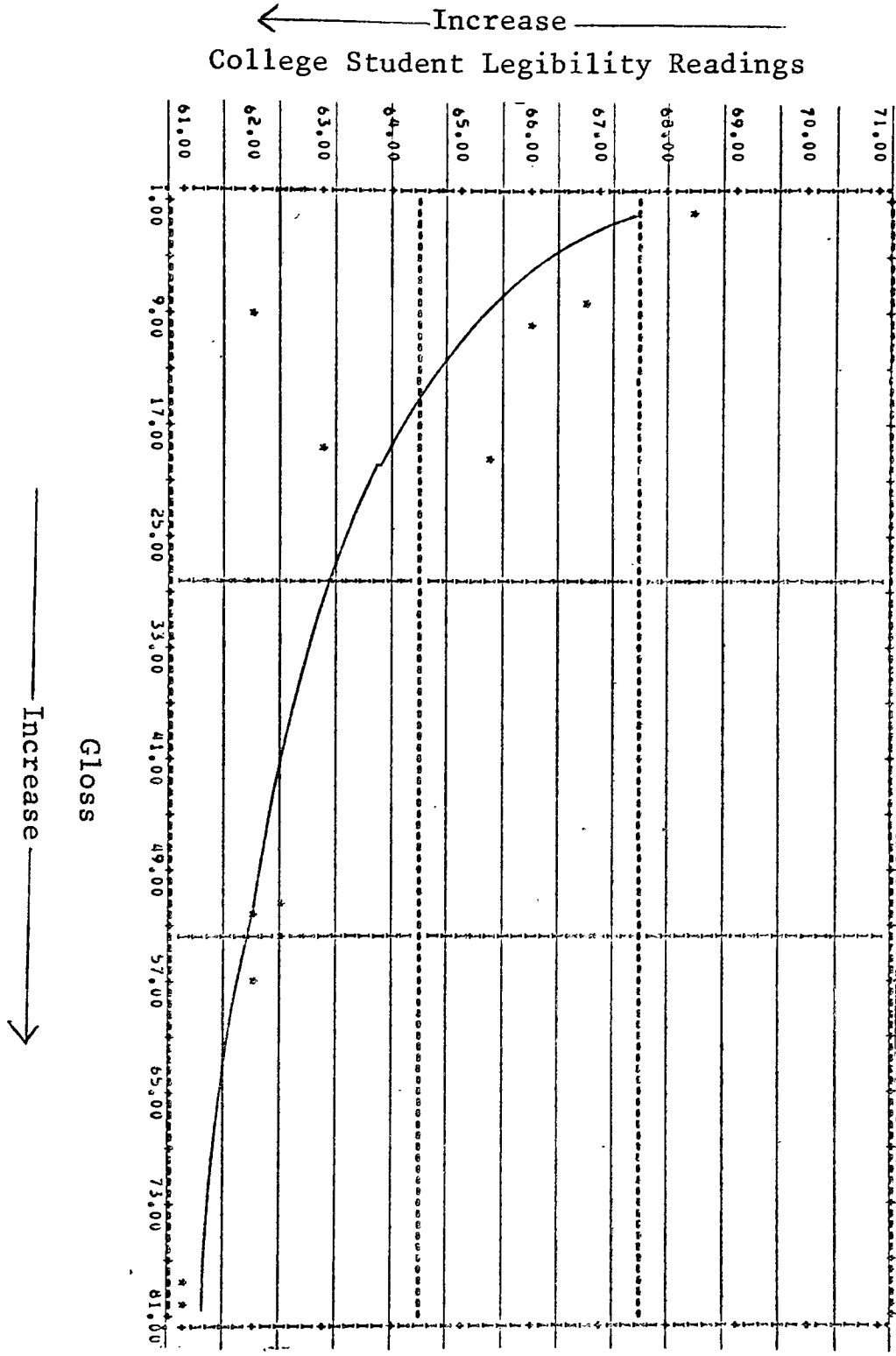


Figure 11.

COLLEGE STUDENTS LEGIBILITY READINGS

	1	2	3	4	5	6	7	8	9	10	$\bar{X}$	s
1A	60	70	70	84	60	70	70	70	60	70	68.4	7.2
1B	50	70	70	70	50	70	70	70	70	70	66.0	8.4
2A	50	70	70	70	60	70	60	70	50	60	63.0	8.2
2B	50	70	70	84	70	70	60	70	50	60	65.4	10.5
3A	50	70	60	70	50	70	60	70	50	60	61.0	8.8
3B	60	70	60	70	50	60	70	60	50	60	61.0	7.4
4A	50	60	70	70	60	70	60	60	60	60	62.0	6.3
4B	50	70	70	84	50	60	60	60	60	60	62.4	10.1
5A	50	60	70	70	50	70	60	70	50	70	62.0	9.2
5B	60	70	60	84	50	84	70	70	60	60	66.8	11.0
6A	50	60	60	70	60	60	70	60	70	60	62.0	6.3
6B	50	70	70	84	50	60	60	70	50	60	62.4	11.1
$\bar{X}$	52.5	67.5	66.7	75.8	55.0	67.8	64.2	66.7	56.7	62.5		
s	4.5	4.5	4.9	7.2	6.7	7.0	5.1	4.9	7.8	4.5		

Table 5.



Gloss Versus College Student Legibility Readings

Figure 12.

Smoothness Versus College Student Legibility Readings

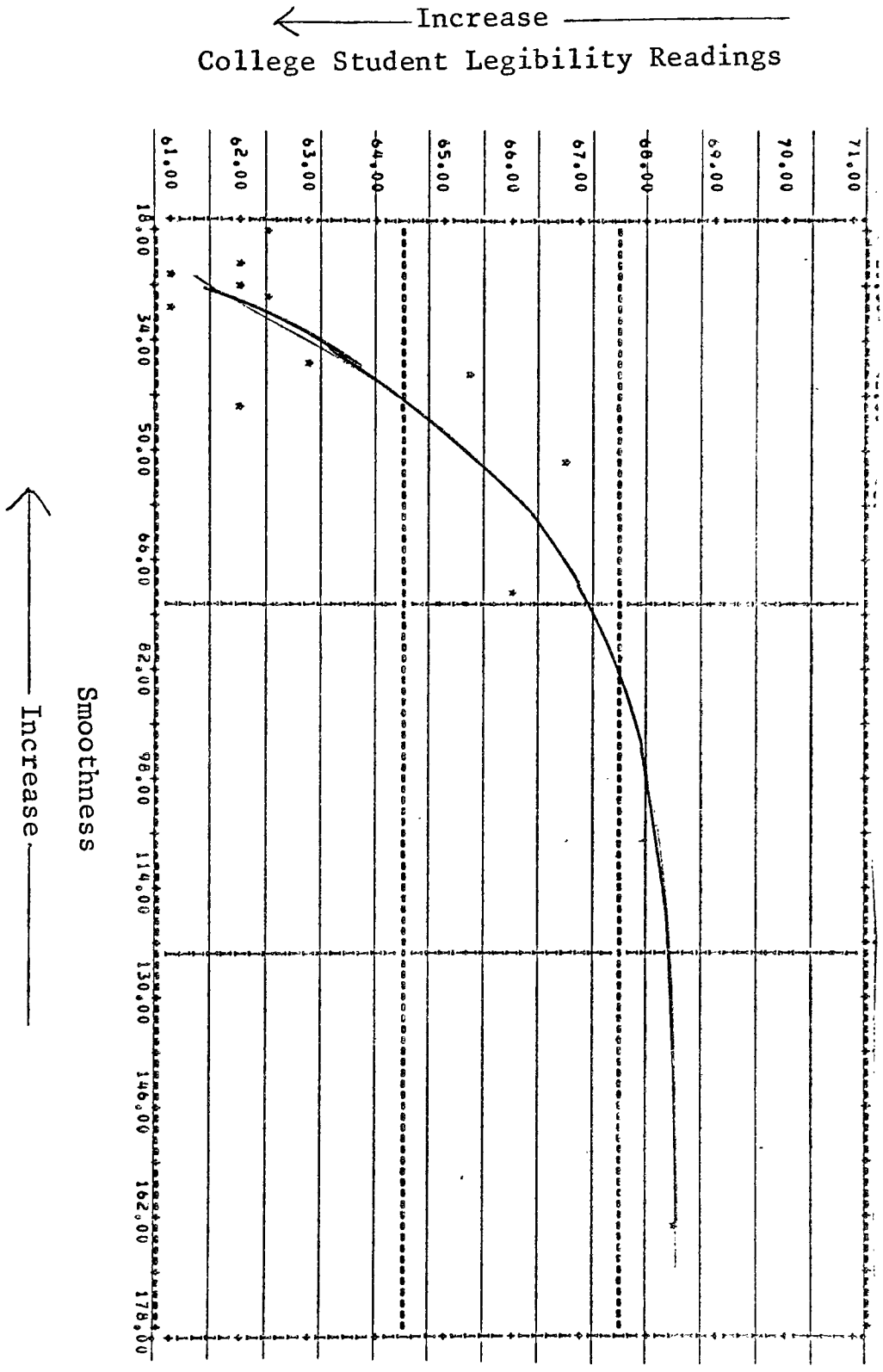


Figure 13.

Paper Legibility Rating

The charts on the following pages compare the test results of the various papers. The charts for senior citizens and college students are shown separately (Tables 6 and 7).

The papers are labeled on the vertical and horizontal axis of the chart. By looking at the vertical and horizontal lines for the papers to be compared and finding their point of intersection, the number used to rate the comparison of the two can be found.

"Two" means the paper on the vertical axis is better for legibility than the paper on the horizontal axis.

"One" means the paper on the vertical axis is equally legible to the paper on the horizontal axis.

"Zero" means the paper on the vertical axis is worse for legibility than the paper on the horizontal axis.

The vertical "total" column can be used to compare the papers, also. The higher the total, the more the paper is perferred. The best value for legibility is 22. The worst value is zero.

PAPER RANKING BY SENIOR CITIZENS

	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	TOTAL
1A	-	2	2	2	0	0	0	2	0	2	2	2	14
1B	0	-	0	2	0	0	0	2	0	0	0	0	4
2A	0	2	-	2	0	0	0	2	0	2	1	1	10
2B	0	0	0	-	0	0	0	2	0	0	0	0	2
3A	2	2	2	2	-	0	1	2	0	2	2	2	17
3B	2	2	2	2	2	-	2	2	0	2	2	2	20
4A	2	2	2	2	1	0	-	2	0	2	2	2	17
4B	0	0	0	0	0	0	0	-	0	0	0	0	0
5A	2	2	2	2	2	2	2	2	-	2	2	2	22
5B	0	2	0	2	0	0	0	2	0	-	0	0	6
6A	0	2	1	2	0	0	0	2	0	2	-	1	10
6B	0	2	1	2	0	0	0	2	0	2	1	-	10

Table 6.

PAPER RANKING BY COLLEGE STUDENTS

	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	TOTAL
1A	-	0	0	0	0	0	0	0	0	0	0	0	0
1B	2	-	0	0	0	0	0	0	0	2	0	0	4
2A	2	2	-	2	0	0	0	0	0	2	0	0	8
2B	2	2	2	-	0	0	0	0	0	2	0	0	8
3A	2	2	2	2	-	1	2	2	2	2	2	2	21
3B	2	2	2	2	1	-	2	2	2	2	2	2	21
4A	2	2	2	2	0	0	-	1	1	2	1	1	14
4B	2	2	2	2	0	0	1	-	1	2	1	1	14
5A	2	2	2	2	0	0	1	1	-	2	1	1	14
5B	2	0	0	0	0	0	0	0	0	-	0	0	2
6A	2	2	2	2	0	0	1	1	1	2	-	1	14
6B	2	2	2	2	0	0	1	1	1	2	1	-	14

Table 7.

FOOTNOTES FOR CHAPTER THREE

1. Graphic Arts Research Center, Instructions for the use of the RIT Alphanumeric Test Objects (Targets), 1963 pages 6-7, 10.

2. International Standard Organization, ISO Recommendation R 435 (April 1965 Reference number: ISO/R 435-1965(E)) section 4.1.

IV. CONCLUSIONS AND RECOMMENDATIONS

In this study a 74 percent correlation between smoothness and gloss was found. As smoothness increased gloss also increased. The correlation of gloss and smoothness was important in studying the two variables. Since there was a correlation, both variables can be studied and the results of one can be checked against the results of the second. This will help verify the results.

This research supports the first two hypotheses. The first hypothesis states that there is a good correlation between gloss and legibility of paper read by college students. A correlation of 74 percent was found. Figure 12 shows that legibility increased as the gloss of the paper increased.

The second hypothesis states that there is a good correlation between smoothness and legibility of paper read by college students. This was also supported by the data. A correlation of 72 percent was found. Figure 13 shows that the legibility of college students increased as smoothness increased.

These results are different than expected. I did not expect to find the best condition of legibility to be in the extremes of the gloss or smoothness values. The results may be explained by the glare of glossy paper which may increase

the visual contrast between the ink and the paper.

The third hypothesis states that there is a good correlation between gloss and legibility of paper read by senior citizens. With a correlation of only 4 percent, this was not supported by the data.

The fourth hypothesis is also incorrect. It states that there is a good correlation between smoothness and legibility of paper read by senior citizens. A correlation of 1 percent was found.

In studying the effects of gloss and smoothness on senior citizens, a very low degree of correlation with legibility was found. Even after ranking the different papers by preference, according to the senior citizens, a very low correlation still existed. This disproves the fifth hypothesis which states that there will be a higher correlation for paper legibility with senior citizens than there is with paper legibility for college students.

This may be because the ISO Character test targets did not work as a legibility test but, rather, as an eye chart testing vision. This may also be caused by the jump from one size ISO Character to the next size. This jump may have been too large for senior citizens. There should have been an intermediate step.

Gloss and smoothness seemed to affect college students in a more predictable way than they affect senior citizens, according to the findings of this study. This conclusion

may change with a different grouping of the ISO test targets for the senior citizens.

As a further investigation, a study was made to see if there is a difference in the effects of the wire and felt sides of the paper on legibility. A correlation of 31 percent was found, showing that the different sides of the paper will effect legibility differently.

The standard deviation of the individual observers was smaller than the standard deviation of the individual papers for both the college students and senior citizens. This shows that there is a greater difference between individuals, in their ability to read on any one paper surface, than any individual will find in himself when viewing several paper surfaces. Therefore, the findings on the effects of gloss and smoothness on legibility are most significant for the population on the whole rather than for any individual.

The results of this study is supported by other studies done in this field. Previous studies have shown that there is a difference in papers effects on legibility but not enough to be statistically significant.

Recommendations

A problem occurred with the senior citizens because no correlation could be obtained. There are two possible explanations of this.

First, the senior citizens had poorer vision than the

college students and this affected the results. Because of this, the experiments should be repeated by first testing the vision of the senior citizens. The results of the vision tests could be used to code the results of the senior citizens in order to take into account their varied individual visual abilities.

Secondly, senior citizens, having poorer vision, read parts of the test target that had greater changes between successive ISO Characters than the parts read by college students. Because of this, the test targets may have become an eye chart rather than a legibility tester. To solve this problem, the test targets must be reconstructed using smaller increments on the samples to be read by the senior citizens.

Other studies should be done with more of a cross section of age in the population.

College students and senior citizens are polarized age groups. Anything that holds true for these two groups may not hold true for other age groups.

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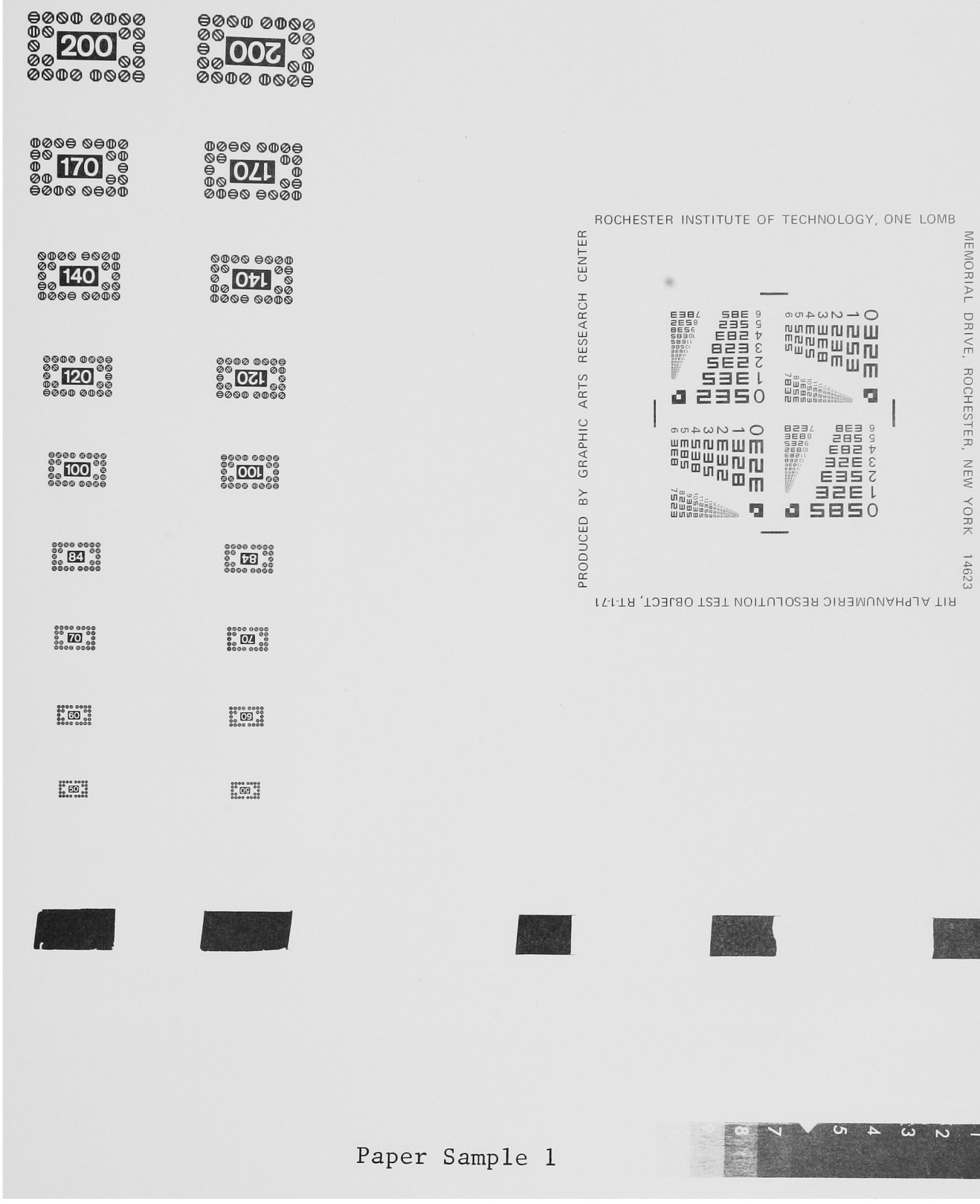

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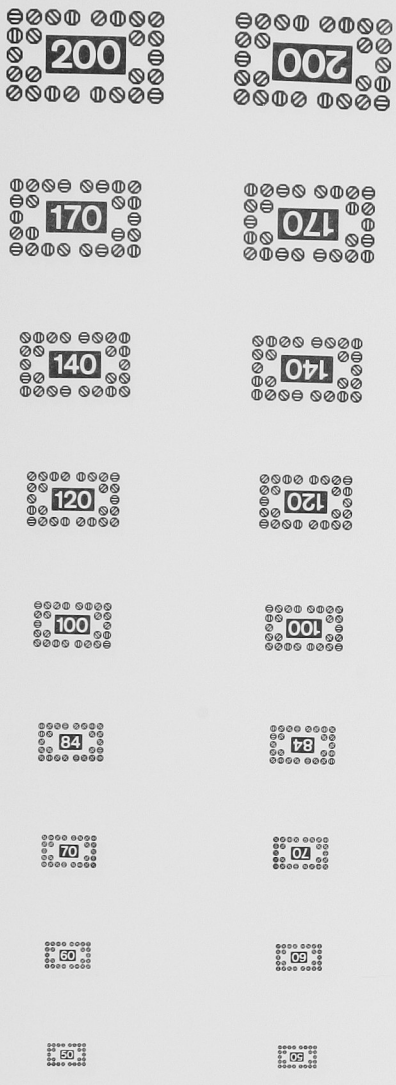

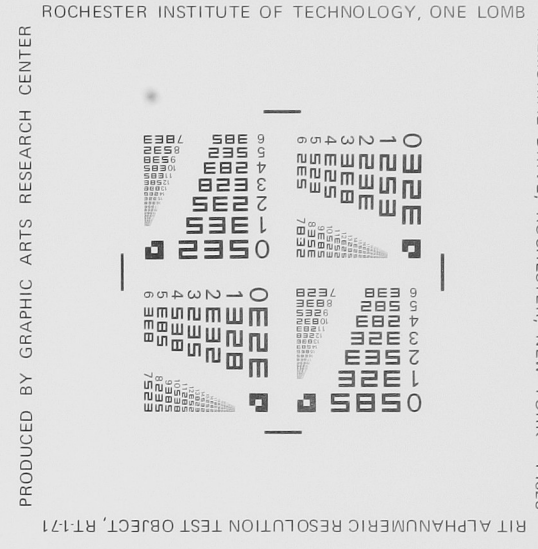

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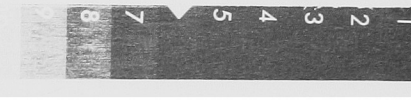

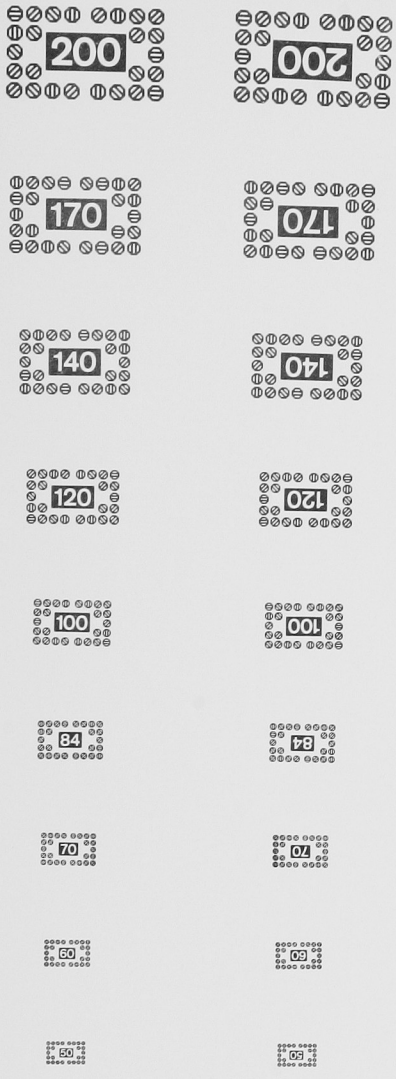

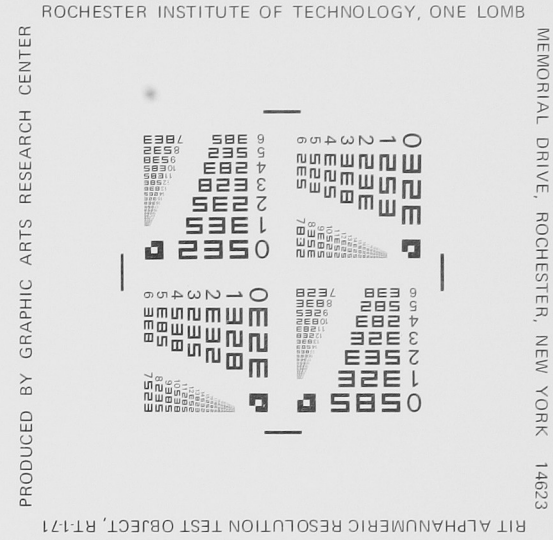

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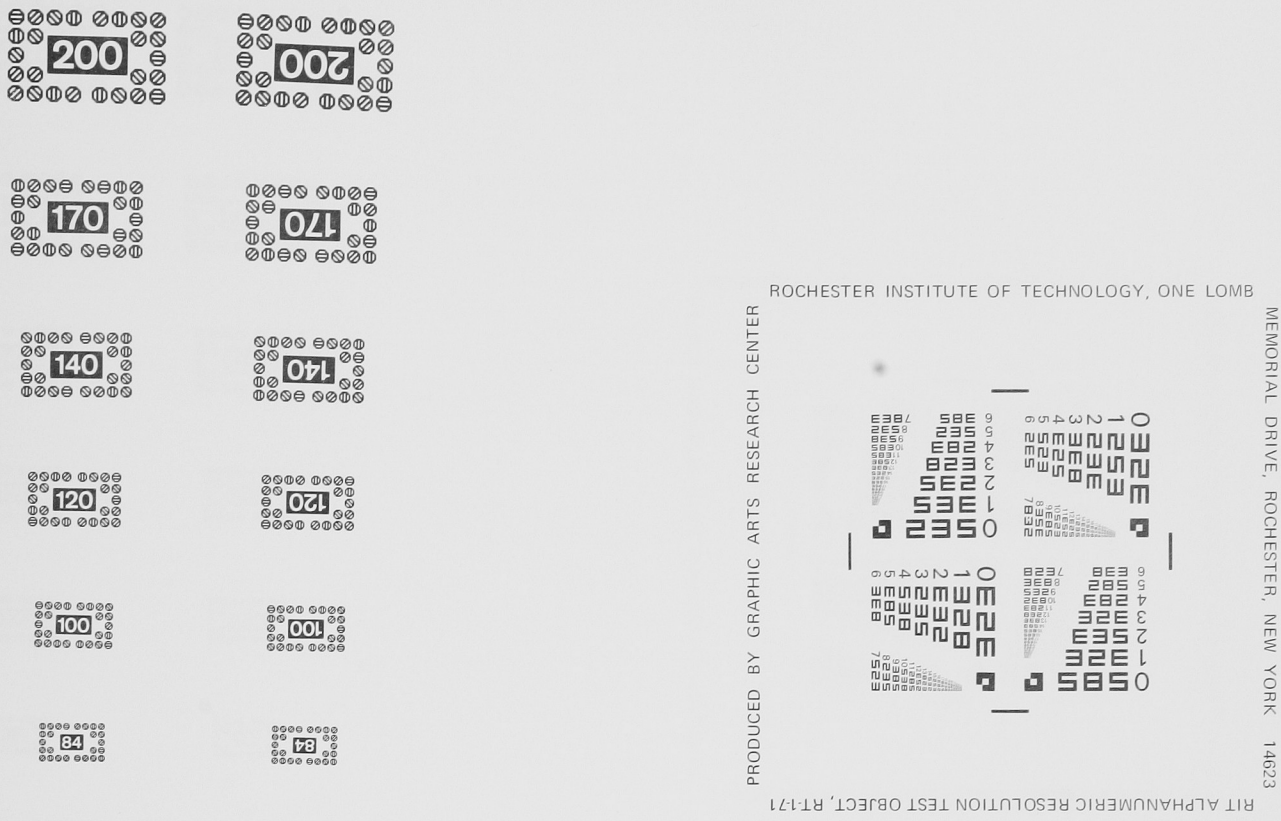

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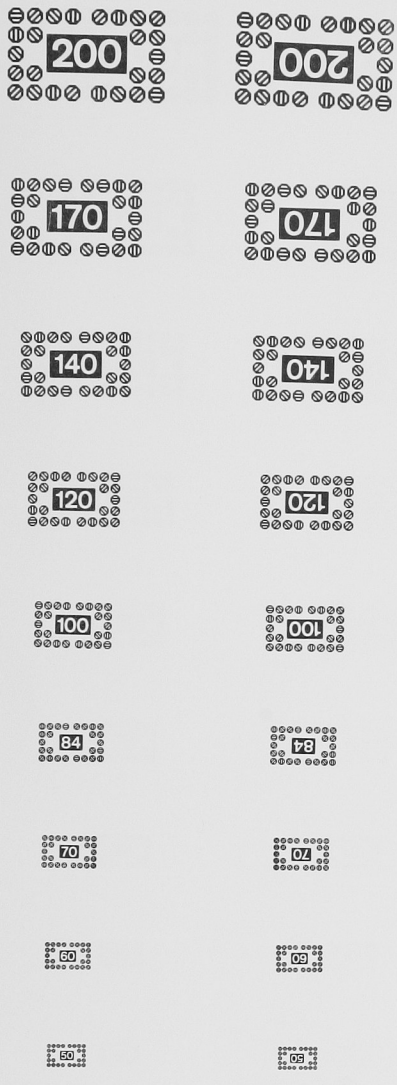

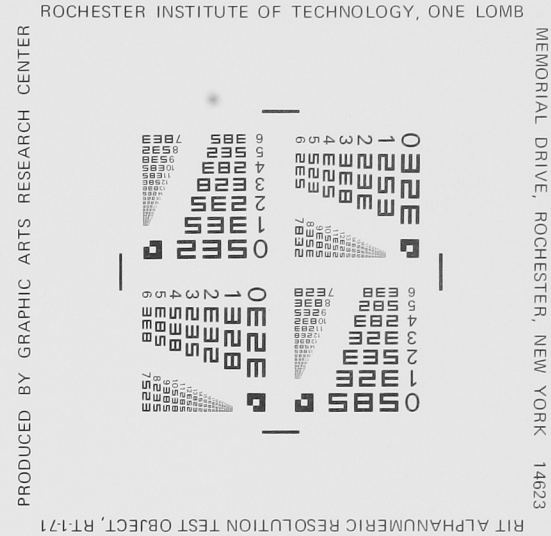

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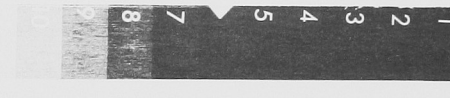

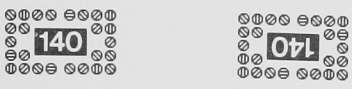

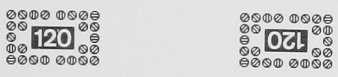

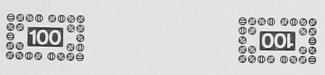

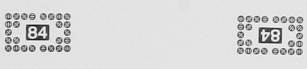

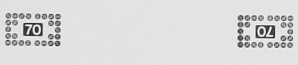

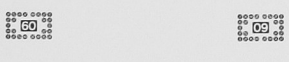

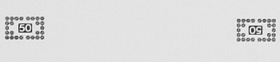

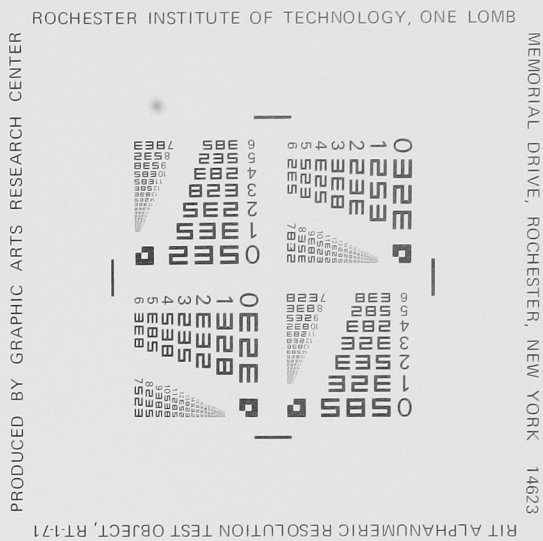

Paper Sample 6